A Tribute to Bob Pease

Pease Porridge – 4 (1999-2001)

BOB PEASE

What's All This Prediction Stuff, Anyhow?

Everybody knows the old statement by Yogi Berra: "Prediction is very hard...particularly of the future..." I love quotes like this. The mere fact that the guy who said this was physicist Niels Bohr, *NOT* Yogi Berra, does not affect the statement's validity. No matter who said it, prediction is a tough business....

I was reading about some executives who gave up on the conventional requirements for a "five-year plan" from their management team. They admitted that predictions as far out as five years were almost entirely baloney and bogus anyhow. But they were willing to accept a three-year plan.

And I recall some recent (1996) "experts" predicting that the semiconductor industry will not have any more boom/bust cycles. This industry analyst for a major stockbroker predicted that all lumps in the growth of our industry are now smoothed out. Constant, smooth, orderly expansion is assured. Of course, when the book-to-bill ratio recently went into the toilet and stayed there, I pointed out his folly. After all, 100 years ago, newspapermen asked J. P. Morgan, "What will the stock market do, Sir?" He wisely replied, "It will fluctuate..."

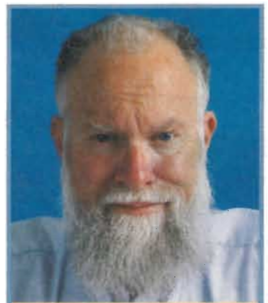
What can I predict? I can predict that many "experts" will continue to blithely promise that mixed-signal ICs (analog on the same chip as digital) are easier to design than you think.

I also can predict that the people who believe that foolishness will continue to try to make such mixed-signal ICs, using SPICE and other computerized, oversimplified analysis tools. It will be much HARDER than predicted to execute the ICs well.

What will be new in electronics in five years? Can I foresee what kind of computer we will be using? *You* may be using a hot new Septentium 777, running at 888 MHz. *I'll* still be running my old XT with the 386. I'll probably still be using 5.25-in. floppies. (I don't use a hard drive, just floppies and more floppies. Hey, I don't type very fast. I can't type at 777 MHz.)

It would be NICE if the Septentium had an option to cut the clock rate down to 8.88 MHz when all you are doing is just *typing*. That would be a neat way to extend battery life. But it's probably too much to ask, expecting computers to be designed with such a practical feature.

Meanwhile, I'll still be using my Alphasmart with a battery life of 60+ hours when I just want to type *(www.alphasmart.com)*. (I gave my TRS-80 Model 120 to a guy who needed one. It didn't have enough memory to be useful.)



BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

What will we be watching on TV? YOU may be watching NFL football on your 16:9 aspect-ratio, large-screen, high-fidelity, high-definition TV. I may be watching a soccer game on my old 13-in. machine (which I must admit does NOT have very many vacuum-tubes in it). After all, some wise person once said, "Soccer is the sport of the future—and it always will be."

Or, I may be editing some video from my most recent trek in Nepal. What will I be using for a camcorder? Digital? Naw. My guess is that the Sony TR-81 I just picked up will still be working fine. I bought a TR-51 that ran quite well for five years. But recently, it began having three *different* intermittent problems. After all, "end of usable life" does make some sense, as a concept. So I have retired it in favor of a "low mileage" TR-81 that's five years old, but "like new." It should be good for at least five more years of reliable service (I mean, my old TR-51 gave me not just five years of use, but hundreds of hours of recording and *thousands* of hours of playback.)

The new digital camcorders ARE nice and light. But if you add in the cassettes to record 12 hours, and the batteries to run that much, that package is NOT so light...not as light as mine. Will I still be using my old hand-crank generator to charge up my camcorder batteries (as I wrote up in *Electronic Design*, March 4, 1993, p. 105)? Naw, I got solar panels that weigh less and put out a lot more current on mostly sunny days.

What are WE gonna be driving in five years? YOU may be driving a car with 20 or 40 or 60 or 80 microprocessors. I'll probably be driving a 1970 Beetle with 256,000 miles on it. You know how many microprocessors THAT has in it.

Will we be buying electric cars? Several people recently asked my opinions of electric cars. I told them that the cars themselves are EXCELLENT. Whereas the lead-acid batteries are still HORRIBLE, too heavy, and too short-lived. The NiMH batteries are really pretty good, but I don't see the price coming out of the stratosphere to where they might be *affordable*. I mean, whenever somebody tells you about a new electric car with really good range, ask them the effective cost per mile of the lease. If it's cheaper than 20 cents per mile, I'll be astonished.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer

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BOB PEASE

Bob's Mailbox

Bob, Bob, Bob:

I have been reading your articles for quite some time now. Granted, sometimes you vent your frustrations that we have all felt as engineers. But, at least it applies to our industry. Don't get me wrong, I enjoy a good pot of red as much as the next Joe, and maybe you decided that most of us engineering "geeks" cannot cook, much less read a cookbook. *(I refuse to believe that. /rap)*

But, if I want a recipe for chili, I think I would get this month's issue of *Family Circle* or something similar. (Although, my pot of red would put yours to shame.) Let's get back to our frustrations with our jobs and leave the chili to boil on its own.

On second thought, perhaps your message did not miss its mark on me. Perhaps, just maybe, this does apply to engineering. *(Yeah. /rap)* Just maybe you meant that no design is perfect, and can be improved upon just like a good pot of red. Or maybe, you mean that the longer we sit on our designs, the better they get. Or, maybe it was just a recipe.

Ron Bell
via e-mail

Ron—my column was not about BEANS. It was about THINKING about beans. Even though I started with a "tried-and-tested" published recipe, I had to cut the salt by a huge factor and revise other ingredients and procedures. And I've now heard some rather favorable comments on my recipe. So, you'll have to swap me your best chili recipe, OK?!—RAP

Dear Bob:

My experience has been that strains on your body due to using the computer have been mainly due to the mouse, and in particular to the clicking operation, not typing. *(Maybe. But even people who just TYPE, without any mouse-work, still have troubles. Luckily, I do not have such troubles. /rap)*

That is why, I think, repetitive stress injury (RSI) was less of a problem for the secretaries and steno pool typists in the early days than it is now. I always tended to use the keyboard shortcuts and still recommend this. They are faster, once you know them, and less stressful. Still, there are some things that are harder to do that way. As part of my plan to beat RSI, I began to mouse lefthanded (I am naturally righthanded). This has a number of benefits, including being able to write and use the arrow keys more or less at the same time as the mouse. I found that I got used to using the mouse lefthanded in a matter of days, and in fact now do other things with my left hand that I would previously have done only with the right.

Recently, I discovered another option as well, with multiple benefits. Select "Control Panel-Accessibility Options" to get there under Win 95. *(I never fool with that. I use a mouse as little as possible. I hate to click; I despise "double-clicking." /rap)* Then select the Mouse tab, and choose "Use Mouse Keys." This turns your numeric keypad into mouse control; you can choose to have it work either with the numeric lock on or off. It is important to note that you are not choosing between using the mouse and using the keypad; you can use both. In fact, if you hold down one of the keypad keys and move the mouse at the same time, the cursor will move as the vector sum of the inputs. This is probably more interesting than useful. What is useful is that you can now get finer control of the cursor than is possible with the mouse. If you tap one of the arrow keys on the keypad, the cursor will move one pixel and no more.

This is useful for those frustrating times using drawing programs when you want to get two shapes to just touch, and similar programs. Furthermore, the 5 (on the keypad) key is now mouse click and the + (on the keypad) key is now double click. This is useful in two ways. First, in drawing programs, you often want to select an item (by clicking on it), but not to move it. With the mouse, there is always the danger that you will move the mouse after clicking. With the 5 key, there is no such danger. Second, I find that depressing keys (i.e., typing) is less stressful for my hands than mouse clicking. It is also possible to right click using the keypad and to move the mouse large distances, though I find it easier to just use the mouse for these operations under normal circumstances.

The name Accessibility Options seems to imply that Microsoft is thinking of this as something useful only for those who have some physical handicap. In fact, it is useful for everyone in my opinion.

Bruce Walker
via e-mail

Bruce, I checked into this. Hundreds of years ago, pianists and organists who practiced long and hard had RSI problems. I hope YOUR advice is useful to people who have to MOUSE a lot.—RAP

Dear Bob:

I've been enjoying your articles and columns for years. Keep up the good work. I also am an analog guy working in this digital world, and I fight the good fight when I can. *(Give 'em hell! /rap)*

I try to spread the word, through the use of your columns and articles, about the analog principles engineers forget about, did not learn, etc. It's quite amazing, as you frequently show in your column, that some engineers forget the old as soon as something "better" or "newer" comes along.

Marty P. Hoar
Seagate Technology
via e-mail

Some people forget old truths; some of us REMEMBER them. I think that those of us who can remember the old stuff are better off.—RAP

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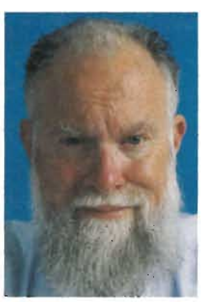
BOB PEASE

What's All This Tax-Deferred Stuff, Anyhow?

Yeah, we just about have to concede that two things are gonna get us sooner or later—death and taxes. But sometimes we read about "tax-deferred" investments (TDIs). They sound like a pretty good concept. If we can find special TDIs for which we don't have to pay any taxes until later—much later—that seems to be a good idea. (*Maybe.*)

Back a couple of years ago, I got a note from Robert Klabis. He griped that a column about TDIs by Henry Wiesel (ELECTRONIC DESIGN, March 4, 1996, p. 64F) was misleading. I tried to figure out what the problem was.

He complained that Mr. Wiesel was neglecting one vital fact. You may appear to gain advantages with TDIs because you avoid taxes early on. But when you do try to get access to your tax-deferred savings, you may have to pay tax rates even higher than when you were making the money in the first place. The effective tax rate can be as high as 28, 35, 45, or 51%. After we went around and around, I realized he was right—at least partly right. The taxes can be severe *(see "TDI Calculations And The Real Tax Rate," p. 114).*



BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

So I debated with the editors at *Electronic Design*: Who should present Mr. Klabis' ideas to the readers, RAP or QuickLook? So here we are. *(Bob, we know that nobody explains things exactly like you do. So you go right ahead and tell it like you see it.—Ed.)*

Here's my theory: If you are 15, 20, or more years from retirement, investing a SMALL PART of your retirement money in TDIs is *probably* a good idea.

If your retirement is less than 15, 10, or 5 years away, TDIs are quite possibly a *lousy* idea. (That's a technical term.) In addition to the poor rates we have been discussing above, there's the possibility that some of the restrictions on TDI funds will be too tight, and you'll wish you hadn't put your money in a place where you can't get at it. In the past, these restrictions have been imposed quite arbitrarily by the IRS, Congress, and the Social Security Administration. And we don't have a lot of guarantees that they won't change them to be even MORE restrictive.

So, whether or not you are less than 20 years from retirement, you'll want to choose your tax or investment advisor very carefully. If your adviser doesn't know about these angles, you might not want to keep him or her. You might or might not want to waste your breath trying to explain it. And you might just walk away and look for a more knowledgeable advisor.

Mr. Wiesel extolled the advantages of TDIs. The mere fact that he works for Salomon Smith Barney, who would be happy to sell you either a TDI or any other kind of taxable investment, stock, or fund, is probably not a big deal. But the principle is important.

The whole *concept* of a TDI sounds quite nice and simple. Let's say you put $1000 into a tax-deferred account THIS year. You take $1000 before taxes, and that might avoid $310 or $360 of federal taxes, or maybe $322 or $387 (Details later). That sounds like a pretty good deal.

But let's say you retire NEXT year. Then you might have an income of $20, $30, or $40K from various investments, or perhaps some consulting work or a spouse's earned income. (Or, maybe that's a few months of salary.) You decide that you want to pull that $1000 out of your tax-deferred account. Will you get that $1000 back without much taxes? Maybe, but maybe not.

I've worked through the math of this. If you actually check out your taxes, the effective tax rate on this $1000 of tax-deferred income may be as high as 35 or 51%. It's true that the higher number tends to apply if you have a fairly high income, around $40K. If your income in retirement is down below $33K, the incremental rates may be lower. But then again, they may not.

First of all, there's no such thing as a 51% tax rate, or a 32 or 39% incremental rate—is there? Oh boy, yes there is. And here's how it works.

First of all, if you are taking itemized deductions and making over $121K per year, every dollar you earn on Line 33 can *decrease* the amount you can deduct on Schedule A, Line 28, at about a 3% rate. So your effective tax rate, even though you think you're in a 31% bracket, can be 31.9%.

Furthermore, if your income is over $181K (or over $90K for individuals), the Personal Exemption available on Line 37 gets decreased by the computations on the Worksheet for Line 37. So even if you THINK you're in a 36% bracket, your effective tax rate may really be up near 38.8 or 39%.

Even when you're paying your taxes on ordinary income, the computations and rates can be pretty weird. I'm NOT saying that the tax rates are so high that it's worth a lot of effort to avoid taxable income. (Hey, back 30 years ago, the tax rates could get up over 70%. A lot of people put in a lot of effort to avoid earning taxable income because the rates were so unfair! And in England, the effective tax rates used to rise as high as 19, 20, or 21 shillings on the pound, which is an incremental tax rate of 95, 100, or 105%—rather a poor incentive for working harder and earning more income, eh?)

I'm just saying that tax rates are not as easy to compute as they would seem to be. Still, if your income is up above $120K, the taxes may be more than they seem. So any of us rich folks get gouged. Maybe that's fair; maybe it's NOT. That's just how it is. And it's not just the guys with a salary over $120K. There are other kinds of income. For example, while the tax rate on capital gains may be lower now, the actual capital gains income pushes up the sum on Line 28. So the *actual* tax rate on capital gains may not be as low as stated.

I once had a theory about people who make a LOT of $. If you make just a bit over $70K per year, you get ONE increased paycheck at the end of the year when your FICA deductions are cut out. If you make *N* times that, the time you have to wait to get a bigger check is reduced by that factor of *N*. But you can't brag about getting that bigger check, because then everybody will know how big *N* is for you. The only person you could talk to is your spouse. And I wouldn't even tell my wife, because she might think that bigger check was just crying out for her to spend it!

I once thought we oughtta have a general-purpose holiday—not to brag about getting a bigger check at any particular time, but to bemoan the fact that the bigger check goes away on January 1. This holiday should be held at a time of year when we don't have enough holidays. Perhaps November 1. But I could never get anybody else interested in endorsing this "holiday," so the idea died out.

Now, let's say you're retired or semi-retired and your income is, as I said, perhaps in the range of $32 to $50K. This isn't too farfetched. If you take $680 or $1000 out of any ordinary savings account, in which you have already paid taxes on it, that makes ZERO effect on your taxes.

But if you asked to get $1000 out of a tax-deferred account, what effect does that have? Well, you have to pay the taxes NOW because you didn't want to pay them earlier.

At what rate do you pay? It all depends. But if you're getting any Social Security income at all, you may get a tax rate of 28, 40, or 51% on that $1000. That's because you have to account for this in the Social Security Benefits Worksheet that applies to line 20b on Form 1040. And if you were getting some income from Social Security and some from a tax-deferred account, your taxes may rise very quickly—to the extent that you might wish you had not taken out that money! In other words, say Uncle Sam thinks you're already making a good bit of money, *plus* a little social security income. If, in addition, you try to access the $1000 you saved up as tax-deferred income, Uncle Sam can take away your Social Security money so fast it will make your head spin! The taxes you pay—BECAUSE of the $1000 you took out—may be very steep.

Now, if you're only making a retirement income of $32K, $22K, or less, that tax rate may not be so bad (in 1998). It might be 15%. This could actually be a good deal.

But you've all heard the joke about the astronaut who went off in suspended animation on a long space voyage. When he got home, he called up and asked his broker how much his retirement account was worth. The broker assured him that his modest savings of $99,000 had matured into $999 billion. He was elated. Just then, the telephone operator announced, "Please deposit $99 billion for the next three minutes." If you think a dollar is going to keep its value, you're indulging in some wishful thinking.

And if you think the IRS (as instructed by Congress) is going to leave our tax rates and Social Security rates alone, with only fair "indexing," for the next 10, 20, or 30 years when you'll be getting ready to retire—gee, you sure are a trusting soul. You trust the IRS and Congress to look out for YOUR best interests? Hmm...Can I sell you a bridge?

TDI Calculations And The Real Tax Rate

Why are TDIs sometimes a good idea? TDIs do NOT usually earn any higher or lower interest rate than taxable ones of comparable risk. The only advantage arises if the tax rate, when you access your TDIs, is lower than the tax rate you were paying when you avoided the tax.

My figures show that if you are retired and making $42K, and take $1K out of a tax-deferred account, the tax rate is that brutal 51%. WHY? Because Social Security payments used to be non-taxable income. But a few years back, Congress decreed that in some cases as much as 50 or 85% of your Social Security income can be taxed. And that amount *increases* as your ordinary income rises. So when you take that $1000 out of the tax-deferred account, your taxable income increases by $1000 and your taxable Social Security income increases by $850. You have to pay the 28% tax rate on BOTH the $1000 and the $850. It's not quite a double whammy—it's sort of 1.85 whammies. The total rate is 51.8%. You can round this off to 51 or 52%, as you prefer. You would never know this unless you have worked through the worksheet for Line 20b. And most people would never guess to look there until after they retire. That's why this tip is so timely. Thanks to Mr. Klabis for speaking out!

If you have an income of $32 to $40K, and you do the computations for Line 20b, the effective tax rate is probably more like 28%. If your income is $32, $42, or $52K, and you pull $5 or $10K out of the tax-deferred account, the effective *average* tax rate may be more like 32 to 42%. I'll tell you one thing: Root-canal work is less painful than trying to compute some of these tax things. Maybe this is where a tax computer program MIGHT be useful. But that's only if I'm doing 27 hypothetical tax examples. For one real example, the tax program may not be much help. I always do my taxes by hand. (I even used to use my slide rule. And I used to use simultaneous equations to compute my state and federal taxes. That may have been wrong, but nobody ever told me I was wrong.)

I think I see that if you earn your salary at high rates and plan to retire to places like Spain, Mexico, or out in the country where low income is required and the tax rates will be low, TDIs may be a pretty good idea. But if you plan to live in a city or suburbia when you retire and do a little consulting, your income may stay up in the area where the tax rates are *painful*.

BOB PEASE

Since the Social Security Benefit Worksheet and its tax rates of up to 51% are so well-hidden that almost nobody knows about them, I'd expect it to be the LEAST responsible place for me to be comfortable. I wouldn't expect my funds to get fair treatment without sneaky or vicious taxation. What do you think?

Do you trust the IRS (and Congress) to NOT change this? Do you expect them to leave it alone? Do you trust them to be fair with you? I don't even trust AARP to be a good watchdog on topics as obscure as this.

So I called up Mr. Wiesel and jawed at him about this. He admitted that maybe I was technically right, in some income situations. But he also observed, "Well, I try to give investment advice that is valid for most people." I explained back to him that when I am trying to invest MY money, I want advice that is suitable for ME. To hell with what is "OK for everybody else." I don't want to be spoon-fed *generalizations*. And to hell with whatever the IRS is trying to bamboozle me into doing.

Then on Oct. 22, 1998, on page 64X of *Electronic Design*, Mr. Wiesel came out again. This time, he recommended that you invest your retirement money using "pre-tax contributions," thereby "reducing your taxable income." Yeah, but if his ideas reduce your POST-tax income when you try to access that tax-deferred money, I am not in favor of that. I've never yet been able to convince Mr. Wiesel that I am right about this. He said that after he conferred with some experts, the *only* case he could see for any disadvantage for TDIs was in the case of people who retire and then UN-retire.

Conversely, my investment broker agrees that I am right: Every investor must question this situation. Tax-deferred investments may be wonderfully right for some people, and horribly wrong for others.

I'm certainly not going to put any significant amounts of my money into tax-deferred income, with one good exception: My company is willing to put MATCHING funds into my 401k retirement account. They put in 40 cents on the dollar to match my tax-deferred investments up to a certain limit, such as 6% of my salary. So I definitely put in about as much money as my company will match. After that, I stop. If your company will put in matching funds, along with yours, into a 401k or similar tax-deferred fund, that's probably a good idea. You should match their matching funds.

If you're getting advice from some kind of tax or investment consultant, make sure you're talking to a knowledgeable one. Make sure the consultant has good advice tailored for YOU, not just for some "average" or "typical" person. If you find some consultants who say RAP is wrong about the 51%, tell 'em that THEY are wrong and walk out. Mail them a copy of this column from a safe distance. Then find a smart advisor.

Right now, as I am 58 years old and probably less than 10 years from retirement, I'm willing to put most of my money into various other investments. Not tax-deferred. Some are risky, some aren't risky. I try to diversify to spread the risk a little. Heck, I'm having too much fun at work. I don't really want to retire, anyhow! But if I can afford to cut back to three or four days per week, that might be nice, someday. If I save my money carefully and play it right, I may be able to go trekking every year! And I might still have a few bucks left for retirement.

I have never yet used the services of a good tax man, but that may change. I may want to DISTINGUISH between my business as an author and my business as a publisher and bookseller—not to mention my business consulting as an engineer. Hmm. Now THIS sounds complicated. Will I have to incorporate four times? Naw, I'm told that, "Piercing the corporate veil" is not a big deal, these days!

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Note: All numbers refer to published 1997 or 1998 tax rates, and most are for a couple filing jointly. All bets are off for any future years. I am not able to comment on your state tax policy.

BOB PEASE

Bob's Mailbox

Dear Bob:

Your characterization of Bipolar illness and Mania missed the mark a bit (ELECTRONIC DESIGN, *Dec. 1, 1998, p. 131*). These problems are not merely attitudes that are somehow a little extreme; these problems are real neurological malfunctions. Mania is not just a spate of enthusiasm and energy. It can be a very difficult situation for those subject to its influence—the person with the illness, as well as their friends and family. In some ways, the disease could be likened to bipolar transistors—without current-limiting resistors or any feedback. This situation may be O.K. for a switch, but totally unstable, thus very lousy for any other application. *(Sounds like me! /rap)*

Not all mania is fully modulated "to the rails." But as manics approach full modulation, they can be a total nuisance, calling everywhere in the world at all times of the day and night *(I just spent $160 calling around the world "day and night" because some IDIOTS wouldn't answer their phones. /rap)* and spending huge amounts of money on illusory projects and grand schemes. *(I just spent $25k on my new books. /rap)*

And all the while they are saying over and over and over again, "I'm doing great! I'm feeling fantastic! I'm on top of the world! I'm so good you just don't understand." *(Sounds like me! /rap)* The problem with mania is that unlike other diseases, where the patient feels sick and may want to do something about it, the manic feels wonderful and does not want to do anything about it. Even when their friends and family start cutting them off, blocking their phone calls, or getting restraining orders against them, they will insist that the problem is not them. It is everyone else.

Typically, this will go on until the afflicted person starts coming down, or they crash into a brick wall at 170 mph, complaining about how slow everyone is. Of course, not all manics crash at 170 mph. Some crash at 125 mph while others cruise along happily at 90 mph, being only a bit "eccentric," if not a little trying, to their community. *(Sounds like me! /rap)*

Unfortunately for us, mania tends to afflict those with sharper minds—doctors, lawyers, and engineers—more often than the general population. Medication exists, but the afflicted are typically not interested in taking a pill that feels like a sedative to them. So it is usually only under extreme duress that a manic will commit to medication. Fortunately, there is help. There is an international support group called the Depressive and Manic Depressive Association (DMDA); (800) 826-3632.

...While they cater to the afflicted, I found that as a family member who has dealt with a manic sister for the last decade, attending a few meetings was extremely helpful to me...I recommend that anyone remotely interested in the complaint, or anyone who feels that they might have a glimmer of mania or depression, take two hours out of an evening and attend. I have been trying to get my sister to attend, but she is way, way, way too busy. Besides, she has heard everything about it already. In fact, she is a real expert in the subject. She is going to become a counselor for those with the problem. She will be the president of a BETTER national organization that really takes the issue where it needs to go. My heartfelt sympathies for your readers who have this illness or family members with it. Hang in there, you are not alone.

MIKE S.
via e-mail

Mike, though my explanation was perhaps imperfect, I'm trying to increase awareness of some CURABLE diseases.—RAP

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BOB PEASE

What's All This Book Stuff, Anyhow?

Before getting into the books, it's time to catch up with a bit of flooby-dust. I should mention that when I wired up the horn-chopper to my horn, I just threw in a couple yards of light hook-up wires (22 gauge) that were sitting around the house. After a while, the horn was not sounding very loud. I bought a new one, but it sounded poor too. I did some checking and found that there was a lot of I ↔ R drop in those thin wires. I actually began to think, hey! The horn was really trying to draw 10 A before it would start to make any sound. Thin wires would hardly let it get started. So I replaced the wires with heavy wire and it works a lot better.

I still haven't found any reasonably priced, 1/4-in. electric drills for sale anywhere—not even in England or India. Maybe my buddy Noah can spot one in China? Surely, they would not be in on the conspiracy to deprive us all of light, inexpensive, high-speed drills....

BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

When I gave the problem of how many cylinders can touch each other in my "April-Fool Stuff" column (ELECTRONIC DESIGN, *April 6, 1998, p. 144*), I had a pretty good solution with seven cylinders. Mr. X had a good solution with EIGHT. Then Ben Grezlik showed me a solution with 10. He found a valid solution because I never stated that the cylinders were all the same length or diameter. So he threw in a couple skinny ones. Elegant! I think it was Mr. Grezlik who also pointed out that if you cut a solid donut with three cuts, you can get 13 pieces. But if you cut a toroidal SHELL, you can get 14 pieces. Sure enough, he's right again!

Steve Scrupski pointed out a web site where one can buy a videotape about guys who know how to provide "alternate energy." You can take a look if you want to at *http://shop.pbs.org/mAfp4AAvu5/products/A3459/*. It refers to several men whose "new and unique views on energy... are changing the way we think and live." One guy "has taken the lead in developing...inventions that produce power from the heat in the air." Another creates "electrical systems that produce more power than they consume." An alternate phrase for that is "over-unity magnetic machines," or antigravity. Not to mention "scalar-potential electromagnetics." If you want to spend $119.95 to see a bunch of HOAXERS peddling their perpetual-motion machines, be my guest. Meanwhile, I'm ashamed of PBS for promoting this.

Now, down to the main topic—books. I did a good job of recommending the book on Analog Design by Dennis Feucht. It was such a good job that he sold out of them and the book is now out of print. *Sorry*. Likewise, the 1991 book by Ian Sinclair about *Passive Components* (Butterworth-Heinemann) was quite good, but it too soon went out of print. I'll say nothing about MY old books except that you can access them at my web pages. You'll see at the end.

Here's a good LITTLE book: *Controller Tuning and Control Loop Performance* by David St. Clair. I still think my column on this, "What's all this PID Stuff, Anyhow?" (ELECTRONIC DESIGN *Analog Supplement*, June 26, 1995, p. 57) is the best primer. But *this* book goes beyond that and talks of practical applications with conventional "PID" controllers. It's about 88 pages. Send $12 to Straight-Line Control, 3 Bridle Brook La., Newark, DE 19711-2003.

If I could recommend a good book on fuzzy logic (FL), I would. But I haven't found one. I will cite another case where FL may be appropriate: optimizing the operation of a big generator. We might assume that an electric generator is a fairly linear critter. But when you push it up near its maximum ratings, it starts getting nonlinear. Since there are a LOT of big generators, and each one generates its product at a rate of thousands of dollars every day, the effort may be justifiable if FL can make even a small improvement. An auto-tune PID controller, however, might also do. The jury is still out.

Here's another big, practical book: *Designing with Motion Handbook*. Featuring good, practical examples, this one's more for people with large, high-tech, serious servo or motion-control problems. It's by Chuck Raskin at Tech 80, 658 Mendelssohn Ave., Minneapolis, MN 55427. At around 400 pages, it costs about $50.

An even bigger, deeper book by Isaac Horowitz is for serious and analytical feedback-control work. Most of it goes over my head. There are lots of root-locus theory, matrices, and convoluted charts in its 489 pages. I'd say *Quantitative Feedback Theory* is for experts only. It'll cost you $40 for ISBN 0-9635760-1-1; QFT Publications, 4470 Grinnell Ave., Boulder, CO 80303.

Making Printed Circuit Boards is a good basic text on how to design and make your own boards. It covers both old-fashioned paste-up and modern computer-generated procedures. And it recommends the proper disposal of any chemicals. About 327 pages, it costs $22.95. Contact Tab Books (McGraw-Hill) for ISBN 0-8306-3951-9. Oh yeah, the author is Jan Axelson.

Richard Jaeger wrote a very good book on *Microelectronic Circuit Design*. About $99 and 1120 pages, it's listed under ISBN 0-07-032482-4. It covers analog AND digital circuits. But it does not say much about layout, which—as I said in "What's All this Common-Centroid Stuff, Anyhow?"—is fairly important (ELECTRONIC DESIGN, Oct. 1, 1996, p. 91). I think Prof. Jaeger is working on some notes on that topic.

A great READ is *The Invention That Changed The World* by Robert Buderi. It tells how a small group of radar pioneers won the Second World War and launched a technical revolution. Lots of anecdotes and insights on

BOB PEASE

the inventors of radar back in the 1930s and '40s. It's 575 pages, about $16, and available through Touchstone (Simon & Schuster); ISBN 0-684-83529-0. It took me all the way from Delhi to LAX to read it.

Set in the same time frame is *Endless Frontier: Vannevar Bush, Engineer of the American Century*. I really want to read this story about an EE who swayed the world. Bush ran the R&D operations in the U.S. during World War II. Also, he founded Raytheon. It got a good review in IEEE *Spectrum*, and I'm going to buy it (ISBN 06848-28219; $32.50).

One guy suggested I read *The Ropes to Know and the Ropes to Skip* by R. Richard Ritti. I read this all the way from LAX to Bangkok. If you want to know all about office politics in a traditional old company, you might get your librarian to buy this. But for a modern company, much of the old office politics are different from the stuff Ritti outlines. Reading this the week my book was being printed, I was very favorably impressed that this book had zero PRINTING errors. You see, it was printed by Malloy Lithographing, Ann Arbor, Mich.—the same printers I contracted with—and they printed my book with zero printing errors, too!

If you're ever interested in writing a book—even if you are not planning to self-publish—you'll want to read *The Self-Publishing Manual* by Dan Poynter. It's $19.95 and about 460 pages from Para Publishing, Santa Barbara, Calif.; ISBN 1-56860-047-X. I learned just about everything necessary to write my own books and then promote them. Even if you have a good publisher, you'll want to understand how many things that person has to do to promote your book well. If you have a *bad* publisher, this book will indicate what *you* have to do.

I got *Dumbth* by Steve Allen. He's written a thoughtful and serious *and* humorous *and* sad book on how thinking is good for you—"101 ways to reason better and improve your mind." It's 445 pages and about $20 from Prometheus Books; ISBN 1-57392-237-4.

If you grew up in the 1940s, as I did, you'll be impressed by *Raised On Radio* by Gerald Nachman. It's about $28.50 and 536 pages from Pantheon/Random House; ISBN 0-375-40287-X. Not quite an encyclopedia, this is a very affectionate review of the glory days of radio. He won't let you forget that the pictures are better on radio. People younger than 45 or 50 probably would have little interest in this.

In my older column on "Tech Reading" (ELECTRONIC DESIGN, *March 7, 1994, p. 85)*, I recommended Geoff Harries' book *ChronDisp I—The Gun From the Past*. It's about $4.00 on a floppy. Now it's printed on PAPER—imagine that! It costs about 20 Deutschmarks for ISBN 3-933523-30-3; AAL Paperbacks, Diesenhofener str., 79C, D81539, Munich, Germany. I hope he enjoys enough success with it that he can bring out ChronDisp III; I think that will make a GREAT movie. Though he's selling the book in Germany, it IS in English.

Come to think of it, there are three new books out on troubleshooting. My old book used to be the clear-cut best, but now it has to share the spotlight with the French, Dutch, and German translations of my original. Any engineers who are most fluent in those languages, should check the web sites at: *www.elektor.presse.fr/bf10903.htm* ("Un coup ca marche, un coup ca marche pas"); *www.elektuur.nl/bn10889.htm* ("Voorkomen is beter"); *www.elektor.de/bd60595.htm* ("Troubleshooting in Analogschaltungen"). The minor drawback is that you have to pay in Francs (249 FF), Guilders (Hfl 74), or Deutschmarks (DM 69,00 or sFr 62,50). But if you live in one of those countries, that should not be a problem. Or, ask your local bookstore to order for you.

I almost forgot a new version of my book, CD included, put out by Interactive Image Technologies. The CD includes all of the circuits in my troubleshooting book. It's good for students. If you like Interactive's "Electronic Workbench," go to *www.interactiv.com*. If you already have my book, you can buy the CD for about $10. Let's not forget John Trudel's *Engines of Prosperity*. See the book at his site: *www.trudelgroup.com*.

All for now. / Comments invited!

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BOB PEASE

Bob's Mailbox

Dear Mr. Pease:

Many thanks for your insightful column on the marginal tax rates on tax-deferred investments. A few years ago (just after Bill Clinton's biggest-ever-in-history tax increase), I suffered a similar tax-torture when I withdrew some money from a tax-deferred account before the age of eligibility. I needed the money fast, because I had a chance to buy a small summer cottage at an attractive price—but only if I could come up with the money down within a few days. It was just another investment, really. At the end of the year, I chugged through the tax calculations for the "with withdrawal" and "without withdrawal" cases and discovered (much to my shock and horror) that my marginal rate (Federal, State, and penalties) on the withdrawal was over 60%! (At the time, I was living in a high-tax northeastern state.)

ANY other way to finance my purchase would have saved me a lot of money. What I should have done is taken some kind of personal loan, made the purchase, and then later refinanced the cottage with a 90% mortgage. This would have actually DECREASED my taxes! Instead, I was absolutely hammered.

So it turns out that the tax-deferred investment is a sham for most people, no matter how you look at it. If you ever need to withdraw money BEFORE eligibility you get slammed, and if you withdraw money AFTER you are receiving Social Security you get slammed again because it reduces your benefits. I guess there is a brief window between 55 and Social Security in which you can withdraw money and pay only your "normal" marginal rate, whatever that may be.

Which brings me to the real point in all of this. People talk a great deal about the long-term funding problems of Social Security. The whole argument gets bogged down in the discussion of whether Social Security should be funded only by FICA taxes or out of "general revenues," and whether Social Security benefits should be taxed or not, and at what rate.

I don't know about you, but when the money's gone from my bank account, I don't really give a hoot where the government says it went. It's gone, and I know it's not coming back. People who work hard, make some money, save, and invest (over a lifetime) can be pretty sure they are never going to see much from the payments they made to Social Security. Meanwhile, the people who didn't accomplish much and never saved a dime can be pretty sure they will receive 50 times what they "contributed."

I wish all the politicians and pundits would play it straight on Social Security and call it what it is: welfare for poor people over 65. If we could all acknowledge that Social Security is just welfare for older citizens, then we could make some rational decisions about eligibility and funding. As things stand, most people don't understand what Social Security is, nor how it works. So rational discourse about funding and eligibility is just about impossible. Please keep poking holes in the nonsense!

STEVE FITZPATRICK
via e-mail

Steve, thanks for reminding us about the penalties for early withdrawal. That's one more place you can get hurt if you don't understand the rules BEFORE you start playing. Other people have similar comments. Short-term capital-gains taxes are much heavier than long term. You have a chance only if you plan ahead and learn the rules.—RAP

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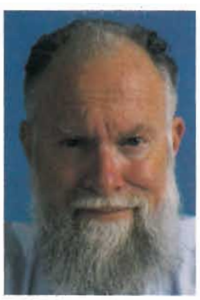
BOB PEASE

What's All This CD4007 Stuff, Anyhow?

I am slow, dumb, STUPIDO. However, the sudden cessation of stupidity is worthy of some mention. I knew about CMOS circuits in the 1970s. I even designed a CMOS operational amplifier back in '74. It used about 15 transistors to run on ±5-V supplies and provide a gain of 10,000. At the time, several engineers looked at my two-stage, cascoded differential amplifier and asked, "Why do you make life so complicated? Why don't you just use TWO transistors of a CMOS inverter for an op amp, like everybody else does?"

I explained that the PSRR of a CMOS inverter was about 24 mV per 1% shift of either supply, and in a real system, that was unacceptable. Maybe 1/2 mV per 1% was tolerable. Further, if V_{TN} changed by 0.09 V, and V_{TP} changed by 0.11 V, the "offset voltage" of the 74C04 "op amp" could change by ±0.2 V—an obvious disaster! Not to mention the power-supply drain that could vary all over the place!



BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

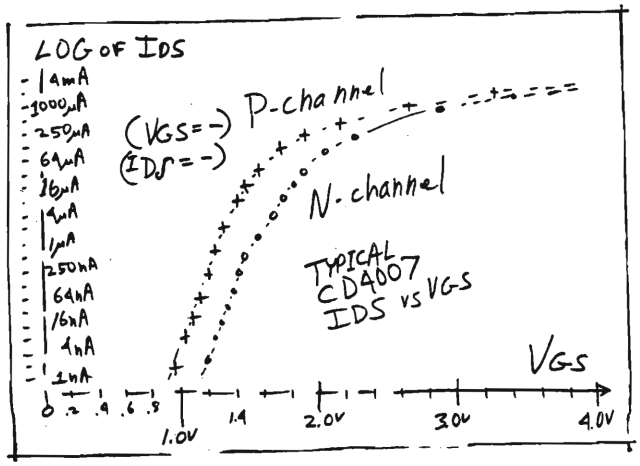
So my critics had to admit that differential amplifiers had advantages versus dumb inverters. This op amp went into the Teledyne Semiconductor 9400 analog to-digital converter with 8-, 10-, or 12-bit resolution. Yes, there were DVM chips out earlier than 1975, but that was the first ADC *characterized* as an analog-to-digital converter (NOT as a DVM). I designed this along with Frank Jones. It used the basic 74C CMOS process that Teledyne had licensed from NSC. While Philbrick had the right to sell this ADC, they declined to do that in 1975 when it came out. The Philbrick marketing people argued that the approval of this project had only been OK'd by some previous marketing guy.

Recently, I was trying to design a little oscillator to run on 1.2 V with very low power drain. Of course, bipolars can do this. But why can't CMOS do it, such as a CD4007? The *CD*4007 has been characterized as a *C*MOS *D*igital IC for what, about 30 years? Obviously, it's not an analog IC. If you want to read about an analog CMOS circuit, you should obviously read AN-88 in NSC's CMOS Databook. (Hey, don't waste your time. It mostly tells you how you can use a 74C04 as an op amp.)

Now we all know that digital ICs are built of DIGITAL transistors and analog ICs are made of ANALOG transistors, right? Wrong. I cannot believe how stupid I've been. The transistors in the CD4007 would be perfectly useful as FETs in analog circuits—if they were properly characterized. Unfortunately, most of the characterization of the CD4007 is: As an inverter, how fast is it? And how many mA can it drive?

But that's not very useful. The proper question is: How many millivolts does it take of V_{GS} to get an n-channel to put out 0.1 or 1 or 10 µA? That's because MOSFETs are pretty good at doing this.

Everybody knows that FETs are characterized by the threshold which causes the FET to put out $I_D = 1$ µA. So currents below 1 µA are sort of imaginary, right? Wrong. Everybody knows that FETs have a square-law characteristic. As the current gets smaller and smaller, the g_m per microampere keeps rising to very high levels. Wrong again.



The g_m per milliampere rises, but tapers up to levels such as 90 or 120 mV per decade. These transistors behave exponentially at low levels, just like bipolars.

I took data and got some curves on various CD4007s. National doesn't even sell them. Fairchild makes them, and so does Harris, Motorola, and a few other guys. Can the CD4007 be used for pretty good analog designs? I bet ya! I plotted V_{GS} versus the I_D at various levels. I may even be able to get some data on matching. The figure shows plots of the LOG of I_D, from 1 nA to 2 mA versus V_{GS}, for the n-channels and the p-channels of the CD4007. THESE plots have never been published for the CD4007. They will permit analog circuit designers to use the CD4007 for real analog circuit designs. These designs may get good micropower results, even with good output drive. We'll use some high-megohm resistors...etc.

Can these circuits run on 1.5 to 1.2 to 0.9 V of supply? Not very well—the threshold voltages are too big. But you can use CD4007s with 3 to 5 V and, if you plan right, even down to 2 V. Will these threshold voltages and V_{GS}s move around ±0.1 or ±0.2 V? Sure, but these FETs will still be usable for analog circuits if you design thoughtfully!

All for now. / Comments invited!

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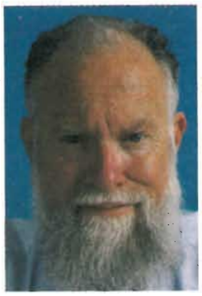
BOB PEASE

Dear Bob:



I want to make a comment on your article, "What's All This Tax-Deferred Stuff, Anyhow?" (ELECTRONIC DESIGN, *Feb. 22, p. 113*).

I just completed my 1998 tax forms, and there is yet another financial vehicle that deserves a skeptical eye: variable life annuities, which are marketed by life insurance companies and fraternal organizations. My wife was the beneficiary of a couple of these annuities during 1998, when her mother passed away. This was a gift, but an inheritance that came with a tax bill.

You see, my dear old mother-in-law was sold on the tax-deferred growth idea by a couple of fraternal organizations. They promised her tax-free growth on her investments and that, upon her passing, these instruments would "pay like life insurance" to her designated beneficiaries. What in fact she bought was a mutual fund with sales commissions and insurance charges eating away at the gains, and yes, tax deferral. The dear old woman watched with great apprehension as these variable life annuities rose and fell with the stock market.

The things that sold her on variable life annuities were the slick salesmen and the illusion of tax-free growth. For you see, Bob, when they pay out upon the annuitant's passing, they come to the beneficiaries with a 1099-R that is taxed as ordinary income. In the case of my wife and I, we were pushed into the 31% federal bracket, lost our 1998 child tax credit, and lost some of our schedule A deductions as a result of this spike in our taxable income. The actual incremental tax rate is more like 35 to 40%.

I'm not complaining too much. It was a gift from one generation to another. But my dear old mother-in-law would have passed on more wealth to her kids and grandkids if she would have simply put her money into T-bills and paid her 15% taxes year by year. Furthermore, she would have lowered her stress level by not participating in funds that fluctuate wildly. There are two folks who would disagree with me—the salesmen that earned a tidy commission for themselves when they sold a pensioner these variable life-annuity contracts. I will approach tax deferral with greater caution, and will avoid variable life-annuity contracts as I plan my own investments.

SCOTT BAER
via e-mail

Gee, Scott, there sure are a lot of tax-related ideas that don't give the advantages they are claimed to, eh?—RAP

Dear Bob:

Re: "Prediction Stuff" (ELECTRONIC DESIGN, *Jan. 11, p.129*).

1. Standard analog video is phasing out so that the TV receiver industry and suppliers can make more money selling us resolution that we don't need to watch drivel we can't stand. Your 13-in. TV will still work, but there may be no more live source material.

2. Thanks for the tip on Alphasmart. It may well fit my travel documentation needs, as well as the note-taking needs of my son, a college student.

3. Lastly, in five years I'll be driving a 1974 BMW. I've been driving it for 25 years and over 0.3 million miles. That's how I pay for #2 above.

DENNIS SEGUINE
via e-mail

I notice Sony and Mitsubishi and four other manufacturers are selling ANALOG TVs costing $1200, $2300, $3600, and up. I'll be greatly amused when they try to tell these guys that their "nearly new" TV sets have to be junked, or else they have to spend $750 on a set-top box. Can you see a FIRESTORM of complaints? I can. We agree on Alphasmart.—RAP

All for now. / Comments invited!
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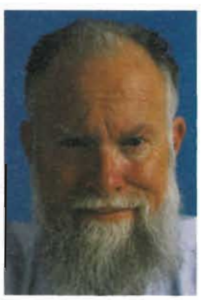
BOB PEASE

What's All This Julie Stuff, Anyhow?

In March of 1992, I went with Frank Goodenough (now deceased) of *Electronic Design* magazine to interview Loebe Julie of Julie Research Labs. Then, Julie was at his old offices on 26th Street in New York City. We really went just to visit, but we asked a lot of questions about "how things used to be" and "how things got the way they are." Fortunately, I brought along my little camcorder, and we recorded about 2 1/2 hours of conversations.

Mr. Julie was, even then, an old-timer. I remember his company as being a staid, conservative company selling high-precision, high-quality resistors back in 1970 when I first did business with them. And here it was over 20 years later.

Parenthetically, I should explain that Julie Research Laboratories has been making some of the world's BEST resistors since the 1950s. Mr. Julie himself is the holder of some 30-plus U.S. Patents, mostly on the design and manufacture of ultra-precision, ultra-stable (1 ppm) wirewound resistors—as well as 1-ppm-accurate dc standards and calibration instruments. (I bought a lot of Julie's 1-Ω and 10-Ω, 0.005% wirewound resistors in four-wire configuration to put in some precision measurement systems. I am sure they are within spec to this day.)



BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

Since Frank and I had always worked a lot with operational amplifiers, we asked Mr. Julie what he could tell us about the early days of op amps. Julie explained that in 1941, he was hired by Professor Louis Ragazzini at Columbia University, New York, N.Y., to do research on analog computers and operational amplifiers. At that time, there was much interest in research for automatically aimed anti-aircraft guns. The war in Europe was in full swing, and the British military forces had a great need for a gun-aiming apparatus (a "Gun Director") that could shoot down enemy bombers. The U.S. Army was very interested in this, just in case the U.S. came into the war. (The U.S. Army also was interested in high-accuracy navigational aids for bombing enemy targets using first-generation guided missiles. But that came rather later....)

The tacit situation—a whole family of vital military secrets—was that a radar had been developed that permitted the U.S. and British ground forces to read the position and elevation of enemy aircraft. If a Gun Director could be made to use this information and aim the guns automatically, enemy planes could be shot down *without anybody ever seeing them.* Since many bomber attacks came at night or in bad weather, this was quite important. Of course, a computer would be needed—a fast *electronic analog computer.*

In those days, George A. Philbrick was a researcher in analog computers that used operational amplifiers. He believed that he could build a Gun Director that could automatically aim the guns, given the basic information. It would just have to LEAD the incoming planes by the proper amount. George had done a lot of study on this.

In those days, operational amplifiers *did* exist. But they were extremely large, bulky, and SLOW. They needed six or more vacuum tubes, and at least three regulated power supplies (+300, –250, and –400 V dc). That's not to mention about 20 W of heater power. And they had a frequency response of about 10 Hz. They had high dc gain, but were stabilized with *very heavy* damping. Thus, they were perfectly suitable for laboratory research and slow analog computers. But they were NOT good at all for real-time computing. I have tried to find out the schematic diagram for these older operational amplifiers, but haven't yet been able to get one. Maybe later.

Loebe Julie, a young electrical engineer of 22, had recently graduated from the College of the City of New York. He thought he could design an operational amplifier that would be a lot smaller, a LOT faster, and with much less power-supply needs. And he believed he could design it quickly, and it would be easy to manufacture after it proved useful. Professor Ragazzini was very negative, and didn't want Julie to try it. But there was a great need for this, as the U.S. could see the clouds of war approaching. Loebe told us that Philbrick, who had some authority and reputation in the field, intervened because he really needed this improved operational amplifier. And off they went.

Julie designed and built a simple, compact (3-in. by 4-in. by 7-in.), modular operational amplifier using two twin triodes similar to the 6SL7GT (which is a high-mu triode similar to the 12AX7). The first stage was differential with balanced plate loads. The output of that stage was coupled through resistive level changers down to the grids of the balanced (differential) second stage at –150 V. The output of the second stage was plate-loaded, and could swing ±75 V. I'll show you the schematic in a future column. And there will be some interesting stuff on what's involved in trying to design a tube op amp nowadays.

The damping was fairly light, and a well-behaved gain-bandwidth product of about 100 kHz resulted. While 100 kHz doesn't sound like a lot, note that in real time, the small-signal step response of a unity-gain inverter could be as quick as 5 μs. So this quick amplifier was the heart of the modern high-speed analog computer. And its power-supply requirements were quite modest, just + and –300 V at 10 mA, plus 5 W of heater power. Consequently, the power supply for a large array of operational amplifiers could be quite small and simple.

BOB PEASE

A batch of 50 copies of Julie's prototype amplifiers, assembled on little aluminum brackets, was wired up quickly. A set of six was provided to the Analog Computer section. In a short time, the M-9 Gun Director was completed and tested. Its demonstrations worked very well, and it was rushed into production. When the M-9 was put into service in England and connected to the system of radar receivers and the anti-aircraft guns, it was quickly put to the test.

When enemy bombers were detected approaching through heavy clouds, the M-9 automatically aimed and fired off the guns. To the amazement of many and the delight of all, enemy bombers began falling out of the clouds! Needless to say, the priority for getting the M-9 Gun Directors into service was redoubled.

After the war, Ragazzini published a paper (Proc. IRE about 1946) explaining how HE had designed the operational amplifiers. In the paper, he took most of the credit for many of the ideas in the M-9 Gun Director. Mr. Julie's name was listed among the contributors, but no proper credit was given. Alas! Publishing procedures and credits for contributors have changed since then—but just a little!

Meanwhile, Philbrick got many of Julie's ideas (which Julie had put in the analog computer) from Henry Paynter. These were amplifier applications circuits for high-speed summing and integrating, as well as the design of stable differentiators. So Mr. Julie must be credited as a major contributor to the invention of the modern high-speed analog computer.

I have seen a picture in the book by Robert Buderi, *The Invention that Changed the World.* This excellent 588-page book explains how radar was extremely valuable in offsetting the military strength of the Axis powers and winning the war. There is a sketch of an M-9 Gun Director on page 133, and some mention of its schedule of completion in late 1942 on pages 132-134.

As the design of the M-9 was outside the purview of that book, no mention was made of Loebe Julie or George Philbrick. But photographs of the M-9 Gun Director show a heavy oblong assemblage enclosed in a heavy metal military-type housing perhaps 3 ft. by 4 ft. by 6 ft.—all on a four-wheel trailer. How many op amps inside? Perhaps a dozen? The original design, as implemented at Columbia, was much more compact. But the fact that it really worked, after all necessary militarization, was nothing short of miraculous.

I recently read a good book by G. Pascal Zachary, *Endless Frontier—Engineer of the American Century.* The book's all about Vannevar Bush, who was the director of the National Defense Research Council (NDRC) during World War II. Was there much more information in this book on the M-9 and its design? Not really in detail. But on page 135, it talks about, "...February 1941, when physicists had begun to build gunlaying radar whose aim was to automate the tracking of enemy targets. Once picked up on the radar screen, the target would be tracked automatically and the necessary information fed into the anti-aircraft gun."

When you can measure what you are speaking about, and express it in numbers, you know something about it...

"If this wasn't incredible enough, the device would automatically aim the gun, too. At the end of May, the tracking system was demonstrated on an airplane (flying overhead). And in December (1941) a truck-mounted system was shown off. Adopted by the Army, the system, dubbed SCR-584, was used virtually unchanged throughout the war.[43] (Rigden pp. 133-145.)." The M-9 was the heart of the SCR-584 system.

Mr. Julie believes that much of that paragraph by Zachary was correct. But he recalls very well that this work started after Pearl Harbor, in Dec. 1941. The actual time of development was probably a year LATER than the schedule listed by Zachary. This is then in good agreement with the timetable listed in the Buderi book.

After the war, Philbrick took the basic Julie operational-amplifier design and revised and developed it into the familiar "K2-W" operational amplifier, which he incorporated into many of his analog computers. The K2-W didn't have a differential second stage, but a single-ended second stage followed by a cathode-follower output buffer. But it had many features of the original Julie operational amplifier. So Julie still claims to be the inventor of the modern operational amplifier, and I believe the results bear out his claims.

After the war, Julie went into the business of manufacturing precision resistors, which are essential in many high-precision instruments. A major need for precision resistors was in inertial navigation. The specific accuracy of an inertial guidance system depends on the integrators. They tell you how fast you're going and how far you've gone. Integrators require excellent resistors.

Julie's best resistors went into the best inertial guidance systems—as needed for national security—in navigation systems for bombers and Inter-Continental Ballistic Missiles. In the 1950s, most "precision wirewound resistors" were not really very accurate or stable. They had barely 0.03% short- or long-term stability, due to improper manufacturing techniques, poor choice of materials, and stress sensitivity. Julie's patents teach many improvements in this art.

Julie Laboratory Standard resistors also went into large and precision electronic analog computers. They were used extensively in the 1-ppm precision voltage-measurement systems (potentiometers). These were used to calibrate the accuracy and confirm the performance of the early accelerometers and inertial guidance systems.

As Lord Kelvin stated 100 years ago, "When you can measure what you are speaking about, and express it in numbers, you know something about it..."* In many cases, imperfections and inaccuracies of inertial guidance systems weren't even *noticed* until high-accuracy measurements were made. Hughes Aircraft was buying some Julie equipment to confirm that some of the Hoffman Reference Diodes they were buying were holding better than 0.01% stability. Julie pointed out that many of the diodes were drifting more than 0.03% per day, a fact not previously known.

BOB PEASE

A recent book by John MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*, covers many aspects of the design of inertial guidance systems from the 1940s to the present time. This book "talked all about accuracy." It talked all about the need for precision designs and components. It talked ALL AROUND the precision resistors. But it didn't go into the actual precision resistors, nor did it provide any mention of Julie's designs and patents or his essential contributions to the development of inertial guidance.

Fortunately, after I brought this unfortunate oversight to his attention, Mr. Julie is writing up notes to give some balance and insight into the importance of his precision resistors in the development of inertial guidance systems.

Since designing a large amount of precision *automated* test-and-measurement equipment in the 1980s, Mr. Julie has more recently been active in designing high-resolution (20-Mpixel by 12-bit by 3-color) computerized photographic-image editing systems. He has largely recovered from a stroke that slowed him down a couple of years ago. Shortly, we hope to see an exhibit of his work at the Smithsonian Institution, Washington, D.C.

So Loebe Julie is a spry old-timer, indeed! You can pronounce his name, "LOWB" (preferred)—or you could call him "LOW-BE"—either way is acceptable to Mr. Julie. Just don't call him late to supper.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer
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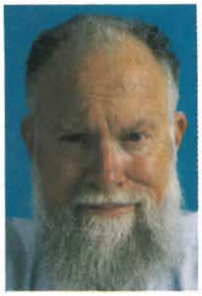
* "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of *science*."—William Thomson, Lord Kelvin, 1824-1907.

BOB PEASE

Bob's Mailbox



Hi Bob:

I don't know if you can count on five more years of service on your low-mileage camcorder. We have one engineer here who had several intermittent problems with his camcorder and took it to his fix-it buddy. His buddy said that the Sony camcorders typically failed from leaking surface-mount electrolytic caps. His buddy said it wasn't worth having fixed. Well, this engineer, seeing the possibility of saving some money and fixing it himself, took his camcorder apart and replaced all of the surface-mount electrolytics with tantalums. There were about 100 caps on various boards, under shields, and in some hard-to-get-at places. When replacing them, he found that at least 50% of the caps had visible signs of leakage. As I was saying, he replaced them all and put his camcorder back together and now it works again. He has been using it for about two months (new baby) and it is working fine.

Well, he mentioned it to me, and I have a Sony that is eight years old. Mine had failed about a year ago, after increasing problems. So, I brought mine in and took it apart. Sure enough, same thing: 50% of the electrolytics on the outer board had visible signs of leakage. We did the same for a third engineer who had a five-year-old camera that had failed—same cap problem.

We are in the process now of scrounging up samples of tantalums to try to fix the other camcorders. Hopefully, we will get long life out of the repaired camcorders with the tantalum caps. I don't hold much hope for you getting five years out of your "like new" five-year-old camcorder. Hopefully you will see; time will tell.

KEVIN CAWLEY
Keithley Instruments
via e-mail

Hi, Kevin. YOU could be right. Replacing electrolytics, two by two, is not my idea of fun. Maybe keeping it COOL will help. Here in California, in SF, our house runs pretty cool. Thanks for the caution.—RAP

Dear Bob:

Thank you for pointing out the hoaxers who promote the "alternative energy" theory. I find those promoting "scalar-potential electromagnetics" to be especially offensive. I have yet to see a paper on this subject that would be acceptable for publication in a physics journal.

I also agree that "inventions that produce power from the heat in the air" are complete and utter nonsense. However, there is a toy that does indeed derive its energy from "heat in the air." I'm referring to the familiar "drinking bird."

The drinking bird is actually a glass tube with bulbs on both ends. The tube is mounted on a stand so that it can swing freely between a vertical position and a horizontal position. The tube contains freon so that the bottom bulb is filled with freon when the "bird" is in the vertical position.

The upper bulb (the bird's "head") is enclosed in a sponge material. An attachment to the upper bulb forms the bird's "beak" and is enclosed by the sponge. If the sponge on the bird's head is wet, the upper bulb is cooled, which causes the freon in the bottom bulb to rise in the tube. This, in turn, causes the tube to tip over into its horizontal position.

Two things happen when the bird is in the horizontal position. First, the bird's "beak" dips into a cup of water placed next to the toy. This serves to keep the sponge wet. Second, the freon flows back into the lower bulb, causing the bird to return to its vertical position.

This entire process repeats itself indefinitely, as long as the cup of water is refilled regularly. I have kept a drinking bird going for several weeks at a time (until I forgot to refill the cup).

The energy to keep the bird swinging and drinking comes from the air. It is through collisions between air molecules and the moisture on the bird's head that the upper bulb is cooled. Therefore, there does exist a device that derives its energy from the "heat in the air."

JOE LEBRITTON
via e-mail

Hello, Joe. One MIGHT say this runs on the heat in the air. But if you put a big glass bell jar over the engine, the water vapor under the cover will soon be at equilibrium. Then it will poop out. It only runs—should I say—by the "coolth" in the air. Or, if you brought it to a warm or humid climate, it might quit. Right?

I'm amused that people say this runs on the energy or heat in the air, because one could just as logically say it is an engine that runs with water for fuel. Of course, the energy you could pry out of it is comparable to the energy that it takes you to fetch the water!!! Eh? Most of those papers are not just unsuitable for publication in a refereed journal. They're useless—except in comic books and science fiction.—RAP

Dear Bob:

There is a lot of difference between mouse switches in the amount of push resistance and "ping" on contact and release. I've noticed these characteristics can vary even with the same make and part number of switch, so I suspect it is from manufacturing tolerances. The "ping" is so bad on some mice that they have made my finger numb with a lot of use. I've tried out whole series of display samples in computer outlets and I found no correlation between expensive or cheap units.

When I find a mouse on display that I like, I then try the boxed unit. There is no correlation there, either. I guess the manufacturers either don't know/care or aren't capable of making consistent switch/damping designs.

BERT LONG
via e-mail

I'm not a big fan of mice. I sure believe what you say; thanks for the warning.—RAP

All for now. / Comments invited!
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BOB PEASE

Bob's Mailbox

Dear Bob:

Re: The letter on "Tax-Deferred Stuff" by Scott Baer (ELECTRONIC DESIGN, *April 19, p. 89*). Scott's dear old mother-in-law could have gone to see an attorney who specialized in "trusts." A "will" is not enough, because Uncle Sam will take all of the inheritance taxes from him. It would raise his tax bracket, as well. With the "trust," he gets a 100% tax-free gift inheritance from his mother-in-law. It is sad that the public doesn't know the difference between "trust" and "will." However, it is a good time for anyone else to start NOW. Get an attorney to prepare all of the trust legal paperworks at a reasonable attorney charge (average $1500). *(It's a dirty, nasty job, but somebody has to do it—explain how you need a trust to keep from getting screwed by these inheritance deals. The new relaxed tax games for inheritance make it sound like people who don't have a million dollars don't have to worry about this stuff. WRONG!! /rap)*

I agree! I learned about this through a seminar last year from an attorney who lectured all about the difference between "wills" and "trusts." I was totally shocked! I always thought a will was good enough. Unfortunately, it was not. I dunno why or how the will was invented, instead of using the trust as a full 100% tax-deferred inheritance. What's more, why do I keep hearing the popular word "will," rather than "trust," through my associates in the past few months? It seems that a will is the cheap and easy way out to receive the inheritance. But, people keep forgetting that there is TAXABLE inheritance if using the will instead of trust—as you can see from Scott Baer's response.

He was forced up to a high tax bracket because he received a big inheritance. If he could have guessed this would happen, a small ($2000) investment in a "trust" would have avoided most of this problem. Always file a trust, not a will, when there's any significant inheritance. *(Rich guys got lawyers to invent loopholes and trusts to avoid inheritance taxes. Now, you don't have to be a millionaire to need that protection for YOUR estate, too. /rap)*

Anyone who went through the tax-shelter schemes got the money for themselves, not for the country. Hence, millions of dollars saved for their big luxury homes and yachts at the harbors. Why didn't the tax men get the shares from them? That's the thing. Tax men don't like to monkey around with CPAs who have better education on tax laws than them! Have you noticed that tax men tend to screw around with people who don't have CPAs? That's where we heard all about those IRS horror stories last year. None of the testimonial people had CPAs on their sides! Clever IRS strategy. CPA is my "IRS audit insurance"! *(Knock on that wood. /rap)*

For example, many years ago, I thought I could go by the 1040EZ for easy tax refunds. But, I learned that if I go by the 1040 long form, I'll receive MORE tax refund! Geez, why couldn't Uncle Sam tell me about that??? Uncle Sam's duty was to provide me all of the tax forms, but he wouldn't tell me which one was best for my tax refund! I had to LOOK for the right form to fill out to receive the maximum refund as much as possible. Since there were so many different tax laws and rulings being changed every year, I lost track of them and didn't have much time to do it. So, I hired a CPA to do it for me annually.

HARRY GIBBENS JR.
via e-mail

Yeah, but do you trust your CPA to put in all the right deductions, and no improper ones?—Good luck!—RAP

All for now. / Comments invited!
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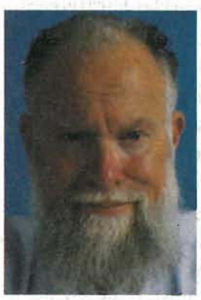
BOB PEASE

What's All This Logarithmic Stuff, Anyhow?

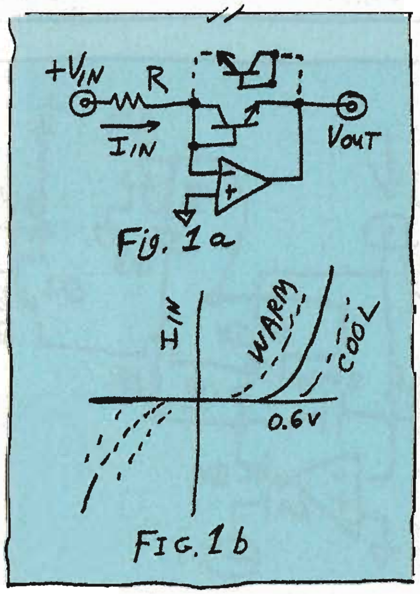
Everybody knows that the V_{BE} of a transistor is a sort of logarithmic function. After you get the transistor up to the right threshold voltage—about 0.6 V for silicon transistors at room temperature—the transistor's collector current rises exponentially whenever the voltage increases slightly. In other words, you might say that the base-emitter voltage rises *logarithmically* as a function of the current.

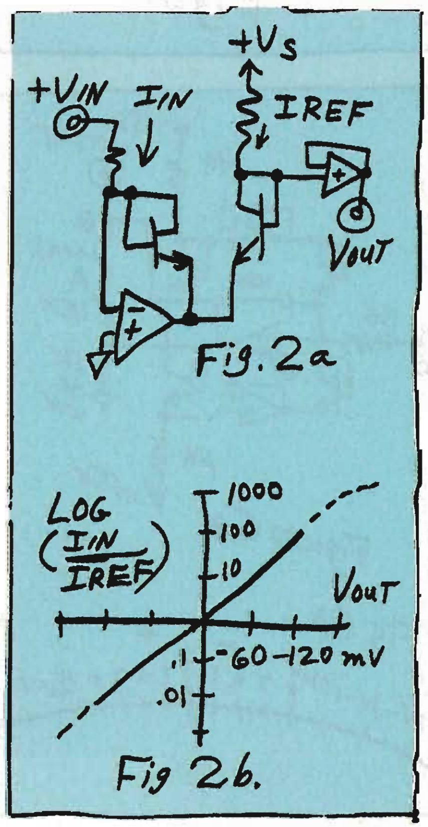
Great! Now, we can cover a wide range of signals by looking at a finite range of voltages. The familiar slope of 60-mV output per decade of input seems nice and handy. You might just put your current into a diode or transistor. Or, you might put the transistor in the feedback loop of an operational amplifier *(Fig. 1a)*.



BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

But, this "exponential" characteristic is really not a realistic, *usable* curve *(Fig. 1b)*. Why not? Well, the familiar "diode equation" is not usually properly written in terms of temperature. I_S is NOT temperature invariant. It varies wildly. If the temperature of a diode or transistor changes, you see the old familiar –2 mV/°C sensitivity. If the junction current is very small, that tempco may be as big as 3 mV/°C. So, if the V_{BE} changes by 18 mV, was this caused because the sun went behind a cloud and the circuit cooled off 9°? Or, was it because there was a 2:1 change of current? Kind of hard to tell. So, the raw V_{BE} of a transistor is NOT a good, useful logarithmic detector.

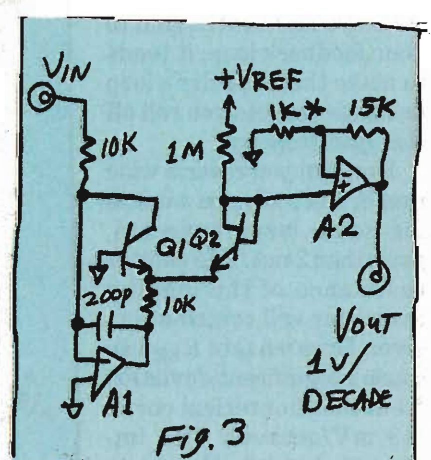




What, then, IS usable? There have been good log detectors around for well over 30 years. You don't just use one V_{BE}; you use a *difference* between two of them. This is much more predictable, and its temperature sensitivity isn't as bad *(Fig. 2a)*. When the currents through the two transistors are *equal*, the output is zero. That is stable with temperature. The output has a slope of 60 mV/decade at room temperature *(Fig. 2b)*. This circuit can easily cover a range of ±2 decades. But, this logger still needs some more improvements.

The seminal papers written by Horn and Gibbons were done in the late 1960s, showing that the logarithmic fidelity of the *collector* current of the transistor is more accurate than the *emitter* current. That's much better than most *diodes*. In Figure 2a, all of the input current flows through the npn's emitter. In Figure 3, all of the input current flows through the *collector*, which makes for a much more accurate log function—especially when the transistor's beta may fall off at low currents.

The voltage at the base of Q2 will move at 60 mV/decade. But, that is linearly proportional to Kelvin temperature. Not so good. So, how do we compensate for that? Take a look at the two resistors around A2. The input resistor is a special wirewound resistance specified at +3400 ppm/°C. There are several suppliers of resistors at this tempco. This compensates for the "gain" of the logger, giving pretty good overall gain.

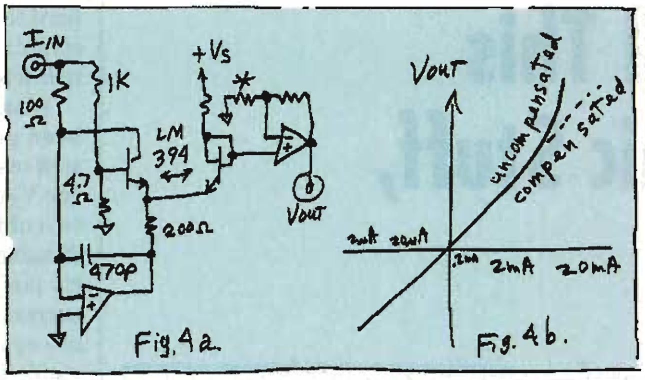


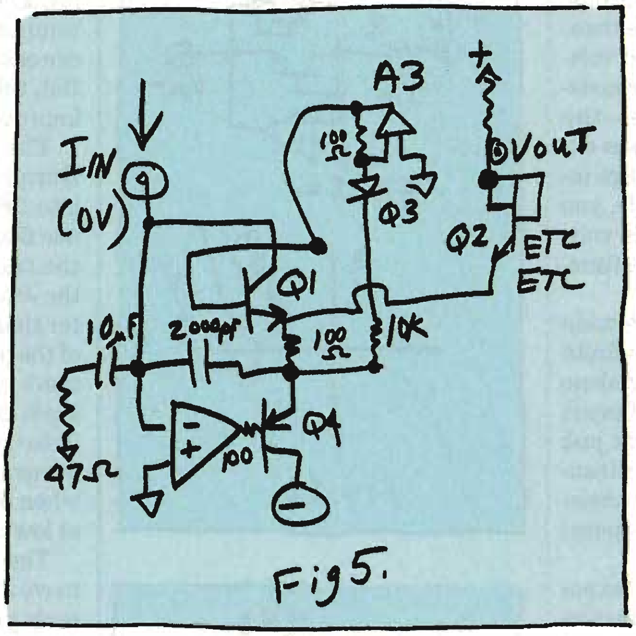
Of course, for best results, you can't expect perfect accuracy if you get far away from room temperature or are taking extremely wide current ranges. The example in Figure 3 covers the range from 10 µA up a couple of decades (to 1 mA), and down to 0.1 µA. Of course, to maintain full accuracy, you would want an op amp that starts out with less than 1 mV of offset. That way, when you trim it down to 10 µV, it will stay there. Cheap grades of OP-07 are often suitable. BiFETs and CMOS amplifiers are sometimes pretty stable.

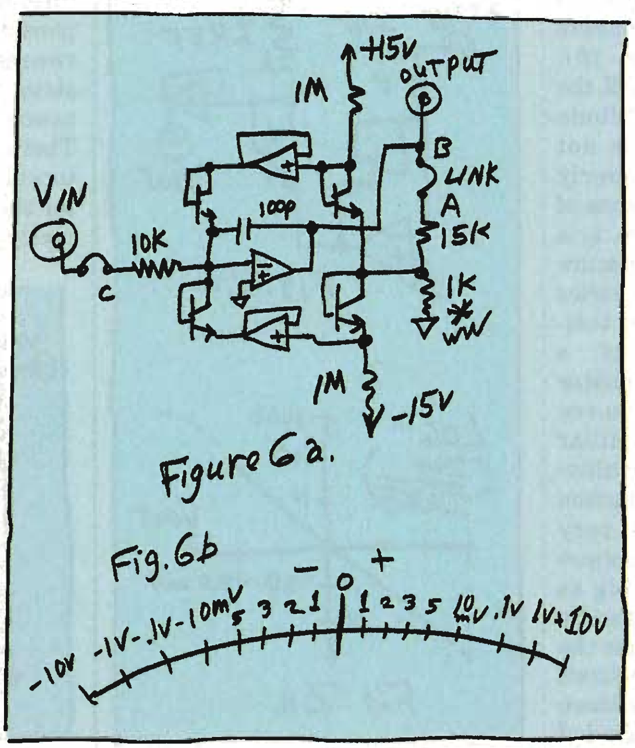
You should note also that the dc output error at the emitter of Q1 is not directly affected by the offset voltage of A1. If you have a 1.0-V signal input, the error caused by 1 mV of offset from A1 will only create a 26-µV error at Q1's emitter. That's because the emitter voltage is established by the fact that the base is tied to ground—NOT to the summing point. If you were using the circuit in Figure 2a, it would cause 1.026 mV of error. So, the Figure 3 circuit will cause less errors in some cases.

Note the feedback capacitor around the first amplifier. The gain of Q1 makes it necessary to add the resistor and capacitor at its output, making the loop stable. The reason is that the transistor adds so much gain to the loop. When you add extra gain to your feedback loop, it tends to make the amplifier's loop unstable—unless you roll off that gain properly.

How can you cover a wide range? Let's say you want to log some large currents, more than 2 mA. The emitter resistance of the logging transistor will contribute to error. Even 0.5 Ω of R_{EE}' can cause a significant deviation from the theoretical curve (18 mV/octave). The improved circuit in Figure 4a







can make good compensation. For example, 10 mA × 0.5 Ω = 5 mV. Here, the signal input is permitted to rise, permitting the transistor's base to be pulled up to compensate for the I × R drop in the emitter. The accuracy, improved up to 20 mA, is shown in Figure 4b.

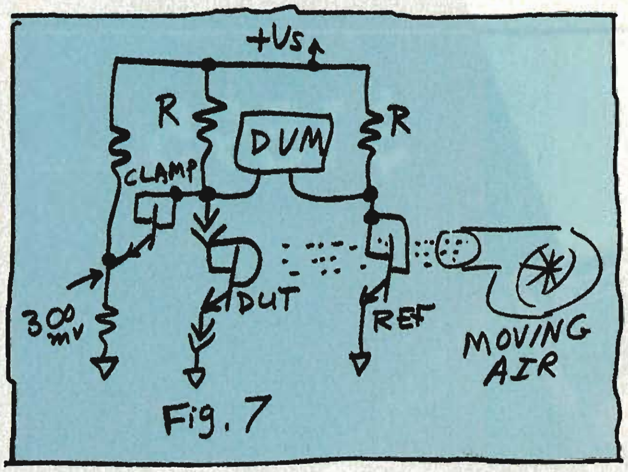
Another version is shown in Figure 5, where the current input (a real summing point) is held strictly at 0 mV. A dummy current is generated through Q3 and this lets A3 pull up the base of Q1. I tried this one at 100 mA, using a big power transistor. It seemed to work OK, though the self-heating in the transistor was not negligible.

Now, we indicated way back at the beginning that somebody might like to do the logarithms of both positive and negative signals. But, just using two diodes in the feedback of an op amp—as shown by the dashed lines in Figure 1a—is a lousy way. Yet, a thoughtful application of the circuit of Figures 2a and 3a can lead to Figure 6a.

This circuit was originally designed as a log null indicator—a semilogarithmic null. It simplifies how you null in a circuit as you trim it. It will have very good resolution for small signals, but you can still see what is happening with small changes of a large null error. First designed as a small, round, epoxy-potted module, it was to be bolted onto the back of an analog meter and called a "meter-mate" by the Nexus guys back in '67. Cute idea.

Then, somebody discovered that this ac null function—$\sinh^{-1}$ function—can be used as a logarithmic *compressor* function for audio signals. Plus, when you take a second one and connect it as an *expander*, it makes a *compander* (that is, a compressor-expander) function. One of these days I

BOB PEASE



may even connect one of these up in my phone system.

Note: the definition of sinh(x) is: $1/2(e^x - e^{-x})$. Thus, the current in this circuit *(Fig. 6a)* increases in magnitude *exponentially* as you get away from the null. Conversely, when you look at the inverse function, $\sinh^{-1}(y)$, it has a flat slope near null. But, as you get far away from null, it looks more and more like a log function, with a scale per Figure 6b.

Just what we wanted! That's what the compressor does—the circuit of Figure 6a. To use this circuit as an expander, apply the input signal to point A, and then connect the output of the op amp from B to C.

Back in the Vietnam era, some guys were proposing to insert this compressor function right after a soldier's microphone to cut down the effect of the sounds of gunfire. These guys were figuring they could bugger around with the transfer function and cut down on the noise of the shots. I don't know if they ever got that to work. But, it was a cute concept. Recently, a guy had a similar requirement: to cut down the impact noise of bowling pins falling!

Of course, for all these logging applications, transistors should be matched in pairs for V_{BE} at a nominal temperature. Specifically, pick up the transistors with tweezers. Insert them into a socket that's adjacent to a reference transistor running at the same current *(Fig. 7)*. Any deviation between the V_{BE} of the DUT and the reference transistor's V_{BE} is used to grade the transistors into bins such as 1 or 2 mV wide. Then, when you take the transistors out of that bin, they are well-matched. Oops! I almost forgot to say that you have to blow a big air blast—a steady flow of room-temperature air—over the DUTs. In fact, the DUTs waiting to go into the test should be kept in that same moving air.

After these transistors are matched, it's important to install them properly to keep them at the same temperature. Use some epoxy and some metal or junk as a thermal mass to keep the transistors at a fairly constant and equal temperature, along with the temperature-compensating resistor.

Another way to get matched transistors is to buy matched pairs, such as LM3046 or LM394. The '3046s are typically matched to within 1 mV, but the specs are about 3 mV max. You get a quad of transistors at this price. The LM394s are a bit more expensive for a dual of WELL-matched transistors. But, you get a spec of 300 µV max for the LM394CH.

So, as you can see, there are many games to play in the area of logarithmic and exponential functions. Stay tuned. I might share some more of them with you. Let me know if you'd like to see more on this subject. But this should give you enough to think about for now.

All for now. / Comments invited!
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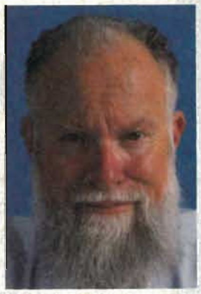

Dear Bob:

I really enjoyed your article on Loebe Julie *(ELECTRONIC DESIGN, May 3, p. 100)*. It made me think of the dc-coupled vacuum-tube circuits I designed at a major aerospace manufacturer between 1983 and 1987. Tube circuits in the '80s? Why not? I had to design several high-voltage dc power supplies using power tubes as the output device. Since the systems had one large tube, I figured why not build them with tubes from the output device on back to the input?

The first circuit was a 200- to 1000-V, 25-mA shunt regulator. It used an asymmetrical input stage using the triode and pentode halves of a 6AN8. This then drove the 6L6GC output tube. Level shifting between stages was accomplished with a zener diode. The circuit also used several TV-damper diode tubes for the pulse clipper.

Another tube circuit I designed was a 500- to 7000-V, 2-kW shunt regulator. I believe it used a 12AX7 diff amp driving a 12AT7 diff amp. This then drove two paralleled 4-1000A glass tubes. It was quite a sight to see the plates glowing orange during full-power operation. Several of these shunt-regulator chassis were electrically stacked with the top chassis at –21 kV.

The third circuit was one of my most fun projects. It was a 30-kV, 6-A, fast-respond series-pass regulator. I had to have it working in 10 days, as the customer for our product had been told that we had been testing it with a regulated source for the past year; and they were coming for a visit! The circuit had to respond to a load change from 0 to 6 A in 3 µs. This circuit used a 12AT7 input diff amp (or, as they used to call them, a cathode-coupled amplifier) driving a 12BH7 cathode follower that drove the grid of an Eimac 4CW25,000. The reference voltage was provided by VR tubes. It regulated during a 1-ms, 6-amp gridded-TWT pulse with only 50 V of droop and used only a 0.5-µF output capacitor. My rival's competing circuit used a 20-µF output capacitor for a droop of 300 V during the 1 ms pulse. Believe me, you DO NOT want to deal with 20 µF at 30 kV if you can help it.

This project was not without its disasters, however. Due to time constraints, I had to beg, borrow, and use parts already in stock. The 4CW25,000 tube and associated circuitry (filament supply, screen supply, enclosure) was originally a shunt regulator for a TWT collector. In collector service, the tube plate is at ground potential. So, standard industrial water can be used to cool it. But in my application, the plate potential was 5 kV dc with peaks to 35 kV during load arcs. Normally, a deionized-water heat exchanger would have been used in this case, but I didn't have an extra one. I did have access to an oil heat exchanger, though. This was pressed into service. But due to the high viscosity of oil and its low specific heat (as compared to water), it didn't do a good job of cooling the tube.

In my rush to get the circuit running, I glossed over this point and ran it anyway. After an hour of operation, with the system running full-bore, there was a tremendous explosion and smoke. The oil had gotten so hot that the water jacket on the 4CW25,000 had come unbrazed! Luckily, the big tube was in a metal enclosure or my very capable technician, Bill Fontana, would have been boiled in oil.

This wasn't the first explosion this project suffered. As I said before, due to time constraints I had to cut corners. I hastily threw together a prototype regulator that involved hanging 50 series-connected, 300-V, 5-W zener diodes, by string, from the ceiling. Our TWT consultant, Bernie Vancil (who badly needed this regulator), was present when this particular circuit was fired-up for the first and last time. The power supply (a cube 10 feet on a side and weighing five tons) was brought up and the circuit was regulating nicely.

I was standing about five feet from the string of zener diodes while Bernie stood on the other side. All of a sudden, the zeners vaporized in a terrific flash and boom. The look on Bernie's face changed instantly from one of utter confidence in me to one of zero confidence mixed with shock and horror. The blast was so unexpected and loud that I staggered away to sit down while people poured in from the far reaches of the plant to see what had happened. It was great!

Due to careful attention to detail (excepting the aforementioned lapses in engineering judgement), the three tube circuits lived long and useful lives without the need for servicing.

DAVE CUTHBERT
via e-mail

Dave, do you have any schematics I could see on these? I'm really impressed. I'm not saying that I couldn't design such circuits, but I'm not exactly well-polished in these kinds of designs. Nor do I have the confidence that I could get them to work by the first or second try. Maybe the third try?—RAP

Hi Bob:

Enjoyed your "Julie Stuff" article on the radar-directed anti-aircraft guns. I read *The Invention that Changed the World* after you mentioned it. I have long been a student of the technology advances of WW II, not to mention over the history of man. I don't think many people ever understood what a fantastic advantage 10-cm radar gave us *(BUT that book by Buderi can change that! /rap)*, which in turn was made possible by the invention of the magnetron. The last day of the V1 attacks Hitler sent 104, and all but four were shot down.

Our skill in code breaking is another story. Of course, all this was top secret at the time. I suppose by the time the whole story was declassified, it was pretty old news.

BRUCE ROE
via e-mail

I agree. Those were amazing stories! Best regards.—RAP

All for now. / Comments invited!
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Santa Clara, CA 95052-8090

BOB PEASE

What's All This Contest Stuff, Anyhow?

Here in San Francisco, we don't have a "county fair" like people in farming country have, with cows and pigs. We got a city-based county fair, since SF is an identity of city and COUNTY. We've got contests for fog-calling, finding parking spaces, and other urban pleasures. About five years ago, I had a great idea for a "contest" for the SF county fair. (But the county fair guys did not buy my idea.)

Often you come around a hill, late in the afternoon, and see a lot of buildings. The sun is reflecting off the windows, and it may be reflecting the beautiful sunset. There's a LOT of windows reflecting.

My contest is: Take a photograph of this. Be sure to note your EXACT location and the exact time, hour, minute, day, and date. This way, BARRING weather changes, anybody could go back to this place and see similar reflections.

BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

One of my favorite places is coming down Route 280 at 5 p.m., just before sunset, on about February 10. You can look across the bay at Oakland and Berkeley. Are there more than 199 windows? Yes, maybe. But you can do better than that.

Keep an inexpensive camera in your car. Put it in an insulated bag or chest so the sun doesn't cook the film. Make notes when you take pictures. Perfect pictures would be nice, but not a big deal. Everybody will be a winner, as we will all get to see glorious pictures and views! More later. In the meantime, send me your ideas for contests you'd like to see. My contest closes in one year (July 30, 2000). Send prints or slides to:

RAP / Robert A. Pease / Engineer
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National Semiconductor
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BOB'S MAILBOX:

Dear Bob:

I was especially interested in your "What's All This Julie Stuff, Anyhow?" (ELECTRONIC DESIGN, *May 3, p. 100)*. It is a fitting tribute to Mr. Julie that he truly understood the importance of resistance. He dedicated his life work to its understanding....

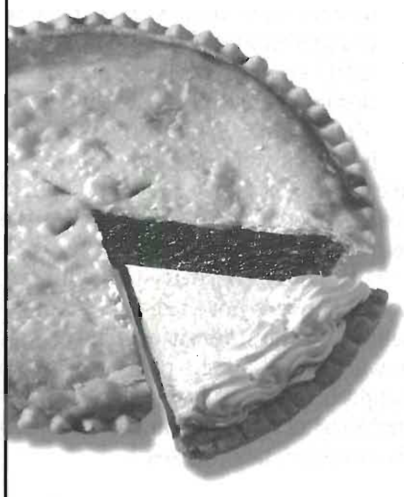
The contribution of high-precision resistors in the early inertial guidance systems caught my attention. One of my hobbies is model and high-power rocketry. For the past few months, I have been working to develop a small inertial measurement unit that will fit in these small rockets to record flight dynamics and altitude.

As I worked on the problem, I quickly realized the importance of accuracy and stability when integrating acceleration into velocity and position. My requirements went from 12- to 16- and now 24-bit resolution on the analog-to-digital converters....

Lord Kelvin was correct when he said, "When you can measure what you are speaking about, and express it in numbers, you know something about it..." My IMU project has required a lot of measurements and my understanding has grown.

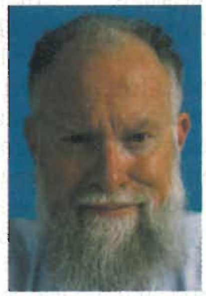
JOHN KRELL
via e-mail

I must say that I am impressed with anybody whose hobby includes REAL inertial guidance of REAL rockets!—RAP



BOB PEASE

Bob's Mailbox



Dear Bob:

It did my heart good to read your column on logarithmic amplifiers (*ELECTRONIC DESIGN, June 14, p. 111*). Long before I became computer-literate, my world was nonlinear analog functions. *(Jolly good. That art is still valuable. /rap)*

I suppose now that I mostly use a computer these days, I am still involved in nonlinear functions, although they do not require quite the flexibility of thought previously required. *(May I recommend that THINKING is still a useful attribute to bring to the party? /rap)*

My reason for composing this is to mention one of my treasures from the '60s, the Philbrick *Applications Manual for Computing Amplifiers for Modeling, Measuring, Manipulating & Much Else.* My current copy, second edition, has been with me since my first copy wore out sometime in mid-1967. Now and again I drag it out when someone claims a "breakthrough" and proceed to demonstrate that this breakthrough is over 30 years old. *(Take good care of it. /rap)*

The accompanying Philbrick application notes, *The Lightning Empiricist,* also added a word to my vocabulary—salient. Unfortunately, I do not have any of "*The Lightning Empiricist*" remaining. *(We can fix this by the use of the photocopier—which is still an analog function, usually. /rap)*

I am pleasantly surprised to reread parts of the manual. Much of the surprise is a delight in the use of clear technical language. I miss that company and its standard of writing.

DAVID HARRISON
MIT Lincoln Laboratory
via e-mail

Read my books. They are not as SEVERE or DRY as George's writing. But I try to include some of his concepts—and enthusiasm (though bridled slightly). Please go to my web site, www.national.com/rap, and check on a few items: Trekking, Horrible, and Book. Also, www.transtronix.com is the site for my new book. If you have any kids or friends learning to drive, they need this book.—RAP

Sir:

Your mailbox column in the May 31 issue regarding CPAs left out an important note. When shopping for a CPA, ask this question: "Are you IRS rated?" I interviewed several recommended CPAs and only one said yes. He said that he had been up against the IRS four times and won all four times. I signed with him and he has my retirement funds and income taxes "tweaked" well enough that I either have a refund or send in $50 to $200 for the dreaded April 15th. The price: some shopping and a yearly $200 fee. Salud! "Confusion to the enemy!" (to quote the movie *Easy Rider*).

PAT KILLMER
via e-mail

Good man! Thanks.—RAP

Dear Bob:

The letters from Harry Gibbens Jr. (ELECTRONIC DESIGN, *May 31, p. 68*) and Scott Baer (ELECTRONIC DESIGN, *April 19, p. 89*) show just how much misinformation is out there. I just went through settling my mother-in-law's estate, so I also have been through it. First, the estate is liable for the inheritance tax, not the heirs. Second, the recipient receives the proceeds tax-free, so the comment about being put in a higher tax bracket is incorrect. Lastly, having an account "in trust for" is not the same thing as having it in a trust.

STEVE GOCH
via e-mail

Hmmm...I gotta think about this. Thanks for writing.—RAP

All for now. / Comments invited!
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BOB PEASE

What's All This Vice-Versa Stuff, Anyhow? (Part II)

I was crossing the Atlantic for the fourth time this year recently, en route to wandering around Europe, and I realized I had a good story. I had explained this story to several people. So I decided to write it down and pass it along to all you guys.

WHY? Why do the French and the Americans and many other people drive on the WRONG side of the road? Why do the British and Indians and Thais drive on the OTHER side? Almost nobody knows how this happened. Here's why:

Back in Roman times, the Roman armies often marched on the road. They did not have vehicles to carry them, so they had to march. The enlisted men had to march on the left-hand side of the road, near or even *in* the ditch. The General walked, of course, on the high middle part, the crown of the road, where it was not so muddy.

BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

Why did he force the rest of the army to be on HIS left? Because he held his sword in his right hand, and he could defend himself best from any attackers if he had other people on his left side. (The guys on the left did not have such good luck, as they might have to defend themselves from attackers on their left. But when you are an enlisted man, your main priority is to defend the general...) So, barring the remote possibility of a left-handed general, the Roman armies marched on the *left* side of the road.

(A related theory says that when the Roman general rode in a chariot, near the left-hand edge of the road, he held his reins in his left hand and his sword in his right. And he drove his chariot on the left side of the road. That theory is consistent with the preceding paragraph.)

The Roman army went all over Europe and even to much of England. The Romans built rather good roads. And when merchants or private citizens met the Roman armies, they too were obliged to walk on the left side of the road. And that was how things stayed for over 1700 years.

In Theory, there's no difference between Theory and Practice... ...But in Practice, there usually is a difference.

When Napoleon Bonaparte came to power, about 1805, he was a strong iconoclast. If any other army came along on its left side of the road, he would oppose it by marching on the *right* side of the road. He was a contrarian. Napoleon conquered almost all of Europe, and his rules caused everybody in Europe to walk and drive their carts on the RIGHT-hand side of the road. But he never conquered England. So the English continued to drive on the left.

The Americans, just like Napoleon, were very contrarian. Whatever the British did, the Yankees would do the reverse or perverse way. When did this occur? Perhaps even before Napoleon did it! I'd always thought that Napoleon did it first. But in retrospect—when I started to write this down—I realized that when you start writing things down and crystallizing your thinking, ideas come into conflict. I bet it will be hard to find (even in my excellent set of *Encyclopedia Britannicas* from 1894) the time when these changeovers occurred.

But anyhow, this is why England and many other countries that got their automotive commerce and culture from England—such as India, Australia, Thailand, and Japan—drive on the left-hand side of the road.

And most of the rest of the world drives on the right out of this sheer contrariness, after about 200 years. While travelling in France, I heard a variation on this theory: The French changed to drive on the right side of the road at the time of the French Revolution, about 1789, *before* Napoleon's time. This is entirely possible—the French revolutionaries were contrarians, too. But that theory STILL places this change in France, *after* the American Revolution.

Has anybody changed, switched over? Yes, Sweden made its change about 35 (that's a guess) years ago. They made sure everybody got home on a Friday night, and then the highway workers got busy, unveiling all new signs for driving on the right, to be in conformance with the rest of mainland Europe. No driving (other than emergency vehicles) was permitted until Monday, and then the speed limit was set at 25 mph until everybody had mastered the new procedures.

(Hey, while lecturing in Europe, I had two good foils. The first one made everybody smile, grin, and titter: "In Theory, there's no difference between Theory and Practice..." That slide was always well-received. But the following one got the ovation: "...but in Practice, there usually is a difference.")

I'm sure glad I never had to drive in a left-hand-drive car, with the driver on the left, in a place where I had to drive on the left-hand side of the road! I depend on the steering-wheel's position to tell me what side of the road to drive on. If I had to drive a British car to France, I would be terribly nervous that I'd make mistakes. Or a French or other left-hand-drive car in England. I'd probably refuse to do it. I just got back from driving a few miles in England and 1900 kilometers in France—

always with the steering wheel nearer to the center-line of the road. I can live with that.

I heard some people pooh-pooh these "reasons." They said that the left/right choice is purely arbitrary. I don't think so. In most cultures throughout the world, a horseback rider mounts his horse from the horse's left side. (I recall that some Native Americans did it from the horse's right?)

If you are standing on the crown of the road, and the horse is standing slightly lower than you are, that puts you facing along the right-hand side of the road as soon as you are in the saddle. So any culture where horseback riding is dominant may favor riding on the right, as we Americans do. Or—can you tell me any society where the rider mounts the horse from the horse's right? Can you give any examples of why a rider would like to stand at the lower level, in the ditch, and mount a horse standing at the higher level, on the crown of the road? That might be a place with TALL men and *short* horses....

But here is a fly in the ointment: In the northern hemisphere, whirlwinds and tornadoes tend to whirl counter-clockwise. When oncoming cars pass, they usually set up little vortices. When these cars are driven on the right-hand side of the road, they generate *counter-clockwise* vortices. These might be blamed for seeding a whirlwind or tornado. So maybe Oklahomans and Kansans are causing a lot of their own problems with their traffic patterns. Maybe they ought to swap their cars—and their road signs—with the Aussies? That would alleviate problems in *both hemispheres*....

All for now. / Comments invited!

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P.S. It sure is fun to tool around England in a left-hand-drive car, with a big DOG in the right-hand passenger seat. Likewise for a British car in the USA with a dog on the left seat. Shakes up the natives. Jolly fun!

BOB PEASE

Bob's Mailbox

Dear Bob:

A few years back, you wrote a column about an earthquake detector (ELECTRONIC DESIGN, *Oct. 24, 1991, p. 119)*. Just recently, I was asked by a friend in Mexico if I knew of a cheap sensor that could detect small events and possibly warn of an impending quake. *(Sounds like wishful thinking...Normally, if a quake is several miles away, the first arriving shocks are no more than you'd get from a truck driving down the street! /rap)*

I looked around and couldn't find anything that would fit the bill. Soooo...To make a long story short, here is what I came up with: Take your garden-variety electret/condenser mike element; I used a Panasonic unit (Digi-Key p/n P9931-ND, \$1.40 each). Carefully remove the baffle or screen and open up the top of the can with a sharp, pointy X-ACTO knife. By open up, I mean enlarge the opening of the top hole to gain access to the Mylar electret membrane.

Once you have exposed this membrane, you can attach a small lead ball that's 10- to 100- mils in diameter with a small drop of super glue. Where do you get this small ball, you ask? Just melt solder on the end of your iron and shake it over a glass of water. You can get any size you want.

Size is important because it impacts the frequency response and the output. Anyway, when finished, select the proper bias resistor for a 9-V supply (6 to 12 kΩ), tune for max, and you have a whopping output. When looking at the signal on a scope, you can tell the direction of the movement *(REALLY?? /rap)* and lots of other things. A small amp, threshold comparator, and alarm finishes the thing. *(I bet this would be pretty good compared to the conventional approach with a LONG pendulum and a HUGE coil of wire! Cute!! /rap)*

Bob, I really enjoy your work and love your column. I have 30 years in the biz as an analog/digital/RF designer. I tutored under Dr. Frank Wanless in the early CMOS days at LSI Systems, and paid my dues as a photo products designer at Fairchild. Much fun and many jobs later, I find myself working in Mexico as a test engineer and looking forward to retirement. I plan on writing and working on the many projects, all analog, I have saved up over the years. Keep up the good work.

NEAL TENHULZEN
via e-mail

P.S. I still miss the good old days in the '70s at the Wagon Wheel.

Yeah. I went there a few years ago. Very quiet. Best regards.—RAP

Dear Bob:

Re: "What's All This Logarithmic Stuff, Anyhow?" (ELECTRONIC DESIGN, *June 14, p. 111)*. At the end of the article, where you were mentioning the CA3046, you missed a very useful feature of the device: The two "spare" transistors can be used as an on-substrate oven, with one transistor doing the heating and the other doing the sensing. Alternatively, a power resistor can be placed on top of the chip to do the heating, while retaining the on-chip temperature-sense transistor. I used this technique several years ago to stabilize a log amp, and it worked well. The idea is not original. I think I got it from a Jim Williams application note. Cheers!

HERB PERTEN
via e-mail

Yeah. Jim Williams used an LM389. I suppose that worked OK, but I never saw any convincing evidence that it worked very well. Thanks for writing.—RAP

All for now. / Comments invited!
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SF Gate

Pease Porridge: An Amazing Stew

JON CARROLL
Monday, August 23, 1999

ROBERT PEASE LOOKS like a madman and may be a genius. He carries his papers in a cardboard box. He laughs frequently; sometimes the proximate cause of his laughter is unclear. He shakes hands by way of expressing agreement. He raises his eyebrows to express astonishment and pulls little tufts of his hair straight up.

He has an Old Testament beard. He is an honored employee of National Semiconductor, for which he ``invents circuits and designs ideas." They send him around the world. His conversation leaps from the cemeteries of Buenos Aires to the problems of home electrical wiring.

His expertise in the latter is unquestioned: He is the distinguished author of ``Troubleshooting Analog Circuits," now in print nine years with 30,000 copies sold. In the old phrase: For the people who like that kind of thing, this is the kind of thing they'd like.

He's also the author of ``How to Drive Into Accidents -- And How Not to." He sent me the book many months ago; I loved it. It is opinionated, repetitious, smart, provocative, loony, pedantic and useful. It is probably the only automotive book with a cover blurb by Otto von Bismarck: ``Fools you are . . . who say you like to learn from your mistakes. . . . I prefer to learn from the mistakes of others, and avoid the cost of my own."

I asked Pease about his mistakes. ``Oh my! Oh my! Chapter 16! I have driven into trees. I have driven into trucks. If people read my book, they will not be as stupid as me. That is my guarantee." He crosses his heart, literally. Then he claps his hands above his head.

It's like talking to Moses during his tenure as a yell leader.

I HAVE A weakness for the prose of engineers. My stepfather, who has been more different kinds of scientist than seems possible (he once tried to give emphysema to monkeys at the behest of SRI; he designed gyroscopes for a while; he got his doctorate from Scripps with a thesis on the purple pigment of the octopus), used to read many jocular scientific publications: the Worm-Runners Journal, Stress Analysis of the Strapless Evening Gown, stuff like that.

I was taught to worship Martin Gardner as a god, even though his prose is free of that too-many-late- nights-at-the-lab feeling.

The prose of ``How to Drive Into Accidents -- And How Not to" has a definite home-hobbyist feel. It has illustrations by the author. It has anecdotes. It has many, many opinions, some more conventional than others. It's all about driving, not a heavily covered topic in literature outside DMV manuals.

I WANTED TO write about the book back when I first got it, but it turned out that it was really not available anywhere. It was self-published and essentially undistributed, except for the free copies to press people.

I was the only press person who even responded; discouraging for the author. But . . . Pease holds up a copy of ``The Self-Publishing Manual'' by Dan Poynter. ``This is the book,'' he said, unaware of the duty of the author to hold up his own book when he says that. ``Poynter knows more than everyone else put together.''

He got Baker and Taylor, a national distributor, to handle the book. He got support from the folks at Green Apple. He persuaded Amazon to list the book, an enviable coup. He is less impressed with the ``Books in Print'' people, who declined to list him, even though his book was clearly in print and for sale.

``I have sent them a strongly worded note. You have to wonder whom they are protecting.'' The way he says it, you do begin to wonder. The Trilateral Commission? The House of Hanover? The Mongolian Hegemony?

The full Pease experience is available at www.transtronix.com. The book itself may even help you drive more safely, which is sort of the point. Unless the point is Pease himself, who flourishes in defiance of convention and has a swell time doing it.

Sweepers with a tightening radius, and other modern motoring problems.

Truckin' off to Buffalo, been thinkin' you got to mellow slow, take time, pick a
jrc@sfgate.com

 Page E - 10

PEASE PORRIDGE

BOB PEASE

What's All This "Why?" Stuff, Anyhow?

Why did primitive man learn to walk on two feet? I heard a lecture by a guy at the University of California at Berkeley, Professor Vincent Sarich. He has a good theory about the reasons and incentives that primitive man would thrive on when standing on two feet.

When a baseball pitcher is delivering a fastball, he must let go of the ball at exactly the right time. And how precisely must that time be programmed? Is it more or less than a millisecond? Don't be silly! How can a guy have a precision or uncertainty for timing the release of a thrown object when it's less than 1 millisecond? Hmmm....

Well, a guy who can throw a baseball and hit the strike zone and the correct corner thereof with a precision of ±3 in. is called a major-league pitcher. He can earn a few million dollars a season for several years. I admit, that's NOT a bad way to make a living. And he has learned to *release* the ball with a precision of as small as 100 µs—just *one tenth* of a millisecond.*

BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCT-OR CORP., SANTA CLARA, CALIF.

But think about this guy's ancestors. Some of them could throw a rock with the same kind of precision. That skilled thrower could bust the hell out of the head of a skulking tiger, or maybe knock him out, with a well-aimed rock. Just when the tiger thought he was at a safe range!

Think of the incentives: The guy who could do that survived, and the guy who couldn't got eaten by the tiger (perhaps). So there is one incentive that may have been very helpful for early man. It may have been a useful trait for survival a couple hundred thousand years ago. Meanwhile, to this day, apes and other modern-day primates are only capable of a release with an uncertainty of about ±5 ms. So throwing stones was not their main mode of defense. As the old saying goes, "Choose your parents wisely." Or your ancestors.

The timing for little David to let his sling loose in order to nail Goliath between the eyes was comparably precise. Even though we do not know exactly how long David's sling was, he had to have had pretty good timing.

Now, let's say you are a caveman who threw a 90-mph rock at the tiger and MISSED. What do you get then?

Now, let's say you are a caveman who threw a 90-mph rock at the tiger and MISSED. What do you get then? You probably get a broken rock, which can easily have a sharp edge or two. And that rock's sharp edge may be useful for dismantling the tiger after you have managed to stun him with another rock. So Professor Sarich has managed to show some nice correlations between the process of learning to stand on two feet and the process of defending one's self against ferocious critters. That correlation sounds good to me. It's a pretty good theory. I can't prove it, but I LIKE it.

Earlier today, as I was hanging around at Chicago's O'Hare airport, I was reading about a theory that some cavemen (I apologize for the imprecise term) were skilled at breaking rocks into sharp edges. These guys would, in theory, pick up a rock and whack it against a big stone. On the first *bang*, they could tell if this rock had good promise. Then they would try to break it into some good blades. But if their judgement said it would likely make a POOR edge, they would flip it away.

Well, some archeologists have found a number of these REJECT rocks that were just tried once, and then thrown over the shoulder, so to speak. They have checked out the stress marks that early man used to TEST the rock hundreds of thousands of years ago. These rejects were found amidst the debris of other edge-making scraps of rock. So maybe some of these old theories are not so dumb, after all??

Can I throw strikes? At any speed? Rarely. And certainly not over 40 mph. Can I whack a golf ball with good range and good angular accuracy? Maybe; I've never tried.

Can I put a hook shot in the basket? Release over my head while I am looking cross-eyed at a defender? Sure, about 1/40 as often as I can throw a baseball into the strike zone. The tigers woulda got ME a long time ago if I did not have better TOOLS.

All for now. / Comments invited!

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*Computations: If a ball at the end of your arm, at a radius of 3 ft., is moving at 90 mph or 132 ft./s, it will change its ANGLE by 0.0044 radians, or 0.252°, every 100 µs. And an angle of 0.0044 radians corresponds with an uncertainty of 6.4 in. (±3.2 in.), after the ball—or rock—has gone 60 ft.

Don't tell me, "60 feet and 6 inches," because the pitcher's release is likely to be a few feet IN FRONT of the pitcher's rubber—so long as the pitcher does not step off the rubber.

BOB PEASE

Bob's Mailbox

Dear Bob:

Re: "What's All This Vice-Versa Stuff, Anyhow? (Part 2)" (ELECTRONIC DESIGN, Aug. 9, p. 107). I take it that in your peripatetic wanderings (Europe, Nepal, etc.), you've never had the joy of visiting St. Thomas in the U.S. Virgin Islands, have you? There, folks drive U.S.-built steering-wheel-on-the-left automobiles, but drive them on the LEFT SIDE of the road, British-style—just like their neighbors in the British Virgin Islands. *(Yeah, scary, man. /rap)*

Needless to say, this gives the driver a really different perspective on what he or she sees out the windshield. It's a real hoot if you're a U.S. "mainlander" driving a rental car from Charlotte Amalie to Magen's Bay (over what must be the granddaddy of twisty mountain roads) and meeting a fully loaded tourist bus careering down your side of the road! A truly trouser-filling experience, let me tell you!

Since you're so interested in the effect the British Empire had on the rest of the world's commerce and traffic patterns, I've got one for you: Why does the Australian rail system have three different rail gauges in use?

E.C. OSTERMEYER
Controller
Com-Tek
via e-mail

I just got back from Argentina, where they have 4-ft., 8-in. gauge (NOT standard gauge, as I measured very carefully), meter gauge, and something like 6 ft. THEY did it to ensure that the Brazilians could not run their trains on Argentine rails, in case of war or invasion.

Free enterprise is great. The U.S.A has had broad gauge (6 ft.), lots of 3-ft. gauge, and even a bit of 2-ft. gauge. England has done very similarly, though not much is left but some 3-ft. and standard gauge. I presume Australia is the same. Is that about right? Tell me! (Of course, narrow gauge is MUCH cheaper, and much easier to lay out for rough terrain, severe curves, etc.) Thanks for the comments.—RAP

Dear Bob:

The rules for retirement change daily. For you, retirement on Social Security is possible anytime after you're 62. The penalties for retiring if you have income other than SS are severe, as you have pointed out. *(Check! /rap)*

There is a bright side to all this, however, if you plan to keep on working. The longer you wait before retiring, the higher your monthly check will be. If you remain employed beyond age 70, the penalty disappears. *(OH, REALLY? I didn't know that!! It sounds as if one might advantageously use one's ORDINARY savings before 70, and the tax-deferred stuff after 70? Yeah, right! I should live so long... /rap)*

You and I will pay only the marginal tax rate on our total income, not the confiscatory penalty. For those of more tender years, the deal is not as good, since the cutoff date recedes into the future depending on your date of birth. Personally, I'd rather not retire at all, since my experience is that when you stop working you start dying. *('ZACKLY... /rap)* Maybe I'll use the Social Security money to go to school. *(Or maybe take up TEACHING?? /rap)*

JIM TAYLOR
via e-mail

Thanks for the enlightenment. If I can't find the weasel words and fine print whereby the Social Security benefits worksheet lets us off the hook at age 70, I'll come back and ask you.—RAP

All for now. / Comments invited!
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BOB PEASE

What's All This Optical Stuff, Anyhow?

One time, a few years ago, I was flying from LAX to Tokyo. Now, if you looked at a Mercator map, you would think a direct route would go near Hawaii on a "straight line." But of course, a proper Great Circle route goes nowhere near Hawaii, but rather closer to Alaska—and Siberia. After several hours, I looked out the window and saw an odd angular object. Was it a Russian airplane? An Optical Ilyushin? Or was it just an Optical ILLUSION? No—it was a perky volcano on an island. It was just an Optical Aleutian.

A few months back, I was drinking a beer with a former National engineer, Bill Gross. He made some observation that audible sound covers a very wide dynamic range. A whisper is at around 20 dB; the smallest sound you can hear is around 0 dB. The sound of a jet engine at full power is 100 to 130 dB, which is getting painful. Thus, a dynamic range of 130 dB is a very wide dynamic range indeed.

BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

I immediately rebutted: "But the dynamic range of light that you SEE is, surely, even wider." He did not want to agree with that. So I looked up some numbers. I read somewhere that the limit of the human eye's ability to see a faint object is equivalent to the light you get from a candle 20 miles away.

Right now, I do not want to get into the question of how many photons per second the eye can see. Let's just talk about the relative energy flow, comparing a candle 20 miles away versus direct sunlight. (Let's leave nuclear explosions out of this. They are very bright—and also very LOUD....)

I jumped into my 40-year-old CRC *Handbook of Chemistry and Physics* and was immediately socked with a bewildering array of terms. How do you compare lamberts, foot-lamberts, candles, foot-candles, steradians, lux, and other forms of light/flux? And what about candelas, milliphots, and stilbs?

> **I jumped into my 40-year-old CRC *Handbook of Chemistry and Physics* and was immediately socked with a bewildering array of terms.**

In general, you don't, and I couldn't. These terms were all cooked up a century or two ago by scientists who used the terms or dimensions that were most convenient for THEM in their own little experiments—not necessarily convenient for us.

I spotted one comparison: The brightness of a candle (as you look at its brightness) is about 3.1 lamberts, whereas the brightness of the sun at noon is about 519,000 lamberts. What does that mean? How can we compare? Let's say the sun subtends an arc of about 0.5°. A candle might have a flame 0.2 by 0.5 in. If that candle is placed about 3 ft. away, it would subtend a similar (solid or spherical) angle.

Thus, the amount of light falling on a surface *might* be in the ballpark of a ratio of 170,000:1, comparing a candle's light at 3 ft. away versus sunlight. Then if we move the candle back from 3 to 105,600 ft. (20 miles), its intensity would drop by a factor of $35{,}200^2$. Using these numbers, the ratio of sunlight, as we see it, to the minimum signal is about 2×10^{14}—or about 143 dB.

So this is comparable to the range of sounds the ear can hear. I didn't feel all that comfortable with this estimate, so I went about it another way: The total energy from sunlight falling on the earth is 1000 watts per square meter per second, according to Fink and other handbooks. Let's assume the visible part is half of that, 500 W/m^2, or 0.05 W/cm^2. What is the LIGHT output of a candle? You cannot use a watt to make 621 lumens, but you can use 621 lumens to make a watt. Thus, 31 $lumens/cm^2$.

A candle puts out 12.57 lumens. If you average this over the area of a 1-ft.-radius sphere, that's 1 lumen per square foot. As there are 930 square centimeters in a square foot, that is 1/930 lumen per square cm. Now increase the radius of that sphere to 3 ft.: There is 1/8370 lumen per cm^2 at that radius. The ratio of sunlight to candlelight is about 259,000:1. That seems like a reasonable approximation that's similar to the earlier data. Again, expand that sphere from 3 ft. to 20 miles, and the light-density ratio becomes 3.2×10^{14}, or about 145 dB.

So the dynamic range for the ear and eye are both OUTRAGEOUSLY large. It's true that a 100-MW generator at a power plant is BIGGER than the 0.01-pW signal that your radio can pull in by a bigger factor than that (perhaps 220 dB?). But it's still pretty impressive, considering that when it comes to eyes and ears, just about everybody's got two of each. Good redundancy.

Let me see how many photons per second are falling on my eye. (Assume 0.5 cm^2.) If we have 1 volt $\times 1.6 \times 10^{-19}$ per second (assume 1 electron volt × 1 photon per second), that's a small number. The candle is putting out 1.6 mW of visible light, total. That would be 127 $\mu W/ft.^2$, or 0.136 $\mu W/cm^2$, at a 1-ft. radius. At a 20-mile radius, that density is about $150 \times 10^{19}/cm^2$, or 38×10^{19} falling on each eye. This is comparable to 25 electrons per second. Not too silly after all.

BOB PEASE

Remember, if we knew some of these physical constants, this would all be back-of-the envelope work. Calculators aren't really required for high accuracy. After all, I don't want to claim that one can SEE a 1-dB change in the intensity of a candle 20 miles away. Nor can one DISCERN a 1-dB change in the brightness of sunlight, or HEAR a 1-dB change in the amplitude of a very faint (0 dB) sound. Nor can someone DETECT a 1-dB shift in the roar of a jet engine. Still, that is the ballpark of the signals we're talking about.

One time, I bought 100 LEDs from Poly-paks (long ago located in Lynnfield, Mass.). I also got 600 LEDs from a barrel of factory rejects that National Semiconductor was giving away. In each case, I was hoping to find some weak LEDs to see what range of output light they covered. In each case, I was disappointed, as none of them seemed to be any weaker in output than the others.

I soon realized that this is partly because the human eye has a HUGE dynamic range—but not very good resolution for less than 1 or 2 dB of brightness. Still, these days, you sometimes pull up behind a car that has a long row of LEDs used as tail lights. Sometimes there are some OBVIOUS dim bulbs in there!

Of course, you have noticed that when you walk into a dark room with a LED-readout clock, the LEDs seem quite bright. As you turn on the room's light, the LEDs become MUCH less bright. Of course, that is due to the eye's iris closing up automatically as the room's light levels come up.

Here's a related phenomenon that I saw recently and never noticed before: When you stare out a window into a bright area, and close your eyes, everybody knows that the eyes retain that shape of brightness. NOW—do that—and then quickly put your hand over your eyes. The bright area gets darker, and the dark area gets darker, too. I'm not sure why or how it does that. The hand is a *fairly* good attenuator of light. Perhaps 80 or 100 dB? But it is not really OPAQUE. Nor are your eyelids.

Neither is the glass seal around the leads of a metal-can transistor. In the old days, when 8-lead TO-5 cans (TO-99s, really) were popular, we used to have to explain to the test engineers that you can't read picoampere currents accurately when bright light is shining around the package. The photons would come through that glass and rattle around inside the metal can, and then get detected by the silicon junctions.

Now we have some new op amps that are packaged in free air. We call it a micro-SMD package. It's die-scale packaging, so the complete dual op amp is just 1.35 by 1.35 by 0.9 mm. There's even a coat of opaque epoxy on the back of the die. Fine. But what's to stop the light from coming in the side of the die? Nothing. The test guys did not think this was a big deal, but I was worried that users might find it a significant problem in ambients where lights might fluctuate.

I set up a couple of test circuits and got some data as I rotated the DUT in full sunlight. The delta V_{OS} was always less than 0.3 mV, worst case. Not so bad. Although the bias current was never worse than 10 nA, the offset current was only about 1/10 or 1/20 of that. So in typical circuits where the impedances at the + and – inputs are balanced, you would barely have to worry about a nanoampere—even in full sunlight!

In a more realistic situation, such as when the devices are a couple of feet away from a 100-W incandescent bulb, these photocurrents are reduced by a factor of ~40 or 60. If you had a fluorescent lamp right down near the IC, just 4 in. away, the ripple current at 120 Hz could be as small as a few dozen picoamperes.

That light sensitivity might make some people nervous. But hey, any 1N914 or 1N4148 glass diode can generate photocurrents TWICE as bad as that! So long as engineers are aware of this small problem, they shouldn't be worried or confused. For further technical information on these small op amps, you could look up AN1112 at NSC's web site, *www.nsc.com.*

All for now. / Comments invited!
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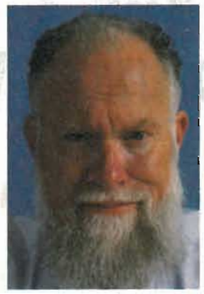
BOB PEASE

Bob's Mailbox



Dear Bob:

I have always wondered whether it was us or the British who were the contrarians. Now I know. *(No, sometimes it's US—sometimes THEM. /rap)* You didn't mention the other examples of contrariness:

1. I used to use a piece of test equipment that was made in Great Britain. The first thing I noticed was that all of the toggle switches were contrary—ON = down, OFF = up. At least the pots still turned CW for maximum voltage, as I recall. *(I think the Germans initiated the right way: A knife switch can fall DOWN, and thus be fail-safe. Can't fall UP. /rap)*

2. The British monochrome TV system used contrary modulation—sync pulses at minimum power. Also, the sound carrier was AM.

3. I have heard that the driveshaft in British rear-wheel drive cars turns CCW, while in American cars it turns CW. Is there some technical reason related to the side of the road, or is this just another opportunity to be contrary? *(I'm no expert on this. I don't know. /rap)*

It's interesting that in the PAL - SECAM debate, the British ended up on our side (in the sense that PAL is similar to NTSC), while it was only the French & Russians who chose to be contrary (from our perspective).

KEN LUNDGREN
via e-mail

Flash! Go to www.travel-library.com at "transportation" for info on LH/RH driving! Thanks for sending me the URL, Richard G.—RAP

Dear Bob:

Re: driving on the "wrong" side. In 1961 the U.S. Navy sent me to Iceland, where they drive on the left side. The base was on an airport that was shared with the Icelandic civil airlines, so we drove to the left there, also. Before joining the Navy, I had never lived anywhere but California, and before going to Iceland, my other duty stations were NAS Kingsville, Texas (hot & dry), and NAS Memphis, Tenn., in the summer (hot and damp). I had never driven on ice, never driven in a snow storm, and never dreamed of driving on the "wrong" side. I was simultaneously introduced to all three in a left-hand drive, stick-shift, '49 Chevy sedan—one of life's cheaper thrills! *(Triple surprise! /rap)*

I quickly graduated to Navy vehicles, which were U.S. configured, too. I have vivid memories of arriving at the chow hall with a van-load of sailors, travelling slowly sideways across the parking lot—kind of tacking into the wind, actually—and trying to look all ways at once. The Swedish changeover that you mentioned was quite recent at that time, and the source of a lot of horror stories. We were glad that the Icelandics hadn't followed suit; they were bad enough drivers doing it the only way they knew how.

Keep on bashing the stereo cable hype. Anybody that loves zip cord for speakers is a man after my own heart!

DAVE COOLIDGE
via e-mail

I cheerfully accept zip cord as adequate. But using 32-conductor cable and paralleling every other conductor just warms the cockles of my heart, as its Z is so low—even if I can't hear any difference versus lamp cord.—RAP

Note: If you are a good hiker, you'll be amused to know how tricky it is to climb Fujiyama—hike up to 12,390 feet—at night. Send me an e-mail or card and I will send you my latest Hiking Trip Report. If you don't like to hike, you could send me a nasty note to tell me how glad you are that I didn't make this into a full COLUMN.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer
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BOB PEASE

Bob's Mailbox

Dear Bob:

Regarding your comments in "What's All This Why Stuff, Anyhow?" (ELECTRONIC DESIGN, *Sept. 7, p. 115*). I doubt if our earliest prehistoric ancestors could throw a rock with the same accuracy and power as a baseball pitcher: *(Yeah, but if the TIGER wasn't expecting it, he doesn't get to eat YOU. If the rabbit wasn't expecting it, you get to eat HIM. /rap)*

1) Unlike baseballs, rocks aren't a standard size, shape, and weight.
2) The "strike zone" wasn't standardized and was probably moving. *(When big cats are STALKING, they tend to stop. /rap)*
3) It was quite likely that the "batter" was about to attack them.
4) There was no umpire with a supply of rocks handy in case they missed the first time. It was a long time before there is any evidence that our ancestors planned ahead and carried their tools with them. *(Hard to say. The smart ones probably DID! /rap)*
5) The earliest bipeds were significantly smaller than modern man. *(All the more reason to have tools. /rap)*

Killing an animal with a rock is problematic at best. Except for intellect, man is not naturally very well equipped to be a predator.

I'm an engineer, not a paleontologist. Even among experts, there tend to be sharp disagreements about the who, when, and where of our ancestors. Our first known bipedal ancestors appeared roughly 4 million years ago. It was certainly a crucial step in the evolution of modern humans. It freed the hands to fashion and use tools and to carry things.

But I believe those gradually came about because they walked upright. The traits didn't evolve simultaneously. The earliest known undisputed tools are about 2 million years old. There were likely primitive tools before then, but they're difficult to identify. A rock used to bash a bone can look pretty much like any other rock. *(Maybe, maybe not. /rap)*

By the way, I read a story a few years ago about a scientist who studied the patterns of the chips of tools that were several hundred thousand years old. He concluded that the makers were right- or left-handed in about the same ratio as modern man.

GARY WELCH
via e-mail

GOOD POINT!! Thanks.—RAP

Dear Bob:

Agreed, the timing of a pitcher's release is critical, but your analysis is not good. Look at your own arm when you throw. Unless you "throw like a girl," your arm follows a path flatter than a circle. *(Not at 90 mph, it don't! /rap)*

Furthermore, a pitcher snaps his wrist toward the end of the arm motion, which complicates the ball's trajectory while it is still in his hand. *(Yeah, maybe he needs 50 µs instead of 100. /rap)* Take a look at the freeze-frame video!

CHRIS MAPLE
via e-mail

That's hard to do at 90 mph!—RAP

Hot Item: "Free Energy?" Electricity for free? Perpetual-motion machines? Don't you love that stuff?! Check out these four web sites, and see which ones YOU believe:

www.teslaelectriccompany.com
www.ucsofa.com
www.phact.org/e/z/leelee.htm
www.voicenet.com/~eric/dennis.html

Aren't you glad you paid attention in Science class?! /rap

All for now. / Comments invited!

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What's All This Floobydust, Anyhow? (Part 8)

Floobydust* season is here! (It's always the right time for Floobydust). This year I visited 16 countries. Every chance I had, I went to hardware stores. In NO place did I find any 1/4-in. electric drills—only 3/8 in. or 10 mm. Sounds like a conspiracy to me, that ALL manufacturers and sellers of nice, light, high-speed drills just *happened to* stop making them at the same time...I think I'll write to the Attorney General.

Slobber: Back in the 1960s (which I'm sure many of you remember), Tektronix wired most of their scopes in the 530 series, and the plug-in preamps, with the components soldered neatly into rows of little NOTCHED ceramic strips, etc. Somebody asked me: "Why did Tek recommend using silver solder to repair the components in these ceramic strips?"

BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

Almost nobody knew the answer. But Jim Williams, an aficionado of old Tek scopes, recalled that if you had to make repeated solder repairs to any point, the metal could separate from the ceramic, causing flaky results. The silver solder could prevent this. But *that* silver solder was made up with 1% or 2% silver.

These kinds of solder typically melt in the range of 179° to 309°C. The silver solder used for soldering steel, with a borax flux, has 75% silver and melts at 1005° C; or if 56% silver, at 983°C. So, those two kinds of "silver solder" are quite a bit different.

Vice-Versa Stuff: I got more letters on "Vice Versa Stuff" (ELECTRONIC DESIGN, *Aug. 9, p. 107*) than on most topics. Many ideas overlapped.

One reader pointed out that fully loaded ore trucks in an open-pit mine ascend on a CW spiral road. And it makes perfect sense to drive on the LH side, near the wall, to avoid breaking down the open edge of the road. The *descending* trucks, empty, drive near the dropoff.

But why are the CW spirals ascending? They could have made the spiral *either way*. The answer lies over 100 years back. When trucks were introduced to take over from ore trains, they followed the same CW spiral. It would be silly to reverse the spiral on existing mines.

I already bought my champagne. There's sure to be severe shortages of good champagne (at any reasonable price) for a couple years.

OK—fine—WHY did the trains run on the left, on the ascent? That goes back over 120 years, and it may be hard to find an answer. I can't guess. Anyhow, the guy pointed out that all such trucks have lefthand drivers, even though they operate on the LH side of the road, in countries where other drivers may be LH or RH.

A couple guys gave the exact date of the RH changeover of Sweden as Sept. 3, 1967. There's info at *www.docs.uu.se/~ei96pem/Hogertrafik/Innehall.htm* that's quite educational—if you read Swedish.

As mentioned earlier, the web page at *www.travel-library.com/general/driving/drive_which_side.html* has over 15 pages about LH/RH driving. There's a complete list of all countries that drive on L or R and many historical items.

There, I learned that Napoleon did NOT cause France to change from L to R in 1805. France had been driving on the right for many years, well back before "recorded history." However, Napoleon *did* force many neighboring countries to change from L to R as he stormed around Europe.

But if the Roman army had all of Europe on the LEFT, France must have changed over sometime between 300 and 1700 A.D. Why? Meanwhile, the British did NOT change. Why not? Various possible theories and reasons have been proposed. Plus, Mr. Lucas argues that HE is not certain that the Romans did march on the left. He doubts if the reason I give is fully correct or accurate. I'll just have to look back in my files and find that old photograph showing the Roman armies marching on the left side of the road....

One sharp engineer pointed out that in a changeover such as Sweden's, you have to change the headlights. The patterns of headlight beams are DIFFERENT for LH/RH drive. Just one more reason I would not want to drive an English car in France, nor vice versa.

Y2WHAT?? A couple of readers thought I ought to write a column on Y2K. I declined, as I have no interest in writing on such digital subjects. And I can't think of much to say that hasn't been said 14 times.

I already bought my champagne. There's sure to be severe shortages of good champagne (at any reasonable price) for a couple years. I bought some rice and beans and put them in a mouseproof container, just in case stores get low on other food that's fancier, but not nearly so nutritious. Plus onions, garlic, and salsa for variety. I'll make sure I have a small stock—the usual two or three weeks—of medicines and prescription drugs, just in case. And candles, matches, and batteries. I have plenty of rechargeable ones, and I'll have my solar array nearby.

BOB PEASE

There is one *caveat* that only ONE guy told me, and I'll pass it along here: Please resist the temptation to jump on the telephone after your first sip of champagne. That surge will surely overload the switchboards and tie all the telephone companies in KNOTS. Just take it easy.

Throwing rocks? Gary Welch told me that he heard about a scientist who studied the patterns of the chips of tools that were several hundred thousand years old. He concluded that the makers were right- or lefthanded in about the same ratio as modern man. H'mmmm.

Tax-Deferred Stuff: I made a little error on the level of income where taxes become vicious: It is the TAXABLE income, not just the gross income at line 31, that has to be above $42k. It is the income after deductions and exemptions that's liable to be taxed at a 52% rate. I showed this column draft to 50 reviewers *plus* Mr. Klabis, and nobody noted my error. I think two readers caught this. Thanks for griping, guys.

WOM? Back about 1972, there was an excellent advertisement for the new WOM made by Signetics. A WOM (write-only memory) is a way to use up and dispose of otherwise unwanted bits. Looking at the text and the drawings, you could easily see that this was a rather witty parody of IC data sheets.

We all make those up from time to time. But THIS advertisement ran in at least one (maybe two?) electronics magazines, and was a four-page ad in full color. WOW, WOM!! Just two questions: Who made up the advertisement? Who the heck paid for it? (If Signetics did it, that sure was a nice sense of humor!)

All for now. / Comments invited!
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* To those of you that haven't seen the term before, Floobydust is just an old name that we coined at NSC, meaning *miscellaneous*.

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BOB PEASE

Bob's Mailbox

Hello Mr. (Dr.?) Pease:

I was interested in your article concerning optical units, the response of the human eye, and photo-currents in solid-state devices (ELECTRONIC DESIGN, *Oct. 4, p. 91*). I am forwarding the following comments concerning the response of the eye near its noise floor. As you will note, I am inclined to agree with your estimates of the detection limits for the human eye based on experimental results. *(Thanks—I thought I made some good back-of-envelope estimates. /rap)*

I often work in the photon-counting regime (1 to 10^6 photons/s) with several electronic detector types. I was initially surprised to note that I could readily observe a stream of about 20 photons/s at visible wavelengths. The optical path in the experiments is easily discernible—if I am working in a dark room and my eyes are well adapted. *(In the old days, people could see the light path when somebody puffed some cigarette smoke. Nobody does THAT in a lab these days! /rap)*

The quantum noise on the light path is also perceptible by eye under these conditions. This light level is similar to that available on a moonless night with about 50% cloud cover and illumination only from stars. In that situation, the scene will have a "grainy" look to most people. The grain is due to the quantum noise. *(Good point! Lousy visibility at night is STILL a much more valuable survivor skill than NO VISIBILITY at all! /rap)*

I saw two other effects:

1. At about 10^9 photons/s and below, the eye loses its ability to perceive color. That is, the photon stream looks the same regardless of wavelength—more or less a gray tone. This is due to the fact that the retina contains two types of receptors. The color receptors have a higher intensity threshold before they respond. *(Yeah, I neglected to mention rods versus cones. /rap)*

The contrast receptors can photon count and integrate down to a few photons per second. As an aside, nocturnal animals usually have few color receptors, since these structures are of no survival value to them. Cats are an example of this natural adaptation. When artists render a night scene, they tend to do it in shades of gray and/or dark blue. I suspect this is a human interpretation of the effect. *(Check. /rap)*

2. Some people in the lab were able to respond to light at ultraviolet wavelengths. (These wavelengths are not visible as direct illumination.) However, they could not focus an image at these wavelengths. The material that fills the eyeball can emit visible light via fluorescent emission after excitation by UV. This perceptible light originates behind the lens, so it does not focus on the retina. In my case, low-level near-UV photon streams produced a diffuse, orange-colored flare superimposed on the darkened lab.

BOB SANTINI
via e-mail

Wow! No kidding! Thanks. —RAP

Dear Bob:

Thanks for a very interesting article. One question: Ratio of sunlight to candle is 2×10^{14}, which in decibels should work out at 286 db ($20 \log 2 \times 10^4 = 20 \log 2 + 20 \times 14 \log 10 = 286$). Where is my error?

A. D.
via e-mail

Your error is that the log of VOLTAGES should be multiplied by 20, but log of POWER should only be multiplied by 10. And I was working in power.—RAP

All for now. / Comments invited!
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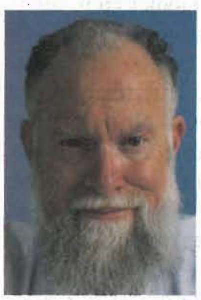
BOB PEASE

What's All This Platinum (Chloride) Stuff, Anyhow?

No, this column has nothing to do with platinum RTD temperature sensors, like the older one.[1] A while back, Chester, one of my old friends, asked me, "Bob, have you heard about this new platinum injector that is supposed to increase your car's gas mileage by 20%?"

I said I didn't think I had heard of it, but it sounded like one of those magical gadgets that are usually found to not work well. It sounded kind of UNLIKELY—like a magnet strapped to the carburetor. A couple of weeks later, Chester said, "Bob—remember that platinum injector? I bought one, and it seems to work."

He explained the arrangement: A little hose from the throttle area draws, by vacuum, a stream of little bubbles through a quart bottle filled with a mix of special liquids. One of these liquids is supposed to be inert, but the other contains a platinum compound. Maybe platinum chloride? The platinum vapor is drawn into the bubbles and goes into the engine and supposedly causes improved combustion. (It's an interesting point that these liquids must not be very poisonous, as there's no warning to not drink them or splash them on your hands.)



BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

Chester said he paid his $99, connected it up, and it seemed to give an honest 10% or 12% improvement in gas mileage right away. (If there was a week or two of gradual improvement, that might have meant it was plating onto the cylinder walls gradually.)

I looked into this. Okay, maybe it sounded like snake oil, but it seemed to work. I sent in my $99, too. I read all of the literature that came with it, and I got a copy of the patent,[2] too. Most of the quasi-technical explanations seemed EXTREMELY unlikely and implausible. The explanations vary between absurd and grotesque. Not QUITE scientific. Yet it seems to work.

The "improvement" came up right away. And after I disconnected the hose, it seemed to hold up for one more tank—but not for a second tank.

I checked my gas mileage fairly carefully before I installed it. I'd been getting 25 mpg at 69 mph, rolling on highway 280. If I go on trips where my speed falls below 65, the mileage rises up to 27 or better. (It used to be better, but the MBTE gasoline in California now gives poorer mileage.) Will my mileage jump to 30? Hold on and you'll find out soon.

This "injector" worked so well on Chester's old 1986 Dodge that he decided to buy another platinum injector to put on his '96 Saturn. Again he took careful data. In this case, the improvement was negligible. Chester suspects that modern cars have enough computerized controls and feedback and exhaust gas sensors that the computer CORRECTS for whatever the platinum tries to do. It won't let the improvement take place. Does that explanation make sense? (This leads to the question, does the platinum cause better or poorer emissions?? It's too early to guess.)

So Chester pulled the "injector" off of his Saturn and put it on his motorcycle. Early data indicate an 8% or 10% improvement, though it's hard to tell as the tank is so small that precision data are hard to get.

Would I recommend this to anybody else? First of all, we're just in the learning stages of what is going on. Anybody with a modern car and computer controls on the combustion would quite possibly NOT find any improvement, we surmise. Anybody with an OLDER car, with carburetor or NOT-computer controls, has a chance to see a 10% improvement. (Just make sure your engine is well-tuned-up and that you have accurate and honest data on your fuel mileage BEFORE you install it.)

However, if you don't drive 20,000 miles per year, then a 10% savings in fuel might *barely* get you a break-even period of over a year. So that might be a poor investment. But if gas prices rise, that would improve your payback —your return on investment, or ROI.

I don't want to exactly RECOMMEND this to anybody, not just yet.[3] But if we can find other people who have tried this successfully, that might help us make up our minds. If anybody has seen any reports that understand why and how it *really* works, that would be very interesting. If anyone knows where and when and why it does work (or does NOT work), that would be valuable to know. So—this time—it is very important when I say at the end of my column: "Your Comments Are Invited!"

What data did *I* see in my 1970 VW Beetle? I saw an immediate improvement of about 7% or 8%, about 2 mpg. Not 20%, which their web site touts is "Guaranteed." The "improvement" came up right away. And after I disconnected the hose, it seemed to hold up for one more tank—but not for a second tank.

Why do I say "about 8%?" Because in any given week, there may be a traffic slowdown. If I slow down from 69 mph to 10 or 20 or 30 for several minutes, should that be expected to *help* or *hurt* the gas mileage compared to 27 mpg? That is very hard to say. But the improvement DOES seem to wobble around 8%. Just about break-even, if I wait 18 months.

All for now. / Comments invited!
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References:
1. "What's All This Platinum Stuff, Anyhow?", *Electronic Design Analog Supplement*, June 27, 1994, p. 50.
2. U.S. Patent #4,295,816, B. Joel Robinson, Oct. 20, 1981.
3. Address to buy is: Platinum Gasaver, National Fuelsaver Corp., 227 California St., Newton, MA 02158. About $99. Phone: (800) LESS GAS or (617) 244-3838. (It's a good idea to pay for this with a credit card in case you have to return it.)

Their web pages *were at*: *www.fuelsaver.co/nz/technical.html.* Note: This URL came up with a "404" on Oct. 29. Ahem. I'll look again, but is this trying to tell us something? (Or did the extradition treaty with New Zealand run out?). But that might have recently been changed to: *www.nationalfuelsaver.com/default.htm.* Two additional working web sites you can try are located at *www.davesfuelsaver.com/dvaillant/pages/view/index.nhtml*, or *www.re-action.com/dc/news/energies/nrgies215.html.*

Note: The "Fuelsaver Prozone" from England, covered by Patent 5,404,913, is NOT AT ALL the same product.

P.S. Okay, why don't I just slow down from 69 mph to 65 mph and get an honest 2-mpg improvement? Very simple: Every gallon of gas that I burn, I'll admit, is gone forever. But every minute that I waste is, LIKEWISE, a minute wasted forever. Is it a fair tradeoff for me to stay at 69 mph and pay $100 to keep the fuel consumption the same, while I save 20 or 30 hours per year? Yeah, I'll pay that price cheerfully. /rap

BOB PEASE

Bob's Mailbox

Dear Bob:

Here are two more examples of contrariness from professional broadcasting:

The Germans: Professional tape recorders, like the Telefunken M 15 A still in use in German broadcasting stations, have a tape transport for reels of tape with the magnetic layer on the *outside* of the (open) reel. But internationally, the magnetic layer of the tapes is on the *inside* of the reel. This seems to stem from the first AEG tape transports built in 1936. The reason for this approach may have been that there is more space available compared to the space between the reels. And space was certainly needed in the beginning, because of the rather bulky tape heads. *(This seems plausible—but ODD!! /rap)*

Regarding tape movement, this is and always has been "normal" from left to right. *(You mean you haven't found anybody to do this backwards? In my kitchen, I have an inexpensive tape machine in which the cassette gets inserted into the door UPSIDE DOWN. Both spools turn CCW during normal playing. But as the tape is at the TOP, it's actually going from right to left as it goes past the heads! That doesn't change the tape flow. It just means that the tape mechanism is upside down. And of course, there are reversible tape decks in which the tape can go alternately LEFT or RIGHT. /rap)*

Initially, a tape speed of 1 m/s was used in Germany (Telefunken K1 of 1936) and later 77 cm/s (Telefunken K7 of 1940). Later, after the war, tape speeds based on inches per second were and are still being used—7.5, 15, and 30 in./s. *(Not only 7.5, but 3.75 and 1-7/8 in./s. Almost all audio cassettes are at 1-7/8 in./s. Except some books on tape are 15/16 in./s, I think. /rap)* It is interesting to note that 30 in./s (76.2 cm/s) is quite close to the 77 cm/s used in 1940—a period of time during which Germany certainly never would have adopted anything based on inches. *(And in 1940, Germany wasn't exactly on the committees to set up international standards! In fact, they just wanted to IMPOSE their standards as universal! /rap)* I believe tape width was initially only 6 mm, compared to 6.25 mm (1/4 in.) as used today.

The British: In professional broadcasting mixers from Britain, it was (and still is?) common to find a fader arrangement where the fader at its top position would give zero volume. All mixing consoles in use elsewhere at that time ('70s and '80s) have their zero volume position at the bottom end. Admittedly, the British way of doing this has the advantage that it will hardly be possible to fade in a signal inadvertently, since this would require pulling rather than pushing—which may happen more easily. Reference: *Penny and Giles Conductive Plastics Ltd. Audio Products Catalogue* of 1983—1500/1900 series faders with the options of "fade up" (infinity towards operator) or "fade down" (infinity away from operator).

WILFRIED ADAM
via e-mail

Hmmm...Yes, that is an OBSCURE kind of contrariness! Thanks for the stories!—RAP

Dear Bob:

I have just read your column, "What's All This Vice-Versa Stuff, Anyhow? (Part II)" (ELECTRONIC DESIGN, *Aug. 9, p. 107)*. It takes a while for it to arrive here in Australia! I just thought I would add some clarification to the "which side of the road do you drive on" discussion. If my memory serves me, there was an international meeting in 1903 to provide some standardization to automobiles. At this time, it was decided that the driver should sit on the left side of the vehicle and drive on the right side of the road. (Here, your arguments may figure in).

After this meeting, Royce (later of Rolls Royce fame) convinced the British Government that if they switched to the left side of the road, it would keep all those nasty foreign cars out of England and, of course, help bolster their English industry.

RICHARD URMONAS
via e-mail

Charming! Very amusing! YOU are the first guy to tell me this! But England had been driving on the left for well over 100 years, officially, and over 1850 years at that point unofficially. So maybe Mr. Royce was just deciding to REFUSE to change over? Considering the turmoil a changeover would have made, I can hardly blame them for staying put! I mean, cars and drivers are hard enough to change over. But getting the HORSES to go along would have been IMPOSSIBLE!!

Dear Bob:

This is in response to the baseball-throwing letter in "Bob's Mailbox," (ELECTRONIC DESIGN, *Oct. 28, p. 100)*. I was not impressed with the presentation of evolution as fact when we all know that it is, like any idea of the beginning of the world, no more than a theory. A theory full of holes, inconsistencies, and a lot of guesswork.

I recognize that it is a theory many believe as fact, although many also believed at one time that the Earth was flat. For many reasons, some of which are scientific, I choose to believe a different theory regarding the creation of the world. I do not mind a good discussion on the topic, however; but let's not forget that what we are dealing with are theories. To present, or to allow to be presented, evolution as fact is somewhat intellectually dishonest at best.

TODD W.
via e-mail

Todd, you can believe any theory you want to. But if you want to say that the "Theory of Evolution" is only a theory because it hasn't been proven to a shadow of a doubt by facts and complete evidence, then there's no point in debating or arguing. Obviously, we have completely different ideas about what "a theory" is. If you don't want to believe in it, you don't have to.—RAP

All for now. / Comments invited!

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pease porridge

What's All This Retrospective Stuff, Anyhow?

January (the month named after Janus, the door-keeper) is the traditional time for looking forward—and backward. The end of a century is a good time for looking back. I'll let all of the other pundits guess what they expect to happen for as much as 100 or 1000 years into the future. (Remember the words of wisdom from Yogi Berra: "Predicting is very hard. Especially about the future." No, NOT Yogi Berra. It was Niels Bohr, who borrowed it from the Danish philosopher Robert Storm Peterson.) Anyhow, looking back can sometimes help you plan for the future, as if you're rowing a rowboat. I'm just going to look back.

I had a pretty good year last year. I went off to lecture in 15 countries, 10 states, and 60 cities. I even got to climb Mt. Fuji in Japan. I met a lot of nice people. I had a pretty good 60 years in the last century. I've still got good health, and I can still see where I am going. No big car crashes.

The electronics business had a pretty good year and a pretty good century. We got radios and TV, we got radar, and we got computers. And most of this was at very cost-effective prices. (Electric cars are pretty good, too. The motors and electronics work FINE. It's just the batteries that aren't so hot!)

Let's take a look back at the last 100 years. Even if the vacuum tube, transistor, and IC hadn't been invented, the 20th century was going to be a big century for electricity. Electric cars were competing quite healthily against the internal combustion engines and steam-powered cars. Electric trains and trolleys were improving the transportation scene without polluting the streets with manure or smog. And ac and dc motors were coming into factories and homes.

In fact, high-power radio transmitters were running without any help from tubes. The microphones did tend to overheat, though, if overdriven too much. The carbon microphone was used to modulate the field of the radio-frequency motor generator. Look, Ma—no tubes!

Thomas A. Edison was one of the greatest engineers of all time. We think of him primarily as an inventor in the 19th century, with 766 patents. Yet he also had over 320 patents in the 20th century. "Incandescing bulbs," motors, voltaic batteries—he was no slouch! A web site lists his many patents: *http://edison.rutgers.edu*.

Where is electronics going next? Will Moore's Law continue to extrapolate the shrinking transistors and costs into the indefinite future?

"Incandescing bulbs" grew into vacuum tubes. You had diodes, triodes, tetrodes, and pentodes all based on a patent by Lee de Forest, even though he did misunderstand what he'd invented....

The tubes led to radios that were better and better, cheaper and cheaper. They weren't just the hobbyists' expensive battery-powered radios of the 1920s, but ac-line-powered radios that became popular in the 1930s. They were radios with convenient super-heterodyne circuits—not just tuned RF or super-regenerative receivers with three or four big globes and a LOT of adjustments! And there were FM receivers (invented by Edwin Armstrong). Let's not forget that the IEEE was made from a merger of the Institute of Electrical Engineers (IEE) and the Institute of Radio Engineers (IRE) back in the 1960s. Television, while invented in the 1930s, became affordable and popular in the 1950s.

What if the British hadn't figured out how to scramble their Spitfires when the Luftwaffe bombers were still out of sight over the horizon? The English-speaking world would've had a lot of trouble! The invention of radar also made a big difference. I've been reading a couple excellent new books on radar. *The Most Secret War* by R. V. Jones is the most recent. Radar was a VITAL invention developed greatly during the 1940s.

My favorite story about radar goes back to August of 1940 (just a week before I was born). The Luftwaffe put in a concerted effort to knock out the RAF "chain home" radar station at Ventnor on the Isle of Wight. They bombed the antenna and the transmitter shacks, damaging them pretty badly. They lost several planes in the effort. But the next day, when they flew over, their crude detectors showed that Ventnor was back on the air. Air Admiral Goering decided that if it was that hard to knock out a radar site, it wasn't worth it. So they stopped trying.

Actually, the radar wasn't really *working*. But the British technicians refused to admit that it had been knocked out. So they put some radar-frequency noise and oscillations into a crude amplifier, and pretended that it was a radar transmitter. Their bluff worked. The Germans went off to bomb different kinds of targets, and the radar sites were spared. Pretty good bluff! That may have been the turning point in the war.

Having better equipment is not the same as knowing how to use it.

Even if the transistor hadn't entered commercial use in the 1950s, electronics was going to be a big business with small circuits. Modular, integrated circuits were pioneered in that decade. An example is Project Tinkertoy, which had thick-film resistors and capacitors on ceramic substrates to be connected up INSIDE a glass bottle with several triodes. Could we have integrated radios or phones running on just a couple of watts, as small as any 1995 cellular phone or walkie-talkie? Yeah, probably. But I'm sure glad the planar transistor came along.

Robert Noyce's planar transistors and ICs drove reliability and performance up, and costs down! Moore's Law was one of the amazing phenomena of the last 50 years. Remember when one transistor cost $8? Now you can buy 250 million transistors in a RAM for that price. Still, there are those of us who observe that one good op amp is worth more than 1000 microprocessors....

What if a lunar lander had gotten to the moon, but the electronics failed and they couldn't take off? That would not have been a good year for a lot of people. I suspect that people's confidence in electronics would not have recovered from THAT for a long while. I met astronaut Buzz Aldrin recently, and he agreed that it would've been a real challenge to try to get that vehicle off the moon with just a slide rule. He was very pleased when the whole system (all built by the lowest bidder) really worked.

As volumes grew and prices dropped, the temptation to manufacture electronic equipment—TVs and radios and transistors—overseas grew just too hard to resist. Prices dropped further. But U.S. manufacturing and engineering jobs have been declining for a long time. Sigh.

So now we've got all these inexpensive, reliable, planar transistors and ICs. What did they lead to? Cheaper (digital) computers, smaller computers, personal computers, laptop computers, programmable calculators, and even information appliances—all of which have more computing power than the first (ENIAC) digital computers. I don't like computers for many uses, but they sure are handy for word processing. I certainly don't want to fool around with vacuum-tube portable radios, calculators, or computers. No analog word processors or hand-set type in printing presses for me, either.

"Hey, Pease, don't you think the Internet is a great invention?" Well, you don't want to hear my REAL comments on that. I'll just tell you a relevant quote from a wise man: "Many people think that information is knowledge. It isn't." I rest my case.

Does the view of the past tell us a lot about the future? What is at our back as we continue to row our rowboat?

Where is electronics going next? Will Moore's Law continue to extrapolate the shrinking transistors and costs into the indefinite future? Maybe not. But engineers will keep competing to invent new circuits and systems, just not at exactly the same logarithmic expansion rate!

Will digital radios be better than old radios? We shall see. Personally, I have never heard any claims for digital radio that I was impressed with, not to mention digital TV.

What the heck is an "information appliance?" My bosses think a lot of people will want those. I think it's a "seamless" integration of web, e-mail, electronic toilets, and automated refrigerators that tell us when our milk is going out of date. Or, maybe it predicts when the head-gasket on my car will blow out. I'll wait and see. I don't HAVE any head-gaskets on my VWs!

All for now. / Comments invited!
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P.S. Comprehensive information on the WOM, one of the greatest inventions of the century, is accessible at: *http://ganssle.com/misc/wom.html* and *www.ariplex.com/tina/tsignet1.htm*.

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

pease porridge

Bob's Mailbox

Dear Bob:

You were talking about the difference in dynamic range of the senses of sight and hearing, and came to the conclusion that there was not a lot of difference. *(I just said that the ranges were COMPARABLY wide. /rap)* There are two other ways in which those senses differ enormously:

One is the resolution of two simultaneous frequencies. Many people can listen to a two-note chord, and sing back each note separately. (Musicians can manage many more, and tell you which instrument is playing which note.) But I don't know anyone who could color-match each component of a colour produced by combining two spectral lines. Yet the eye has more resolution in space! And—remember—the ear can hear fairly well over a 10-octave span of frequency—with perhaps 12 notes per octave—whereas the eye can hardly see over one octave!!

The other way is the spatial resolution of a light or sound source. The eye can resolve position to a fraction of a degree *(or, more correctly, a fraction of 1/60th of a degree—a fraction of a minute /rap)*. The ear, meanwhile, is accurate only to tens of degrees. *(Well, the ear can detect an angle a LITTLE better than 10 degrees. /rap)* The reason is obvious when you think of the actual transducers. The eye has only three types of color discriminator, but they are repeated spatially thousands of times. The ears, on the other hand, have many different frequency discriminators, but they are only repeated twice, once in each ear.

PETER HESKETH
via e-mail

You are right: Each transducer is optimized for us to survive and thrive! Thanks for the comments!—RAP

Dear Bob:

The Nov. 22, 1999 "Bob's Mailbox" was quite timely. On Thanksgiving at the in-laws, I wandered into my nephew's eerily "backlit" room. Lots of little glowing dust motes between the garish posters. I turned to face the blacklight tube and got an eyeful of white glow. It was pretty obvious that the light was coming from inside my eye as it filled my entire field of view.

I've also experienced discomfort looking at neon advertising signs with gases that emit at opposite ends of the visible spectrum. Our eyes have sufficient chromatic aberration that we cannot simultaneously focus on red and violet. A sign that contains only those colors (providing the violet is really violet and not a mix of blue and red) causes our visual system to continually hunt for focus. The eye strain is immediately felt.

That brings up another curiosity about our vision. Recalling ROY G BIV, we see that violet is as far from red as it can get and blue is between them. Yet as children, we all learned that you get violet by mixing red and blue. I haven't had the time to check the literature, but it seems obvious that our red and blue cones are both sensitive to violet. That's why we have a color circle with violet right between red and blue.

I recently had to get a gallon of "off-white" paint to match an old one. The manufacturer had changed their base and colorants since the first gallon. To my surprise, they were unable to match the old paint across different lighting. If it matched in sunlight, it didn't match under incandescent lighting and vice versa. I hypothesized that the new base paint's "peaky" absorption spectrum was quite different from the old one, and that it was impossible to pull them into alignment with the colorants. The perceived color of a surface is the product of its absorption spectrum, the source spectrum, and the eye's spectral sensitivity. Since all of these spectra are complex, with peaks and valleys, it is certainly possible to create a new base paint with peaks or valleys in places that simply cannot be compensated for. By examining the equations for a few other off-white colors, I determined that the new base was actually a little purple. To get my requested off-white, they added lots of yellow. The original paint was tinted with raw umber (orange-brown). So they were trying to make orange from yellow and blue. I don't know what the absorption spectrum for raw umber looks like, but I bet it doesn't look like yellow plus purple. Under sunlight, you might get the two paints' absorption spectra to light up your eye the same way. But change the source spectrum and all bets are off.

As an extreme example of this, imagine having a perfect red paint (absorbs all but one red wavelength) and a perfect blue paint (absorbs all but one blue wavelength). Mix them together and view them under sunlight. You see violet. View them under violet light and you see nothing. So much neat stuff to know. Life's too short!

SCOTT KROEGER
via e-mail

What can I say? That is wild!!! Thanks for the insight.—RAP

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pease porridge

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What's All This Battery-Charging Stuff, Anyhow?

On October 4, at noon, I sat down at my breakfast table, and plugged in my soldering iron. I was going to build the circuit shown in Figure 1. I had one hour to put it together, which was enough time, and then I was going to drive down to the airport to fly to Kathmandu.

As the soldering iron was warming up, I looked for the collection of parts that I needed for this circuit and had shoved into an envelope. Rats! Where were they? I knew I had left the parts in a safe place. I searched in every reasonable spot, every pocket of my briefcase, and all around my house. After 10 minutes, I gave up and unplugged the soldering iron. (Later, 10 miles up the trail above Namche, I found the parts in an envelope in my trousers' left front pocket, which, of course, was a "safe place.")

Fortunately, the circuit that I was going to build was just a spare, a back-up, and we never needed it. So, it wasn't a big deal that it didn't get built.

About eight years ago, I explained in "What's All This Battery-Powered Stuff, Anyhow?" that I used a gear-motor with a hand crank, at about 40 RPM, to charge up the batteries for my new Sony camcorder when I was off backpacking or trekking. That was better than nothing. But the gear-motor's maximum output—barely 2 W!—was limited NOT by the motor, nor by the strength of your arm, but by the gears' maximum allowed torque, which was NOT a lot. So a couple of years later, I bought a small solar panel that could put out much more charge on a typical sunny day. Next, I bought a bigger, yet lighter panel. Then when I was in Kathmandu, I discovered that one of my panels had apparently quit (really, it hadn't), so I bought another panel from Lotus Energy *(see the table)*.

Because my camcorder batteries have been mostly NiCads, I used a simple circuit and just let the solar panel's photocurrents flow into my batteries. The circuit shown in Figure 2 is merely a simple scheme with a Schottky rectifier to connect the solar panel's output to the battery, plus a detector to show if the battery isn't connected. If the battery is below 8 or 9 V, the LED will NOT turn ON, and that's GOOD. That means the battery is getting charged, and holding the voltage low. But if the voltage is above 10 V, the LED will turn on, indicating that the battery is NOT getting charged. This is a bad thing, so the LED signifies bad news. It's time to re-adjust the rubber bands! I mount the LED right near the banana plugs, which I keep outside of my pack's back pocket, while the battery rides inside the pocket. The solar panel is lashed on top of my pack.

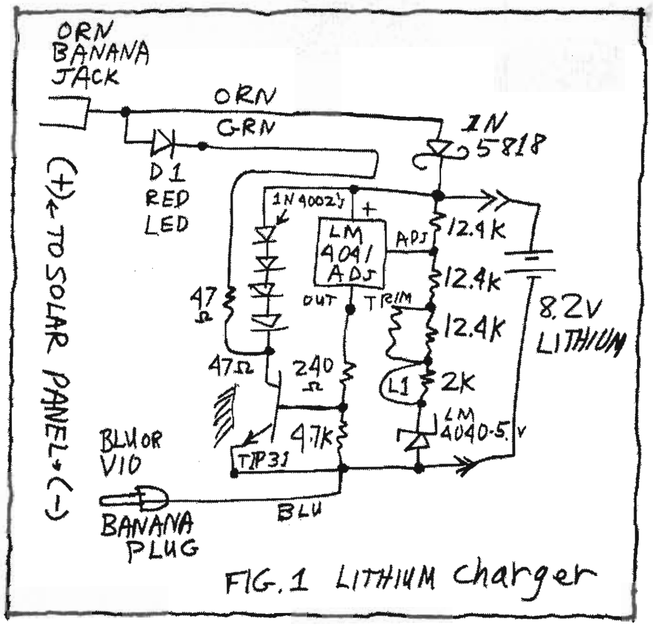


FIG. 1 LITHIUM Charger

The number of 1N4002s in series at D2, D2.5, D3, D3.5 should be perhaps two or three, but maybe more, depending on your actual battery. I recently found that one of my batteries has six NiCad cells in it, not the usual five, so I had to use a couple of extra diodes in series, or the LED wouldn't have gone out!

Many SONY and RCA camcorders have a simple flat interface to the battery, where it was easy for me to set up a couple of small blunt bolts or pins, to be pressed against the recessed terminals of the battery. The connector should be arranged and keyed in such a way that it cannot be applied BACKWARDS to the battery. The sketch of how I did mine is shown in Figure 3. I used tin snips to cut copper-clad 1/16-in. epoxy material into thin strips, such as 3/8-in. wide. And I used a hacksaw blade to saw a dozen gaps in the copper. I soldered three of these thin strips (at the places marked with S) to make a triangular frame, which is easy to strap to the battery with a few rubber bands. I used the isolated foil areas to solder up circuit nodes, such as the LM334 and various diodes.

How do I know how much charge to put into a NiCad battery? I have several two-hour NiCads (2000 mA-H). If the battery gets low, and the camcorder shuts off because it's low, then I can put in well over 1 A-H, or 0.3 A × 3 or 4 hr., before I need to taper off. Usually, if I'm charging up one battery, I'm using another one to record with, so rather than worry about EXACTLY how full it is, I just swap batteries and fill up the one I was using.

What if I'm going to leave camp and leave my battery charging in the sun? I will usually put the solar panel in a sunny place, and lay it out at an angle so that the solar radiation will get more oblique as the day goes on, and the rate of charge will taper off. I might just put the panel FLAT on the ground. At noon, the sun will come booming in, but in the afternoon, the panel's output will drop a lot. If the panel's output falls to 0.2 A, a 2-A-H battery can take that much current in for a long time with no harm (C/10 rate). My panels can put out about 0.4 A, which is NOT a horrible amount.

Many modern camcorders have a gauge to tell you if the battery is nearly full, or what. (Some batteries come with a "fuel gauge," and most of those are rather optimistic; after one-half hour of charge, they say that the battery is full, which is obviously malarkey!) Of course, the correct way to terminate charging on NiCads is to detect when the battery has a rapid rate of rise in temperature. But I have never had to do that when hiking. For a fixed installation, I would probably set one up.

One of my trekking friends had NiMH batteries for his newer camcorder. I checked it out, and NiMHs like to get charged the same way as NiCads. Just push in the amperes until the battery is nearly full, but be sure to taper off to C/10 when it gets full. I told him to do exactly what I was doing, and he made similar adapters.

But a couple of my trekking friends had new camcorders with lithium batteries. I knew that you have to be very careful with them, because overcharging a lithium battery can lead to RAPID DISASSEMBLY. Most of you guys know what that is...or you can figure it out.

So, it's important to have a reliable regulator that will charge your lithium battery up to 8.200 V (or 8.400 V) and no higher.

NSC makes two nice little ICs that can do that, the LM3420 and LM3620. These are nice, accurate series regulators, but they're NOT easy to turn into shunt regulators. I want a shunt regulator, and here's why:

A solar panel is a current source. It puts out an approximately constant current into any load that you connect to it—even a short circuit. Plus, even if you leave its output open-circuited, it isn't unhappy. When you think about it, it's fundamentally different from any ordinary voltage source. (For further notes on 50 good current sources, see the Web seminar I gave on Dec. 6, 2000, in the archives at *www.netseminar.com*.)

When I put the output of a 20-V solar panel into an 8-V battery, some power is wasted, but that's not a big deal. The battery and the solar panel are both happy about this situation.

If I want to get all of the energy possible from that solar panel, I feed that current into a series stack of two 8-V batteries. To do that, you need current-mode charging, and you need *shunt* regulators, not series regulators. Then if my batteries are low and I'm just coming into a period of sunshine after a long spell of clouds, I can simply stack two of them in series and shove the current through BOTH of them. Best of all, these batteries, with their shunt regulators, are mix-and-match, so I can stack any two in series. I can charge up one of my NiCads in series with an 8.2-V lithium, or a NiMH in series with an 8.4-V lithium, and the solar panel just kicks the charge into both. If one of the lithiums gets full, the charge is shunted through the power transistor and it keeps flowing through the other battery, so charging continues. This wouldn't be possible with a series regulator. Because we had about 12 batteries, four solar panels, and about 10 regulator modules on our trek, we weren't only self-sufficient, but we were inter-operable. As a result, the loss of any one regulator or any one panel wouldn't stop us. It would barely slow us down.

Could I use a switching regulator to convert 20 V at 300 mA into 8 V at 700 mA? YES, in theory I could. But I don't usually need quite that much efficiency. I built one, once, and it did work, but it wasn't a winner even though it weighed only 1 ounce. Usually, it's just fine to stack the two batteries in series. Simplicity is a great virtue—even though I have to carry around two batteries that tend to get a bit heavy!

Connectors

We have all seen power systems using fancy connectors. When they get banged up, they're impossible to repair. Our Head Porter had a solar panel that *he* carried on his back every day, thus making five of us solar guys on this trek. His panel fed into the batteries that he used to run

SOME AVAILABLE SOLAR PANELS

	Weight (lb.)	L × W (in.)	Output	Price	Supplier
#1	1.5	12 × 13	0.30 A × 20 V	$140	Backwoods Electric
#2	1.0	10 × 20	0.40 A × 20 V	$110	West Marine
#3	1.4	10 × 16	0.40 A × 14 V	$105	Lotus Energy
#4	1.0	10 × 20	0.40 A × 20 V	$100	West Marine

Of course, #3 can't charge two 8-V batteries in series. But OK.

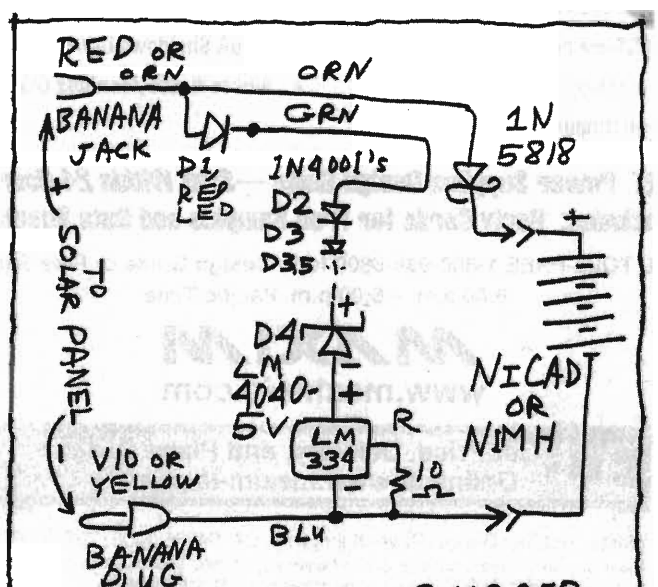


FIGURE 2, SIMPLE CHARGER

our fluorescent lantern. But his connectors were RCA phono plugs, and when they got abused, they were not only unreplaceable (Namche Bazaar has a few radio repair shops, but had ZERO pieces of RCA plugs/jacks that could be bought or scavenged for repairs), but they were nonrepairable.

For nine years, I have used as my *standard convention*, that the + wire from the solar panel has an orange (or red) banana plug, which mates with an orange (or red) banana jack, and an orange (or red) wire going to the battery. The – side is reversed in gender: a violet (or blue or yellow) banana jack from the solar panel, and a violet plug tied to the battery. This makes it easy to connect two batteries in series. (Yes, I know it looks funny when the two batteries are connected in series by plugging a yellow plug into an orange jack, but it's perfectly OK, and nothing can go wrong.)

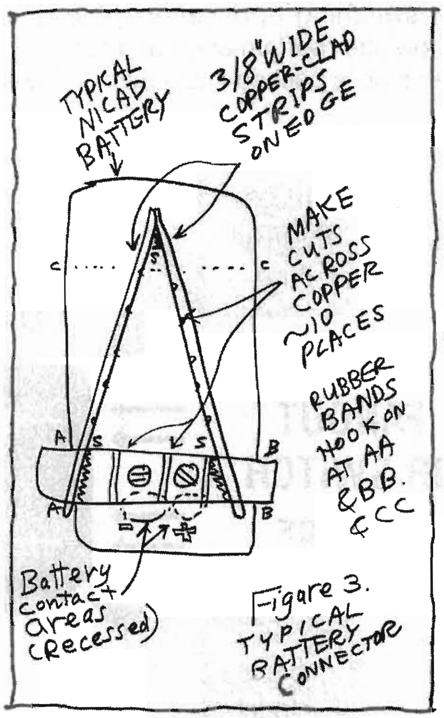


Figure 3. TYPICAL BATTERY CONNECTOR

Further, there's hardly ANYTHING more repairable than a banana plug (which works great with no solder) or a banana jack (wrap the wire around the tab and crimp it or put on a minigator clip). We had zero trouble on the trek with our wires or connectors. (When the porter's RCA plugs failed, we managed to coyote them up—lashed them in parallel—and the lamp kept working every night.)

Now let's look at the circuit of Figure 1, the critical one for Lithium batteries. The LM4041-ADJ is basically OFF if the battery voltage is below 8.2 V. The circuit draws only 140 µA. This means that all of the current from the solar panel flows into the battery. When the voltage gets up to 8.2 V, the LM4041 sees 1.24 V at its ADJUST pin, so it turns on, and it turns on the big NPN to shunt off all current necessary to hold the battery voltage at 8.2 V. When this happens, there's enough current to turn on the red LED. So, if the battery is fully charged, the red LED turns ON and tells you this. Or, if the battery isn't connected, the red LED will also turn on. You may have to check your connections to tell which is happening. Still, it's a good two-mode indicator. It only wastes 10 mA in the LED when the battery is NOT getting charged. But the big NPN has to carry as much as 400 mA, and it can get hot, so be sure to provide an adequate heat fin.

This circuit is set up to be trimmed to 8.2 V, but if you disconnect the link L1, the voltage goes to 8.40 V. Which one should YOU trim for?

Connect a couple of small wires to your lithium battery's terminals, and monitor the voltage with a DVM as you charge it. If it stops at 8.2 V, that's what you need. One of our guys had an 8.2-V battery in his Canon Elura. The other guy had an 8.4-V lithium in his Sony. Most people would set up the regulator for just their battery. The circuit of Figure 1 was going to be trimmed for BOTH voltages, with a link to snip to get the higher voltage. How do we know for sure? We brought two DVMs to Kathmandu, and then we brought the lighter one along on the trek. We just trimmed the basic circuit of Figure 1 to 8.2 V by adding various high-value resistors across the 12.4 k in order to get the voltage to 8.2 V ± 0.25%. Then if we needed 8.4 *(see the table)*, we would just undo the link. (Because we had low-temperature solder from Radio Shack, we could reconnect any wires using a match for heat.)

The 8.2-V battery for the Elura clipped onto its regulator by rubberbands. The 8.4-V battery for the Sony had two small sockets set into the battery, and a couple of MINI banana plugs matched those sockets perfectly. I used to be nervous about lithium batteries, but now I'm perfectly comfortable with them. When you charge the battery with this circuit, it pulls the battery right up to 8.2 V, and then it keeps it at a full state. The LED tells you that it's full. Even if something FALLS OFF, the battery cannot be over-voltaged or overcharged.

What's the right way to charge lead-acids? *(Fig. 4)*. That circuit can put out 14.4 V to bring a "12-V battery" up quickly. But after it gets up there, hysteresis is added through the 18 k, to bring the voltage down to a float voltage of 13.4 V. This circuit does have temperature compensation, because on a hiking trip or trek, you could easily have a working temperature range between +120°F and 0°F. You wouldn't want to over-charge the battery when hot, and you wouldn't want to under-charge it when cold, which is what would happen if you charged it to a fixed 13.4 V at all temperatures. (The other types of batteries don't need temperature compensation.)

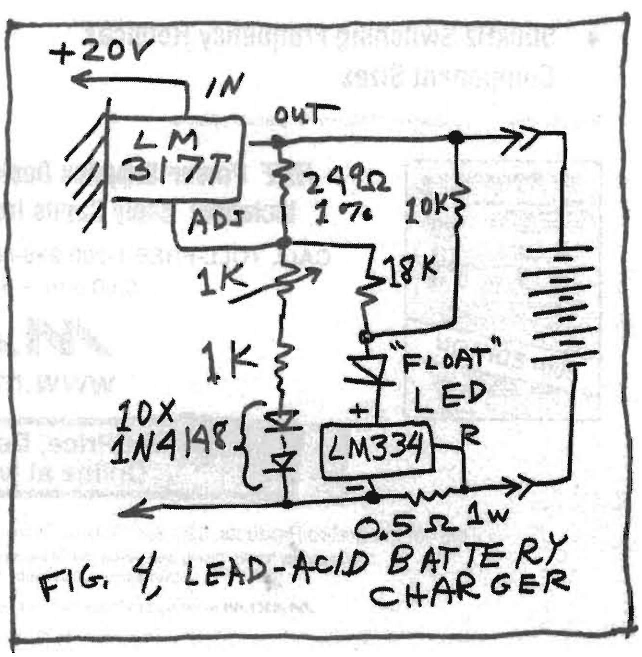
So trim that pot to get 13.4-V DC at no load at 25°C, and (13.4 V – 22 mV/degree) at temperatures away from +25°. In this circuit, the LM334 is NOT used as a current-source, but as a low-voltage comparator. This circuit is a series regulator because you won't be stacking two of these!

(The town of Namche Bazaar has good reliable 220-V AC power. But some of the innkeepers have learned to charge tourists and trekkers high prices—as high as $4 to $7 for charging one battery. When they get you over a barrel, they really know how to get you! Also, above Namche, there isn't a lot of reliable electricity available. Therefore, it would be very hard and/or expensive to bring a group of batteries and only record a LITTLE. By bringing my own charging equipment, I had no trouble recording 23 hours of video in 35 days on the trail. Of course, it took up a lot of my Christmas vacation to get all of the video listed and ready to edit down to a few one-hour tapes!)

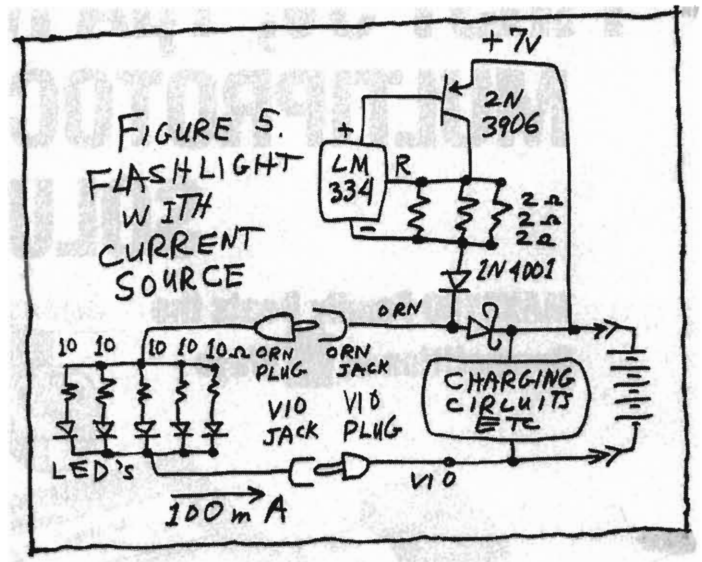
Several people along the trek asked why we were carrying these solar panels, and we explained. Some of them said, "Hey, that sounds like a really good idea. I left my camcorder at home because I couldn't figure out how to charge its batteries. Let me know when you can tell me how to do it!" Well, that's what this column is about.

The flashlight that I hooked up to a battery can be seen in Figure 5. The LM334 and 2N3906 form a 100-mA current source. When you unplug the solar panel and plug in this flashlight, it's a pretty good little light. Normally, you wouldn't want any discharge path if you shorted the orange and violet terminals together. But because this is just a regulated 100 mA, the battery won't be abused. The components of the little current regulator are easy to mount inside of one of the A-frame members. You might switch out one or two of those 2-Ω resistors to adjust the brightness.

I arranged the LEDs (Digikey Part CMD333UWC-ND, about $3) in a fan array, to make it easy for reading. You can point them anywhere you want, though. The current source shown here isn't as efficient in voltage as the one I showed back in the September 5 issue. I did that on purpose, because I wanted this circuit to quit drawing



current if the voltage supply gets down to 6 V to protect the battery. This circuit does have the advantage that it connects to the load and the battery with just two wires, rather than four. Therefore, the wiring is much easier and safer. Now my best flashlight is easy to recharge! A solar-powered night-light!



These are some of the circuits and procedures, the tricks, and the connectors that kept us running with plenty of charge for over a month. Did our batteries ever get low? Yeah, after three days of gray weather. That's why we like to keep our batteries charged up pretty full, almost all the time!

All for now. / Comments invited!
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pease porridge

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What's All This Amelia Stuff, Anyhow?

I suppose I could've called this, "What's All This Baby Stuff?" But in this case, I think it's fair to particularize, not generalize. Last year, our younger son and his wife had a nice healthy baby. At the time, my wife and I were hiking up at Pangpema in eastern Nepal, at 16,400-ft. elevation, 90 miles from the nearest road, and 10 days hike from the nearest airport. We didn't know if the baby was a boy or a girl.

I went to the nearest phone booth and put my dime in the machine. Actually, there was a British medical expedition and they had a satellite phone. I called home and found out that our new granddaughter was named Amelia. Not a bad price: $42 for 2.7 minutes. A good investment.

Like most babies, Amelia is beautiful in many ways (and ordinary in others). But we sure like her. We think she's pretty bright and agreeable. And she has a long attention span, which I think is great.

(What's All this Zarf Stuff, Anyhow?) When Amelia was just big enough to sit up (at about 6 months), we sat her in a high chair and she joined us at the dinner table. I took a red plastic zarf, which is the sort of funnel that you use to filter your coffee. It's good for kids to play with because it has a handle and no sharp edges. I took her favorite red plastic ducky, put it under the zarf, and slid it over toward Amelia. She tried to grab the zarf quite awkwardly at first. After a while, she figured out how to pick it up, and there was the ducky. Okay!

After a minute, I put the ducky under the zarf again and offered it to her. Again, she figured out how to uncover her ducky. We played this game 11 times in a row with the same positive result.

The twelfth time, she just *ignored* the zarf. Later, I tried it a few more times. She continued to ignore this test. Smart kid. Independent! (I got this on videotape.)

A few months later, when Amelia was about 10 months old, we were playing with blocks and little colored rings that went on a central spindle. At the end of the evening, I mused, "I wonder if she knows about colors." I held out two blocks to her and asked, "Hey, Amelia, which one of these is red?"

Amelia's eyes *snapped* to the red one. Then she slowly held out her hand and pointed at it.

Amelia's mother said, "Oh, that's just a lucky coincidence. I can't believe she *really* knows red." Well, we asked the same question—"Which one of these is red?"—about four more times using DIFFERENT toys with red and other colors. She was right five times in a row. So we were impressed. First of all, Amelia is not colorblind. She also isn't deaf. And she understands *red*. Not bad!

It wasn't until a week later that I realized that Amelia also understands, *"Which one of these is ___?"* That's pretty good, too, for a little kid.

My wife has always observed that kids may not know how to talk, but they do know a lot about words. A small person might know how to respond to a word quite well, even if he or she could not speak it.

One time we had a drought. Our older son was not talking much at that time. He spoke just a very small number of words. Then one morning I went down with him, opened the kitchen door, and it was raining. He looked at this and said, "Hmm, rain..." We thought about this. We were quite sure he had never spoken the word "rain" to us (though maybe to himself). Anyhow, he knew what he was talking about.

We bought the new book by Alison Gopnik, *The Scientist in the Crib.*[1] It's pretty thoughtful. It's NOT necessarily anything you wouldn't have guessed or figured out by yourself, but it's nice to see it confirmed. It points out that babies really *do* start learning their language skills at the age of zero and even earlier. Talking to a baby really does work. Singing, too. This is *essential* for a baby to learn to talk. Babies in a bad old orphanage, where nobody ever talks to them, are in DEEP trouble for language skills. Conversely, babies who are fed two different languages can assimilate them easily. Wonderful!

The book starts out by proving that an infant who's just an hour old can respond to the sight of a person sticking out a tongue by sticking out his or her tongue. Hmmm...how does a baby know to do that? You may not need to BUY this book, but it's definitely a good book for any parent to get his or her librarian to purchase. You should get in the HABIT of recommending good books that your librarian ought to buy.

This Column is NOT about kids or babies. Don't complain to me that I am wasting trees on irrelevant topics. It is about the kind of learning that people and kids do.

Several years ago, in a football locker room, a woman reporter was accosted by a football player because she was allegedly looking at part of a football player's body. Some people might have thought of this as the kind of racist or sexist happening that just occurs when a woman reporter is allowed to go into a locker room.

But I realized that this is ENTIRELY related to what a defensive back does in his job. He looks at the quarterback's eyes and tries to guess where the ball will be going. A good cornerback can look in the eyes of a mediocre quarterback and go *right* to the place where the ball is going to be thrown. On the other hand, a skillful quarterback can look *here*, and then suddenly throw the ball *there,* and the defensive back can't guess where the ball is going. So of course the football player was watching the reporter's eyes to see where they were looking.

We watched where Amelia was focusing her eyes. It was very educational. Sometimes we watched her watch a certain corner of a mural as we carried her around the room. Every time we came around a corner, her eyes would be *locked* on a certain section of the mural. We never did figure out *exactly* what was so interesting there.

What else are we learning? The usual. How to make a baby happy. How to learn from the baby, and how to teach the appropriate little skills. I love to see a child's "wheels going around"—see how his/her head is learning to learn. On a good day, it is MOST fun and rather hard and exhausting work.

Amelia might be characterized by some people as a "baby." But she often acts as a small but thoughtful and independent person—and as a very good little learning machine.

One of Amelia's favorite recent discoveries is doors with hinges. She was standing there, a week ago, in front of two small cabinet doors. She was carefully opening and closing them. Then she went over and stood right by the doors. She put her hand in the doors and carefully pinched it. She *practiced* at pinching her hand just a little, not too much. Pretty smart kid! (I must admit, I failed to ask her to pinch my hand a little. Maybe next Sunday.)

One of my favorite kinds of story is about a kid who (apparently) doesn't learn how to speak, but then starts talking in sentences. For example, a boy was over three years old, yet didn't talk at all. One day, driving through the woods, he saw that part of the forest was on fire. He said, "Mommy, Mommy, the forest is on fire!" Later, they asked him why he hadn't talked before. He said, "Well, there was never anything important to talk about." Another kid who had never talked said, "Mother, my toast is burned." When asked why she'd never spoken, she said, "The toast was always okay before." Another line, for a kid's first words, is the sentence, "Did you know?! Squirrels go to sleep in trees!"

Of course, the parent of a child who refuses to talk until he or she decides to talk in sentences must go crazy wondering why the kid doesn't talk. If you have any true stories of kids who didn't talk until they were ready to speak IN SENTENCES, I would like to hear about them. What did they say?

(This column is NOT about kids or babies. Don't complain to me that I am wasting trees on irrelevant topics. It is about the kind of learning done by people and kids. We all have different things to learn. Right?)

I'm going back to trek in Nepal this fall. I was looking in a Nepali phrasebook. I'd been discussing with a friend that Thailand is a wonderful place, except the language is quite difficult and hard for us to learn, as it depends a lot on tones and nuances. So—by comparison—maybe Nepali is *easy*?

I'd been discussing with a friend that Thailand is a wonderful place, except the language is quite difficult and hard to learn.

Looking in that Nepali phrasebook,[2] I realized that some of the words in Nepali that have the same sounds are written with the same symbols: the Devanagari symbols. In about 5 min., I figured out that the "alphabet" of Nepali symbols is really very simple and neat. Why, even *I* could learn that! I looked up a couple dozen words that I knew and puzzled out the "codes" for b, i, a, o p, s, t, m, n, and r. And l and p and j. Hey, this is fun and almost EASY! So I'm spending a few minutes every day studying and *decoding* Nepali words and symbols.

There are still a few puzzling things in Nepali. The diphthongs are sometimes tricky. In English, "ph" sounds different from p and different from h. So in Nepali, the symbols for diphthongs are puzzling as I have not seen them so often. But Nepali doesn't have a lot of different ways that a symbol sounds. It always sounds the same. That's a big help. Also, Nepali doesn't have upper and lower cases, nor different printed and written letters. So the number of alphabets one has to learn is simpler than in English, even if there are 58 symbols.

The Nepali word for big sister is *didi.* I have known that for 10 years. But when written in the Nepali symbols, the symbols are arranged *iddi.* That's okay, but I haven't yet learned why. Likewise, *sisi* is written as *issi.*

In fairness to me, I went back and checked several of my other Nepali phrasebooks. They listed the English and Nepali words, but *not* the spelling in Nepali. They just had the sounds an American would say. So it's not entirely my fault that I never figured this out before until the right book came along. If Thai is difficult, Nepali is easy. And India uses MANY of the same words, alphabets, and symbols. I'm learning much about Hindi, the language of India, too. Two for the price of one!

Hey, I'm in the education business, too—educating not just Amelia, but *myself.* I'm going to ask Peter Owens what signs one expects to see in the streets of Nepal. Then I can see, read, understand, and *write* some old friends (that is, *words*) when I get there.

When I went back to Japan for the first time in 26 years, I'd spent some more time reading Len Walsh's excellent book, *Read Japanese Today.*[3] It is, of course, true that speaking and understanding all of the Japanese language is rather challenging. But you really can look at signs and see *friends,* symbols that you learned this morning and understand this afternoon. If you're going to Japan, this is a great little book.

I was able to ride all around Tokyo on the subways, read the maps, hike the streets for *miles,* and read many of the Japanese signs (although most of the signs ARE in English, too).

All for now. / Comments invited!
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References:
1. Gopnik, Alison et al., *The Scientist in the Crib,* William Morrow, 1999, ISBN 0688159885. About $24.
2. O'Rourke, Mary-Jo, and Shrestha, Bimal, *Lonely Planet Nepali Phrasebook,* Lonely Planet, 1996, ISBN 08644 23454. About $6.
3. Walsh, Len, *Read Japanese Today,* Charles E. Tuttle Co., 1969, ISBN 0804 804966. About $9.

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pease porridge

Bob's Mailbox

Dear Bob:

I'm a scientist who trained at Cambridge University in the days when the emphasis was on fundamentals, not frills, and when we made virtually all our own research equipment. So when I receive my copy of *Electronic Design*, I invariably turn first to your page. I enjoy your habit of reducing problems to basic principles, but I was somewhat shaken today to find "watts per second" being used as a unit of energy! Of course, joules per second would look even worse.

ADRIAN MARCH
via e-mail

Okay, Adrian, I goofed, and none of my reviewers or editors spotted it. Usually I am careful and meticulous about dimensions and labels of units, except when I goof! Sorry! YOU knew what I meant! And Joules/s would be just fine!—RAP

Dear Bob:

I always enjoy your column in *Electronic Design*, and I have just finished reading, "What's All This Optical Stuff, Anyhow?"

I note that you use direct sunlight as the top end of the "dynamic range" of the eye. We in the U.K. were struck by "Eclipse Fever" back in August when the path of totality passed over mainland England. At that time, we were warned (repeatedly and at great length) not to look at the sun directly as this causes permanent damage to the eye, as if we didn't know. But surely this advice, and common sense, indicate that the energy in direct sunlight exceeds the range of the human eye? For "permanent damage," read "saturation?"

CHRIS BULLARD
via e-mail

Okay, okay, you are quite right. Several people have properly pointed this out. BUT overloading your EARS to the extent of 165 dB is similarly a bad idea!! An attenuator would be appropriate for THAT, too! Still, the dynamic ranges of the eyes and ears ARE comparable.—RAP

Hi Bob:

I did a little research and came up with the following. The percentage of solar energy falling onto the Earth's surface is split up as follows:

0-300 nm	1.2%
300-400 nm (UV)	7.8%
400-700 nm (visible/PAR)	39.8%
700-1500 (near IR)	38.8%
1500 nm and up	12.4%

(PAR stands for photosynthetically active radiation, that portion of the spectrum for photosynthesis). The reference is *Principles of Environmental Physics* (second edition); Monteith and Unsworth, Arnold, 1990, ISBN 0-7131-2931-X.

PHIL GEARY
via e-mail

OK, I said 50%. I was off by a couple of dBs, not a big deal for these back-of-envelope computations.—RAP

Hi Bob:

It's very interesting how electronics evolved over the last decades. My special interest is T&M instruments and their use. The question that came up in my mind is why on earth nearly everyone is using buttons and knobs that are so small that I have to use my fingernails to operate them.

Compared to my friends, I'm lucky enough to feature "piano" fingers—but they're too big, too. Every time after being frustrated in the office, I will go into my home lab, power-on my Tek 545 and other classics, and enjoy knobs fitting into my hand as if they were made specially for me. I don't necessarily want to go back to ancient times, but isn't operator convenience an important consideration? Maybe in the near future it will be possible to cultivate engineers with fingers fitting to 100-mil grids.

You're welcome to visit the past at *www.planet-interkom.de/stgraef.*

STEFAN GRAEF
Germany
via e-mail

Hello, Stefan, you are right. Even in 1970—about 30 years ago—the Tektronix 7704 scopes had TINY buttons to push. What's worse than an instrument with tiny buttons? I'll tell you: an instrument with NO KNOBS or BUTTONS at all. It's all done with MENUS. This makes me very ill, and makes it nearly impossible for me to use that instrument, because they are so DEVIOUS and sneaky—and you can get LOST!! Bleah!! TERRIBLE!!—RAP

Dear Mr. Pease:

Sorry to trouble you, but in a recent column you referred to a paper by Horn and Gibbons. I have tried to find a copy of this paper, with no success. Can you supply some more details, please? I like reading your articles. You seem to have a handle on the real world.

ALLAN EMERY
via e-mail

It's in the 1964 "IEEE Transactions on Circuit Theory," p. 378.—RAP

All for now. / Comments invited!
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What's All This Address Stuff, Anyhow?

For over 40 years, I've kept a pretty good "Christmas Card List." It's a list of addresses and phone numbers of my friends and our family's friends. For a long time, we kept them on 3- by 5-in. cards. That was pretty good. But the cards got all raunchy and cluttered up. Plus, a lot of cards needed to be added and updated. And they wouldn't even fit in *two* card-file boxes.

So my wife typed up the information off these cards on her Mac. This was actually quite useful. We could print out the eight pages, photocopy them at 70%, and carry a really compact list along in any briefcase or pocketbook. I mean, when you copy properly, double-sided, eight pages weigh just 14 grams—barely half an ounce.

I had typed up a smaller list of business contacts. I shrank these by 2:1 and kept a copy in my wallet. THAT list carried approximately 122 names and weighed 2.8 grams, just 1/10 of an ounce. I actually had a front-back copy, on the theory that if one side gets crumpled up, the other will be legible through redundancy.

I looked at one friend's Access list. It had a LOT of white space, and his took more paper than mine for 1/4 as many names. I certainly don't want my address list as loosely compacted as that.

When we first went to Nepal, we brought along a condensed list of people and addresses to whom we'd send postcards. Nancy sent cards to some of our friends, and I sent to others. We both wrote our kids.

I remember very plainly the night when we were camped up at Lama Hotel in 1989. I had to go to the latrine at midnight. At the appropriate time, I reached in my little plastic bag. But I'd brought the wrong bag. It was not the bag of toilet paper, but the bag of postcards and the postcard list. Tricky, there!

On our third trek, we STARTED writing postcards during the first half of the trip and wrote in the addresses. But we didn't want to mail them until we made it over the high pass at 17,771 ft. After we made it over that pass, we finished the cards and tried to buy some stamps. But there were very few post offices, and they only had 1-rupee stamps for local mail. They had very few 16-rupee stamps, which we needed for overseas postcards. We bought out all the 4-, 8-, and 16-rupee stamps for the next 60 miles. Finally, when we were four miles from the road, I was able to buy enough stamps to mail all of my cards in Birethanti.

Note that a 16-rupee stamp is worth about 25 U.S. cents. So the postage in Nepal costs even less than U.S. postage for an overseas postcard. That is, again, MUCH less than the 80 cents or $1.20 they charge for an overseas postcard in some other countries!

I've been adding new addresses on little pieces of paper for a couple years, and saving these scraps in envelopes and boxes. When the box overflowed, I put the scraps of paper in a BAG. When the bag began to overflow, I had to actually sit down and type up an expanded list. After all, the time I was wasting fishing through the bag to find a recent address was getting quite silly!

The total amount of scrap paper was about 4 lb. The paper that actually had addresses or e-mail addresses on it was about 1 lb.—not to mention another pound of specialized address lists, such as trekkers' addresses. And I had spare copies. Hey, I recycle all this paper.

I typed up the addresses in a straight list. I didn't bother to arrange all of the names *within* the A's alphabetically, but I did group all of the A's together. After I got all of the addresses typed, I merged the old list with this new list. I put in all the old A's and then all the new A's, etc. I checked for duplication. I still did NOT alphabetize them within each letter.

After I get the list printed out, I always check all of these addresses for common sense. I double check them against the addresses on the old scraps of paper. It's all too easy to copy an address wrong, and it takes a long time to figure out why the letter won't go. Or the e-mail. Or the telephone call.

Then I photocopy a full-size copy for use around the house and a couple sets to shrink. Maybe even another set that is actually smaller, for when I want to send a few postcards. But even when I'm on a short, strange trip, I can't just bring a tiny truncated list. I may run into some amazing happening that leads me to write a postcard to a friend whom I wasn't planning to contact.

For example, I was driving along the west coast of Newfoundland when I got to the village of Malpeque. I couldn't resist sending a card to my old friend Mal Peck.

Some people say they prefer to use a standard computer program, such as Microsoft Access. They point out that it can automatically align all of the names and addresses in neat columns, leaving blank spaces if there's no e-mail or phone. It alphabetizes everything, so there's no thinking required. That's fine for some people. I looked at one friend's Access list. It had a LOT of white space, and his took more paper than mine for 1/4 as many names. I certainly don't want my address list as loosely compacted as that. It would be 18 pages thick and weigh 2 oz., even after shrinking. I prefer to compact and crunch my own list, and think about it as I go....

My list is pretty complete and correct now. Of course, it will become obsolete at the rate of about 1% every month. People change jobs, home addresses, or e-mail providers. It can't be helped!

Still, my list will not need much work for a year. And I can carry around with me a copy of this list that has over 700 names and a lot of addresses, e-mails, and phone numbers. Yet it weighs less than an ounce. It's not exactly better than a floppy or a computer in every way, but it's easier to access than a floppy! No batteries, no power required. And it's quite impervious to a hard-disk crash. I'll keep two copies on floppies as backup, and I'll e-mail a set to my wife so she can keep a copy.

Yes, it is a bummer that telephone area codes are getting split up so badly, so often. Hey, if the phone companies have to split an exchange every three years, why do they just split it *in half*?

My suggestion is that if they have to split, they should split a busy exchange into FOUR exchanges. Then the next splits will not have to be made sooner than *six* or *eight* years. That would be much less disruptive.

Remember that little TRS-80 Model 120 that I wrote about a few years ago? It had nice handy capabilities for keeping a phone/address list. But its total storage for all computing functions, documents, mail, and addresses was 30 kbytes. My address list is about 38 kbytes. That little 3-lb. laptop computer had the right CONCEPT. It just didn't have enough capacity. So I gave it away. At present, our best portable keyboard (Alphasmart)* has 128 kbytes of memory. But I'm not about to fill it 30% of the way up with just addresses. For typing notes, 128 kbytes is just about the right size for a 2-week trip.

In a while, I'll write some more about similar exercises: What's All This *Sorting* Stuff, Anyhow?

All for now. / Comments invited!
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**www.Alphasmart.com*

P.S. After I got this list all neatly typed, I got letters showing ALL KINDS of changes. People that hadn't moved in 10 or 20 years suddenly decided to move, as soon as they knew I had typed this list. It figures... /rap

P.P.S. I haven't gotten many entries for my CONTEST. Keep your eyes peeled for great views of windows reflecting the sunset—or sunrise. (ELECTRONIC DESIGN, *July 12, 1999, p. 93*). Check it out on the web site: *www.elecdesign.com/mainframe.htm?content=Pages/sitepage/extras/columns.htm*. Keep a camera handy! /rap

Bob's Mailbox

Sir:

I have read your column for a little over a year now and am an avid fan. I have received a request from my management to provide some form of research article proving that tobacco smoke harms electronic systems and components. I used to work in the hybrid/microelectronic industry and saw what contamination could do to the passivation layers of die. However, I cannot provide written documentation to prove my point: that it is not healthy to the equipment. Do you know of any articles that I can download and print? Thank you in advance for your time.

BOB McCUTCHEN
via e-mail

Hello, Bob. I have never heard ANY comments on this. But it's well known that sodium is bad for most chips—threshold shifts, leakages, etc. If somebody can PROVE that cigarette smoke has no sodium, then that's one case. Since that's not likely to happen, finding sodium in tobacco smoke will prove that you should keep it AWAY.—RAP

Dear Bob:

Perhaps sometime when you're entertaining ideas for "Pease Porridge," you'll consider an update to "What's All This Incandescent Stuff, Anyhow?" (ELECTRONIC DESIGN, *Dec. 17, 1992, p. 71*). The home centers now carry a bewildering array of lighting devices, making the selection among lumens, color rendering, radiation angles, life, cost, and energy usage quite a project. It's all straightforward engineering, of course, but I've found that assembling and tabulating the data takes a lot of "legwork." *(A lot of this is just special hype, fancy styling, special daylight spectrum, etc., etc. SOME of it is useful for high efficiency, but I'm not sure I trust all of those guys. Here at NSC, I noticed some new high-intensity lighting in our stairwells. Most fluorescent lighting is pretty darned dim, but THIS isn't bad. I don't know much about it but will try to find out. /rap)*

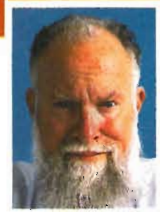
As an avid backpacker, you might also be able to relate some experiences with the equally bewildering number of flashlights and lanterns on the market (or maybe you just go to sleep with the sun). The LED lights are really coming on strong now *(See at www.lightechnology.com—I'm buying one. /rap)*, as well as the "high-tech" flashlights. Somehow, these pricey gems don't seem to offer much more than a sensibly made, boring old flashlight. At any rate, whatever you decide to write about, I'll probably enjoy some of it.

STEVE WISE
via e-mail

I have not looked into this, as I usually do not need a very fancy flashlight. There's one thing I'll caution you about: Almost any flashlight that claims to be ultra efficient or ultra high tech should be ASSUMED to have a short bulb life. Carry spares. Many have a bulb life worse than five hours. When I went up Mt. Fuji by flashlight, I did NOT bring a spare bulb. I brought a whole spare flashlight. (Like if you drop your first one, you can always use your second one to look for the first one, but you can't do that with spare batteries and a spare bulb!)

If you use a LOT of flashlight time—like cops do—you ought to consider nicad batteries, which might soon save a lot of dollars. For ordinary reading around a camp, fluorescents are pretty good. Peter Owens carries a solar-powered fluorescent with gel cells. After a sunny day, it works REALLY well. On a grey day, it turns off after 10 or 20 minutes. Then we just burn a bit more kerosene. I don't think I'm much of an expert on flashlights. I just know a little bit, which is more than most people know unless they do a lot of research.—RAP

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*



pease porridge

Bob's Mailbox

TREKKING?

Is anybody interested in joining us on our next TREK in Nepal? We had such good hiking on our LAST trek that we're planning to go back for 31 days this October (to the Everest/Kala Pattar/Gokyo region). Inquire by snail- or e-mail to the usual address. And start saving up your VACATION TIME... (and a little money). /rap

Dear Bob:

Since you like the strange and bizarre with a funny side to it, I thought you'd like to hear what happened to me on Jan. 1, 2000. All my computers are running the Linux operating system. Well, all except one, which has DOS on it because I have a few old DOS programs and they're so good that I never felt any urge to replace them. Because of this, there was not going to be any trouble or unexpected crashes due to the Y2K Bug. And all the computers have a BIOS that will recognize year 2000. So I had no problem there, as I knew I would not.

However, I have an electromechanical clock—not sure if it can be described as analog or digital. It operates like this: It has a storage of steel balls that are lifted every minute on the top by a mechanical arm. The ball then rolls down an inclined guide rail on a seesaw arrangement. Once there are more balls on the right side, it tips over, sends one ball to the next lower seesaw, and the rest roll down to the storage bin. There are three of those seesaws. The first one indicates minutes (0-4), the second has increments of 5 minutes (5 to 55), and the last has hours (1-12; the 1 has the ball permanently fixed there). It is driven by a synchronous motor and, as I said, one ball rolls every minute. I had this clock for quite a while and it always worked well with an unprecedented accuracy, because our mains here in Australia are kept precisely at 50 Hz. They actually count the cycles and make corrections every day at the power stations, so there are 4,320,000 cycles every 24 hours. *(Yeah, these clocks are fun. I've seen them. /rap)*

I was rather astonished when, on New Year's Day, I found the clock stopped at 1:03 a.m. and all the balls scattered at the bottom. The reason? Well, it's now summer in Australia. At this time of year, we have a "plague" of small beetles called, appropriately, the "Christmas Beetle." One of those crawled inside the clock, up the inclined ramp, and there it got rolled over by the ball and jammed it. Naturally, all the other balls that followed just fell down from the ramp. So it can truly be said that I actually caught the real Y2K bug and killed it!

MILLAN Y. XENO
via e-mail

Now that is FUNNY! That's what happens when an analog problem gets into a DIGITAL clock.—RAP

Dear Bob:

In the Jan. 10 issue of *Electronic Design*, you mention that in the good old days, high-frequency alternators were field-modulated to produce AM. Actually, that was not the case. The high-power machines (200 kW) were modulated by a magnetic amplifier reactively shunting the output. A very complete description of the New Brunswick Maine transmitter, circa 1920, is given in a book titled *Magnetic Amplifiers* by H.F. Storm. The chapter on "Magnetic Amplifiers for Radiotelephony." was actually written by E.F.W. Alexanderson, the well-known designer of alternators who worked for General Electric.

Papers published by Alexanderson in the *Proceedings of the IRE* Vol. 8, 1920, and Vol. 9, 1921, give detailed descriptions of the transatlantic communication facility and even oscillographs of the actual modulated RF waveforms. At 30 kHz, this was possible in 1920.

The Alexanderson alternators were quite famous in their day and provided reliable and vital military transatlantic communication during the WWI conflict. In fact, Woodrow Wilson's famous 14 Points leading to the armistice was broadcast using CW to all of Europe from the New Brunswick station.

Predating all of this, in 1906, the irascible but talented R.A. Fessenden used a 2-kW alternator (it was designed by Alexanderson and Steinmetz of GE) for radio-telephone experiments. In this case, he modulated the alternator output with a carbon-button microphone in series with the antenna. His rather *glowing* account of this is described in Vol. 27, 1908, *Proceedings of the AIEE.*

BILL WOODWORTH
via e-mail

Hello, Bill. Since I am such an EXPERT on RF and transmitters—i.e., I am NOT an expert—I apologize. Now, you are saying that substantially NONE of these transmitters worked by modulation of the field? Maybe you are quite right. I may have misremembered or misunderstood what I read. Or, maybe somebody else misstated it before I read it—unlikely. Thanks for setting me straight. I'll look into this a bit more. Up to now, nobody else has corrected me on this.—RAP

All for now. / Comments invited!
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pease porridge

What's All This Perpetual Motion Stuff, Anyhow?

Once upon a time, the greatest minds in Europe were trying to meet the challenge of turning lead into gold. Lead is heavy and cheap. Gold is heavy and quite valuable. Surely it can't be THAT hard to transmute lead into gold, can it? So the greatest alchemists in medieval Europe tried to find ways to convert lead into gold.

It wasn't so easy. After much effort, some guys said they had learned how to convert lead into—well, it looked like gold. The skill needed to do this was that of the magician, or prestidigitation—sleight of hand. They would start out with a piece of lead and put it into a magical machine. After a suitable delay, it came out as (apparently) gold. If the moves were done properly, it could even pass assay. The opportunities for *bunco artists* were quite good in those days.

People really wanted to BELIEVE that they could get a ton of gold just starting from a ton of lead. The development of modern chemistry put an end to this. These days, almost nobody wastes much time trying to convert dross into gold. There are *better* projects....

As we've seen, these better ways to generate money involve perpetual-motion (P/M for short) machines. Sometimes, euphemistically, they're called "over unity" or "free energy." They claim they can provide an energy output that is "over unity" compared to the amount of energy input. Of course, people have long been trying to make P/M machines using obscure mechanical or electrical schemes.

Many times, these inventors were sincere—but mistaken—about how their scheme did (or did not) have fatal flaws. But since the demand and desires were so great, some of these "inventors" would make up elaborate fakes of getting out energy with no visible input. Whether the basic scheme was mechanical, chemical, or electrical, they would make sophisticated cheats to keep it running. Some guys used compressed air in hidden chambers to keep it running. Other times, it was hidden batteries or cords and cables activated by a remote partner. So the art of ingenious contrivance made it seem that the energy was generated INSIDE the invention. Actually, it was just the power source that was hidden inside. (Recently a sphere was shown that would rotate for an indefinite time—just sitting there spinning—and it wasn't even in a vacuum. Yeah, it would spin until the hidden battery in it ran down.)

I remember the Dean Drive. That goes way back. Mr. Dean first invented a set of levers so that his invention would climb up a pole or rope (U.S. Patent 2,886,976, filed 1956, issued 1959). Then he claimed that he had improved the invention so the machine would ascend and levitate in the air without *any* pole or rope! The mechanism he designed was a set of levers and counterweights and gears. The principle was claimed to be "rectifying centrifugal force." This was demonstrated by setting this machine on a bathroom scale and applying ac line power to a motor that turned the machine's input shaft. The scale would show a decrease in weight!

Wow, just keep that up, continue the improvements, and it will *levitate* right off the ground! (Of course, the possibility that a bathroom scale would have some dynamic nonlinearity and could give a false reading in the presence of ordinary vibration wasn't obvious to most people.) If you could generate a little force with a little power, you could generate MORE levitation force with more power.

So let's connect a whole ARRAY of these "Dean Drives" to a nuclear submarine, which would provide the electrical power. It took only a little arm-waving to prove that this could levitate and *lift* the nuclear submarine right up into space. Back in 1955, we could use a batch of Mr. Dean's drives to generate our space program without any need for expensive rockets.

I recall reading this in *ANALOG Science Fiction* magazine. I was a little skeptical. There MUST be something wrong with this scheme. Then I figured it out: If you could use a Dean Drive to generate a *force* in the middle of the air, without grabbing onto anything, then you could put it on the end of a long arm and provide it some power. The force it generated would start the arm rotating. When the arm got up to a high enough speed (e.g., in a vacuum), that force multiplied by the speed would be LARGER than the input power. One could extract more energy than the input and generate a perpetual-motion machine. Since this was not possible, the Dean Drive was surely a hoax.

Of course, the marvelous disclaimer in the front end of the magazine was a clue: "Everything in this magazine has no basis in fact, and nothing is necessarily true..." (a paraphrase). It was hard for me to reconcile this with the sincere statements in the stories, but I finally figured out where the truth lay.

Since the demand and desires were so great, some of these "inventors" would make up elaborate fakes of getting out energy with no visible input.

The study of thermodynamics has been very serious and intense for over 150 years. The First Law of Thermodynamics states that energy is always conserved and is not created or destroyed. Thus, you cannot get out of a system more energy than you put in. (Let's leave $e = mc^2$ out of this.)

The Second Law of Thermodynamics can be phrased this way: While the quantity of energy is conserved, the quality of it may be degraded. This is expressed in terms of entropy. One fairly obvious example is that a container of hot water and an adjacent container of cold water will tend to share their heat to become warm. However, two containers of warm water will never turn into one hot and one cold container unless a lot of energy is added. Entropy always tends to increase, unless the special addition of energy makes it SEEM that entropy is decreasing. Refer to *www.entropysystems.com/Historyofentropy.htm.*

The Third Law states that the amount of effort to cool an object down toward Absolute Zero becomes progressively greater as that minimum temperature is approached. It's related to the statement that the efficiency of a heat engine can not exceed $1 - T_{MIN} / T_{MAX}$.

Sophomores have paraphrased these into the format of a gambler's lament:

Rule 1: You can't win.
Rule 2: You can't break even.
Rule 3: You can't get out of the game.

On their web site *(www.entropysystems.com/Product.htm)*, Entropy Systems does admit that some people think its inventions are NOT GOOD SCIENCE, while others think they are GOOD STUFF. It claims that using its inventions, entropy doesn't have to increase any more while low-quality energy is converted to high-quality power. Most scientists consider this quite unlikely, but can't get enough details about the processes to show where that is wrong. I have my own opinions, especially when they say they can take in energy at ANY temperature ("even sub-zero temperatures") and convert it to usable power.

Their machine, based on the "Amin Cycle," claims to put out power (high-quality power, such as electrical power) while taking in only very LOW-QUALITY energy, such as warm or even cold water. You can read about this on their web page: *www.entropysystems.com/WhatisEntropyEngine.htm.* They claim this is based on a couple of patented devices (U.S. patents 5,547,341 and 5,765,387) that can take in air and split it into hot and cold air, *even* while putting out high-quality power.

Hey, isn't it illegal to convert motion or power into a separation of hot and cold air with no moving mechanical parts? No, it is NOT against any law of thermodynamics. But this process, often done with a vortex or impeller, is *very* inefficient and quite noisy. It's not likely to be found at the heart of any machine that generates power. Yet here we have a machine that claims to put out high-quality power while taking in just low-quality heat, using inventions that are patented. Did you just hear something that sounds like "a patented Perpetual Motion machine?" Well, not exactly, but close. Just keep moving your lips, and it sounds about the same....

So much for the concept that MOST laymen would be impressed by "no more current than a transistor-radio battery."

My big file that I keep on perpetual motion is marked as "dimbulb." I find that some of the guys who promote P/M do fall into this category. I conversed by e-mail with a guy who was proposing to make a light bulb run on MUCH LESS POWER than any normal light bulb. Check the web page at *http://members.aol.com/Apsinfo.* He claimed to put in 30 W and generate more light—12 W of light energy—than an ordinary 100-W bulb.

How did he make this high efficiency? He used an SCR chopper circuit to generate narrow pulses of voltage and current to apply to a low-voltage light bulb.

How did he measure this? He measured the *averaged* voltage and the *averaged* current—with ordinary dc voltmeters—and multiplied these, $V_{AVERAGE} \times I_{AVERAGE}$, to show the "average power." I tried to explain to him why this was not correct, but he did not want to listen to me. I even volunteered to talk to his old science teacher to see if his teacher could talk him out of it. But he did not want to listen to anybody because he was right and everybody else was wrong. The mathematical analysis of why people ought not to fool themselves with this old and simplistic error has been well documented by Don Lancaster in his web pages at *www.tinaja.com/glib/muse113.pdf.*

I said to the inventor guy, "Now, your present scheme puts out 12 W of light (about the same amount of light that a 100-W light bulb puts out in view of its 12% efficiency) with only 30 W of input power. That's because your patented invention (U.S. patent 5,463,307) *chops* the voltage and current. If you can *chop* the input power with a small duty cycle to get this improved efficiency, why not chop this with a *higher* input voltage and *smaller* duty cycle? Then you can generate MORE power output in the form of light than the electrical power you are putting in." He quickly backpedaled, saying, "No, I could not do that." I tried to ask him, "Well, why not?" But he bailed out.

I suppose I should mention Joe Newman, who claimed he could drive an electric *car* on the same dc current as a transistor radio battery puts out. What could be clearer evidence than that of great efficiency??

Of course, he would assemble a SERIES STACK of a few thousand 9-V batteries and connect these (250 lb. of them) to his special high-voltage electric motor in a car. He could drive this car around at a very slow speed for a few minutes. So much for the concept that MOST laymen would be impressed by "no more current than a transistor-radio battery."

His motor, especially designed for high-voltage, would run on 50 mA × 15 kV. That is 750 W, or about 1 horsepower. That's enough to drive, with suitable gearing, a car with high-pressure tires for a short time at low speed.

Newman *also* showed everybody that this motor would put out more power than it takes in. His instruments did seem to show that the V × I was smaller on the input than the output power. The courts presented this "ultra-high-efficiency" motor to the NBS (now NIST) to determine if it really had more power out than coming in. The NBS observed that Newman's instruments were not suitable to measure the waveforms of V and I, which—not surprisingly—had very NARROW spikes and small duty cycles. When they used proper instruments, which had enough bandwidth to handle the narrow spikes, the efficiency was of course well below 1. Newman claimed that the NBS was incompetent to measure such things and stormed off. He has not been heard from for several years.

I mentioned a few months ago that Dennis Lee had a big barnstorming tour pitching his "free energy." As I said: "HOT ITEM!!—Free Energy? Electricity for free? Perpetual-motion machines? Don't you love that stuff?! Check out these web sites, and see which one YOU believe: *www.teslaelectriccompany.com*; *www.ucsofa.com*; *www.phact.org/e/z/leelee.htm*; and *www.voicenet.com/~eric/dennis.html*. Aren't you glad you paid attention in Science class?! /rap"

I don't think Mr. Lee has yet delivered any free-energy generators. If the authorities put Dennis Lee in jail, he would just point out that he would've delivered free energy, but he was being suppressed and oppressed by the power companies. He'd love to be able to say *that*.

My justice would be simple: Lock him up in a laboratory and don't let him out UNTIL he shows a valid demonstration of a "free-energy machine" that puts out more power than it takes in. That might take him a while, and it would serve him right!

When I mentioned in "Retrospective Stuff" (ELECTRONIC DESIGN, *Jan. 10, p. 145*) that Thomas Edison had been a great inventor in the 20th century as well as the 19th, several people asked me why I didn't say anything good about Nikola Tesla. After all, Tesla's ac motors have eclipsed many of Edison's inventions.

True, but in later life, Tesla was involved in many "over unity" inventions. For example, "Tesla's mechanical oscillator...was built in the form of an air cylinder and contained several chambers, each of which successively cools the air until it becomes liquid. Tesla stated that the device was highly efficient and could be used as a power-generating system if magnets were attached to the oscillating pistons." Yeah, sure, and "death rays," too. His proposals to transmit a billion watts from one side of the world to the exact opposite side, using huge coils and towers, never accomplished a thing—except blowing out the power house.

This is NOT perpetual motion, though it seems pretty close. It is really just a HOAX. I heard about it from Tom and Ray Magliozzi on the radio show "Car-Talk," as well as from several other places:

"What if a guy sends you a letter every week—for eight weeks in a row—and he predicts something, such as the outcome of a football game? And after you get the letter, the game does come out the way he predicted! At the end of eight weeks, this person asks you to send him $1000 and then he will tell you the winner of the NEXT game. Should you send him $1000?" They pointed out correctly that this was the scam of an opportunist who sends out 256 letters to 256 randomly chosen people. Half of the letters predict that one team will win, and half of them predict the opposite.

After the first week, there is no point in sending any more letters to half the people where he guessed *wrong*, but he keeps sending *split* predictions to the other 128, 64, and 32, etc., suckers. Football games are better for this than trying to guess the stock market. After eight weeks, 255 people will know his predictions are imperfect. But *one person* will have gotten the sequence of letters that indicate he is a *wizard* at guessing the winners. A lovely scam!

But one of the Magliozzis proposed that they ought to demand just $50, rather than $1000, because $50 is a good amount. Their pop psychology is good, but they neglected to check their math. Sending all those letters at 33 cents of postage (plus printing and overhead costs) will be over $170. So the $1000 "advice fee" would give a moderate return on the hoaxer's investment.

The $50 would work only if he set the hook after about four rounds. So this is consistent with the idea that, "If something seems too good to be true, it probably is." You probably won't be SUCKERED. I don't get suckered very often, but you never can tell for sure!

Some people thought I was badly fooled by the platinum injector. It took me quite a while to convince some of them that I was not fooling myself or them. With the "platinum injector," you can't get "something for nothing." But if you have an older car, it's possible to generate an ROI that is POSITIVE.

All for now. / Comments invited!
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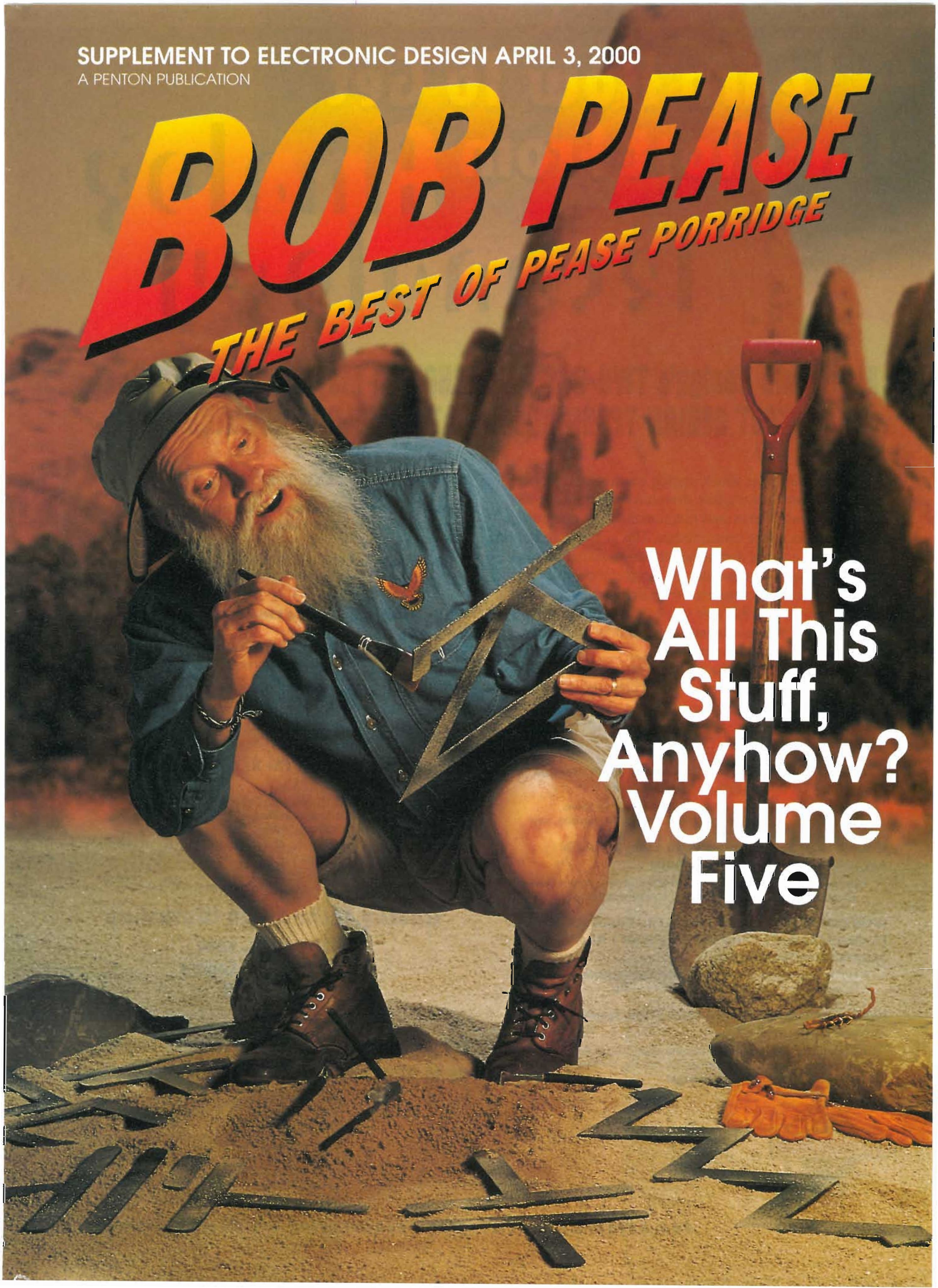
BOB PEASE

THE BEST OF PEASE PORRIDGE

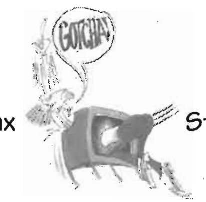


What's All This Stuff, Anyhow? Volume Five

The Best Of Bob Pease Volume V Contents

C•ll Photography

Bob Pease was awarded a Jesse H. Neal Certificate of Merit by the American Business Press for his "Pease Porridge" columns in 1992.



The Best Of Bob Pease Volume V

What's All This Searchin' Stuff (Part II)?

The other day, I decided to help a new friend do some *searchin'* on the web. Go ahead and laugh, but while I'm a hopeless KLUTZ at using the web, I figured it would be fun to try. This friend has web access, but it's slow. So I decided to try my faster access during lunch.

This guy is a serious bicycle trekker. He had already bicycled over high passes in the Alps, over the Andes, and many American roads higher than 14,000 ft. Now he wanted to try the Himalayas, and I just happened to meet him when he was starting his search. I volunteered to put my Nepali knowledge and contacts to work.

I went into Amazon.com's site. (More on this later.) I started searching for books that related to Nepal and bicycle trekking. I typed in Nepal bicycle trekking and got a strange mishmash of books: some related to Nepal, some to bicycle trekking, and some NOT AT ALL.

Then I remembered—ah—try: Nepal + Bicycle + Trekking. That got me to a DIFFERENT set of strange books and even some trekking organizations that would presumably sell you nice bicycle tours—though not necessarily in Nepal.

Then I recalled that to get a true logical selection of (Nepal + X + Y), you have to type in: "Nepal + X + Y" (including the quotes). So I tried THAT and got yet a third collection of oddities. I found several books about bicycling in the high areas of Nepal and the Himalayas. Some were out of print.

Hey, good news! If the book was out of print, that says it sold out. There was more demand for the book than the publisher expected. That is GOOD news, not bad news! Besides, Amazon.com is *surprisingly good* at finding out-of-print books. I've had good luck with that company finding books that I gave up searchin' for 10 or 20 years ago. When Amazon wants to find such a book, it must have a *really good* network.

Anyway, I then tried "metacrawler"—*www.metacrawler.com*. Apparently, a crawler is some kind of OVERALL search engine that searches several other search engines. They gave me several other sites to moose around, search, and look at LOTS of funny places—many of which were quite unrelated to bicycle trekking in the Himalayas. But enough were of interest to save my friend a lot of trouble searching....

Recently, I was trying to find a book that some friends had told me about: *The Hassidic Driving Training Manual*. Or was it the *Rabbinic* or *Rabbinical* manual? I figured it would be interesting to see the philosophy behind it. I went off searching. Amazon soon replied that they could not find this book. But they counterproposed a couple of other similar books on related topics. I was not interested in any of those.

Then I went to *www.addall.com*. It claims to be able to find all books at good competitive prices. THAT search engine promptly replied that it had found this book in 21 places. I went down the list. Twelve of the 21 had nothing to do with driving. Most of them had nothing to do with ANYTHING. None of them had anything to do with "Rabbinical" or "Hassidic." Some search engines are just so *CLUELESS*! Meanwhile, whenever I see a poor search engine (which is, alas, all too often), I think, "Well, this one is about 45 dB worse than Amazon's." Or maybe 65 or 85 dB. Do you guys have any good techniques for searching? Or do I just have to SEARCH for them?—*RAP*

All for now. / Comments invited! / RAP / Robert A. Pease / Engineer / rap@galaxy.nsc.com—or:

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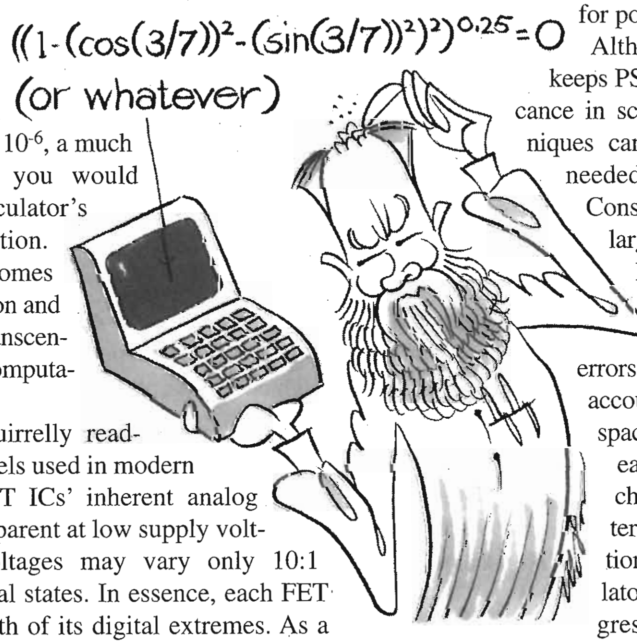
What's All This Calculator Stuff, Anyhow?

(Thoughts on the Accuracy Limits of Scientific Calculators...)

How willingly we trust our calculators! Yet, like everything else, these ubiquitous tools do have limits. In particular, their accuracy limits are beginning to show in our ever more complex and precise engineering calculations. To illustrate the problem, here's a simple calculation that you can work on your own calculator:

$$((1-(\cos(3/7))^2-(\sin(3/7))^2)^2)^{0.25} = 0\ ????$$

Remembering the trigonometric identity for squared sines and cosines, you know the answer has to be zero. But your 10-digit calculator probably gives an answer on the order of 4×10^{-6}, a much larger discrepancy than you would expect from the calculator's claimed 10-digit resolution. This error, of course, comes from accumulated truncation and round-off errors in the transcendental algorithms—the computational version of NOISE.



Another source of squirrelly readings is the low voltage levels used in modern calculators. The MOSFET ICs' inherent analog underpinnings become apparent at low supply voltages, where channel voltages may vary only 10:1 between the 1 and 0 digital states. In essence, each FET is a linear amplifier at both of its digital extremes. As a linear amplifier, it can pick up and amplify strong RF or pulsed fields. For some plastic-cased models, operation near a terminal's horizontal transformer, a radar transmitter, or a medium-frequency broadcast station can jump the display reading without any apparent cause.

The calculator IC's analog roots are, in fact, the reason why you can't buy portable scientific calculators with better than 12-digit precision. It becomes a matter of voltage regulation. The battery's voltage drops about 40% as its energy is drained. Ordinary calculator chips have Power-Supply Rejection Ratios on the order of 180 to 210 dB, allowing 8 to 10 digit calculators to operate without error ($10^{(200/20)}$ dB = 10^{10} = 10 digits). Leading-edge companies like HP and TI use voltage regulators and factory calibration to gain another 60 dB of suppression, bringing dependable performance to the 13-digit level. But that's about it for portable units.

Although careful analog design keeps PSRR errors below digital significance in scientific calculators, those techniques can't provide the high precision needed in accounting calculators. Consequently, calculating a really large number— such as the bottom line for the second overrun of a military hardware contract— will show some variable errors in the last digits on a 14-digit accounting calculator. In fact, aerospace accountants are rumored to earn their lunch money simply by changing to fresh calculator batteries before the final column addition. Fortunately for them, "calculator faith" hides these small transgressions from the GAO (Government Accounting Office).

The accounting calculators represent a large market, and their accuracy demands will likely fuel research for improved battery and regulator technology in the next decade. Japanese researchers hope to produce accurate 14-digit machines by the turn of the century, spurred by suspicions of low-battery use when converting trade-balance dollars to yen. Despite these incremental improvements, however, some analog experts smugly hint that digital engineers will never design a calculator accurate to one part in 10^{16}.

Analog engineers in the know infer that the Digital Illusion can't be supported beyond 16 digits. At that precision, the digital two-state simplicity collapses and all circuits revert to their basic analog nature. The prima donna digital engineers must then face the dirty "real world" uncertainties that we analog engineers face every day. Just as playtime for digital bus design ended at 20-MHz data rates, the Digital Illusion ends at 16 digits.

The analog engineer—always thoughtful, physically attractive, and suave—doesn't base the Digital Illusion's limit on mere speculation. Nay, this limit has roots deep in theoretical physics, a subject quite familiar to the analog engineer's restless intellect. In fact, it's the famous Heisenberg Uncertainty Principle that imposes an absolute 19-digit limit on digital-calculator accuracy. In 1927, as many experienced analog engineers will recall, Heisenberg recognized that the minimum energy kicked into a system (when making a measurement) is inversely proportional to the measurement time. That is, $dE \times dt$ can never be less than Planck's constant, 4.14×10^{-15} electron volts per Hertz (eV/Hz). Consequently, the longer you take to do something, the less disruptive energy is injected, and the more exact the result.

The occurrence of an Uncertainty Error is, of course, probabilistic. It can occur in any calculation, as students of engineering quickly discover, but it is much larger and more likely in calculations where the disruptive energy is large—i.e., where the calculation time is short (*or* when you are in a big hurry). Consider some facts from your own experience...calculations done on a Cray super-computer at gigaflops rates (earthquake prediction, rainfall prediction, national debt prediction, origins of the universe) are subject to great uncertainties, whereas computations done on a slide rule at deciflops rates (resistor values, the price of 12 op amps) are seldom wrong by more than 5%. These Uncertainty Ratios remain valid even at microflop rates. For example, computer programs that require several man-years of debugging are much more reliable than those that work the first time.

Calculating the 19-digit limit is beyond the scope of this short article, but is recommended as an exercise for the Gentle Reader. Start with Maxwell's equations. Use a 3.6-V lithium battery, 2N3904 transistors, and 99.2 eV (12.648 nm) lithography to establish boundary conditions (savvy analog engineers will use their slide rule's div, curl, and grad scales to make quick work of the vector differential equations). Your answer may differ somewhat from 19, depending on how much you rush the calculations. If you must use a digital computer, analog engineers amicably recommend that you stick with an Apple I, Altair 680, IMSAI 8080, or PDP-8 models to minimize spurious answers.

I hope this peek into calculator theory will dispel the blind trust in calculator and computer results, and in all that complex digital stuff. Now that you've been alerted to a future of continuing digital problems, you will not be surprised when your naive colleague's new 17-digit calculator sinks into Digital Nirvana when trying to pin down the penultimate digit. You will know that calculators, like everything else, face limits. The Digital Illusion can't shelter us indefinitely.

Although the affable, warm-hearted analog engineers have used all of the technology at their disposal to stretch the Illusion over the last 40 years, their numbers dwindle, and the digital engineer's age of innocence must end. A moment of silence, please, for those generous analog folks who have worked so continuously and indiscreetly during these long, hard years....

Now just a couple of final comments from RAP: While I would love to say that I wrote this, I must give all the credit to James A. Kuzdrall, P. E., Chief Engineer at Intrel Service Co., P.O. Box 1247, Nashua, NH 03061; e-mail: jak2@intrel.com. When I saw Mr. Kuzdrall's draft of this, I knew it was a perfect choice for this guest editorial. He's a man after my own heart.

And, lastly, April Fool!

Comments invited! / RAP
Robert A. Pease / Engineer

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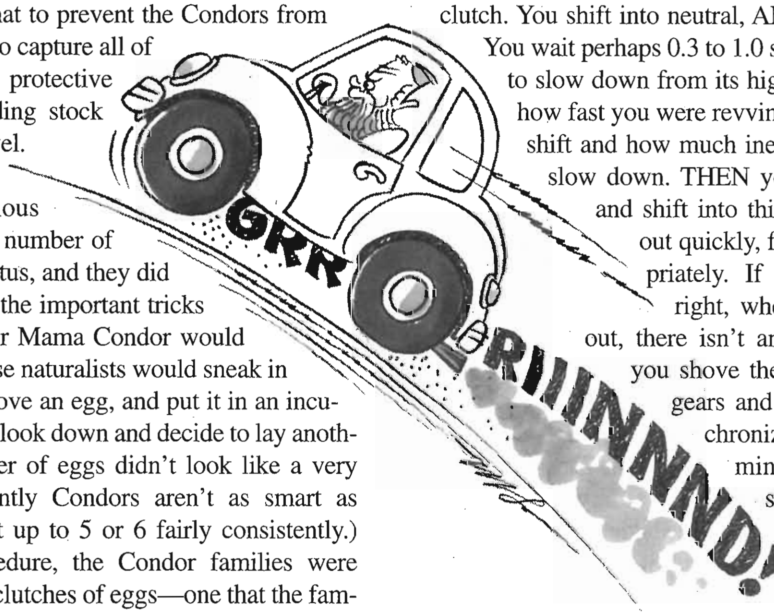
ELECTRONIC DESIGN, *April 2, 1992*

RAP's 2000 comments: In addition to the letters from guys who enjoyed this hoax, I also got a couple letters from overseas, asking *exactly what formula* they should use to compute this 19-digit limit. I had to write a very polite letter, to explain what kind of April Fools joke this was. I asked some friends, "Haven't they heard of April Fools jokes in France, or Japan?" People told me, yes, these are generally well known. But apparently a couple guys were a little too slow (or too serious) to catch on... —*rap*

What's All This Double-Clutching Stuff, Anyhow?

Recently [in 1992], a pair of California Condors were released into the wilds of the San Gorgonio wilderness area of Southern California. This was a significant event, because there had been Condors flying around those mountains from the year 60,000,000 B.C. to 1986 A.D. But in 1986, the naturalists convinced the California Fish and Game Dept. that to prevent the Condors from going extinct, they had to capture all of them and put them into protective custody until the breeding stock had reached a viable level.



For six years, these naturalists tried various approaches to bring the number of Condors to a healthy status, and they did finally succeed. One of the important tricks they used was whenever Mama Condor would lay two eggs, one of these naturalists would sneak in through a trapdoor, remove an egg, and put it in an incubator. The Mama would look down and decide to lay another egg, since the number of eggs didn't look like a very large number. (Apparently Condors aren't as smart as crows, which can count up to 5 or 6 fairly consistently.) Anyhow, by this procedure, the Condor families were tricked into raising two clutches of eggs—one that the family would raise, and another that would be hatched and raised by the naturalists, behind the scenes. This trick was called, "Double-clutching."

Now, if you have driven old cars, or trucks, or sports or racing cars, you will be amused at this play on words. That's because double-clutching is also a procedure to save wear and tear on your gearbox, and on your clutch, at the expense of a little extra work for your left leg. What exactly is double-clutching (or, as the British call it, "double de-clutching"), and why is it significant?

Let's say you're accelerating in second gear. When you're ready to shift into third, you decide not to use the standard approach, which is just to tromp on the clutch, take your foot off the gas, shove the shift lever into third, and let the clutch back out. Instead, you opt to double-clutch properly:

First, you take your foot off the gas and kick in the clutch. You shift into neutral, AND let the clutch out. You wait perhaps 0.3 to 1.0 seconds for the engine to slow down from its high revs, depending on how fast you were revving when you started to shift and how much inertia the engine has to slow down. THEN you kick in the clutch and shift into third, and let the clutch out quickly, feeding the gas appropriately. If you have judged it right, when you let the clutch out, there isn't any JERK. And when you shove the lever into third, the gears and engine are at a synchronized speed, so there's minimum wear on the synchronizers, which are the tiny clutches that bring the clutch plate and the gears into smooth synchrony. There's also usually less wear on the clutch plates.

What's the big deal? The main point is that when you try to shift into third gear, the engine has slowed itself and the clutch plate down to the right speed—just about the same speed as the gearbox—so it saves wear on the synchronizers and the clutch. It can also save shock and strain on the whole drive-train, because the speeds are just about synchronized when you let out the clutch.

Well, big deal, you say. Cars haven't needed double-clutching since the synchromesh transmission was popularized 50 years ago. Why bother? Why fool around with anachronistic motions? Isn't it just buying trouble? Even Tom and Ray Magliozzi* claim that double-clutching is silly and stupid and wasteful of energy. Ah, but I can give you reasons why it is beneficial.

First, in most cars, the actual gears are always in constant mesh, and the synchronizers only decide which pair of gears to connect to their shaft. But many trucks and some racing cars are still set up with a non-synchromesh gearbox. With trucks, because they have so many gears, it's noticeably more efficient not to have all of the gears in mesh all of the time. So with the "crash-box," you HAVE TO double-clutch, or you will not be able to shift. The same holds true for racing cars—to gain the last couple percent of efficiency, only one set of gears is in mesh at any time, and you have to actually synchronize their speeds or you can't get it in gear. Despite the obvious drawbacks of having to double-clutch, the gearbox is stronger and more efficient than a comparable synchromesh one, and has less tendency to overheat.

Other reasons for double-clutching: Because it is the right way to operate the clutch. Because it saves wear and tear on your synchronizers in the long run, if you're planning to run your car over 200,000 miles, as I do. Because it is fun to do. Because in *very* cold weather, (–10° F, for example) you may *have* to double-clutch to shift gears at all, at least for the first few miles.

One very important reason is that, if your clutch linkage ever fails, you can still shift and get home by double-clutching, getting the engine and gears' speeds synchronized and then just EASING the shifter into the right gear. In the last 1,050,000 miles of driving VWs, I have lost my clutch about 3 times, and each time, with careful planning, I've been able to drive home safely. One time I pulled into the Customs House at Calais, Maine, and discovered my clutch was out. I eased along carefully and managed to get all the way home, 350 miles, to Boston, where it was convenient to put the car in the shop to have the clutch repaired—much more convenient than in the middle of a vacation, or the middle of Maine.

Another reason is that on some old cars, first gear isn't synchromesh, so if you need to shift into first without coming to a full stop, you have to double-clutch. Also, a lot of cars these days are made with weak, chintzy synchros, so they soon wear out, and to drive them gracefully, you need to double-clutch.

Note, when down-shifting, you have to shift into neutral and then *blip* the throttle momentarily before you shift into the lower gear. It requires practice and a good feel, a good touch, to do it right, especially considering the embarrassing noises you make if you miss your shift into a low gear on a crash-box. For example, you should aim to have the revs just a little high, so if you miss, the engine will soon slow down, and then gears will be at the right speed to mesh and the cogs will slip in....

OKAY, Pease, I'll try this double-clutching some day; but why do you bring up all *this* stuff in an electronics magazine? Ah, there's an excellent analogy: In most conventional switching regulators, the power transistor turns on while there's lots of voltage across it, and after it turns off, the voltage usually increases to a large voltage. When the transistors turn on, the diodes are already carrying significant current, and the transistors have to turn the diodes off. This is all somewhat stressful, and causes the transistors and diodes to have large turn-on and turn-off surges—pulses of power on every cycle. Of course, diodes and transistors have been designed to withstand these stresses and surges with excellent reliability; we see them all the time.

Still, people have specially designed "resonant mode" switchers to have zero-voltage and zero-current switching. In these regulators, most turn-on and turn-off stresses are eliminated, because the transistor is at a very low voltage when you turn it on, and at a very low current when you're ready to turn it off. Consequently, most voltage and current transients are greatly decreased. Less filtering and shielding is therefore required, enabling the complete regulator to have low Radio Frequency Interference (RFI). Now, to design such a supply takes a more complicated controller IC, more expensive parts, a very careful layout, and a lot of expertise in the electrical design. So while you get some advantages, you have to pay for them.

Now, when you want to build a compact, high-performance, switch-mode regulator at switching frequencies up to about 1 MHz, conventional switchers can do at least as well as resonant ones in terms of cost, size, and performance. But if you need a switcher even smaller and faster than that (most users do not), when the switching frequency rises above 2 MHz, the resonant-mode switchers begin to show real advantages.

At this time, National doesn't make these resonant-mode switchers, so I can't offer you any detailed info about all of their advantages and disadvantages. But I have explained most of their key features. And now you can see why the smooth, stressless turn-on and turn-off of the transistors and diodes in these resonant-mode switchers are analogous to double-clutching your shifts.

Comments invited! / RAP
Robert A. Pease / Engineer

P.S. Even if you double-clutch your shifts most of the time, as I do, do you know when it's a good idea NOT to double-clutch? My primary answer would be either when you're in complicated traffic and you don't want to fool around, or when you're really struggling on an upgrade and a speed-shift prevents you from losing speed. So, as it is with every rule, you should be aware that there are times when the rule doesn't apply. Some day I'm going to write a column about that topic....

*CAR-TALK, on many National Public Radio stations, is a wild mixture of automotive wisdom and entertaining banter about cars that's hosted by Tom and Ray Magliozzi. I tune in nearly every Saturday morning. Ask your local NPR station for their broadcast time—if you like *my* stuff, you'll probably like *theirs*.

Originally published in
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RAP's 2000 comments: After I published this, I was wondering if I really do double-clutch most of my shifts. One morning I got my shoelaces wet before I left for work. I noticed that every time I shifted, my wet shoelaces slapped my left calf TWO times. Since then I am more observant. About 1% of the time I just speed-shift when I'm in a big hurry. About 10% of the time, I do a "normal" shift. About 40% of the time, I double-clutch. About 48% of the time, I "single-clutch"—I shift OUT of the gear without using the clutch, but then complete the double-clutch. And about 1% of the time, I shift from gear to gear without depressing the clutch at all. In fact, one time, I realized that I had downshifted from 4th to 3rd without using the clutch, without planning that, and without even *thinking* about what I was going to do. So, just as shifting can become an "automatic" habit, so can double-clutching.

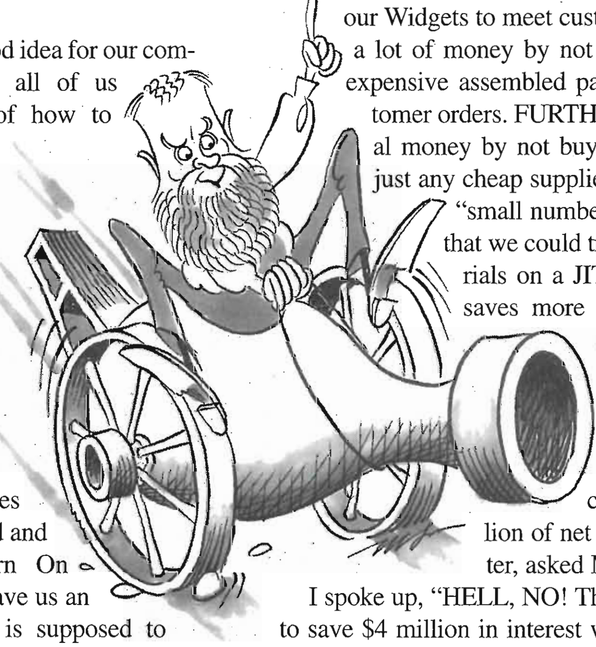
One guy asked me if double-clutching wouldn't wear out the clutch cable twice as fast?! Good question! I think not. Because when the cable is new and well-lubricated, a large number of clutch-depressions does *not* wear out the cable. Only when it gets old and dry and rusty does it start to wear out rapidly. Besides, if I "single-clutch" as described above, I only depress the clutch once per shift, but I get all the advantages of double-clutching. Right now my '68 Beetle is up at 365k miles. The clutch is showing no problems after 132k miles.—*rap*

P.S. This column is featured as Appendix M in my new book, *How to Drive Into ACCIDENTS...And How NOT To*. See *www.transtronix.com* or e-mail rap at rap@transtronix.com.

What's All This Apples & Oranges Stuff, Anyhow?

Yes, recently I was invited to take yet another "Training Course," following in the path of great successes such as Taguchi Methods, Fuzzy Logic, and Time Management. But why would this course on basic accounting and economics be called "Apples and Oranges"? Because, the course's leader explained, if one person has apples and another person has oranges, the only way to quantify the sum total of the two fruits is their value in dollars. So we quickly dropped the old aphorism that "you can't compare apples and oranges," and started talking about dollars.

We soon agreed that it was a good idea for our company to be profitable, and that all of us employees ought to be aware of how to improve profitability. But, how is the profit to be measured—how do we do the accounting? We started out with a little game from Learning Methods International, Box 50, S-230-42 Tygelsjo, Sweden. The purpose of the game is to teach you which expenditures of a manufacturing plant are used to compute the profits, and how the costs and expenses and assets are added and subtracted and divided to compute the Return On Investment. Michael, the leader, gave us an explanation of how the "game" is supposed to run—a discussion of how this little hypothetical "factory" buys raw materials and adds labor to accomplish the manufacturing of Widgets. Then the Widgets were put into "Finished Goods" to await customer orders. Over the course of a year, this factory was able to show a good operating profit. But after expenses for interest and taxes, the after-tax profit was only $2 million—not a very good profit on $80 million of sales.



Michael suggested that we go back and recompute the profits if we went back and followed a different game plan: We should pay off $20 million of our liabilities (bank loans) with some of our cash. Sure enough, at the end of the year, the net profits looked considerably better, about $3 million. Further, he suggested that we should not keep a lot of our finished products in Finished Goods (or, "Box Stock," as we call it at National), but we might plan to just build our Widgets to meet customer orders. We could save a lot of money by not having a 3-month stock of expensive assembled parts waiting around for customer orders. FURTHER, we could save additional money by not buying our raw materials from just any cheap suppliers, but rather by choosing a "small number of very reliable suppliers" that we could trust to ship us our raw materials on a JIT (Just-In-Time) basis. This saves more money by not having raw materials sitting in our storehouse for a long time. Altogether, after we ran the numbers through the exercise, our new lean, mean company had made $6 million of net profit. Wasn't that a lot better, asked Michael?

I spoke up, "HELL, NO! The only reason we were able to save $4 million in interest was because this whole scenario was set up badly. In the base example, the company treasurer sat on an average of $51 million of cash, and never even put it in the bank to earn daily interest. The only way we could show an improvement of $4 million on interest was to ignore the fact that the treasurer had wasted $8 or $10 million in interest he could have earned. Even in the second scenario, there was $3 or $4 million left lying on the table due to the treasurer's ignorance and/or incompetence.

"It's absurd to argue that one plan shows superiority if it's only compared to a Straw Man." (As you can see, I am not a big fan of Straw Man comparisons....) So the lecturer immediately spotted me as a troublemaker. "Well, yes, you are right, but we just have to follow these examples and procedures for accounting, which are, of course, simplified."

Next I complained that if you order your raw materials from "a limited number of highly reliable suppliers" for the purpose of getting "JIT delivery," you should honestly expect to pay more for that. I've heard that half the trucks in Tokyo are driving around in circles, half-empty, wasting time so they can show up at JUST the right minute, neither late nor early.

This might make your assembly operations simpler, but that JIT service is NOT free, and not necessarily cheap. Somewhere, somehow, you will pay for it. Further, one traffic jam, one flat tire, and your production line goes down. "Yes, but we are just following our guidelines, which are of course simplified..."

Later, I pointed out, after the game had been played for three years of financial analysis, "Isn't it kind of stupid to make only $80 million a year of these Widgets? What the heck is going on? In most cases, if you spent another $1 million to hire some better salesmen, you could sell a lot MORE than $80 million, and the increased profits would more than pay for the cost of sales." NOW, I must admit, in a hypothetical example, maybe we can't be more specific on what a Widget really is. So if a "Widget" is a kind of commodity such that, no matter how many you have, no matter how smart the salesmen are, they could not sell more than the customer was planning to buy—then we should not insist on hiring better salesmen. But otherwise, we would be remiss if we didn't study that possibility. The Instructor agreed that, in some cases, expanding sales is indeed the right thing to do, but there was no room to show that in this simplified example.

After Michael begged me not to be such a disruptive influence during the class, I met with him during lunch hour. I pointed out that in his "simplified" example, he claimed that he was able to sell the same $80 million of Widgets by manufacturing them on a Just-In-Time basis. But at NSC, we often found customers who WANTED to buy a product from stock RIGHT AWAY, but if we had nothing in stock, they would have to buy elsewhere.

So IF you're in a business in which you're SURE that nobody will buy MORE parts just because they are on the shelf, and you're SURE nobody will buy LESS just because the parts are NOT on the shelf, well, go ahead and do your JIT manufacturing. But I warned him that this OVERSIMPLIFICATION was NOT necessarily good for business, NOT good for profits, and NOT valid for improving ROI. He conceded that my arguments might have some truth—but there was no room for them in this simplified analysis.

One of the other students said, "Well, Bob, you may not like the simplified stuff in this course, but it sure got you thinking." I replied that I had been thinking about this very seriously for several years, and I already figured out some of the weaknesses of JIT manufacturing. Hearing this guy just preaching oversimplified economics got me so ticked off that I was going to do something about correcting this problem. And even though *your* company may not make the same kind of products as mine, you probably face the same kinds of issues.

Where I work, I'm often concerned about how we can avoid a complaint from a prospective customer: "How can I design in your parts right away if your samples are only available on a three-week delivery from Malacca?" So I worked pretty hard with our planners to maximize our ability to ship evaluation samples overnight, or in 1 or 2 days. But I have to fight with some guys who think that keeping our samples in the low-rent district of Timbuktu is a great way to save money. I certainly don't need a training course to simplify things to the point where people think that the cheapest costs are always the right solution.

Furthermore, I do get calls like—"After I get your new parts designed in, how can I go into pilot production if the availability is 6 weeks?" I point out to them that while we may not necessarily have these parts in stock, we have distributors who do a pretty good job of keeping at least small or medium quantities in stock, so you can order them and get prompt delivery. We want to keep a lean (but not *zero*) inventory.

Now, if a guy complains "I ordered the ICs for my first production run; then the product got HOT and I wanted to double my production run—but the availability of parts was not good. What do I do now?" I've been arguing for years that we should make sure our sole-sourced parts, our proprietary ICs, and, for that matter, any of our products that have a decent volume and good profitability are kept in stock in some reasonable quantity. The alternative is to tell your customers, "We can't help you; you will have to design in our competitor's parts." So when I heard this nincompoop at the training session arguing that we should show a better ROI by only selling Widgets to people who can place orders well in advance of when they needed them, I decided to start chomping my teeth into peoples' ankles to straighten out this oversimplified economic foolishness.

One copy of my first draft went right to our Chief Executive Officer, Gil Amelio, and I have also brought it to the attention of *lots* of other people in sales, marketing, and planning areas. These guys have given me much support and encouragement. Maybe Michael doesn't want any loose cannons in his lecture room, but in the real world, if somebody else doesn't complain about stupid, oversimplified strategies, then it becomes my job. Go ahead, tell me that I'm a loose cannon. We all already knew that. Even a loose cannon can do some good if it sweeps away cobwebs. Maybe I can't tell the difference between apples and oranges, but I can tell the difference between bad economic theory, OVERSIMPLIFICATION, and the real world.

Now, speaking of oversimplification, when I propose keeping these new, proprietary or sole-sourced parts in stock, I shouldn't imply that it's *easy* to do. Murphy's Law says that as soon as I see a part selling with good volume, and I put a fat amount of them in stock, then people will stop buying them. If I put the expensive one in stock, people will want to buy the cheap ones (and vice-versa); if I stock the mini-DIPs, engineers will specify the surface-mount versions. So if I indicated that keeping the right balance of parts in stock would be easy, I must apologize for my own oversimplification.

We have to try to anticipate our customers' ordering patterns. We have to try to keep a reasonable bank of good, tested dice, so no matter which packages the customers ask for, we can assemble the right ones quickly. To do this promptly may require an agile, fast-response assembly group. This may cost a little more, but the advantages may well be worth it in terms of being able to respond and fulfill customer needs.

Also, that doesn't mean that we just have to keep lots of parts in our store rooms. If one distributor is keeping one part in stock, and another is stocking another part, then we may not have to keep many of those parts around at all. But we have to keep a few around for quick sampling.

I talked with some of the guys who designed the original three-day comprehensive lecture about reality and economics. They were surprised to see how unrealistic and badly oversimplified the economic studies became when they were pared down to a one-day course. They agreed it was probably time to see what we could do to restore some reality to that little course. I sent in five scribbled pages of my suggestions on how to restore some of the redeeming factors. I also invited the accountants who really know what's important in fiscal matters to add comments about things I didn't notice, or am not very knowledgeable about. Maybe next year, the "Apples and Oranges" course will not only be "training," but will really *educate* us on how to make our company more profitable! The best way for all you managers out there (and other workers, too) to please *your* customers may involve *thinking*—NOT just referring to some old obsolete formula or cookbook.

Comments invited! / RAP
Robert A. Pease / Engineer

P. S. Mark Levi, who was involved in the design of the original Apples and Oranges course, and who helped me a lot in getting this column into good shape, suggested I read a book: *The Goal*, by Eliyahu M. Goldratt and Jeff Cox. This is written in the form of a novel about a guy who is trying to run a manufacturing plant in the midst of *all sorts of* trouble. His customers are screaming about late delivery, his workers are setting contradictory rules, his most efficient machines are being misused, and his boss is threatening him.

Meanwhile the bean counters tell him everything he does to improve the situation is wrong. A very stressful job—trying to bring in a few more dollars to show his boss why the plant should not be shut down. This is a COMPLETE antithesis of Apples and Oranges, that Pollyannaish waste of time. However, Mr. Goldratt doesn't gratuitously overcomplicate things—he sets reasonable examples and covers one or two problems at a time. Good thinking, good writing. The book was published in 1986 by North River Press, Box 567, Great Barrington, MA 02130.

You can order by calling (413) 528-0034 or (800) 486-2665. Price is about $19.95. Bravo to a good story-teller, explaining how the real world is horribly different from those orderly, sterile optimization situations you learn about in school. —RAP

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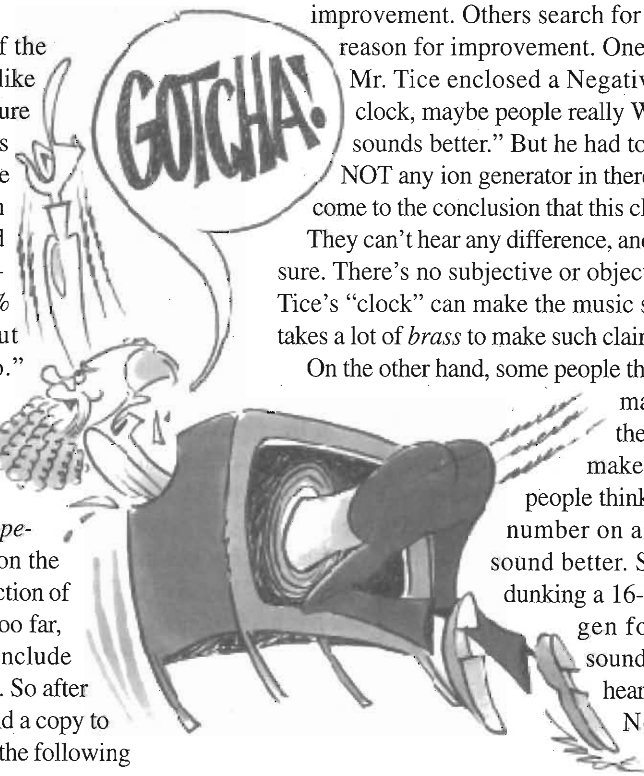
RAP's 2000 comments: No additional comments. I said it all the first time. Many readers agreed.—*rap*

What's All This Hoax Stuff, Anyhow?

As I warned you guys, April is a good time of year to write about hoaxes, and several people have sent me some neat ideas. But one guy asked, "Bob, what is the difference between a Hoax and an April Fool joke?" I told him that you can't tell from the way it starts out, but by the time you get to the end, a good April Fool joke should give you enough clues so you can start to smile. But if you're merely puzzled, or skeptical, that could be a hoax. Conversely, if the guy tops off his story with "and send money," that's a clue that it may be turning into fraud. But sometimes, the guy isn't aware that the situation is impossible. He has fooled himself badly, and may be unaware of the truth.

So if you're just listening to the start of the story, *or the end*, you can't always tell.

As I mentioned earlier, some of the stories about Fuzzy Logic start out like an April Fool joke, but after you figure out that the guy is serious, then it's only just funny. However, we have seen some claims, such as "only with Fuzzy Logic can an elevator avoid lurching." That's more like self-deception. Or, "The Sendai train is 10% more efficient than a train without Fuzzy Logic, and runs faster, too." That's a *scream*!! (Details available on request.)



Back in October, I heard a good program about hoaxes on the radio and sent away for the *Encyclopedia of Hoaxes* that they mentioned on the show.[1] It really is a pretty good collection of Hoaxes, April Fool jokes that went too far, etc. But, unfortunately, it doesn't include any hoaxes in the field of electronics. So after I publish this column, I'll have to send a copy to the author so he can include some of the following stories about hoaxes in electronics.

Let me start out with the Tice Clock. This clock is a basic LED digital clock, substantially identical to a $30 clock sold by Radio Shack. But George Tice sells this for $270. He makes some very lavish claims that by plugging this clock into your audio amplifier's main 115-V power socket, the clock will make all your audio equipment sound much better—that is, if you have a "Golden Ear." However, if you can't hear any difference, then you're admitting that you don't have a Golden Ear—that you have only limited auditory capability to appreciate the BEST in audio.

Many reviewers for hi-fi magazines have agonized over this. A few think it's great—the reviewer can really *hear* the improvement. Others search for any plausible technical reason for improvement. One reviewer observed, "If Mr. Tice enclosed a Negative Ion Generator in his clock, maybe people really WOULD think the music sounds better." But he had to concede that there was NOT any ion generator in there. So, many people have come to the conclusion that this clock is (at best) a hoax. They can't hear any difference, and there's nothing to measure. There's no subjective or objective reason to think that Tice's "clock" can make the music sound better. But it sure takes a lot of *brass* to make such claims.

On the other hand, some people think that painting a green magic marker line around the circumference of a CD makes it sound better. Some people think that putting a new part number on an old op amp makes it sound better. Some people think that dunking a 16-bit DAC in liquid nitrogen for a while makes *that* sound better. Maybe you can hear the difference. I can't.

Now, let me digress briefly. Let's say you have demonstration models of some good loudspeakers. How do you decide that type A is better than type B, or, that it's *different*? Mr. David L. Clark, Chief Engineer, DLC Designs, Farmington Hills, Mich., combined a set of relays and a random number generator to make an "ABX" tester. If you push the switch for A, the tester connects to the A speakers, or the A set of wires, or whatever. Then you can listen intently and decide that the sound you're listening to is the "A" sound.

If you hit B, you get channel B, and you listen to "the B sound." If you push X, you get a randomized selection and you jot down whether it's channel A or B. At the end of 10 tests, let's say that you have listed: A, B, A, B, B, B, A, A, A, B. Once that sequence is completed, the ABX box will tell you what it ACTUALLY connected. If you listed eight out of 10 correctly, that's a lot better than just guessing—you probably did hear a difference. If it's four or five, well... Who knows? In some cases, some people with really good ears can hear things that I cannot. In other cases, they're unable to tell. In yet other cases, they refuse to try because they don't like the test.

Still, when speaker cables of different types or characteristics are connected through an ABX box, some people with "really good ears" might hear the difference IF the wires have different amounts of inductance, capacitance, or resistance. It's generally admitted that no matter how exotic the materials or the construction techniques, if two sets of wires have the same R, L, and C, you can't tell them apart. Nobody can.

So you'll find that one guy wants to sell you 10 feet of speaker cable for $100; another guy claims his are a LOT better, and they MUST be better *because* they cost $300 for 10 feet; and then a similar claim is made for a $480 cable. But if they all have the same R, L, and C—and each one spouts claims such as..."superior imaging"..."finer presence and less phase shift," etc., etc.—that strikes me as somewhere between fraud and hoax.

You can spend your money any way you want to. You can say that you hear a difference. But if I offer you an ABX test, you should not get mad at me and stalk out.

Some of my favorite "hoax" stories are just the claims that manufacturers of speaker cables tell about their wires. I really like the cable with "large-diameter wires to carry the low-frequency music, and small-diameter wires to carry the high-frequency music." (Of course, it's easy to compute that the skin effect of copper wire will make a 3° difference in the phase shift of the thin/fat wires at about 300 kHz. And, since the fat wires and the skinny wires are paralleled, you won't be able to see any significant difference in phase shift at 20 or 30 kHz.)

The other cable I'm impressed with is the stuff that has a conductive "insulation." When this cable's resistive losses match the capacitive and inductive attenuation and the conductive losses, and the phase shift is minimized, it should sound better.

Well, if it sounds better to *you*, go ahead and buy it. But, if it just sounds *different*, then maybe you do want to buy it—or maybe you don't. Maybe when you really turn up the volume, the conductive "insulator" will start to get hot??

Speaking of cables, my friend Tom said that his wife recently went to buy some new speakers at Circuit City. The salesman sold her some new speaker wires "because the old ones were probably worn out."

Additional amazing audio quasihoaxes:

(a) When you have line-level cables (with RCA-type phono jacks), the expensive cables sound *much better* than inexpensive ones.

(b) After you decide to specify the expensive cables, the ones with gold plated jacks sound *much better* than the solder-plated ones.

(c) These cables have a preferred direction, and sound better when you connect them up in the preferred direction, with the arrows pointing *from* the tuner *toward* the amplifier.

(d) In addition, these cables sound better if they have been broken in, or aged, with a special ac signal forced through the cable.

(e) The best burn-in fixture for these audio cables uses *digital* signals to force current through the cables.

Needless to say, I've never heard of any one of these wonder cables being tested with an ABX box. Probably the "Golden Ear" person would object to the relays in the ABX box, as they would *corrupt* the signal. But maybe we could overcome those objections by using a digital burn-in circuit to burn in the ABX box...

The next area I'll mention briefly is the "vacuum tube sound." This isn't about a hoax, but rather a chameleon. It's well known that some audiophiles prefer audio amplifiers made with vacuum tubes. They claim that the ratio of 2nd-order harmonic distortion versus the 3rd-order is more pleasing with a good vacuum-tube amplifier. Maybe so. Myself, I've got a tin ear, not golden, so I'm not very picky. (Maybe I did too much chainsawing as a youth, or turned up the volume on Chuck Berry too many times.)

But Mr. Carver, an excellent designer of audio equipment, came up with a beautiful ploy: He took one of his low-distortion solid-state amplifiers, and added a circuit with a little bit of 2nd harmonic to make it "sound like" a vacuum-tube amplifier.

I'm not familiar with this amplifier's ABX comparisons, but I think it's a NEAT idea to make a chameleon amplifier like that. I think it's great to see if the Golden Ear guys can be fooled.

About 30 years ago, when transistors did not have much performance, a contest was run to make a small high-performance audio amplifier. The late Peter Lefferts won the prize, with a small (6-in. cube) block and heat fins. Inside were a couple of small (6L6GB?) tubes running hot but with good heat sinking. They were legal under the rules, and nobody else thought of doing that.

A friend told me about a promoter with this scheme: They had a conventional TV transmitter, and at the end of each cycle, just before the zero crossing, they would insert a brief pulse signal before the normal RF signal resumed. Then a specially designed receiver could detect those pulse signals and extract additional info. At 200 MHz, you could also get 200 Mbits/s, free, *without any increase* of the RF bandwidth.

Further, this excellent communication scheme was backed up with a U.S. Patent and a big development company formed by a guy named Gerdes. As soon as I heard this line, I got VERY suspicious. My friend promptly admitted, "Of course, after a big press conference where this great technology was announced to the world, several engineers confronted the inventor and insisted that any studies showing you could do that without requiring more bandwidth were obviously malarkey."

"The development company folded up... The promoter hasn't been seen since." Yes, *that* sounds like a hoax—or a marvelous example of self-delusion. These days, there are entirely too many cases where computer simulation leads an inventor to believe it will work...

Gunnar Englund of Gransbergsdal, Sweden, once proposed some filters for line power that would filter out any electric power generated with nuclear power. He figured he could sell lots of them to environmental fanatics, with the guarantee that the output power will not show any nuclear residues. But then he got nervous about prospects of a criminal record, even though his guarantee would surely hold up.

Here's another good hoax: Mr. H. told about a group of engineers at Northrup, who in the 1960s invented a "metric tensor sensor"—a meaningless non-invention with a melodious name. They even got a dummy patent application all drafted. Unfortunately, the senior manager signed it off and sent it to the Patent Office before anybody could explain. THEN they had some explaining to do...

An engineer from Basingstoke, England, sent in a classy little pamphlet produced by Motorola (U.K.) showing a new non-electromagnetic telephone that used the scientific principles embodied in two tin cans and a length of string. VERY nicely done. They even had a rare-earth barrier to protect the inner "Lirpaloof" fiber from fiber-eating locusts. Jolly good.

I have the Abstract of a U.S. Patent—a "Permanent-Magnet-Powered Motor".[2] Of course, the Patent Office won't approve a patent on a perpetual-motion machine. But this one apparently snuck through.

Then there's Joe Newman, who back in the 1980s invented a motor with *very* high efficiency.[3] It's so efficient, he claimed, that it puts out more power than it takes in. Further, he claimed that he could run a car with no more current than a transistor radio needs. Of course, when engineers saw him loading 1800 9-V batteries into the car, all stacked up in series, they realized that such a battery can indeed provide a full 1/3 horsepower when loaded with 16 mA. If you have a motor that's designed to work at that high voltage, you can indeed move a car at a slow speed for a short distance, as Mr. Newman has indeed demonstrated.

This was the guy who sued the Patent Office after they refused to patent his motor. When the NBS showed that his motor only *appeared* to put out more power than it took in, because he used an RMS voltmeter that couldn't accurately handle the low duty cycles and high harmonics that his motor ran on, he accused them of being incompetent at measuring things!! I've inquired about his progress at promoting his motor, and ran a literature search in our library, but nobody has heard *anything* from him for eight years.

In a scheme with similar ramifications, Norman Dean invented, back in 1956, a machine to "rectify centrifugal force."[4] First he set it up so that incoming rotary energy would cause some jerking motions. These could be synchronously detected by some clamps on a pole, which this apparatus could climb. Then Mr. Dean got the same basic scheme to run *without the pole,* just sitting in thin air! It could turn *energy* into *force*. He proved that it would do this because he could start it up on a bathroom scale, which would then start to read negative weight! Of course, nonlinearity of the scale mechanism was never considered. I first read about this in "*Analog Science Fiction*" magazine (which has nothing to do with analog circuitry), in which its masthead conceded that there wasn't necessarily a dot of truth in anything they published. Lovely!!

However, Mr. Dean proposed a large-scale demonstration. Get four of these "Dean Drives," one on each corner of a nuclear submarine, and—presto—you have a nice little space ship! "Why won't the Congress give a fair consideration of my invention?" he bleated.

My demonstration would be even more fun: get a couple of these "Dean Drives" running on the tips of a long rotor in a vacuum. You could put in 100 W, which would generate a certain number of ounces of force. Then, when you get the speed of the rotor up high enough, that few ounces of force would generate more power than the input power—thus, a perpetual-motion machine. Needless to say, this machine generated a LOT of controversy and head-scratching in its day.

Let's mention computers (some people have suggested that almost any use of a digital computer can be considered a hoax ...). How fast can a computer display write? One well-known computer benchmarking program yields a result called a "Winmark." Part of the test originally consisted of repeatedly writing to the display: "The quick brown fox jumped over the lazy dog." However, some bright young guy figured out that if he set up a detector for that phrase, he could then shift into a hot-rod mode that couldn't handle anything else, but it could display *that* phrase *really fast*. His Winmark rating was much superior to anything else in his price range, until the trick was discovered. Then, every time a new task was set up, detectors would be told to search for the phrase and go into fast graphics mode. I think they finally gave up on that.

But, that's exactly like the Corvettes that have come out over the last couple years: If you start out moderately in first gear and try to shift up between 16 and 20 mph, a computer predicts that you must be trying to do an EPA test, locking out gears 2 and 3 and forcing you to shift to 4th gear. With this ruse, passing the EPA tests is easy. If you want to defeat this lockout, just wind it out to 25 mph, and then you can shift into any gear you want, because the computer knows you're not an EPA guy.

A couple of people told me about the young fellow who found a way to get much faster results in general-purpose computing by just adding a capacitor to the main board. Everybody was impressed with his excellent Whetstones! It took several days before some guy with a stopwatch realized that it didn't complete the task any faster—it just slowed down the clock for the task timer. The guy who had made a "lucky guess" did apologize—he really didn't know how he was being fooled.

Bob Dobkin was at National in 1975 when he invented a Darkness Emitting Arsenide Diode. This had many features—light output never fell off with time, and they were cheap due to high yield. Just check the acronym. Then in 1979, Dobkin "invented" a BD-1, a Battery-Discharger circuit. You manufacture this by taking a TO-3 regulator that's dead, and cutting off both pins. Then the resistance from one bolt-hole to the other is about 0.9 mΩ, and thus can be used to carry hundreds of amperes to discharge batteries, etc. ... He got a good paragraph write-up in the April 1 issue of an electronics magazine. We all smiled at that one.

Then a few days later, I ran into Roy Essex, the marketing manager for power regulators. Roy was in a grouchy mood. I asked him why. He rambled on that a customer had called several times to get more information on some absurd Battery-Discharger chip, and he wasn't able to get any information about it, and the customer was getting madder and madder, and if there was any such chip, *he* should know about it, but he had no idea what the customer was talking about...

I replied, "Roy, did he call that chip-the BD-1?" Roy spun around: "How did you know that?" I tried to explain that it was just an April Fool joke. That made Roy even madder. Then we realized that the silly customer didn't realize it was an April Fool joke, as he could not find where it was announced in the magazine. That really got him mad! Roy was mad at Bob Dobkin, and, it seemed, at the rest of the WORLD for several YEARS.

Ham radio guys are always inventing and building equipment, so they're prime targets for pranksters. In 1966, Tom Kneitel published plans in *S9* magazine for a small, low-cost antenna made of two 100-Ω resistors.

He claimed that, "It has the lowest possible VSWR across the entire band with a perfect match to any rig; exhibits an omni-directional null radiation pattern; eliminates adjacent channel overload from strong local signals; may be used either horizontally or vertically; completely ends TVI problems; is impervious to auto ignition noise; and has maximum efficiency at any height. Rust-, corrosion-, and lightning-proof, it can be carried around in your pocket for walkie-talkie use."

Of course, many Hams built it and complained that they could not get this antenna to transmit or receive *anything*. Exactly... a dummy load. Other famous April Fool stories are about tall antennas that can't be seen due to use of stealth paint, etc.

When Nikolai Tesla invented the ac induction motor in 1877,[5] which ran with no brushes and no commutator, it was greeted with severe skepticism—must be a hoax. I'm sure if I had been there, I would have been incredulous, too. However, some of the later claims of Tesla border on the bizarre, and may fall over into hoaxery. Claims that electricity can be transmitted around the world with no losses, megavolt sparks under complete control, and an oscillator with an output of 10,000,000 horsepower were pretty wild, impossible to duplicate, and pretty hard to prove or disprove, theoretically or otherwise.

Heck, that reminds me of the April Fool circuit that was alleged to cause the end of the world if turned on. Some guy wrote that he built it and pushed the button, but complained that the world did *not* end when he pushed the button. Tesla's ghost??

Because I'm not knowledgeable about Software, I will not have much to say here, except to quote from a News Release—*Vogon News*[6]: "In an announcement that has stunned the computer industry, Ken Thompson, Dennis Ritchie, and Brian Kernighan admitted that the UNIX operating system and C programming language created by them is an elaborate April Fools prank kept alive for over 20 years... 'As a lark, we decided to do parodies of the Multics environment and Pascal... We stopped when we got a clean compile on the following syntax:

```
for(;P("\n"),R-;P("|"))for(e=C;e-;P("_"
+(*u++/8)%2))P("| "+(*u/4)%2);
```

"To think that modern programmers would try to use a language that allowed such a statement was beyond comprehension! We actually thought of selling this to the Soviets, to set their computer science progress back 20 or more years. Imagine our surprise when AT&T and other U.S. corporations actually began to use Unix and C!..." Beyond that, RAP has no comment. (Complete details available from RAP with SASE.)

In another case of subterfuge, a friend gave me a copy of a Special Announcement: "After a long period of research and development, Mohawk Engineering announces a revolutionary new switch and charging system...which allows a battery system of any type to supply power to a load or device while automatically and simultaneously allowing the battery to recharge itself." Complete blueprints can be obtained for just $100 from a post office box in Springfield, Mass.

Back in 1958, some engineers were quite unhappy about the quality of papers being published at conferences, so they wrote up a marvelous piece of puffery about their new "Linistor." This paper was accepted at WESCON. Then they revealed that their new invention was an alternate way to describe the *resistor*. Their prank had the desired effect when technical conferences began screening the papers more closely.

Recently, a Reviewer was evaluating a "Scantrack 18 Golfball Finder"[7]. After diligent and fruitless efforts to find any "output" from this little $89.95 gem, which uses "new microchip technology" to detect the "molecular wavelengths emitted by golf balls," he got mad and X-rayed it, and found it completely empty. No circuitry at all. Wonderful hoax.

What was the year—1978?—when Signetics brought out the WOM—the Write-Only Memory? Not just any simple April Fool joke, this marvelous invention was professionally presented in full color in a four-page foldout section of electronics magazines. Even us Analog guys got a good giggle out of that one! I've occasionally wondered what $ was paid for the publication of that fine joke—and by whom!!

One does still see, in cheap magazines and on odd radio stations, advertisements for the little box that "turns your house wiring into a giant TV antenna." I asked my friends who are knowledgeable about TV and ham radio. One said it was just stupid, because it did all of the wrong things with the signals. Another guy said its theory was dubious, but actually he had seen it work better than a rabbit-ears antenna. *Consumer Reports* says this kind of antenna usually does more harm than good[8]—a bad investment for $1.99 in 1973, and a bad investment for $19.95 in 1994.

At least one guy thinks that ISO 9000 is a first-class hoax. I will admit that we may be forced to conform to the minimum requirements of these regulations drafted by a bunch of European bureaucrats, in order to do business with Europe. However, I agree with George Lohrer of Programmed Test Sources Inc.[9] that some of the zeal we see for super-compliance and "we can meet ISO 9000 better than you can" is pretty disgusting. Copies of his letter available from RAP per SASE.

One of my readers spotted a case where a hobby magazine ran a build-it-yourself article. A special 24-pin IC, available from the author for just $30, was used to make an interface between a Macintosh computer and an ordinary video display. However, the actual circuitry inside this 24-pin IC was just a 7404 inverter IC, encapsulated with a funny pin-out. Ahem.

Obviously, I don't know half of the good electronic hoax stories in the world, but, hey, we have run out of room, so we will just print what we got. If you know a better one, we may run it next year.

Comments invited!/RAP
Robert A. Pease/Engineer

1. *Encyclopedia of Hoaxes*, Gordon Stein, Gale Research, Detroit, 1993. ISBN # 0-8103-8414-0. About $49.95; phone: 800-877-GALE; fax: 313-961-6083.

2. U.S. Patent 4,151,431, "A Permanent-Magnet-Powered Motor," Howard Johnson. Filed Dec. 6, 1973; issued April 24, 1979.

3. "Energy machine floats in perpetual limbo among agencies, court," *Electronic Design*, July 24, 1986, p. 155.

4. U.S. Patent 2,886,976, "System for Converting Rotary Motion into Unidirectional Motion," Norman L. Dean. Filed July 13, 1956; issued May 19, 1959.

5. "*The Fantastic Inventions of Nikolai Tesla*," by Nikolai Tesla and David H. Childress, Adventures Unlimited, Stelle, Ill., 1993. About $17.

6. *Vogon News*, Vol. 1, No. 1, June 1991; VLSI Technology Watch, 100 Business St., San Jose, CA. (Contributed by Bernard L. Hayes, *Computer World*, April 1).

7. "Scantrak 18 Golfball Finder," $89.95 from Lil' Orbits Inc., Minneapolis, MN. Reviewed in *Popular Electronics*, Jan. 1994.

8. *Consumer Reports*, Jan. 1989, p. 5.

9. "ISO 9000: Barking up the Wrong Tree?" Letter to the Editor by George H. Lohrer, President, Programmed Test Sources, P.O. Box 517, Littleton, MA 01460; published in RF Design, Oct. 1993, p. 14.

Originally published in
Electronic Design, April 4, 1994

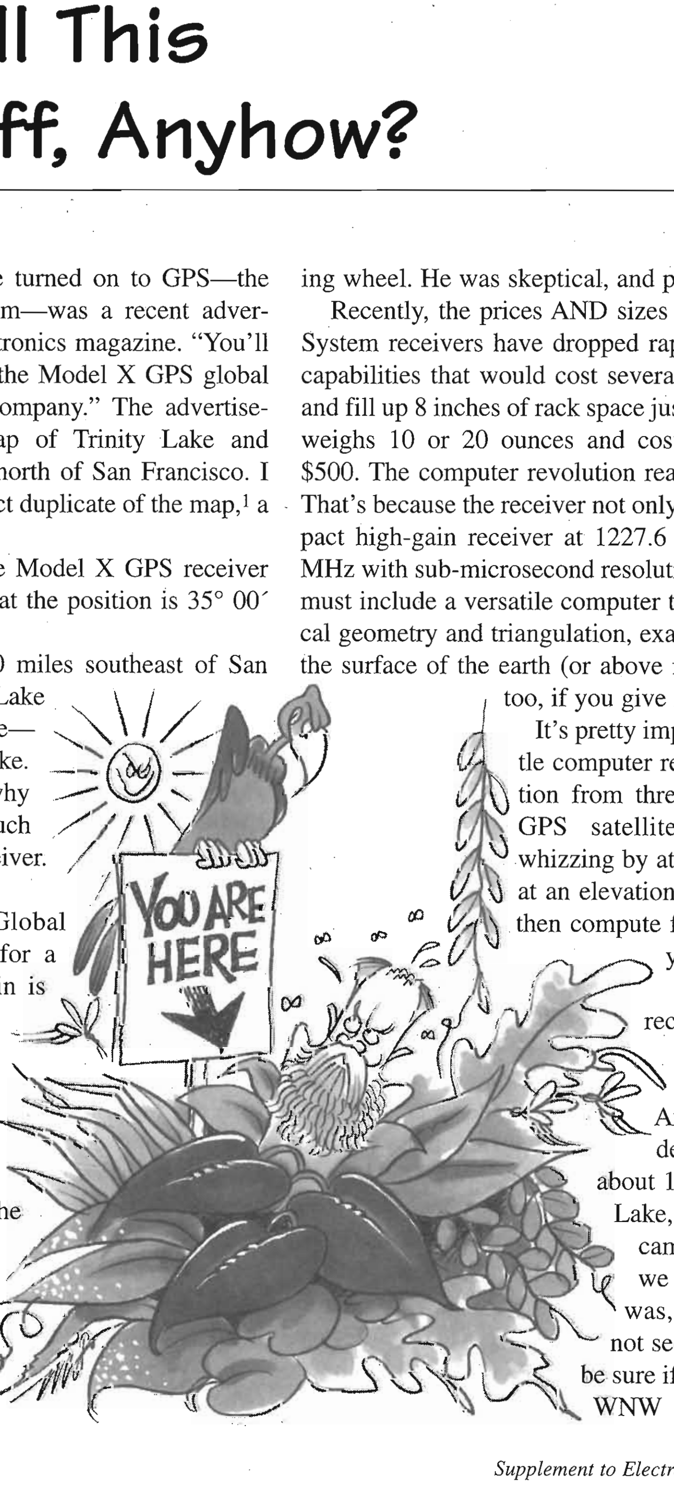
RAP's 2000 comments: We sure had a lot of fun with this one. After this came out, people sent me stories of hoaxes for years. Of course, the most popular hoaxes they sent in were about fancy, overpriced speaker cables and all the fantastic claims about them. Then one day I got a letter from Tom Nousaine explaining that he had run a number of tests on Golden-ear people who were sure they could hear a big difference between their expensive speaker cables and ordinary lamp cord. Read on!—*rap*

What's All This GPS Stuff, Anyhow?

The thing that just got me turned on to GPS—the Global Positioning System—was a recent advertisement I saw in an electronics magazine. "You'll never get lost when you carry the Model X GPS global positioning system from our company." The advertisement also showed a nice map of Trinity Lake and Weaverville, Calif., 200 miles north of San Francisco. I know this because I own an exact duplicate of the map,[1] a very nice map.

Yet in the advertisement, the Model X GPS receiver indicates on its LCD display that the position is 35° 00′ North, and 117° 52.3′ West.

That just happens to be 250 miles southeast of San Francisco, down by Muroc Dry Lake and Edwards Air Force Base—about 425 miles from Trinity Lake. So I was a little piqued at why these guys were bragging so much about their particular GPS receiver. ".... never get lost...." —???



I've been interested in Global Positioning System machines for a couple years. My son Benjamin is interested in building trails in the hills around here, and I'm interested in building trails, and hiking on them, too. After he and his colleagues have built a good trail, he likes to make a map so people can see where the trail goes. I suggested that a GPS machine might be helpful when he's gathering the basic information for the map, rather than the old method of using compass and measuring wheel. He was skeptical, and properly so.

Recently, the prices AND sizes of Global Positioning System receivers have dropped rapidly. A machine with capabilities that would cost several thousands of dollars and fill up 8 inches of rack space just a few years ago now weighs 10 or 20 ounces and costs somewhere around $500. The computer revolution really is applicable here. That's because the receiver not only has to include a compact high-gain receiver at 1227.6 MHz and at 1575.42 MHz with sub-microsecond resolution in real time, it also must include a versatile computer to compute, by spherical geometry and triangulation, exactly where you are on the surface of the earth (or above it). And the elevation, too, if you give it a little extra time.

It's pretty impressive to watch a little computer receive coded information from three or more of the 24 GPS satellites that are always whizzing by at 27,000 ft. per second at an elevation of 15,000 miles, and then compute for you exactly where you are located.

Before I had a GPS receiver, a group of us were hiking up a trail in Yosemite Park. After a few hours, we deduced that we were about 1/4 mile east of Edson Lake, where we wanted to camp for the night. But we could not tell where it was, exactly—we could not see it, and we could not be sure if it was WSW or W or WNW of where we stood.

And there was no trail to use. So we sent out three scouts. After half an hour, all three scouts returned, and admitted they had not found the lake.

We sent out more scouts, and within an hour we found the lake. What a silly waste of time! And it's a wonder that nobody got hurt, thrashing through the underbrush just to find where *we* were, with respect to a lake that was not lost at all. It had never been any place but right where it always had been....

So as the time for our next annual backpack trip approached, I decided to buy a GPS receiver to help us with any difficult navigational tasks. I went to West Marine[2] and checked out the two lightest, smallest receivers. The Garmin GPS-45 was the lightest—about 9 oz.—but the Magellan Meridian seemed to have the right features, and at 14 oz., it cost $100 less than the GPS-45 (about $411 including tax). Now, I'm often willing to pay a reasonable premium for lighter backpacking equipment. But paying $20 per ounce saved seemed a bit steep. So I bought the heavier but more reasonably priced Meridian. I slapped some batteries into it, and started on our backpacking trip.

First of all, let me explain a new deal to those of you who haven't worked in this field. Of course, every USGS topographical map carries full information in degrees, minutes, and seconds. By using some interpolation with a scale or piece of folded paper, you can tell where the map says you are. Standard navigation. BUT, the user's manual on the GPS receiver explained the new UTM (Universal Transverse Mercator) grid. All recent USGS maps show where you're located on an arbitrary grid—a 1000-meter grid—which is drawn on the maps.

It's a LOT easier to interpolate on this grid, because the grid lines are only an inch or two away from any location. So I've done most of my computations and estimates on the UTM scale. It does seem to be quite convenient, and I'll recommend it. But if you're using old maps, you lose this convenience.

Obviously, with any new system, you try to calibrate it. So, at the trail-head, I sat down at a well-defined location and turned on the receiver. After a couple minutes, the receiver said that I was at a location, which grew better-defined after another minute. But this location was up on a rocky hillside, 100 yards *north* of where the map said we were.

A few hours later, we sat on the north shore of Golden Trout Lake. I turned on the GPS receiver—and it said we were 100 yards away, on the *south* shore of the lake. About 10 times during the hike, I tried to get a correlation between the map's location and the GPS's location. Every time, the GPS had a disagreement of 100 yards north (or south) of where the map said we were (one time, it was 100 yards east).*

Well, I knew that the basic military system accuracy of the GPS was very good, but for commercial uses, there were errors added by "Selective Availability," so it could not be used at full accuracy. I hadn't expected the error to have a constant magnitude and a random angle. But in retrospect, it made perfect sense. I mean, if the error was random in magnitude, one could take a large number of readings, and average them out, so as to get low errors. If the error had a constant magnitude, but a random direction, as I was seeing, it would be hard to average or cancel out the error. I also learned a few more interesting things about GPS....

One day, the "Battery Low" flag displayed on the LCD display. I decided to leave the battery pack disconnected, so I could not turn on the receiver by accident. When I turned the machine ON a couple days later, it had forgotten all of the info I had keyed into it. I thought there must be some EEPROM to save all of the info while you change your battery. Wrong.

I guess if you bought the most expensive machine in sight, you might get that kind of feature. I presume it will remember the data for a few minutes while you change batteries. It probably has a 0.1-farad capacitor to retain power to the CMOS RAM—and the instrument's main timebase.

On the way back from our trip, I tuned in the receiver and we got rolling on the road. With 55 mph indicated on the speedometer, the GPS said we were going 53.5 mph, which was exactly the calibration error I had expected on my speedometer. The receiver is rated to be able to tell your velocity at any speed from 2.0 mph to 951 mph.

Let me also say that I'm not a sailor, so I'm slow to appreciate all of the nice navigational features that this machine can do. I *DO*, however, appreciate that when you're out on the ocean, and there are no landmarks, a GPS receiver would be very helpful to get you where you're going.

I *ALSO* appreciate that one should not rely solely on the GPS receiver for navigation—if you were counting on the GPS machine, and you ran your last battery down, and you left your sextant home, you might be in REAL TROUBLE. So Magellan Corp. was quite correct in cautioning you not to rely solely on the Global Positioning System.

After all, when we had been hiking four days, my little receiver said that we were just 7.8 miles from our trail-head, due east. But in actuality, we had to go 18 miles to get back to the trail-head, because of the wall of cliffs that stood in the way. Our maps were quite valuable in showing us that we could not reasonably or safely get up those cliffs. A straight line may be the shortest distance between two points, but it's not always the best way to get there.

Another time, we had been debating—which of those mountains over there is Mount Starr King? I thought it was THIS one, and other people insisted it was THAT one. If I had my GPS machine, I could have keyed in the location for three mountains, and the machine could have given me the compass bearing of all three. We could have proved which of the mountains was the one we were looking at. So that's a useful kind of feature.

I'm going to start petitioning my Senators and Representatives to convince the Air Force to turn off the Selective Availability—the code that will let only military users of GPS achieve full accuracy. Since the Russians and our military people aren't targeting missiles at each other any more, it's silly to crank a purposeful error into the system, especially during peace time. Besides, the Russians are already claiming that *their* GPS system has better accuracy than *our* system, so long as we refuse to turn off the error-causing code....

While my GPS receiver isn't yet a precision machine, and while I haven't yet found it highly useful, I think it will become useful in the future—NOT a bad investment. After all, if I aim for a lake that is 200 yards long, I'm pretty sure to be able to find it with the help of a GPS machine, even if its accuracy is just ±100 yards.

Comments invited! / RAP
Robert A. Pease / Engineer

References:

1. *Northern California Atlas and Gazetteer*, by DeLorme Mapping Company, Yarmouth, Maine; phone: (207) 846-7000; website: *www.delorme.com.* This map covers all of Northern California at a scale of 2 miles per inch, with *nice* resolution. Now available for all 50 states. The price is about $13.00. The only minor drawback is that elevations and contours are listed in meters....

2. West Marine is located at 850 San Antonio Rd., Mountain View, Calif., just off Bayshore. Website: *www.westmarine.com.* Also at 45 other locations in the U.S. You can order by phone from 1-(800)-538-0775, or (831) 728-2700. Ask them for a catalog, which has much useful technical info. (Yes, you can now buy GPS machines at Fry's.)

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ELECTRONIC DESIGN, *October 25, 1994*

RAP's 2000 comments: *I mentioned in one of my "Floobydust" columns the reason for most of the 100-yard errors that I saw up near Golden Trout Lake: I was using the wrong "Datum" in my receiver. Most USGS maps are marked as being referred to "North America Datum of 1927" or "NAD27." When I inserted that into my GPS machine, most of the errors shrank to 50 yards or so, rms, typical. Even though my Owner's Manual recommended using the Datum of "WGS84," for precise work you must plug in the same DATUM as the map-maker used! It might make a difference whether your boat is 100 yards offshore or right on the rocks!

Several people sent me news clippings about foolish people who went out hiking in a wilderness relying on their GPS receiver. But no map!! When they got REALLY LOST, they realized that without a map, a GPS reading does NOT help tell you "where you are."

In May of 1996, President Clinton instructed the Air Force to turn off the "Selective Availablity" errors. I did not hear *when* this is expected to happen. It hasn't happened yet. Four years later, nobody is talking about this. Isn't it strange how slow the military industrial complex can move sometimes?

These days, GPS receivers are better and cheaper than ever. Prices are down near $150 for the (surprisingly good) Garmin and Magellan machines. Lighter weight, too, and longer battery life. Any serious hiker can think of occasions when a GPS receiver could help you avoid being lost for an hour or two. When the SA goes away, even my son can use one for checking his maps!

My wife took my GPS receiver to Nepal in '95. Her readings indicated that many of the passes and towns were 800 feet higher than the old maps. I believe that. It will be interesting to see if the new maps support that. Nepal is soon getting EXCELLENT maps, as good as USGS maps. When I find out where one can buy these maps, I'll let you know. I took my GPS receiver to Nepal in 1996. It refused to work at all. Had to get it repaired when I got home! Waste of time and weight—I carried those 14 ounces 150 miles, for nothing. Sigh. In 1997, it worked fine. Refer to *www.national.com/rap/nepal/gps.html.* However, it was not essential or even very useful, so in 1998 I left it home.

My newest GPS receiver (Garmin GPS12) has 12 receiver channels and can even pick up valid readings listening at the window of a jetliner (with the captain's permission). When I see an interesting mountain, town, river, or bay, I can log its position, as well as the plane's heading (264°), elevation (39,200 ft,), and speed (486 mph). Of course, all the new machines cost and weigh much less than the original numbers. These days, $99 will get you a pretty nice 5-oz. machine!—*rap*

P.S. For more information all about the GPS system, and about specific products, you can go to *www.garmin.com,* or *www.magellangps.com* or similar sites.

Analog Learning Curve

Two-Day Analog Workshop

ing digital receivers. Understanding DAC specifications will also be covered, as it simplifies the workings of direct digital synthesis. Optimizing DAC performance is also the topic to be discussed. Finally, this workshop will demonstrate the use of ADCs and DACs in high-speed communications systems.

- **Instructor:** Paul Hendriks, Senior Applications Engineer, High-speed Data Converter Group, Analog Devices Inc., e-mail: Paul.hendriks@analog.com

WEDNESDAY, MAY 3, 2000

WORKSHOP 5. Performance Verification For High-Resolution Data Converters-Getting All The Bits You Paid For

Instrumentation, waveform generation, data acquisition, feedback control systems and other applications are utilizing high-resolution ADCs and DACs. 16-, 18-, and even 20-bit resolution measurements are becoming increasingly common. This lecture describes hardware based methods for verifying high-resolution converter performance. In particular, settling time measurements of 16-bit DACs is covered. Additionally, techniques for testing ADC linearity beyond 20 bits are also presented.

- **Instructor:** Jim Williams, Staff Scientist, Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7487, Tel: (408) 432-1900

WORKSHOP 6. Designing Efficient Switching Power Supplies

This workshop will start with an introduction to switching techniques and topologies, and then go directly into practical topologies for off-line applications, DC/DC converters, and AC/DC converters. In this discussion it will also describe specialized topologies such as compound converter, resonant, and soft-switching topologies. Additionally, it will also focus on component considerations in the design of switch-mode power supplies, as well as magnetic fundamentals including inductor and transformer designs. Finally, the workshop will address myriad control issues and solutions, as it presents design examples to highlight the control methodology.

- **Instructor:** Robert A. Mammano, Vice President of Advanced Technologies, Texas Instruments Inc., Tel: (949) 475-9192

WORKSHOP 7. Design Of AC/DC Motor Control Circuits

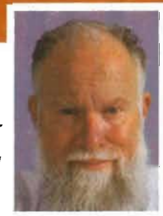
The purpose of this workshop is to provide basic concepts and technical skills necessary to design various types of AC and DC motor drives. Types of motors to be discussed will include brushed and brushless DC, stepper, reluctance, and induction motors, with special emphasis on low to medium power drives. Practical and useful procedures in selecting components and control methods, design rules, performance vs cost tradeoff will be discussed.

- **Instructor:** Dal Y. Ohm, Principal Consultant, Drivetech Research, e-mail: ohm@usit.net

WORKSHOP 8. Building The RF Front-end For A Software Radio

There are powerful reasons for providing an analog RF downconverter prior to digitizing the signal for a software radio. Amongst them, dynamic range and the signal environment are a couple of most important. We start with the need for dynamic range, phase noise and aperture jitter and derive the theoretical equations that relate them. Then we develop a clear perspective of the physical processes and requirements that need to be met for a modern software radio which is also able to cope with the high accuracy (amplitude and phase response) necessary for more advanced digital modulations (high order m-ary PSK and QAM). The newer evolving architectures for both the receive and transmit RF elements are considered along with ways of correcting for the amplitude and phase errors encountered in practical components.

- **Instructor:** Clive Winkler, Vice President, Engineering, Cubic Communications, San Diego, CA 92121, e-mail: clive.winkler@cubic.com



BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Dear Bob:

Re: your comments about "menus vs. knobs" in "Bob's Mailbox" (ELECTRONIC DESIGN, *Feb. 21, p. 133*). So you think you're frustrated with menus too? So are a lot of musicians out there.

There's an interesting parallel between musicians and engineers and the tools they use. Like many engineers, I have had a lifelong fascination with analog synthesizers because they're the perfect bridge between my profession (electronic engineering) and my hobby (music).

I play piano and analog synthesizers. I've been a performing musician by night and an engineer by day for the last 20 years. Back in the '70s and early '80s, synthesizers came standard with a panel full of knobs and buttons. I cut my teeth on instruments from that era. Incidentally, your friend Al Pearlman was a big contributor to this area with his ARP instruments until they were liquidated in 1981. His instruments were brilliant!

In the early '80s, knobs and buttons were replaced by menus to cut down on cost or to provide more bells and whistles at the same price. I absolutely detested that interface and hung onto my "antique equipment." When you're really interested in creating sounds, like I am, a real-time interface with knobs and buttons is *far more* efficient to work with. I can create the sound I want 10 times faster with knobs than with menus, and that means making the most of that moment of inspiration.

Other musicians laughed at me. While everybody else was buying the latest and greatest digital dinner bell with menus, I bought up their "obsolete" analog synthesizers that they were dumping (at bargain-basement prices) so they could finance their new purchase. *(Smart man! /rap)*

Then they wised up. One, they got tired of the constant debt from buying the new-model-year keyboard that was rendering their previous purchase obsolete (for which they hadn't finished paying yet). Two, they were tired of the learning curve associated with each new interface—lost time learning a new system. Three, in the frustration of dealing with menus, they were reduced to using the presets in the machines. Suddenly everyone sounded the same and there was no individuality—something that is sacred to the art of music. *(Why would musicians be SLOW to understand that? Digital seduction, I guess... /rap)*

I stuck out like a sore thumb. People suddenly noticed that I had a unique voice when I played in clubs, and I started getting calls to write songs and make money using my "antique equipment"—an unplanned but fortunate consequence of my stubbornness. *(Nicely put! /rap)* I could provide clients with exactly what they wanted in less time than my other musician friends.

Starting about 1990, musicians caved in to their frustrations with menus. They rediscovered the knobs on the old stuff and fell in love again. Old analog synthesizers became the rage. The value of my collection has increased at least 500%, while the digital dinner bells fell to rock-bottom market prices. This has been happening all over the world. Now who's laughing?

But those old pieces come with a price of admission. Most are over 20 years old and are malfunctioning, and there are precious few people left with the knowledge to fix them. The knowledgeable techs still in business are swamped with work.

Engineering does have its rewards, however. Over the years, I learned to keep my machines running (on multimeters and analog scopes with no menus, of course). Now musicians are calling me for repairs. Now who's REALLY laughing?

The manufacturers heard our cry and wised up. Today, knobs and buttons are coming back. A musician can find plenty of new keyboards with a generous set of controls and can happily tweak sounds to their delight. No more frustrations with menus! Now if the test industry would just wise up and make engineers' lives easier....

MICHAEL E. CALOROSO
via e-mail

Hello, Michael C. At first I thought I'd have a LOT of comments on your letter, here. But I have almost NOTHING to add. YOU have said it all. You know the value of good analog interaction—intuitive interactions—between people and systems, using analog controls, sliders, knobs, etc. You're right to point out how many people foolishly went AWAY from that. If they're coming back now, then they are getting smart even though it's a bit LATE.

I know (knew) some of the guys who made analog electronic music instruments—Lyricon, Novaline, and ARP. They were KEENLY—almost fanatically—interested in those intuitive interactions. So we are preaching to the choir. I just hope other guys have not thrown away their scopes with six (or more) knobs.—RAP

Starting about 1990, musicians caved in to their frustrations with menus. They rediscovered the knobs on the old stuff and fell in love again. Old analog synthesizers became the rage.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer
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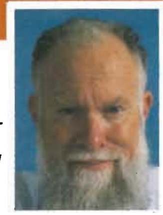
pease porridge



BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This Compensation Stuff, Anyhow? (Part II)

When you read the following joke, you'll understand why this column should have been subtitled: Outlandish expectations or what? This old joke came over the web. My friend Nathan posted one copy on a bulletin board and brought another over to me:

Reaching the end of a job interview, the human-resources person asked the hotshot, young engineer fresh out of MIT, "And what starting salary were you looking for?" The engineer coolly responded, "In the neighborhood of $125,000 a year, depending on the benefits package."

The interviewer replied, "Well, what would you say to a package that included five weeks of vacation, 14 paid holidays, full medical and dental insurance, company-matched retirement-fund contributions of up to 50% of your salary, and a company car leased every two years. For starters, how about a red Corvette?"

The engineer tried to control his excitement, but sat straight up and said, "Wow! Are you kidding?" The interviewer shrugged, "Yeah, but you started it."

One guy observed sardonically, "This story got it wrong. That's the kind of offer that would be made to some high- school dropout, writing software for an Internet startup company."

Another guy giggled, "OHHHH-HH! Now I finally got the joke. It's absurdity humor because it's about a technically oriented person who receives an offer that would, in reality, be given only to a marketing or management person. Very clever!"

I put in my two cents. With a straight face I asked, "Okay, Nathan. What's so funny about that? What's the point? What's supposed to be funny here? Is that the end of the joke? Or did the punchline get lost?"

"After all, out here, some of the best young engineers DO get such deals." (Well, most of the guys commanding money like that are fairly accomplished. They're not just green kids out of school with a shiny new BSEE. Some actually ARE bright Masters and PhDs that are really worth that money—and they can get it.)

Then I saw the point. "Ohhhhh! I see the point of the story! Hilarious! This hotshot kid is supposed to be so DAMN SMART. Yet he didn't even see that the fairly splashy-looking benefits package didn't mention any STOCK OPTIONS!

"Dumb kid. I guess he failed the test. I would never take an offer like that without stock options. Sometimes big companies tend to slough off. Startups, though, wouldn't be foolish enough to offer a job without stock options, unless they wanted to see if the kid was sloppy or inattentive." Nathan had to agree that the kid wasn't very sharp.

Earlier this year, a story on page B1 of the *San Francisco Chronicle* pointed out that the starting salary for young lawyers just joining law firms in San Francisco had escalated from $100k to $125k. Maybe some of them should make that money. I know some that are worth it. You certainly want to keep your new lawyers HAPPY while you find out if they are good enough to KEEP. (And they understand that if they perform, they have a chance to become a partner.)

Experts on software teams writing new computer games get paid well, too. And the bonuses for a winning team on a profitable video game can be very rewarding. Of course, they are usually the TOP software writers working on a hot, high-priority team. Most aren't inexperienced, just right out of school.

Should any young engineers, just out of school, make such high figures? Yeah, a few! Those are the ones I want to keep. In about another month, I'll comment on, "Do we want to have a LOT of engineers or just some GOOD ones?" You can guess my opinion and my thoughts about stock options for the good ones....

"Do we want to have a LOT of engineers or just some GOOD ones?" You can guess my opinion and my thoughts about stock options for the good ones....

So although this old joke (that was out of date even when it first came around on the WEB a couple of years ago) has some silly stuff involved, we can still learn something from it! I suppose I might have called this column, "What's All this Stock Option Stuff, Anyhow?" But.... that would have given away the story too soon.

All for now. / Comments invited!
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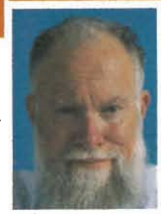
P.S. Any engineer hired who did NOT get $125k should not feel insulted. This is just a hypothetical case. Even here at NSC, it doesn't happen every day! /rap



BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Dear Bob:

A reader recently wrote in "Bob's Mailbox" about how small the knobs and buttons are on new instruments (ELECTRONIC DESIGN, *Feb. 21, p. 133*). I design marine equipment and we just released a new product. Everyone who looks inside asks why we couldn't have made it smaller? Two years ago I established the basic size of the front panel. I put on a pair of diver's gloves to see how closely the connectors could be spaced and still leave room for my fingers. All other dimensions were based on that 1.25-in. benchmark. Sure, it kind of echoes inside that box. But, when your fingers are freezing from digging the ice and sand out of the connectors, it's nice to have things on a human scale.

I designed a small plastic box 15 years ago with some idiot lights to go on the end of a stiff cable. I put in a half-pound brass weight so the cable wouldn't drag the box off the table. I got a lot of grief, but my boss, and mentor, made sure that weight stayed in the design.

DOUGLAS BUTLER
via e-mail

Doug, it's wonderful to insist on good HUMAN ENGINEERING in your controls and interfaces. I sincerely hope your customers will support you in the long run! But, would a clamp or sand be better than just brass weight? I don't know. You were there, and I wasn't.—RAP

Dear Mr. Pease:

I recently read a letter that someone sent to you about oscilloscopes and knobs. I, too, really miss knobs. I do a lot of field-service work and sometimes I'm forced to use the customer's scope. Well, a lot of valuable time is wasted trying to set up the scope to trigger, etc. Even the customer doesn't know how to set it up. You may ask why don't you take your own scope? I travel all over the world and it's not very easy to take a scope with you. I want my knobs back! I don't want to have to go three menus deep to set up my triggering or to use the cursors. I can understand menus for portable scopes to save space. But, not for larger scopes.

KEVIN SHAR
via e-mail

Kevin, I don't know how to teach all my customers to buy good analog scopes WITH KNOBS. For my good, for your good, and for their own good, they SHOULD. I guess we have to encourage the smart ones !—RAP

Hi Bob:

In the Feb. 21 issue, Stefan Graef wrote to you about instruments with tiny knobs and buttons. You took his argument one step farther and commented on instruments with no knobs. I couldn't agree more. As an experienced two-way radio tech and television engineer, I'm accustomed to using a calibrated RF generator to check FM receiver performance. One technique for doing this is running the attenuator up and down, listening to the squelch characteristics, measuring squelch threshold, 12-dB SINAD, etc.

The current crop of communications system analyzers have no knobs. In particular, the ones from Broken Batwings, known as type M, lack knobs. Everything is menu driven. It's quite obvious that these instruments aren't designed by people who have used one in the real word. Pity.

BOB SCHROEDER, BSEE
via e-mail

Bob, I certainly agree that we must buy and use instruments that have SUITABLE controls. Sometimes digital ones are just WRONG. Two weeks ago, we heard how the pendulum is swinging back to real analog interfaces. Digital controls and menus are being rejected. Let's fight back!—RAP

Dear Mr. Pease:

One of the reader letters in your recent column mentioned light-emitting diode (LED) flashlights (ELECTRONIC DESIGN, *March 6, p. 138*). I thought that I might pass along the web site *www.hdssystems.com.* It contains some information on a top-end type of flashlight created for spelunkers and others who really care about reliable light. Though it's quite expensive, the web site tells an interesting story about how the flashlight was designed.

E. LEE
via e-mail

Yeah, E. Lee, but this sells for $334, WITH batteries! Unless I was a serious caver, astronaut, or Everest-climber, I'd much rather have two $20 LED flashlights and $280 left over. I just purchased one. Really, one EXCELLENT flashlight is rarely better than two good ones. My technical report will follow soon.—RAP

Dear Bob:

Recently, while transferring a customer's parts list to our internal build sheet, I came across an interesting component spec. We're new to the contract manufacturing scene and it literally saved me the embarrassment of falling asleep due to number-induced mental numbness. This particular list called out a 0-Ω, 5%, 1/10-W SMT resistor!

JOE UTASI
via e-mail

Well, Joe, for sure you will never find such a resistor out of spec on the LOW side. But because 5% of zero is ZERO, even a measured 5 or 10 mΩ will be out of spec on the high side! Thus, the manufacturer should REFUSE to accept your order until you fix that tolerance! Normally zero-ohm resistors are spec'd not with %, but with 10 or 20 mΩ MAX. So the guy placing the order was probably just using a DUMB computer program that spits out ±5% as a default value, unless otherwise stated.—RAP

All for now. / Comments invited!
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pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Sir:

Very good letter and comments about analog test equipment with knobs instead of pull-down menus (ELECTRONIC DESIGN, *Feb. 21, p. 133*). Our company just bought a Tektronix TDS-3014 and I'm frustrated by the menu structure—But the thing is still incredible.

Anyway, I hate to bother you, but I'm at my wit's end trying to find a reasonable source of repair for my aging collection of oscilloscopes (453 and 454). I know one enterprising man who fills his retirement years restoring and rebuilding Simpson 260s (another fine analog instrument, my collection now numbers about 15), and selling them on eBay. He also has repaired some of mine at modest prices. I need someone like that to work on the old Tektronix 453 and 454 oscilloscopes in my very modest test-equipment collection. I don't need calibration certificates. I'm more interested in just having an operational unit. Do you know of anyone who may be able to help me?

In my TV/VCR shop days, I aligned many tape paths and troubleshot many video and audio circuits with a 453. But as your other readers said, finding repair people for the older equipment is becoming impossible. *(If people who can repair them are hard to find—repair PARTS may be VERY hard to find. /rap)*

MATTHEW JONES, Electrical Engineer
Kobelco America Inc.
via e-mail

Hello, Matthew. I'm sure that here in the SF Bay area, I could easily find people who do that. HALTEK in Mountain View has a lot of good old Tek equipment to sell, and the place next-door does too. But scopes are heavy. Largely, you want to know the people in YOUR area who can do it. You certainly wouldn't want to ship your scope a big distance, and then risk it getting rattled out of shape, or out of calibration, when it's sent back to you. So, you need to find a place near you. Where are you? I can't solve everybody's problems, but I can find a cure for yours. Best regards.—RAP

Dear Bob:

I just finished reading your latest "Bob's Mailbox" article on Knobs vs. Menus (ELECTRONIC DESIGN, *April 17, p. 127*). This is a topic that has come up several times here at Fender. We could not agree more. I design vacuum-tube guitar amps, which was pretty difficult to learn about in school during the late '80s/early '90s. But tube guys still lurk in the basement corners of universities, even today. *(Check. /rap)*

I bought your troubleshooting book directly from you and you hand corrected it for me. Thank you. It's great.

We love your articles on speaker-wire hoaxes/frauds. Recently, we had a guy send us a high-zoot, braided wacky-skin-effect, directional, million-dollar guitar cable for evaluation. We plugged it into a high-gain guitar amp and it sounded like a rain-stick (an instrument which creates a sound like rain hitting a tin roof) anytime it was ever so slightly moved. Even our marketing people laughed at that. *(Hilarious! /rap)*

Another topic that comes up a lot here is analog vs. digital scopes. We have both, but I keep my 465B on my bench and the digital scope in storage. They each do their own things as well. *(EXACTLY. /rap)* For most stuff, though, I like the old knobs and switches on the 465 vs. the menus on the TDS320. *(Check: Me, too. /rap)* The 465's will show you things that the digital scopes seem to miss when sampling. The digital scopes are handy for storing transient events and their measurement utilities.

I agree that the difference between a low-distortion solid-state amp and a low-distortion tube amp is very difficult to hear, but the difference becomes much more apparent when the amp is designed to run into distortion, like in a guitar amp. *(WELL, YEAH. /rap)*

The reason that I can still get paid to design tube guitar amps is that most guitarists prefer the sound of tube distortion. Maybe it's because that sound was used to create all the original Rock 'n Roll albums that they love? *(Let 'em roll. /rap)*

I just think that a tube amplifier pushed into distortion sounds better. Someday you should stop by and listen for yourself. We make both kinds and they all sound good. We are in Scottsdale, Ariz., so try coming in the winter when it's not 120° here.

At the end of the Mailbox you wrote, "I know [knew] some of the guys who made analog electronic music instruments." I just thought you should know a guy who makes analog (tube even) musical instruments.

MIKE COZZA, Sr. Design Engineer
Fender Musical Instruments.
via e-mail

Thanks for the comments! If I had to listen to guitar sounds pushed through solid-state amplifiers and distorters, I might easily say, "That doesn't sound RIGHT." RIGHT is what we've been listening to for many years—and high fidelity doesn't necessarily have anything to do with it!—RAP

I might easily say, "That doesn't sound RIGHT." RIGHT is what we've been listening to for many years—and high fidelity does not necessarily have anything to do with it.

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***BOB PEASE** obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This "More Engineers" Stuff, Anyhow?

I was reading the junk mail on my breakfast table, and listening to Garrison Keillor's NEWS FROM.... Suddenly, I jumped up and strode to the dining room, where my computer was simmering away. Why the rush? Because if I didn't jot this down quickly, I might not have remembered to do it correctly. I was at a lecture, a couple of years ago, when a guy asked me a good question. If I could find a guy to ALWAYS ask me such juicy questions, I would put him on my payroll, pronto.

The guy inquired, "Mr. Pease, how are we going to get a lot more analog circuit engineers?" I don't get a question like THAT, every day. So, I figured I should cook up a good response. I replied that "I don't want a lot of engineers to hire. I just want a few good ones. Think about the law of supply and demand. If the supply were greater than the demand—what does that say about the VALUE per unit? After all, what if there were twice as many engineers in this conference room—and we each got paid half as much as we are now paid? Do you think THAT is a good idea? I don't think so."

Now, let's think about the rules of supply and demand. If there's a lot of demand—suddenly—and there's no way to instantaneously increase the supply, then the commodity will be priced highly. H'mmmm.

How about RF engineers? I was asked at a press conference in Tokyo, how will the industry fulfill its needs for analog engineers, such as dc, audio, and RF engineers? I explained that analog is analog. It's challenging to teach—and to learn. But, RF is an ART that's very different from all the other aspects of analog stuff, and it requires new insights. I probably would never make a good RF engineer, even though I'm able to make pulsed circuits work cleanly, as fast as 200 MHz. RF is NOT just a higher-frequency extension of analog circuits. It's not quite like analog circuit design or analysis. It requires some art and insights, that certainly seem different to me. If the RF people say that they have different skills and different insights, I'm NOT going to argue with them.

Are schools putting out good RF engineers? Recently, I ran into a senior who had studied RF. I suggested that we hire him PRONTO, because there aren't a lot of schools that teach RF design. I was reading the University of California at Santa Cruz (UCSC) course bulletin, and found they are teaching many kinds of hardware, software, and systems engineering in their curriculum. Analog Circuits? RF design? Forget that obsolete stuff. It's not trendy, and you can't do it with just a computer—with no thinking required!

From where do we hire engineers? Well, we do hire some of them from conventional schools. For example, UC Berkeley actually has a few courses in analog circuits. And, they do have one course in RF. (Of course it's called RF and wireless technology).

As far as I'm concerned, I DON'T expect to be able to hire an engineer right out of school. I want a person with just the right amount of basics that he learned in school. Then, I expect that guy to be learning the ropes. One time, I hired the best TV repairman in Tehran. HE was GOOD at lots of things. Usually, he learned faster than I taught him.

Other times, I prefer to hire good technicians. Once they're a little experienced, THEY start to do real engineering work. Some have become REAL design engineers. (Hey, many people may study engineering. But it used to be easier, in the old days, to learn DESIGN, as you could study the schematics of good oscilloscopes, DVMs, or meters. Back then, designing circuits wasn't as obscure as it is now. These days, many digital functions are well-hidden in secret chips.)

But it used to be easier, in the old days, to learn DESIGN, as you could study the schematics of good oscilloscopes, DVMs or meters.

A while back, we interviewed 10 young guys. (I think I recall, one was a woman; I'm kind of a unisex writer, and there are male and female "guys.") They all seemed to have fairly equal qualifications. So, we hired who we thought were the two best candidates.

One was adequate, a fairly competent engineer. The other learned very fast, figured things out, and made things happen. What was the deal? Why was he a much better young engineer than all the rest? Why didn't we recognize this earlier? We checked back and found the "difference." He was a hobbyist, who liked to design and build little circuits. He enjoyed making them work! That gave him the excellence we saw in his performance on the job.

"Supply and demand" is a cruel mistress. In my next column we'll discuss the other side of the coin—"Compensation Part III."

All for now. / Comments invited!

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Bob's Mailbox

Hi Robert:

I recently picked up a Tektronix 284 Pulse Generator from eBay. The 284 is used for scope calibration/performance evaluation. A few weeks later I got the manual for the same product—from eBay, of course. The manual was dated 1986, but the first printing was 1967! In 1967, I started my first engineering job right out of college.

Anyway, I was fascinated with less than 70-ps pulse-rise-time circuitry that incorporates a tunnel diode. So, I thought it would be fun to build a tunnel-diode pulser for my own amusement. Tektronix doesn't supply the TEK 284 tunnel diode. I then asked the original maker of the TEK tunnel diode, Germanium Power Devices Corp., for pricing and availability. They want a mere $250.00 each (Qty. 1-99) for the SMTD892 tunnel-diode device, and a three-week lead time.

Yeah, I'll take a hundred. <LOL> I'm sure there are more tunnel diodes sitting in garages than there are on the shelves of distributors. It's disappointing when you can't get your hands on some of the old discrete parts to play with—takes some of the fun out of engineering <IMO>.

I'm waiting for a reply to an e-mail sent to American Microsemiconductor, inquiring about their tunnel diodes. I asked for ten diodes each of three types, so those guys must be really excited about that order of perhaps $7,500 worth of parts. I made my request before I discovered that a $250.00 diode really existed on this planet.

I design analog circuits, often with discrete components, and often purchasing components from obsolete semiconductor parts houses! Try to purchase a 2N2222A from Newark—the part is now obsolete! I suppose I'll be retired within the next 20 years (I'll be 75 by then), so hopefully the completely depleted stock of all discrete semiconductor components won't have much of a personal impact on me. <grin> But it will eventually be very difficult, sometime in the future, to build some of those specialized circuits that an off-the-shelf IC can't provide.

Oh well, the above represents all of my gripes for this week. Next week I've got a smog check on an Audi. <groan>

BILL RUSSELL, Sr. Electronics Engineer
Digital Instruments Inc.
Santa Barbara, Calif.
via e-mail

You can buy a "PN2222" or similar, in plastic, which is more reliable than most of the MIL-2N2222s that were ever built, unless you flog them above 100°C of junction temperature. Hey, nobody is BUYING real 2N2222s. I bet you can buy JAN ones for $20, but even my rich Uncle Sam isn't buying. Nobody is buying tunnel diodes either. If you just want to see subnanosecond rise times, then setup a couple of "PN918s" or similar as an emitter-coupled multivibrator. That will get WAY below 1/4 ns.—RAP

Hello Mr. Pease:

I enjoy your column in *Electronic Design*, and always read it first when my copy arrives. I'm sending to you by regular mail a copy of an article entitled *"Sound Man,"* from the March 26 issue of the *Boston Globe Magazine*. Its subject is Vladimir Shushurin and the very high quality, very expensive ($16k to $30k) stereo amplifiers he hand makes.

He contends that the conventional total-harmonic-distortion values advertised for commercial amplifiers don't translate to good sound. His philosophy is described in the article, and I would like your thoughts on whether most listeners could notice much difference between his and typical stereo components that most of us buy. *(My guess is that MOST of us probably cannot. More on this later. But if someone wants to, fine, let him pay. /RAP)* Congratulations on writing such interesting and readable columns on a variety of topics!

KEN MORMAN, Quality Engineer
FLIR Systems
via e-mail

Hi, Ken. I'm sure he is, in many cases, right. However, if he says there are NO GOOD SOLID-STATE amplifiers that sound good, hey, I'd like to challenge him to a really blind test! Especially compared to a good amplifier costing 1/5 to 1/10 to even 1/20 of what his cost.—RAP

Hello Bob:

All of your arguments on "over unity" etc. also were applied to the Curies' in their day. They were actually accused of trying to build a perpetual-motion machine. *(I didn't know that, but I'm not surprised. /RAP)*

I use my spare time to explore the impossible (low temperature/energy nuclear reactions). I'm not entirely sure these reactions are nuclear, but for now nothing else explains them. Ten years ago this was thought impossible, but not anymore. *(MOST people still think they are impossible, but I don't. Yet on the other hand, I do not foresee that it will be EASY! Do you think you can get the tritium to make a lot of power output? /RAP)* Don't throw the baby out with the bath water. We have not yet discovered all things in this universe.

BRUCE VICKNAIR
via e-mail

Agreed! Give it a good try, Bruce! Best wishes.—RAP

All for now. / Comments invited!
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Note: As of May 1, the U.S. Air Force shut off the "selective availability" (random noise and errors) that civilian GPS users have endured. The new accuracy, and freedom from noise, is wonderful! Now, GPS can perform very accurately—check it out! /RAP

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pease porridge

What's All This Compensation Stuff, Anyhow? (Part III)

I got an e-mail from a reader: "I sat down hoping to read about compensation of op amps and feedback loops. What I got was your 'Compensation Part II'—a bummer." Hey, I'm sorry. I think I will soon be able to write *"Part IV"* on the compensation of op amps and feedback loops.

But first, as we were saying, most of us engineers want a fair deal. We like to work hard, and sometimes we don't mind working some long hours, because often our work is FUN! But we do like to get paid for it. And, it's usually better to get paid more, rather than less. Check out *"What's All This Compensation Stuff, Anyhow,"* (ELECTRONIC DESIGN, *Feb. 4, 1993, p. 80)* and *"Part II"* (ELECTRONIC DESIGN, *May 1, p. 135)*.

So, last year when I saw that the U.S. Senate approved a bill authorizing 115,000 green-card workers in engineering and high-tech fields, I was a bit suspicious and skeptical. Is it GOOD for the U.S. engineering profession to have a WIDE gate for immigrants to enter and compete with us natives? I mean, I wouldn't want to be unfair to immigrants, but it does seem more fair if they stay and compete from home.

Then this spring, I grew quite grouchy when I saw that the U.S. Senate was asked to increase the number of green cards by an ADDITIONAL 100,000. Do the large U.S. companies really have to just say "please, we really need it," and the Senate will give them anything they ask for? Yeah, probably.

Are there really so few high-tech workers available in the U.S. that we need to allow another 100,000 in? Isn't this just another case of, "We want lots of workers, and we want them cheap, and if we can get them, good?" Yes.

Sure, there are older, under-employed, and unemployed engineers who could (some of them) be trained for new projects, and on new software languages. But nobody wants to give them a break. Employers want *young* employees who can be hired *cheaply*.

Are foreign workers, engineers, often BETTER? Well, I hate to see any generalization carried too far. I mean, some are EAGER, and have good INCENTIVES to do a good job. Some may have received good training and educations. But let's not over-simplify things. I have seen that some Czechs like Bob Widlar and Jiri Dostal are very good at analog circuit design. Still, I certainly wouldn't want to argue that there aren't some POOR engineers in any country. We should avoid foolish generalizations.

What can WE ENGINEERS say and do to prevent the laws of Supply And Demand from being used against us? I'm not sure, but we had better pay attention, and think about it.

I have heard that it isn't EASY to find recent U.S. graduates who are smart about engineering linear circuits. But, I don't think it's that easy to find them overseas either. Why should the U.S. be responsible for a world-wide brain-drain of engineers into the country? Just because U.S. companies can afford to pay for it? Yeah. Plus, a *lot* of people want to come here.

Next case: I read in the *San Francisco Chronicle* that "German Politics (are) Roiled by Plan to Lure Foreign High-Tech Workers." Some German politicians and organizations observed that it was "ludicrous" to bring in 20,000 software writers from India while a few million Germans are out of work. I haven't yet heard the resolution of this contest, but I can guess.

Then, I saw a little fine print from the *Chronicle News Services:* "US Exceeded Visa Limit for Skilled Workers." Apparently our Immigration and Naturalization Service inadvertently exceeded the congressionally-mandated limit by about 22,000 engineers (in the range 21,888 to 23,385) for the fiscal year ending Sept. 30, 1999. That's 22,000 *over* the initial amount of 115,000 that was supposed to be a temporary ceiling.

Do you really believe the senators will listen to the captains of industry, who want to find a broad supply of engineers at reasonable (cheap) wages? You bet. Will the IEEE be able to argue successfully against opening the flood-gates? I don't have a lot of serious hope.

How can we help the IEEE get its point out? Is there anybody else who cares? Do we engineers need to form UNIONS? Maybe we do, if that's the only way to attain a fair deal.

If it's such a good idea to get Indian engineers to write Software, then why can't they write it in India? Why should they come to the U.S. where typically they are treated badly? Even though they earn more money when they come here, they have to spend a lot more on living expenses. Don't misunderstand me. Some of my good friends are Indian. Some work in the U.S., and some work in India. Some are very good at their jobs. I would have to say, though, I am skeptical about some, as from *any* country, because they don't have much experience. Sometimes you get what you pay for. After all, these Indian software writers *all* make more errors in their software than I do. I'm one of the very few engineers who doesn't make *any* mistakes when writing Software. But that's because I never write Software. Heck, I almost never USE software. What I use for writing is PC Write Lite, available for about $50 from Starlight Software; (360) 385-7125. It's very basic and simple. And, I like it.

I looked up the IEEE website: *www.ieee.org/web/search/* and searched on "immigrant engineers." The search turned up about 58,582 items. Some were of definite interest. For example, the "IEEE-USA Testimony on High Tech Worker Shortages and Immigration Policy (2/24/98)" by John Reinert, president of the IEEE. You can find it at *www.ieeeusa.org/FORUM/POLICY/1998/98feb25.html.* He observed that while we don't want the U.S. industry to be stalled by an alleged inability to hire enough engineers, Information Technology (IT) workers, and computer scientists, it also is NOT a good idea to allow so many engineers in that wages become depressed, and the laws of supply and demand get warped.

After all, he observed, if we had a real shortage, then the wages of such engineers and IT workers should be going up rapidly—but they weren't. In 1998, the IEEE president's speech didn't prevent Congress from opening the gates. What will the IEEE say this year to prevent Congress from opening them wider? The present IEEE president, Merrill W. Buckley Jr., made a very good column on this: *www.ieeeusa.org/intro/buckley/buckleyapr00.html.* But is the Senate likely to be swayed by that?

What can WE ENGINEERS say and do to prevent the laws of Supply And Demand from being used against us? I'm not sure, but we had better pay attention, and think about it, and watch to see what is happening. Or else the "$150,000 engineer" in *"Compensation II"* will just about disappear, and all our wages will be depressed.

My colleagues who reviewed the early drafts of this have been quite outspoken. Some think I'm not nearly forceful enough, much too Politically Correct. At the same time, others think I'm too unfair, and Politically UN-Correct. And, what is your opinion?

All for now. / Comments invited!
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pease porridge

Bob's Mailbox

Dear Bob:

I have enjoyed your column for many years. I also am an analog guy, working as the chief engineer for a PBS station.

As an avid boater, Douglas Butler caught my attention (ELECTRONIC DESIGN, *May 15, p. 135*). I cannot find a marine radio large enough for a decent user interface. Knobs are small, or worse yet, up/down buttons. Changing channels by pushing the up button 20 times is insane. Even worse is the speaker. A 2- to 3-in. loudspeaker cannot move enough air to be heard while under way in a power boat. So, you have to buy an external speaker that costs more and takes up more room. I got lucky, and found and repaired a 20-year-old Regency radio with a 5-in. speaker, decent knobs, and direct channel entry.

Bill Schwartz
via e-mail

It sounds like you used SCROUNGING to find a good solution! Furthermore, you found a good old radio with PROVEN reliability. If it has lasted this far, it should be reliable a good bit LONGER!—RAP

Dear Bob:

Here's another interesting Analog vs. Digital debacle: I recently read that a certain company in Texas is trying to push digital projection systems into movie theatres around the country. Disney is currently releasing a feature film around the country to showcase this technology. Worldwide movie distribution will be revolutionized, and customers will get incredible digital quality. All is great, right? Wrong!

Although the technology will bring many benefits and cost reductions to studios, distribution houses, and large cinema conglomerates, there are certain very significant disadvantages from a consumer point of view:

The current systems support only 1 million pixels. That's a huge step backward from the 35-mm analog format that has up to 4000- by 3000-pixel resolution. It doesn't even compare to the roughly 2 million pixels of digital TV, available at your local electronics store.

S.J.
via e-mail

H'mmm—the digital guys are trying to swindle us again, eh?—RAP

Dear Bob:

I'm not a circuit designer by any stretch of the imagination, but I just have to know if the 0-Ω resistor is real. I never heard of such a thing. If I had, I would have put it into the same category as the darkness-emitting diode (DED). Your reply implies that they exist, so I just have to know—why?

ABB (Another Bearded Bob)
via e-mail

OF COURSE there are "0-Ω resistors." They have been around for over 30 years. They act like a jumper. But, as they are the same as a standard resistor in size, they are easier to handle than a jumper. Look them up in any decent catalog, like Digi-Key, Newark, Allied, etc.—RAP

Hi Bob:

It isn't often that I catch you in a blunder, but I think I have now. Your comments that a "DUMB computer program" spits out 5% as a default value isn't true. I used to use 0-Ω resistors a lot, but I was never a distributor for any. If you think about it, all distributors price resistors by tolerance. So a 0-Ω resistor can't be 5% out, but he's telling the sales people to sell them at the same price as a 5% resistor. Now that you realize this, ain't you ashamed?

Joe Stern
via e-mail

Joe, I'll be darned if I'll pay any more than the "20%" price for these cheap resistors. If someone wants to charge the "5%" price, then they won't get any business from me! Best Regards.—RAP

Dear Bob:

I, too, liked your article on knobs vs. menus. But it's worse than you made it seem. It's really about analog versus digital scopes. Analog scopes show you the "real" waveform. Digital scopes show you what some computer chip thought some analog-to-digital converter thought it saw at some point in time—averaged/sampled, or whatever, over some period of time.

Generally, I find it very difficult to troubleshoot a circuit with a digital scope. The thing takes forever to sync, and just about can't display anything but a clean repetitive waveform. Almost ALL waveforms have noise on them (when I know I have no noise), which I have to mentally subtract out.

About the only thing a digital scope is good for is getting numerical data on the waveform (rise time, etc.). So I keep both kinds of scopes on my bench, as do most of the people I work with.

Tom Mills
via e-mail

Of course, you are GENERALLY RIGHT. I agree. But, you also will agree that for certain rare cases, a FAST digital scope is JUST RIGHT, and better than an analog scope—sometimes even better than an analog Memory Scope. About once or twice a year, RIGHT?—RAP

Dear Bob:

This link: *www.alibris.com/* is to a company called Alibris that buys and sells out-of-print books. I hope this helps your searching.

Richard M. Saur
via e-mail

I will try on the "Farm Journal Pie Cookbook." Hey, they seem to have it. I may try to buy TWO—and, "A Race On The Edge Of Time." They are doing at least as well as Amazon. Thanks, Richard!—RAP

All for now. / Comments invited!
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The Fire Is Still Burning
I greatly enjoyed the subject of the editorial column . I believe the reason you do your job well (as it appears to me) is that you have the passion you referred to, and the wonder at new technologies is still quick to surface.

I believe that passion and excellence are nearly inseparable. I do not know of an example of someone who has excelled in a field who is not also passionate about it, and the converse is true. I am not quite sure which comes first, but probably it is a piece of the passion (curiosity? interest?) which drives one to learn, apply, and excel, which in turn seems to pique the interest and thus the passion.

I do not hold myself as an example of excellence, but I do know that to whatever degree I have progressed in my field, it has been due to my passion for both electronics engineering and teaching. I certainly do not do it for the financial reward; there are many more lucrative things one can do. But financial reward does not bring deep personal satisfaction. Studies on this fact are replete. Excelling (or at least doing one's very best) in a field DOES bring deep satisfaction. That's why I continue in the field.

And yes, the wonder is still profound. The more I know about a field, the more wonder I feel each time I read about a new development. This is truly an exciting time to be here!

With so many of the people I know lusting after getting their IPO millions, I have been wondering if I am the only weirdo left who is interested in getting out beneficial products. Your words make me more hopeful that people like me aren't an endangered species.

Yes, I'm an engineer because I found that what I like most is making things that do something useful. (I started out with a degree in physics.) Sure, I like making an engineer's salary. And, I wouldn't mind at all if I became rich because of one of my designs. But if I became independently wealthy tomorrow, I feel confident in saying that I would still want to be making useful things the day after. (Okay, maybe a few months after. A good vacation would be nice too.)

I am looking forward to finding out how many responses you get like mine—not percentage, but actual numbers. I doubt you will get very many people writing in just to admit they are doing what they are just for the bucks, no matter how true it may be.

The fire is still there for me, though it has been burning rather low lately. You have fanned the flames a bit and helped remind me why I'm doing this stuff.

The Computer As An Appliance
Your editorialbrought my 1980 Atari computer to mind. It booted up as quickly as my television set and had just about as many features. I don't believe it's "the industry" to blame, only Microsoft.com. I only use about 5% of the features of any of Microsoft's Windows applications. All of the applications I use during a typical computer session could fit in a ROM pack or Flash card, if their features were limited to the ones I normally use. If the Atari's 6502-based board was replaced by a modern one running, say, 400 MHz, it would probably boot in the time it takes the CRT to warm up. I know I must sound like Bob Pease here, but it's my honest opinion.

You mention the two-minute boot-up time for your PC. The problem, as I see it, is misapplication of technology. The Commodore 64 must have had the slowest disc drive interface ever devised, yet my son's C64 can boot up and load the Geos GUI from floppies and get into something useful faster than my Pentium can load Windows and get into an application!

I still use DOS-based applications for most of my work, and keep them on a separate computer to keep them safe from Windows and from Internet viruses and hackers. The programmers' text editor I use most has a point-and-click interface, as does my PC-board CAD, EPROM programmer, and others. But, they are DOS-based. They load and run much, much faster than my Windows applications, they're easier to use, they don't crash, and I have more control with them.

The computers you dream about exist already. They are called MacIntosh computers! They have been using USB as their exclusive low-speed I/O bus for about two years now, in case you haven't noticed. They have had PCI exclusively for some time now and have IEEE-1394 (Firewire) on most of their recent machines—a step forward in higher speed communications. And they have "instant on," something of a more friendly user interface, etc., etc.
Your magazine equates PC to "Wintel Computer," a rather myopic view and one, as a reader, I find somewhat annoying. If you and your magazine would equate PC to "personal computer," you would greatly expand your horizons. Many of the "breakthroughs" you announce have existed on personal computers for some time, just not on Wintel machines.

So, unless you would like to remain in Microsoft's pocket, unconsciously I hope, many of your readers would appreciate a broader view of the personal computer industry.

pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This Sudden Cessation Of Stupidity (SCS) Stuff, Anyhow?

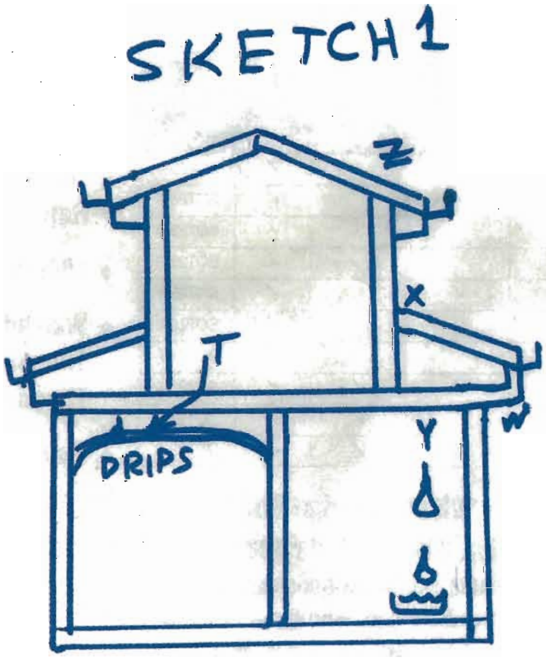
Sometimes when I learn *something*, and write a column about it, the payment I receive for the column is enough to pay for the *something*. But, that may not be the case this time. Still, the (Sudden) Cessation Of Stupidity is actually much better than the alternatives.

When I moved into my house (built in 1918) 23 years ago, it was in pretty good shape. But there were some water stains in odd places along the walls and ceilings. I wondered, should I have the roof replaced? Well, maybe not just yet. Perhaps I could figure out how to stop the leaks.

The worst leak was in the middle of the kitchen, over by the dishwasher. When the rain began, at first nothing happened, but later the ceiling would start to drip. We could put out newspapers, buckets, rags, pots; but when heavy rain began to fall, we had to be prepared for that darned internal leak. Sometimes, but not always. Not even very often. Not often enough to make it easy to find, but enough to be annoying. This leak was four feet from the wall, BUT there was a second-floor outside wall overhead. The outside wall for the second story was set about five feet inside the wall for the first story.

One year I laid out some fiberglass panels on the roof, and that seemed to cut the number of leakage episodes in half. Well, that was good, "but no cigar." The main problem remained: when the rain came in from above, it came out below at places that were NOT OBVIOUSLY connected. Could the rain do that? Could the rain come in at place X, run over at an angle, and drip down at place Y, several feet away from under the place where it went in? Yes, it could. Apparently it did. *(See Sketch 1.)*

Other years, when we had severe storms blowing in from odd angles, such as the east, northeast, or northwest, the rain came in at places and times DIFFERENT from those we were suspecting. Mop it up, fellah.... It seemed to me that when the driven rain came blasting down at heavy rates and severe angles, it would hit the walls, run down, and sneak in at funny little cracks. I tried caulking those cracks, at the bottom of window sills or similarly strange places. Good theory—those cracks did have to get sealed up. But, doing so didn't really stop the leaks.



We had the house painted one year. Still, while certain areas of potential leakage were carefully treated, the sneak paths continued to annoy us. Another year I hired a guy for $250 to put a good tar PATCH on the roof, in the area X, where the leaks were occurring. I never bothered to complain, just because the leaks continued (occasionally) despite the patch.

In 1999, I heard some very suspicious drips that seemed to be right on the ceiling, over my head (T), as I lay in bed. Was I imagining things? I NEVER saw a wet spot on the ceiling. Sketch 1 shows that this is vaguely under the second-story wall, four feet inside the first-floor wall.

But five months later, the ceiling began to lose small swatches of paint in that area. How annoying! What would I do? Ke garne! (That's a common Nepali phrase we bring out when we are PUZZLED! "Ke garne?" just means, "What to do?") As I said, that was in 1999. In January of 2000, I heard another drip, right over my head. And, a different one—then ANOTHER—finally even a little SPLISH. THAT was intolerable! It was WAR!

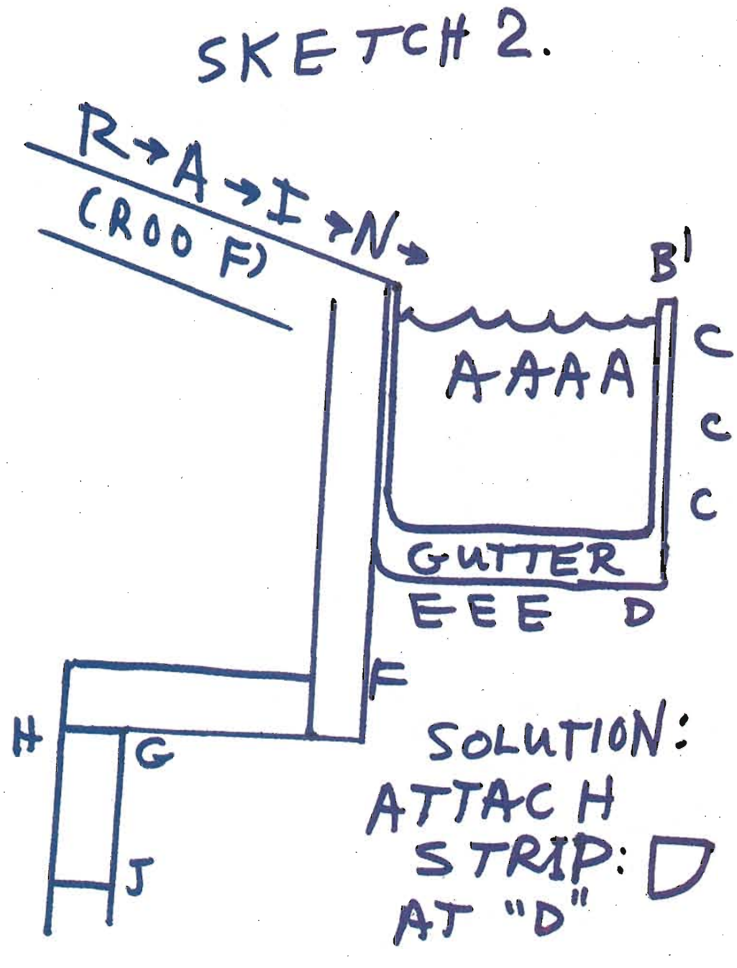
I went out and bought several slabs of fiberglass corrugated sheeting. I put them on the roof, right over my head, extending for a couple of yards in all appropriate directions. That night, a long soaking rain began, and no drips were heard overhead. Had I solved the problem? Sure....until two nights later, when a strong driving rain led to more sets of drips and splishes. Rats! (I even checked under the fiberglass sheets, and it was completely DRY.)

Then I remembered something my wife had said a year before: "The rain is running over the edge of the downspouts and it's STAINING the new PAINT on the outside wall." She had not said it loud enough, nor insistently enough, but I gradually caught on.

When the rain comes down during

the DAYTIME, she is home to watch. When I'm there, the rain is usually falling at night, and it's hard to see what is happening. When the water runs off the upper roof and falls into the rain-gutter at AAAA, it could drain down the proper path—but not in case of a problem. *(Refer to Sketch 2.)* There are three problems which can easily occur:

1. If the gutter has filled up with pebbles, the rain can't go along the gutters, so it goes over the edge.
2. If the downspouts become clogged up with leaves, the gutters will likewise overflow.
3. If the gutters have sagged at all, they can overflow even if the other problems of proper maintenance have not occurred.



When the rain overflows the edge at B′ and down the edge at C, some of it may drip off at D. But, some of it may hang around at EEE—and cling to the bottom of the gutter. Then it can get close to the house at F. That's a *sneak path*. Occasionally, there's a small crack between two boards at G, or further down at J.

The capillary action just sucks the water inside at H. Then, it runs down six feet and drips onto the top of my ceiling. That's where we see trouble. (Note that while I heard drips over my head on the north of the house, I never *heard* any drips at the kitchen leak on the south side.) I looked and searched for, sealed, and caulked any possible crack within five feet of the drip point. But, I didn't notice the sneak paths eight feet over the drips. Pretty dumb, eh?

Anyhow, all of the logical paths had been well sealed off. But when the drips continued, I kept SEARCHING to find the actual path. My wife hadn't noticed it for 22 years, and I hadn't noticed it for 23. But I caught it now. Finally, it made sense that all of the different sneaky leaks came in at unsuspected places. WHO would suspect that the rain actually came into the house at a place that was protected from the rain—never hit by rain? I had looked at every place the rain hit, but not at the sneak path.

The solution was surprisingly simple: add a little strip of wood or plastic along the bottom of the gutter. I bought about 20 yards of half-round wood strip, painted it white, and glued it onto the bottom of the gutters, up at D. I used Goop, a kind of rubber cement. Now I'm waiting for the next rain. After all, some systems cannot be tested until extraordinary conditions occur. You can't just DO the test. (Still waiting—no hard rain....)

(Is it true that all houses in San Francisco are required to have gutters and downspouts that drain into the city sewers? Also, is it so that in Daly City, the next town south, the houses are required to have gutters and downspouts that do NOT drain into the city sewer, but instead onto the ground?)

Presuming this works well, I will make many copies of this story and hand one to each of the houses in my neighborhood. Then, I will try to get the local newspapers to publish it too.

Meanwhile, Jeaneen Bacon, the person who I purchased my house from, will be ASTONISHED, because it was obvious that she had these problems for years before she sold the house. I don't know if she believes in CUSSING, but she may be doing that now. Especially when I tell her how easy this is to FIX, after I figured out where the sneak path was—after only 23 years.

Some old turkey will say "H'mph, I could have told you that." But no old turkey did. This seems to be one of those not-well-known problems. Can I find this in any home-repair book? I bet not. If it were so obvious, storm gutters would be extruded with a little rim along there, to make sure the water can't run back toward the house. But, is it well-known that severe ice and snow build-up can clog gutters, and force water back up through shingles into the house? Yes. That's in many books.

Anyway, you readers are the first beneficiaries of this SOLUTION. If you have roof leaks, or water leakage along walls, this may help. Pass it along to your friends: a little strip, just a 1/4-in. square, (or half-round) glued to the bottom of the storm gutters may prevent water from running down the outside (and the inside) of your walls.

Now, it's a good idea to keep the pebbles and debris out of your gutters. It also is a good idea to keep your downspouts unclogged. But, you can't always be perfect. So when overflow occurs, you shouldn't be penalized. I rest my case.

All for now. / Comments invited!

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pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Hello Mr. Pease:

Good article on "More Engineers Stuff" (ELECTRONIC DESIGN, *June 12, p. 151*). There's a whole other road to travel when talking about "good work." I will shorten my version to say that "good work" lies in the relationship between the maker and the user—both love the thing they are doing. The guy who makes every solder joint shiny, or makes sure that all the flux is off the board, does it because it's good, not because it interferes with the circuit or because it's in a spec. *(I'll agree, that's a fair point, although there are times when "good enough" is good enough. Not every piece of work needs to be gold-plated. /rap)* You can't "educate" someone to be good. They have to learn it on their own from living in the thing they do.

I worked at the Navy's EMC test facility for a while. RF isn't an art, but more like lunacy. Aircraft RF is lunacy in a can. Navy aircraft RF is lunacy in a can, in a microwave oven, on top of a cookie sheet—a very BIG cookie sheet, covered with salt water. *(Nicely put! /rap)*

In response to the question, "Where do you find RF engineers?" You hire military technicians—the good ones. *(There are a FEW coming out of colleges. I might like some of THOSE better than military technicians who are mostly only trained to follow cook-book troubleshooting procedures. Are they EDUCATED in theory? I doubt there are many who are. /rap)* But even they are getting fewer as computerization takes over. I learned about AND gates as a complete circuit board. Now, an AND gate is just a symbol that refers to something magic in a chip.

Once they stop teaching tactical air navigation (TACAN), the true insights into RF will be lost. Everything after that is just digital. Then, all you have to know is if it's ON or OFF. *(And when GPS is working well, HECK, that makes everything else obsolete, anyhow! /rap)*

I feel old when I think about the lost arts I have learned. I was born when you graduated from MIT. How does that make you feel? I can only say, "Thanks for all the slide rule work." *(I still use mine, but I do most of my math in my HEAD. /rap)* Can you imagine what the carpal tunnel people would say today if we still used those little wonders?

Dan Conine
via e-mail

Typing the answers would get you into trouble! But writing the numbers down on paper is slow enough, so most people would have a lot less carpal or "Repetitive Stress Injury" (RSI). Thanks for the comments, Dan.—RAP

Dear Bob:

I would like to comment on your various "Mailbox" letters that old equipment ain't obsolete. What got me thinking about this was having my favorite 4-1/2-digit panel meter go funny. The zero-input reading started creeping upward from the usual zero or one count to about 15±3. *(What time is it when the clock strikes 15? Time to fix the clock! /rap)* It's old, having been made in 1978. This is only the second time in 22 years that it has needed repairs. It comes in handy when a 3-1/2-digit DMM isn't good enough, which happens regularly. Action was needed.

Instead of junking it and getting a new one, I looked inside. The +5-V supply was a bit low and the raw voltage feeding it also was below 5 V. Feeling around with my finger, I found no hot ICs. But, I found a too-warm bridge rectifier feeding the 5-V regulator. A new bridge fixed it. Because the meter was open, the big capacitor next to the bridge also was replaced. It had run for about 17 years with that aluminum electrolytic.

It was also dusted and the analog section of the board was washed with alcohol. It's good for another decade or two. The insides, mostly CMOS MSI chips, are all very repairable. The maker had even included a schematic in the manual. There may be a selected part or two, but no embedded processor with proprietary firmware or board-mounted chips covered with epoxy blobs. It's almost indefinitely repairable.

Probably a lot of older gear is simpler and easier to repair than the current equivalent. Fixing my meter took less elapsed time than having a replacement delivered. Plus, for geezers like me, the parts are all big enough to see without a combination of glasses and headband magnifier. It's a pretty good deal.

Jon Wexler
via e-mail

Hi, Jon. Take good care of your good old stuff—your wife, too. (They ain't making neither of 'em like that anymore....)—RAP

Dear Mr. Pease:

If compensation is based on supply and demand, then there must be a severe shortage of CEOs in this country. Why aren't we raising the immigration limits on CEOs allowed into this country? *(A very good point! Actually, CEOs can and do move across national boundaries much easier than peons.... /rap)* Go to the web site *www.aflcio.org/paywatch/ceou_compare.htm* to find out what your annual pay would be if it had risen as much as CEOs' pay has risen in the past five years.

Allen Smith
via e-mail

I'm not griping about my salary. But thanks for raising this point!!—RAP

TREKKING: We have nearly filled up our trek to Nepal (Oct. 4 to Nov. 17) with 10 people, and there's only room for one or two more hikers. In case you missed the earlier invitation, e-mail me to inquire about the details.

All for now. / Comments invited!
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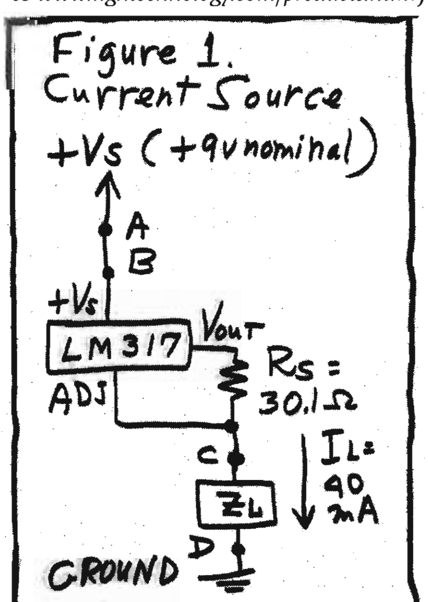
BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This Current Limiter Stuff, Anyhow?

The other day I was studying a current limiter using a basic current regulator, which used an old LM317LZ *(Fig. 1)*. I did the design on this IC about 20 years ago, with a little advice from Bob Dobkin. The LM317 was trying to force 40 mA into a white light-emitting diode (LED), so that 1.25 V across R_S, the 30.1-Ω sense resistor, would cause a 41-mA current to flow—if you had enough voltage. (This is a GOOD standard application shown in every LM317 data sheet.) Because the output pin is 1.25 V above the adjust pin, the current I = 1.25 V/R_S will flow—if there's enough voltage.

It worked fine with an input voltage of 9 V, or 8 V. But, of course, when it hit 7.4 V, it began dropping out of regulation. This was the basic design for a flashlight, using a white LED and a 9-V battery. The flashlight would run with R_S = 30 Ω for a BRIGHT output, or 120 Ω for long battery life, and still enough light to hike with on a trail in the pitch dark. (For info on this $20 flashlight, go to *www.lightechnology.com/products.htm.*)



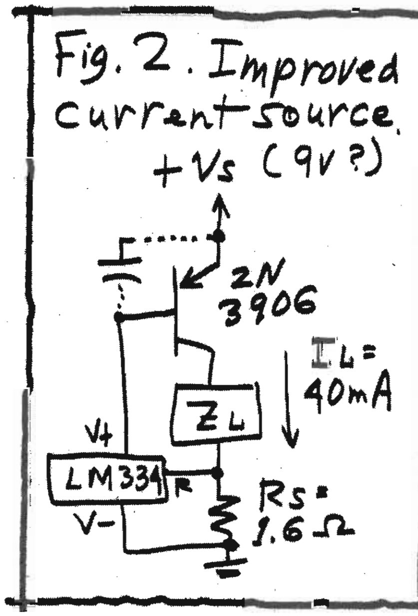
I pondered this for a while. Would it do any better if I put the load in the + supply path of the LM317? How about installing the load between A and B, and placing a jumper wire between C and D? No, it would work just as well—and just as badly.

Then a few days later, I realized—I could do a lot better than that! Yes, a low-drop-out (LDO) regulator, such as an LP2950, might do a tiny bit better than an LM317. But see Figure 2. The LM334N can regulate with not 1.25 V across the sense resistor—but just 64 mV. So a 1.6-Ω resistor will let you source 40 mA quite handily. And the voltage across the load does NOT have 0.7 V in series with it, so it regulates down MUCH better than Figure 1.

How much voltage is across the transistor? An ordinary 2N3906 will keep working down to 65 mV. So you can force 40 mA into a white LED that runs at 4.0 V, even down to a 4.13-V battery voltage. If you want to put 20 mA into a series stack of red LEDs, the conventional LM317 scheme will light two LEDs with a battery down to 6.3 V. But the LM334 scheme can drive three LEDs in series, with the same voltage. So it's not a bad circuit. This is a useful trick, *especially* if you have a load that's floating, and isn't grounded to either supply.

THIS circuit doesn't have a low tempco. Its output current increases at +0.33%/°C. But that's plenty good enough for many cases—like in a flashlight! If you need a better tempco than that, we know several ways to do it. Still, this will let you regulate the current into a red LED down to 2.1 V of supply voltage, or a white one down to 4.2 V—MUCH better than 7.4 V.

OH—I almost forgot to say—the LM334 sometimes needs a series RC damper. My first guess was 2 µF and 22 Ω across the base-emitter of the PNP. Actually, this circuit didn't oscillate or



ring badly without an added capacitor, but the noise was a bit quieter when I added a 2- or 10-µF electrolytic.

If you really want a low tempco, use copper wire (magnet wire) for the resistor—that will cancel out nicely. You'll need 6 ft. of #34 gauge, or 10 ft. of #32.

Even if you did have a grounded load, this circuit would regulate down to 5.4 V—considerably better than 7.4 V.

A few months earlier, I received a request for a somewhat-larger current limiter, that would pass 280 mA (200 mA ac rms) at 115 V ac, but no more than 300 mA. I thought a few seconds and scribbled out the basic circuit of Figure 3.

I told the guy, "This will probably work, but the FET has to be a big one, such as an IRF640 or IRF740, with a large heat sink, as it will have to handle 30 W. And the current limit isn't perfectly constant, or well defined, as the current limiter gets smaller at warm temperatures. I don't know if that's what you want, but that's what you get. Tell me if that's unacceptable. And if you nail the output with a short-circuit load, it will probably blow out."

Later, I thought about this circuit. Would it be possible to design in some improvements, to avoid some of these disadvantages?

When a shorted load is applied, the drain-source voltage will rise instantly to +150 volts, and the gate-drain capacitance will try to pull the gate to +130 V. That's not so good! Maybe the 10 µF + 0.1 µF across the zener, with the Schottky diode D2 added, will help clamp the gate to +15 V well enough to survive a momentary short? *(Fig. 4.)*

The temperature coefficient problem gets solved next. The V_{BE} shrinks at 0.3%/°C in Figure 3. But the improved circuit of Figure 4 gets a better tempco of the current limit, by compensating for that V_{BE} tempco with the tempco of the Schottky rectifier D3.

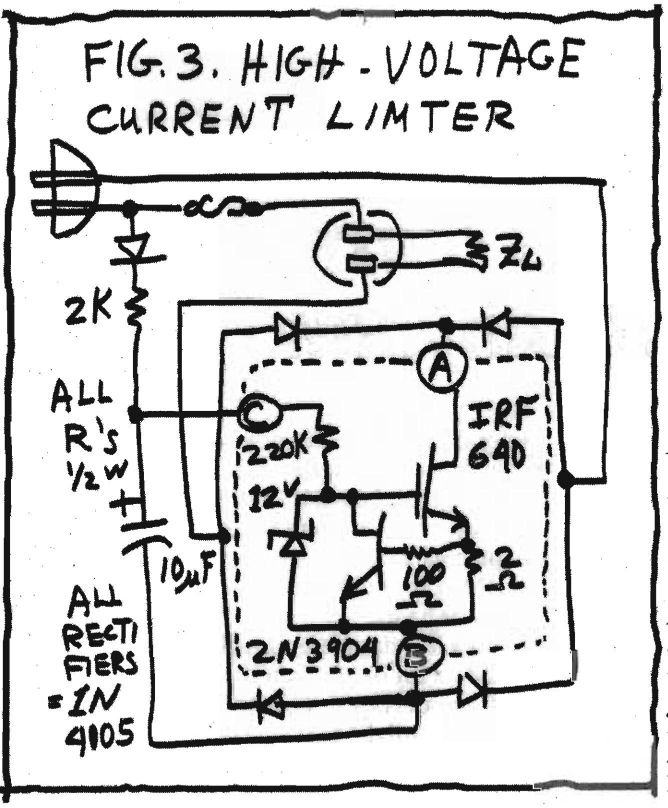


FIG. 3. HIGH-VOLTAGE CURRENT LIMTER

While this will provide a good current limit with well-behaved loads, it may not turn on the 2N3904 quickly enough with severe loads. So I added the little diode D4. This will give a short-term current limit at perhaps 1 A, which will rapidly fall to 0.3 A.

Now how about the long-term current limit, in case of a short? That FET is going to get HOT!

Well—why don't I add R6 and R7? Normally, the voltage across the FET is less than 0.1 V. When it goes into current limit, and the voltage across the FET increases toward 100 V, the current through R7 requires the current-limit voltage across R5 to decrease. So in case of a short, or a very heavy load, the current limit folds back, and the heat in the FET decreases. That sounds pretty good. But what if you need to start-up a heavy load? That current through R6 would prevent the limiter from starting in case of filament inrush current, or filter capacitors that need to be charged.

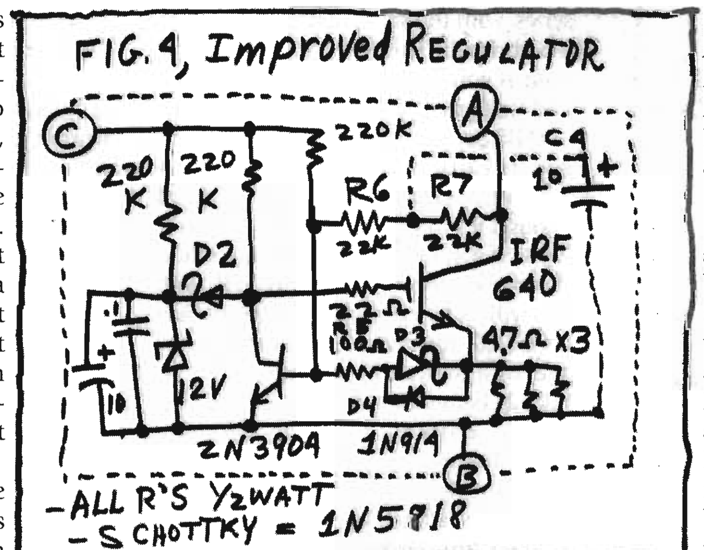


FIG. 4, Improved REGULATOR

Well—let's add one more Band-aid. Let's add C4. This will let the limiter put out a LOT of current for a short time, for start-up. How much power loss? At 0.3 A, the burden (IR drop) is only 0.4 V for the limiter circuit, plus 1.2 V for the rectifiers.

Well—that sounds like a good theory. Does it work? Let's see. When I drafted this, I hadn't yet built this. But I felt it was well engineered, so I wasn't *too* surprised that it really did work as designed, when I built it.

I evaluated it very gingerly with light loads, moderate loads, full loads, and overloads. I ran it on a curve-tracer, and turned up the voltage very carefully. When I saw that it met every requirement, I dropped a short across the load. The curve tracer grunted, but the regulator survived.

Then, I plugged that circuit into the WALL and applied all kind of loads. After it survived every test, I shorted the load *again.* I was pleased to see that it ran cheerfully, it survived, and it didn't get very hot.

DISCLAIMER: Kids, DON'T just try this at home. Working with high voltages can be lethal if you get sloppy. When working on this circuit, turn the power OFF and unplug the cord. If possible, use an isolation transformer. Additionally, use a variac so you can turn up the voltage gradually when starting out. Wear safety glasses for all high-voltage testing. Keep one of your hands in your pocket when actually working on the circuit, to prevent a loop that could send lethal currents through your chest. Be careful of high voltages. If possible, work on this ONLY when somebody is around to give you first aid and call a medic, in case of shock or explosion. This high-voltage circuit is NOT guaranteed for anything. It does NOT come with a guarantee of some safety margin. Plus, it hasn't been evaluated with any loads other than resistive. Still—it's a pretty good place to start. /rap

All for now. / Comments invited!

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P.S. The last time I designed such an "electronic fuse," it blew up the FET three times in a row when I applied a short. I then gave up. This design seems to work much better. But if I keep decreasing the sense resistor by 3 dB at a time, I wonder how far up the current limit can go before it starts blowing up! But I'm not going to look at that tonight!

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This Perfect 10 Stuff, Anyhow?

No, these words aren't from Bob Pease. In fact, he won't even know about this until he opens *his own* copy of the magazine. *Electronic Design* is "borrowing" this column to recognize Bob's 10th anniversary of writing "Pease Porridge" columns. In all those years, he never missed a column. So congratulations, Bob, for scoring a PERFECT 10!

And let me tell you, keeping that perfect record took some work. You see, Bob gets to proof the final version of each column before we print it. He came through, no matter where he was on the globe. Recently, for example, if you were at a certain airport overseas, you would have seen Bob on his knees beside an awkwardly placed telephone stand. He had five minutes to catch his flight to another country and was still trying to tell me about some last-minute "tweaks" for a column. (There I was, at the other end of the phone trying to find the same version of that column.) Yup, things got a little hectic, but we worked it out. Bob made his flight, and the tweaks were added.

For those of you who weren't around at the beginning, we have reproduced his original "What's All This Analog Stuff, Anyhow?" column following this one. Then you can turn to the Real Thing and read Bob's latest thoughts on "What's All this Current Limiter Stuff, Anyhow?" (p. 187).

You will notice that we introduced his first column by offering to bring you "Bob's seemingly off-the-wall, yet insightful view of the engineering world." Who would have thought that he would still be going strong a decade later? Most of you will probably agree that he delivered on the *insightful* part. As for the *seemingly off-the-wall part*, well, that was undoubtedly an understatement. You see, Bob started sharing his views on not just the engineering world, but the whole world around him (and the rest of us).

I vividly remember hitting my voice-mail button 10 short years ago and hearing, "Brrrppp, Bleep, Dootleloo, Twerrrpp, Brrriinngg," and then finally, "Hello, this is Bob Pease." To this day I'm not sure what he was doing. I have ruled out indigestion, so I'm betting he was trying to impersonate a fax machine or a modem—an *analog* one, naturally.

The rest of the message went something like, "I know we have to trim my column to fit. But, oh those words. I love my words, I hate to see any of them go." Well, some of them did go, but we trimmed them very carefully. That's when I began to get caught in between Bob and Roger Engelke, who was then our chief copy editor.

I would approach Roger with one of Bob's columns and our conversation would go something like this. Roger: "WHAT!! What is this? This isn't correct usage of the English language." Me: "Well, if we put it all into proper English, it won't sound like Pease." Roger: "Grrrrr! Look at all those upper-case and italic words, and all those em-dashes. Nobody writes like that." Me: "Well, if we put it all into proper English it won't sound like Pease." Roger: "Grrrrr!"

Over the years, we managed to compromise pretty well. We bent some of our rules, we stuck to our guns on others, and Bob did the same on his end. Of course, Roger gradually got a bit of revenge. Column by column, he would change just a little bit more and see if it would pass by Bob. He pretty much succeeded. Bob was a good sport about the whole thing. And I think you will agree that when you read a "Pease Porridge" column, there's no doubt about who wrote it. Sometimes, the whole English language doesn't contain exactly the right word, so Bob just invents another, like "Floobydust." Right on Bob! I'm on your side.

Then there are the letters. No matter what Bob writes about, it generates lots of letters. You readers only get to see a tiny fraction of them in "Bob's Mailbox," but we try to print the most interesting ones.

One letter in particular stands out in my mind. There was a reader who met all of the requirements to go on a trek with Bob, except he couldn't take his dialysis machine with him. I was really touched when Bob replied that he would send him pictures and a video of the trek, and further said, "I'll walk a mile for you."

Of course, all our regular readers know of Bob's battles with Spice and computers. But technology marches on. When we started out, there was no such thing as the World Wide Web. Now Bob is on e-mail, and can even be found browsing the web on occasion. Naturally, he's encountered a new foe on the Internet—the dreaded Search Engine. He's still on the quest for a Search Engine that gives good hits when he types in "Bicycles with black pedals and chrome handlebars for rent when trekking in Nepal."

Hopefully, you have enjoyed this slightly irreverent tribute to Bob. I'll finish up with one final comment. Speaking for all of us at *Electronic Design*, you have taken us on a wild trip so far. Keep it up. And for me personally, it has been a REAL PLEASURE, Bob.

Bob Milne, Chief Technology Editor; bmilne@penton.com

PEASE PORRIDGE

WHAT'S ALL THIS ANALOG STUFF, ANYHOW?

This is the first of a series of columns about analog and "linear" circuits written by Bob Pease, Staff Scientist at National Semiconductor Corp, Santa Clara Calif. We think our readers will get a lot out of Bob's seemingly off-the-wall, yet insightful views of the engineering world.

Why? Why am I going to all the trouble of writing about "linear" and analog circuits? Everybody knows that linear circuits are dead. Nobody's buying or designing in linear circuits; they are all being replaced by digital signal processors. Analog computers have been dead for years. Why bother?

Well, these days, even though there are trends to perform a lot of functions with digital computations, people are finding that there are still a huge number of things that cannot be done properly without analog circuits. It's true that some of the trendy new radios claim to use a lot of digital techniques, but even there, the receivers and amplifiers are analog circuits—even if the the receiver's frequency appears to be digitally controlled.

BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

When people are designing digital computers, they need analog techniques to make good layouts for fast buses. They need power supplies— either linear ICs or switch-mode circuits (which use analog circuits internally). And, as for us analog designers, the old-timers and the rookie engineers—well— this column is intended as a soapbox for me to talk about linear circuits, and then for me to listen to your opinions and comments and questions.

I have a lot of opinions, but I'm also very interested in what makes you tick. I may not be the smartest engineer in the whole analog jungle, but I have sort of volunteered to start writing this, and we'll see what happens—what interesting debates we get into. I have a bunch of opinions about ICs, data sheets, testing, computer simulation, education, troubleshooting, along with a whole slew of little topics.

In every darned issue of Electronic Design, I'll try to have some provocative or insightful topic. Some will be pretty technical, others will be more philosophical in nature. But one thing's for sure, I'll try not to bore you. For example: What's all this heuristic stuff, anyhow?

HEURISTICS?

The other day I was talking with a young college graduate from a prestigious Eastern engineering school. He explained that his specialty was analog synthesis. I perked up my ears—I hadn't heard much about that. Where could I read more about this? "Oh," he said, "in some of the IEEE journals." Hmm. He started to explain the approach. It's a heuristic approach, he said. Hmm. What's a heuristic? He said, "You don't know what a heuristic is? Really?" I explained no, that we didn't have any heuristics when I was in school.

(Note: Mr. Webster says that heuristic means "serving to guide, discover, or reveal; specif.: valuable for stimulating or conducting empirical research but unproved or incapable of proof—often used of arguments, methods, or constructs that assume or postulate what remains to be proven or that leads a person to find out for himself.—from the Greek, heuriskein, to discover, find.")—Gee, that sounds like analysis or optimization to me—not synthesis.

The young man explained that when you make a lot of optimization experiments, heuristic refers to the starting place, the initial guess. H'mm. He said, "You feed in some requirements and some specifications, and it optimizes the performance." Hmm. Now, what circuit does it use? "Oh, it uses the circuit that you give it." Hmm.

THE KEY QUESTION

If you give it a circuit that doesn't work well enough, how does it generate a circuit that works better? "Oh, it doesn't." I explained to this young fellow, that in our whole product line, about 99% of the circuits are not optimized at all—at least not "optimized" in the sense he understands. If you really OPTIMIZED them, they would all be a little different than they are now. But each one has a different circuit that is a revolutionary—not just an evolutionary—change from any previous circuit. So there may be places in our company where optimization is useful and a good idea.

But I wish he wouldn't call it "analog synthesis," that seems to be a misnomer. The circuits around our area—the ones in the NSC Linear data books (and, I bet, in the PMI and Analog Devices data books, too), were not "synthesized" except by bright engineers who knew that the old circuits wouldn't cut it, and a new circuit was needed. Good luck, young fellow!

All for now. / Comments invited! / RAP / Robert A. Pease / Engineer

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Bob's Mailbox

Hi Bob:

Read your article *"What's All This Compensation Stuff, Anyhow? (Part III)"* (ELECTRONIC DESIGN, *July 10, p. 147*). Very interesting. The U.K. is introducing 150,000 "fast track" visas for foreign IT workers (largely drawn from India and Asia) to attempt to fill some of the shortfall in qualified technical staff. Some of our government ministers have even been over to the U.S. attempting to repatriate Brits who emigrated years ago.

Bizarrely, at the same time, they've introduced new tax legislation called "IR35," which is making it impossible for small IT, engineering, oil/gas, aerospace, and other "personal service" companies to remain in business by "deeming" (the government's word) that 95% of company income is in fact the personal salary of anyone with more than a 20% stake in the company. And, that amount is then taxed as if they were a regular employee of the end client. Plus, they have to also pay the 12.2% Employer National Insurance contribution—but they're not eligible for any of the usual employee benefits.

Nonshareholding employees of affected companies, therefore, have to be paid out of already taxed income, (i.e., the director's "deemed" salary), upon which they have to then pay their own income tax and national insurance contributions. *(JEEEZZZ!!!! /rap)*

Overall, this amounts to taxation at a rate of 74.5%. Large companies aren't affected, and lawyers are exempt. Both Tony Blair and his wife are lawyers—what a surprise! 66,000+ small businesses are expected to close as a direct result (government's figure). As many of these are young, mobile, Internet-aware professionals, they're quite naturally fleeing the country in droves. About 40% of contractors have already left or are planning to leave in the next year.

This is decimating the "e-conomy" of the U.K. and has paralyzed the IT and engineering sectors. Because the rules are so arcane, even the Treasury and Inland Revenue can't understand them to the point of giving clear advice. They have even admitted that the measure introduces double and triple taxation in certain cases, but they say "tough—it's the Law." The government estimates around 500 million increase in tax take in the first year, due to the new measure, but it costs 1 billion to implement the new revenue system, and 1.2 billion corporation and other taxes are heading overseas as a result. So, they have actually lost around 1.7 billion—quite apart from the knock-on effects of turning the U.K. into an IT and engineering wasteland.

Just to put the icing on the cake, the government has just implemented its Removal of Individual Privacy (RIP) Bill 2000, whereby all e-mail and web traffic is routed to the government's agents for monitoring. ISPs are required to install black boxes on their networks to facilitate this. Encryption is outlawed. Failure to disclose a plain-text version of an encrypted file is punishable by two years in prison, and disclosing that you have been asked for a plain-text version of an encrypted file gets you five years. A large number of ISPs are moving offshore, and inward investment to the country is on hold because few international companies want their currently private, secure e-mail exchanges with other offices to be snooped by the U.K. government. *(Bizarre! /rap)*

So, we're leaving. And where can we go? Europe's good, but the U.S. is better —cheaper petrol, cheaper food, cheaper housing, cheaper computer equipment, cheaper Internet access, more space, more freedom, better governmental system. Watch out, the Brits are coming! (Haven't you heard that one before?) This time, we would very much like to live quietly with you folks.

Simon Banton
via e-mail

We would love to have you as neighbors and co-workers, but watch out for the U.S. bureaucrats when they open the floodgates to EE and IT engineers from Asia and other low-rent places. Best wishes!—RAP

Dear Bob Pease:

I'm a professor at the University of Texas. I am of the vacuum-tube generation and have been teaching linear electronics and instrumentation for over 30 years. Your article *"What's All This Compensation Stuff Anyhow? (Part III)"* just struck a chord and resonated with my thoughts. I'm a proud engineer and I like to keep the profession respected. Did you ever hear that the AMA has imported physicians to our country, even though there's a shortage of physicians in some locations? I think the answer is clear. *(One guy said that the AMA did and does let in a lot of foreign doctors, but I don't have to believe that. /rap)*

Another issue is that the basics of linear discrete electronics are being buried under software and computers. I have nothing against software and computers, but I hate to see how today's students don't even know what biasing of a transistor means! If this trend continues, I don't know where the electrical engineering profession will be going. *(Very simple: it's going all software. Straight to hell in a handbasket. /rap)* Maybe we have to import some more engineers who have the basic knowledge.

Samir H. Manoli
via e-mail

Hello, Samir. NSC has several dozen design engineers working in design centers overseas. MOST are working and living in their home countries. And many are working on linear ICs.—RAP

All for now. / Comments invited!
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pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

What's All This VW Stuff, Anyhow?

As you read this column, Bob Pease is off trekking in Nepal. But he figured you might like to read some old stories—with some new TWISTS added.—ED

When I was a kid, my first car was a black 1941 Chevy, and it was a piece of junk. I think I paid Johnny Vinscunas about $25 to take it out of his back yard, from the weed patch behind his chicken coop. That was in the summer of 1957, when I was 17 years old. I bought this old clunker just to drive it around on farm roads. It was NOT a good car. It was a piece of junk. I doubt that it ever went more than 35 mph. The brakes were kind of dubious and if I had tried to rebuild them, they could have easily gotten *worse*. So, I gave it away that fall when I went off to MIT.

Next I bought a Studebaker. In 1961, I purchased an aqua 1950 Studebaker. Although it was only 11 years old, it was tired. It would go 55 mph. But because it only had three gears and no overdrive, it wouldn't get out of its own way. One day when I was minding my own business, driving up Route 1 in Saugus, I heard a thump-thump-scrape. The right rear wheel had fallen off. It didn't go rolling past me, but was trapped in the wheel well. The rear axle nut had stripped its threads.

I jacked up the car, positioned the rear wheel on the axle, in about the right place, and thought about this problem. If the rear axle was that *soft*—would that help provide a solution to my problem? I went to a nearby junkyard and found an axle nut from another car. It was slightly smaller in diameter than the Studebaker's axle. I turned that nut on and off the rear axle of the Studebaker until it cut its own threads. Then, I torqued it on, good and tight, and wired it up tight, and I drove home VERY carefully, avoiding big bridges and high-speed roads.

The next day, I took it in for repairs. That was the day I placed the order for my first VW, a 1962 Beetle. A couple months later, my 1962 Gulf-Blue Beetle arrived. I left the Studebaker in the morning and took a trolley to work. That night I rode out on the trolley and picked up my $1680 beetle, and I never looked back. Ever since then, over 1,400,000 miles, I've been a VW man.

So what am I driving these days? A 1970 VW Beetle with about 157,000 miles on it. It runs very nicely at 69 mph. I get adequate gas mileage. It's very reliable. But it sure is amusing....

What's so funny? In 1957, I had a 16-year-old car—and it was a piece of junk. In 1961, I bought an 11-year-old car—and IT was a piece of junk. NOW I have a 30-year-old car that's NOT a piece of junk. It's a pretty good car! It's hardly rusty at all. It gets 27+ mpg at 69 mph. It goes, and it stops, and I can out-corner most of the cars on the road. That's because they don't care what they do, and I care.

Why do I like VWs? Well, I have gotten a lot of reliable miles, and a lot of enjoyable miles, in the last 40 years in VWs. I don't want to bore you, but I have some good feelings about them. They are fun and interesting and challenging to drive. I mean, if you like to just climb into a car, and step on the gas and go, well, that's a different car. I like to shift. I like to think. I like to feel the road under me. I like to feel the torque rise up. Even old VW Beetles had some of this *"Fahrvergnugen."* All that word means is, Enjoyment (vergnugen) of driving (fahren).

Not Boring? I have driven a bunch of cars recently, and when you step on the gas, they are BORING. (I have listed them in an Appendix on Rentals.) Yes, they will eventually go fast. But when you get in a VW Rabbit or Golf, or an *interesting* car, as you start out in first, and shift into second, and *nail* it—really floor it—in just a couple of seconds, the acceleration really turns on, and the

LIST OF RAP'S VWS

Vehicle	Color	Miles	Condition	Engines
1. 1962 Beetle	Blue	0 to 169k	Retired, running w/ bad bearings,rusty.	1
2. 1965 Bus	White	0 to 160k	Traded in, running ok. (rusty)	2
3. 1968 Beetle	Tan	35k to 115k	Accident when running strong. (rusty)	1
4. 1970 Beetle	Blue	79k to 249k	Auto. Retired, Running but leaking oil	4
5. 1972 Bus	Red	0 to 162k	Retired with smoking exhaust. Not rusty	2
6. 1968 Beetle	Tan	47k to 365k	Running strong when retired	2
7. 1969 Beetle	Red	95k to 218k	Running strong	1
8. 1974 Beetle	Tan	45k to 90k	Running strong	1
9. 1985 Bus	Blue	9k to 135k	Running strong	1
10. 1970 Beetle	Red	117k to 157k	Running strong. Well broken in	?

Total number of miles (air-cooled)—1,266,000 plus
Total number of miles (all VWs)—1,392,000 plus

torque is coming up, and you have to get ready to shift really soon. Then in third, you have to think and plan. Where is the first curve? When do I have to ease my foot off the gas? I really like that. Even a VW Beetle accelerates crisply enough to make you think.

The Shape of the Acceleration Curve: Ya know—I built myself an accelerometer. I set it up to take some data. I should take some curves on the acceleration of different cars. Yeah, I should have done that—but I didn't have time to do that right.

If you like to drive a big Chrysler or a Chevy Caprice or a Ford Taurus, they may have more acceleration. But if a VW Rabbit has a better torque curve, you may have more fun driving it. You may be more alert and interested in driving. I happen to think that's good. I think it's safer too. Whatever *you* prefer, well, *you* drive it.

Meanwhile, here is a list of the VWs I have owned *(see the table)*. (Refer to RAP's BOOK, page 396—this is an UPDATED version.)

Hey, I won't say I haven't ever had any troubles with my VWs. I can't say I never had to spend any money on any repairs. But I have had a lot of fun, a lot of good miles, and pretty good luck. I have no gripes. VWs have run pretty well for me. I don't baby them too much, but I do try to treat them fairly as I work them hard. Note, if you divide 1,392,000 miles by 15 engines, that's better than 90,000 miles per engine—and still rolling, on at least four of them. And a lot of miles to go. That's not bad, considering I bought some used cars with a good bit of miles on them, and still received good service.

Old Joke: Question: Why is it that VWs don't slow down for corners? Answer: Because if they did, they would never be able to get up to speed again.

That may be some kind of old joke, but VW drivers have always found it fun, and challenging, to get through corners as fast as they can. Slowing down for corners is for other drivers to do. A VW Beetle isn't exactly a "sports car," but it can be driven as a sporty car. The steering is light, so you can tell if you are getting into trouble by going too fast. Of course, if you try to be the fastest car on the road, then you can spin out and get in real trouble. On the other hand, on a snowy day, it's easy to be faster than 99% of the cars on the road, and quite safely. That's a lot of the fun of a VW.

Obsolete? Are VW Beetles obsolete? You might say that. Many cars are obsolete the day that they are made. But there are still a lot of old VWs running strong, out here in the West. So there are still a lot of people who enjoy their VWs, and we don't care if some people think they are "obsolete." Hey, there are MILLIONS of Fords and Chevys and "you-name-its" that were built after my '69 or '70 Beetle, and a lot of them have been junked. Out of all those other old cars that were NOT junked—how many of those cars are better than mine? How many of them have a lower operating cost? How many are fun to drive? I rest my case.

The sound of the flat-four engine, with the pistons reciprocating like crazy, shuttling back and forth, is NOT like the sound of any other car.

When is a VW not a VW? You might say, "Pease—you only know how to drive old junky cars." That isn't exactly true. One time Porsche of America invited me to test drive some of their cars. The instructor showed us a test of driving in a loop around some cones. He got a Porsche 911 around these cones in 5.4 seconds. When it was my turn, I got the 911 around those cones in 5.4 seconds, also. That 240-hp car, on good pavement, had the same feel as a VW on snow—except it was faster and quicker. I figured that out as soon as I floored the gas on a machine that I had never driven before. I have driven Corvettes and hot Mustangs, and a Chevy Corsica that really liked to MOVE. And I even managed to keep them all on the road.

Buying a Used Car? If you want to buy an old VW Beetle or Bus, I would caution you where to look to see if there is rust—such as, under the spare tire. Plus, you would need an experienced guy to drive it and see if it feels right. The late John Muir wrote the book, *How to Keep Your VW Alive,* John Muir Press, 1992, about $25. That's a classic book. If you want to buy and drive an old VW, that's the book that you need, as it has a chapter on How to Buy a Used Car. I don't know how many Beetles and Busses are still running, but there's a LOT.

Nonpolluting Cars? Pease, you drive all these miles—but these old cars are all a lot of polluters. You must be responsible for smogging up the whole San Francisco Bay area—eh? Not really. I keep my car tuned up, and it rarely falls below 27 mpg. My car usually passes its smog test with no problems. Even though there are no required tests for CO and NO_x on old cars, my car continues to pass those tests, even though it is not required to. So, it's not so bad.

My Next Car? OK, Pease, you drive this old 1970 clunker. When it gives out, you can't buy another one. So what are you going to buy?

Well, it's NOT true that I can't buy another one. Every week I see three or four advertisements for a 1968, 1969, or 1970 Beetle in very good shape, with prices in the range $900 to $2000. So if an elephant comes along and sits on my good old 1970 car—I'll just buy another one. Really!

New Beetle? Pease—what do you think about the New Beetle? I haven't yet driven one, but obviously it's a pretty good car, and a *fun* car, and I smile and giggle every time I see one. But I'm certainly not going to invest THAT kind of $$,$$$ just to have people giggle at ME! I prefer to pay just $$$. You can still laugh at me. It's permitted.

The Sound of WHAT? Recently I figured out perhaps another reason why I like VWs. The sound of the flat-four engine, with the pistons reciprocating like crazy, shuttling back and forth, is NOT like the sound of any other car. But it does sound like my mother's old White sewing machine. That's another very comforting sound that I have heard over many thousands of hours.

All for now. / Comments invited!
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Note: This column is excerpted from *How to Drive into ACCIDENTS—And How NOT TO*, Robert A. Pease, Pease Publishing, 1998. For more information, inquire at the address above or see at *www.transtronix.com.*

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

pease porridge

Bob's Mailbox

Dear Bob:

I couldn't ignore the letter from S.J. regarding digital projection in cinemas (ELECTRONIC DESIGN, *July 24, p. 139*). It's true that film can deliver excellent dynamic range and resolution. But, in the real world, this doesn't happen unless the image is static and projected from a single frame of film. Conventional film projection suffers from scratches and dust (especially after multiple showings), as well as from a loss of definition and contrast caused by multiple-generation copying.

Add to this the fact that on successive frames the film may be in different positions in the projector mechanism (in all three axes). So, the apparent high resolution of the film starts to become less relevant. Not only is the film analog, but so is the projection method. In reality we see that grain detail is lost by duplication and then it's blurred in three dimensions—x (weave), y (jitter), and z (focus flutter).

To many people, the digital version is the more watchable with much greater image stability, better coloration, excellent resolution, and zero blemishes. I know that "zero blemishes" is a digital artifact, but it's one that I'm happy to live with. Most people who have seen this technology in action rate it consistently better than the traditional film-based projection.

Recently, I had the good fortune of seeing both film and digital versions of Toy Story 2. I cannot wait for more film producers and cinemas to adopt this technology. I say this both as a film lover and as an engineer who loves things analog, rather than as an employee of any particular company.

Leslie F. Mable
via e-mail

Hello, Leslie. Well, YOU find that digital movies look better, but it seems that not everybody feels the same. Remember when CDs first came out? Many people said that music on CD's was better—just fine. But the people that don't like it, and CAN hear a difference, are very bitter and strong in their condemnation of the drawbacks of CD's for music. THEY have kept their vinyl records (as have I). It looks as though we are in for another (digitized) love-hate experience. Besides, if you see a REAL movie, with some REAL cinematography and not just some digitally generated cartoons, then the ANALOG movie might look a LOT better! Gotta make a reasonable test!—RAP

Hello Bob:

Just read your article on water in the house (ELECTRONIC DESIGN *Aug. 7, p. 134*). Over here in Europe, we don't see this problem. Why? Because in Europe, the rain gutters have a semicircular profile (like a U). Perhaps someone many years ago already found your problem/solution? The U profile, however, is harder to connect and mount.

Anders Boecher
via e-mail

In the USA, some rain gutters are half-round, but rectangular ones are much more popular DESPITE their drawbacks! —RAP

Dear Bob:

If I may, I'd like to return to the esoteric audio thread that has been a feature of your mailbox. I'm actually reading the June 26 issue right now, but I'm a bit behind with things. I, for one, found that the biggest improvement I ever made to my home-designed and built system was to stop reading the hi-fi magazines. *[Is that anything like "The Sudden Cessation of Stupidity???" /rap]*

Most of my system's drawbacks were merely psychosomatic ills which went away when there was no one to point them out, and I saved money too. Twenty three years later, my unassuming power-amplifier design is still giving good service—good enough for me and my family, anyway.

About 15 years ago, I went for a job interview with one of the U.K.'s most highly regarded hi-fi manufacturers. In their listening room, I correctly identified the differences between variously tweaked pieces of equipment. But, I wouldn't have cared which one I used every day. Eventually they decided that because I was a musician, I might be tempted to actually listen to the music being played rather than the equipment itself (SIN! That isn't what we make this stuff for!), and I didn't get the job. *[THAT is so funny that it's SAD!!! /rap]*

So, although exotic components can make a difference, it doesn't mean that there's no scientific reason behind it. And it doesn't mean that one is necessarily better than another. The differences in production values and the equipment used to make a particular recording always far outweigh the tiny subtleties which the hi-fi nuts seem to focus on. To echo another correspondent in that issue, don't throw out the baby with the bath water!

Peter Maydew
via e-mail

Thanks for the thoughtful comments and Best Regards! But I bet that you STILL can't hear any difference between different SPEAKER CABLES!—RAP

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Note: If you send an e-mail to rap right now, you will only get an Autoreply saying that Bob is hiking somewhere above 17,000 feet. But if you leave your e-mail return address with a request for "minireport," Bob will send you his minireport on his trek, as soon as he gets home. How does it feel, to come down to 13,000 feet after a couple weeks above 14? We shall see! Ten people are on the trek, including five guys returning to Nepal and five newbies; three women and seven men; eight engineers and two sane people.

pease porridge

***BOB PEASE** obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Mailbox

October 30, 2000

Re-Read Reveals Growth

I particularly enjoyed [Steve Scrupski's] contributions in the Sept. 5 issue . They brought back a flood of memories.

In June of '62, I started as a junior engineer at Motorola. One of the first things I worked on was teleprinters that were going into the Minuteman missile silos. At the time, we were using core rope memories to convert ASCII to 5- by 7-dot matrices. The print was produced on a coated carbon-impregnated paper. This paper was selectively zapped with high voltages to blast away the coating to form dots on it. Our circuits included a smattering of the logic family that had been introduced not long before, emitter-coupled logic (ECL). We marveled then at the prospect of someday obtaining memory for as little as a penny per bit.

Shortly thereafter, I generated a proposal meant to produce a research grant for us. I did considerable reading about bionics, including frogs' eyes, adaptive systems, self-organizing logic—that sort of thing. Much of the reading was from the proceedings of one of the Bionics Symposiums that had been held at the Wright-Patterson Air Force Base. For some reason, I even recall the name of one of the prominent authors in the field, Marvin Minsky.

Recently, I had the occasion to re-read my proposal and I believe that I understand why we didn't get the grant. Mostly, it was because a certain junior engineer was so wet behind the ears. In the re-read, I was embarrassed to discover how little I knew then, especially compared to what I have learned in the many years since. This sort of exercise isn't recommended for those who suffer from any lack of self-esteem.

Stainless Probes Are The Way To Go

Unfortunately, until you get into the real world and realize that water is corrosive (pure water is nonconductive), you can get away with circuitry like this . The dc potential applied to probes will promote corrosion. National builds a wonderful IC, the LM1830, which applies a low-level ac to the probes. I believe that they recommend, and I heartily agree, stainless (300 series) probes. Stainless passivates more readily than most other metals, and the ac doesn't give the liquid molecules time to polarize.

I once built a water-detection circuit for a fuel filter for my friend who went on a two-year sailing cruise. I was worried that the diesel fuel would contaminate the probes, or react with them, or whatever. Four years later, in Mexico, the alarm went off. My friend had forgotten that he had it and had to trace down the noise. There was water in the filter, but it was caught in time to save the injectors.

What One Man Would Do

Thank you for your tribute to Bob Pease ! Let me tell you another story to indicate what sort of person Bob is, although I'm sure that you know already. Within the last few days, I was having trouble finding a dual-voltage (110/220) battery charger for NiMH batteries. This is for my daughter to take on a long trip, initially going to Nepal. (That made me think of Bob.)

When I mentioned to a group of hardware engineers that I had sent an e-mail to Bob, it turned out that every one of them was familiar with his column. Several suggested that he was likely to respond by jotting a circuit down on a piece of paper and sending it to me.

Bob and I were only two classes apart at MIT, although we never met there. In fact, I've never met him, although he once did telephone me out of the blue when he got excited by something in an e-mail that I sent him. Nevertheless, when I mentioned to him, via e-mail, my difficulty finding what I was after, Bob wrote back and said he would check for me to see what was available at Fry's Electronics, and if he could find the right piece of equipment, he would buy it and mail it to me! Then, when he didn't find anything appropriate at Fry's, he checked at the San Francisco Airport, where he happened to be going over the weekend—all this for someone he had never met!

By the way, we did find the charger. My wife found it, using a search engine that I never use, "Ask Jeeves." It was mixed in with a bunch of hits on the San Diego Chargers (must be an electrifying team), but there it was.

Bob's a great guy! I won't be able to answer any return mail right away. I'm leaving tomorrow for Italy, and I won't be back until Oct. 5. I'm glad that I saw the article just before leaving, so I could get this message off. You'll notice that without much time to spare, the first thing I looked at when the magazine came in was Bob's column.

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Dear Bob:

I realize that you work in the analog realm, but you may have heard of the latest fad in digital circuit design—spread-spectrum clock generators. *(No, I hadn't. Wild! /rap)* These are phase-locked-loop circuits that generate a clock signal that's frequency-modulated with a 100-kHz or so triangle wave. This trick is employed to transform the clock EMI spike seen on a spectrum analyzer into a flat-topped mesa shape, so that the peak EMI from the device appears to be 5- or 10-dB lower and the device will gain FCC approval. The ads for these clock generators typically claim that they "reduce EMI." *(Yeah, sure! /rap)*

Now, you and I both know that frequency modulation does not reduce signal amplitude. It has no discernable effect in the time domain. The clock signal will have the same wave shape and size as before when it's viewed on an oscilloscope or detected with an RF power meter.

This trick is only being used because the swept-frequency spectrum analyzer employed by EMI testing labs is a poor indicator of actual signal amplitude. This machine consists of a radio receiver whose receive frequency is swept through the frequency range of interest. The EMI signal from a test antenna is passed through the spectrum analyzer's IF amplifier and video detector. These circuits have low enough bandwidths that they don't "see" a 1-MHz-wide FM signal at its full amplitude. What's the result? Reduced EMI! *(Or, "APPARENTLY reduced" EMI! /rap)*

Now back to the real world. The practical EMI-reduction effect of modulating the clock frequency is negligible on a TV receiver "victim," as it has a 4-MHz-wide IF strip. And the resultant herringbone interference pattern will just get a bit wiggly if it's frequency-modulated. *(Have you tried this? I haven't. /rap)*

Because the amplitude of the interfering spread-spectrum clock signal is permitted to be higher than a single-frequency clock and still pass FCC muster, it's more likely to annoy the user. That's when the problems begin.

Sooner or later, the folks at the FCC will catch on. They will see more complaints of interference caused by approved devices with spread-spectrum clock generators, and change the rules so higher-fidelity EMI sensing equipment will be used. At that time, the spread-spectrum clock circuits will become poison. *(Check. Ha! Cheaters do not ALWAYS get caught, but they should think about the rule-benders who will get caught! /rap)* Is there any way to put a stop to this silliness before it takes over the world of PCs and set-top boxes?

David Forbes
via e-mail

Probably not. But thank you for griping!—RAP

Hi Bob:

I just finished reading *Electronic Design* and the thought struck me with some force: there must be a lot of analog design engineers out there who are faced with either becoming programmers (yuck), or moving their design skills to silicon. *(This may be PARTLY true, but there are a LOT of people who can integrate a SYSTEM using purchased parts. For sure, that's a MAJOR part of the electronics business—often WITH a processor, but sometimes WITHOUT one. /rap)*

I find that analog people have a keen desire to touch the reality of the stuff, whereas programmers are somehow fascinated by other areas, such as their own cleverness. *(That's one way to put it. /rap)* My point is that for a guy who loves analog, the decision to go software is probably fundamentally unacceptable. Opening a fish-and-chips shop would be more satisfying.

So, the action moves from circuit boards to chips. Obviously you made that jump some time ago. But, the subject that many of us might like to read about is how we should go about it ourselves. *(Wow. There was still a need 25 years ago for small but tricky circuits, where good straightforward engineering gave you a pretty good chance to get an IC working on the second try. These days, most ICs are more complicated, involving perhaps hundreds or thousands of transistors, and two, three, or four levels of CAD—Spice; Layout; Logic; Timing. /rap)*

A lot of us have large amounts of applications experience (mine is audio, for example) and could probably be an asset in the right structure. *(I do know several "discrete" engineers who went into applications engineering. We who have bought and used ICs for YEARS have a lot of the necessary EMPATHY for other people who buy chips and design with chips. Not so many have gone into IC design. It's possible to learn in school some of the skills needed to design ICs. But, it's NOT so easy to learn the skills required to APPLY them. /rap)* What do you think?

Dave Mate
U.K.
via e-mail

I think that's a hell of a GOOD and TOUGH question, and I'll ask some guys. Give me a reminder every WEEK for three weeks, and we'll see if I get any answers.—RAP

Subject: Bob Pease

Electronic Design has a great asset in Bob. Long may his pen trail the ink.

Bernard Sharnbrook
U.K.
via e-mail

Keep writing? I'll keep on trying. In fact, Bob Milne sometimes says I'm VERY TRYING! But, does my pen "trail ink?" Maybe it's more likely that my floppies keep dribbling out the bytes.—RAP

All for now. / Comments invited!
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pease porridge

What's All This Fuzzy Logic Stuff, Anyhow? (Part IV)

Recently, one of my far-flung friends sent me a magazine article, along with his puzzled comment: "Can Fuzzy Logic REALLY do THIS—and nobody else can do it?" I read the story. It explained that in Europe, there was a requirement for a speed limiter for heavy trucks, at 53.4 mph (86 km/hr). The article claimed that such a speed limiter couldn't be done by any conventional controller.

This was partly because it was very hard to design a model for a truck. There were so many different kinds and versions and manufacturers of trucks. Plus, there were heavy trucks and lightly loaded modes of operation. The truck model would have to work on upgrades and downgrades. Also, the task was claimed to be very nonlinear. So, the author proposed using Fuzzy Logic (FL) to accomplish this. Because his controller would be very versatile and very robust, it wouldn't need to be programmed differently for different types of trucks.

Now, if this article said there were something that I couldn't do with op amps, resistors, and capacitors, then that would present kind of a serious challenge, eh? I always like challenges.

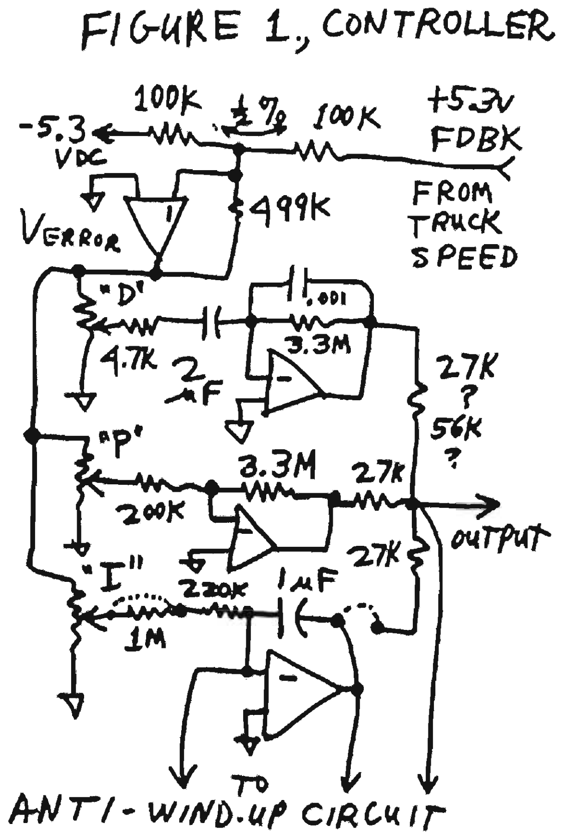
I thought about this. A truck tends to accelerate over a wide range of speeds. It picks up speed, faster or slower, according to its load, proportional to its accelerator-pedal setting, and based on how the engine's torque is geared to the load and influenced by the grade of the road. That sounds like an integrator—an integrator with a larger or smaller feedback capacitor (to represent how the mass of the truck changes), with a positive bias (in case it's "on a downgrade"), or with a negative bias (in case it's "on an upgrade").

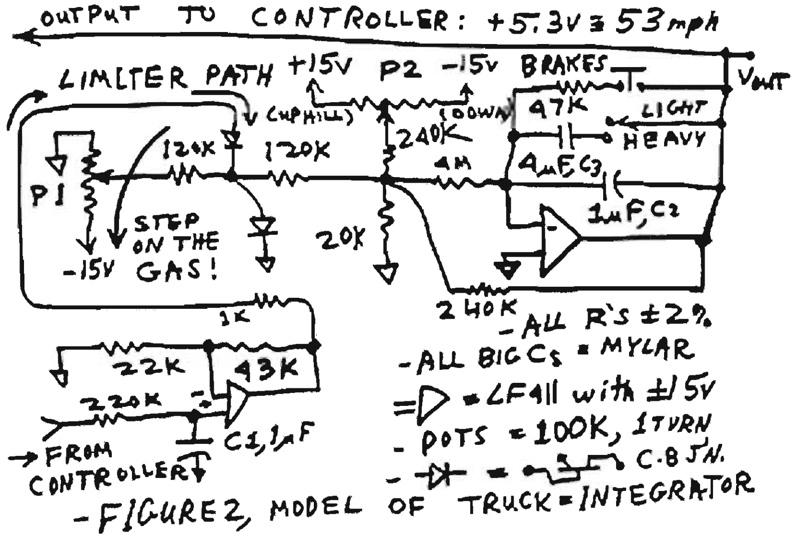
A truck's model sounds pretty easy to me—an integrator with some biases, varying gains, and a little lag in the control path. I could then use the model to drive an analog controller like the one shown in Figure 1. Now, I concede that it would be hard to model a truck for every situation, at all speeds. But in this case, a model that's fairly realistic at around 45 to 55 mph is easy to design. See Figure 2—an integrator with a controller input (with a little lag). What's so difficult about that?

So I sat down with a big sheet of paper, added a few control elements to a simple PID loop, proposed some nominal component values, and drew up a couple of wires to connect this to the model of the truck (Fig. 1, again). This is very much like the controller for my "Ball-On-Beam Balancer" (Electronic Design analog supplement, Nov. 20, 1995, p. 50).

Next, I started to draw up some waveforms to show how it would work. In my book,[1] I call this a "choreography" to illustrate how each waveform relates to one another. I convinced myself that this loop could be stable and wouldn't oscillate. This is largely related to the way that a control loop can be fairly SIMPLE, NIMBLE, and quick to increase or decrease gas-pedal settings. The truck can accelerate at about 0.01 to 0.05 G's if it's heavily loaded, or perhaps at five or 10 times that rate if it's empty. ANY driver can easily pull his foot off the gas pedal when he wants to avoid exceeding a speed limit—if he wants to, and if he remembers to. Even an FL controller can do that. Even a PID controller can do that. Controlling the speed of a vehicle isn't too difficult. Anybody can do it.

That's because a truck trying to accelerate with a nominal amount of power, driving a wide-range load, is only an integrator, just like an op amp. Everybody likes op amps because it's easy to close a loop around them—whether at high gain, or at low gain—because the phase-shift of an integrator is 90°. Therefore, the loop will be stable. But then I saw the flaw in my first-draft controller circuit: The PID controller has probably been trying to accelerate at full power for a long time, because the vehicle's speed is below the limit. The integrator has, thus, been fed a large dc error signal for a long time—and its output would be near the negative limit! That could easily cause overshoot, and the loop couldn't help it. Overshoot would occur, even though stable operation would eventually take over.





How can I avoid this overshoot? After all, in a speed limiter, overshoot is a really bad kind of performance. The requirement for this limiter is pretty strict, allowing only a small amount of overshoot (about 3 mph max).

Then I remembered some notes by Dave St. Clair2 about "wind-up." Any PID controller can have its integrator term go off to a limit when you don't want it to, such as when the loop isn't in control for a long time. That's called wind-up. How do we avoid this? After all, any PID controller tends to exhibit this wind-up, if it's tasked to pull a large inertial MASS up to a new level. This is NOT a new or unique task. Actually, some PID controllers do very well at this!

I recalled that the remedy is termed "anti-wind-up." I tried looking this up in several books. I found it really hard to find any further mention of wind-up, or of how to perform anti-wind-up. Still, I figured out that it isn't rocket science! This is a special case of analog computation—with a bit of hybrid/digital control.

Then I remembered seeing some sketches that had the same shape (Fig. 3) as my crude first-hack PID controller with wind-up. In the old book by MacNeill and Freiberger, Fuzzy Logic,3 about the origins of FL in control loops, there was that sketch on page 115 showing the performance of a little boiler. McNeill said that the "conventional controller" would cause overshoot, whereas an FL controller, designed by Mr. Mamdani, seemed to avoid overshoot. Ahem! I realized that this was an example where a PID controller was said to give poor performance—because it was MIS-applied. It had a big overshoot, a result of its integrator term having a lot of wind-up. If I were foolish enough to disregard wind-up, then my controller would show bad overshoot too!

Why didn't Mamdani's FL controller have a lot of wind-up? Aha—it didn't have any integrator term. Then why did it slow down and converge on the right answer without overshoot? It was easy to see that was due to the FL controller cutting its gain back severely, as it approached the null—because it ran out of gain.

The example showed that the FL controller's response seemed to be very nice, well-behaved, and slow as it approached the target. But the book didn't show how that controller would react when a load was placed on the boiler to draw off steam, so that it could do some useful WORK. I could see what was going on: the FL system didn't have much gain, and it would look good only if you didn't put on a load. The FL controller had P and D terms, but it didn't have any integrator to provide high gain against a dc load.

Now, after learning about this problem, could I design a controller for a truck's speed limiter? Sure. Could I invent a decent anti-wind-up circuit? Certainly (Fig. 4). The detector can tell if the controller's error is far from null, and it applies a RESET switch across the integrator. The integrator is reset to zero output, until the controller begins to take effect, and then the integrator in the controller begins to servo out the dc error. Of course, this circuit is much more complicated and more versatile than I would really require. But, I wanted to conduct some experiments.

Do I have confidence that this controller will work well, and won't overshoot? I definitely do. I don't know how the FL controller was designed, and I don't know what features it has. I don't know how much it would slow down under load either. But I'm convinced that my speed limiter would work well, would NOT overshoot, hunt, ring, or oscillate, and would work well under all conditions of light, medium, or heavy loads, as well as on upgrades, downgrades, and flat terrain. Plus, it wouldn't work so jerkily as to make the truck driver grouchy. It would have high accuracy, with high gain and quick response. It really would be interesting to compare it to an FL controller. But I should be able to show you the controller's performance in the next issue of Electronic Design.

One guy asked me, "Bob, why do you call this a controller, when the requirement is for a speed limiter?" I thought about it and ex-plained, "This circuit can do EITHER. To turn it into a controller—just like a cruise control in a car—simply reverse the diode that goes to the two 120-k resistors in Figure 2."

Furthermore, it would be easy to make it work on just about any truck. The good news is that most trucks, if they are heavily loaded so as to have markedly different dynamics, are SLOWER. It might be hard to design a speed controller for a very fast vehicle, under all of those conditions. It may be difficult if a four-ton truck were changed to a weight of one ton, instead of loaded to 20 or 40 tons. But if my controller will work on a lightly loaded truck, it will EASILY work on a heavily loaded truck, with slow acceleration. The wide range doesn't make it hard to control the loop—it makes it easier.

Of course, if the truck is on a downgrade, the controller will have to pull the throttle nearly closed. On an upgrade, the controller will have to allow the throttle to stay nearly wide-open without much error. Still, that's not a big deal for a decent PID controller.

Have I built this controller? Not yet. But I bought some parts, some one-turn pots and 1-µF capacitors. I grabbed a bunch of LF412s to make it simple to cover a wide dynamic range, with ±12-V signals. When I'm finished, this function will probably require only one or two dual op amps to make the controller, in the ultimate simplified version, all running on +5 V dc.

Will this controller work for all trucks? Yeah, I think so. It's difficult to imagine a truck that wouldn't be controllable by this controller. (If there were such a truck, it couldn't be controlled by a driver.)

More comments will come later. We'll let you know how this all works out in two weeks. Meanwhile, I must say that I often agree with the author—that he usually shows us some very good work with FL. But that's not always the case—not here.

So, we finally figured out why the FL guys keep stating that conventional controllers are really hard to apply. We realized that they say the conventional controller would work badly because the system was claimed to be very nonlinear. The reason behind this was a misunderstanding of PID. Also, they only made a comparison to PID controllers that are MIS-applied, such as without anti-wind-up, as I suspected all along.

I have been assured that Electronic Design will give any promoters of Fuzzy Logic a chance to respond to my columns in print. But save THIS column because it will be referred to in the next one. In the meantime, if you see any Fuzzy Logic controllers that are able to hold a boiler's pressure constant, even when you begin to draw off a lot of steam, or a truck speed limiter that can go up hills without slowing down, please let me know where.

References:

1. Pease, R.A., Troubleshooting Analog Circuits, 1991, p. 126-127.
2. St. Clair, David, Controller Tuning and Control Loop Performance, Straight-Line Controls, 3 Bridle Brook Lane, Newark, DE 19711-2003 (About $16). The URL is http://members.aol.com/ pidcontrol/booklet.html.
3. McNeill and Freiberger, Fuzzy Logic, 1994, p. 107-116.

P.S. Would it be easy to make a similar controller for a steam boiler? Not QUITE that easy, because there may be a LARGE time lag between turning up the heat and seeing an increase in pressure. If there were some data on this lag, it would be fairly easy to design a simple PID with anti-wind-up, which could easily outperform a Fuzzy Logic controller in any specific application—unless the Fuzzy Logic controller had full-featured P, D, and I terms in its control. Still, controlling a boiler tends to be more difficult than servoing around an integrator, because the thermal lags can cause the loop gain to roll off MORE STEEPLY than 6 dB/octave.

Of course, you would want to design that controller so that no overshoot can cause the maximum steam pressure to be exceeded, whether the boiler is nearly empty or nearly full of hot water. Yes, the safety valve can release excess pressure, but it's nice to avoid that, as well as to avoid wasting energy.

The speed limiter for trucks won't have large, unspecified lags of many seconds, as any well-designed electrical, hydraulic, or pneumatic actuator can cut back on the throttle in a small part of a second. Even if the speed limiter is slow or nonlinear, the PID controller is nimble enough. The lag of the actuator is compensated for by the lead of the PID controller. If the gain of the actuator isn't linear, then the PID controller will have enough gain margin to accommodate that too.

All for now. / Comments invited!

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Mailbox

Interpreting A Difficult Equation

I read the article. My division studies and produces payloads for satellites in experimental space applications. The subject of this article is very interesting for my application, but I don't really understand equation (1),

$$SNR_{JITTER} = -20\log_{10}\left[\frac{\frac{V_{FSR}}{2}(2\pi F_{IN})10^{\frac{V_{IN}}{20}} \times JITTER}{\sqrt{2}}\right] \qquad (1)$$

which describes the SNR due to the jitter clock. You get the ratio signal to jitter noise in terms of rms and I have done the calculus considering a sinus function with V_{FSR} voltage peak-to-peak and frequency F_{IN}, but I didn't find your expression. The term V_{IN} (ADC input level relative to full-scale in dB) isn't clear, nor is its position in the equation.

$$V_{IN} = 20\log(p - p\ Input / V_{FSR}) \qquad (2)$$

Thanks For All Those Years

Thanks for your word of tribute to Bob Pease for his 10 years of Pease Porridge in . I have enjoyed reading the columns since they began 10 years ago and even kept up my subscription to the magazine after retirement, mainly so I could continue to read Pease Porridge. For many years I would clip each column from the magazine and file it for rereading later. Hopefully, Bob will keep writing the column for many years to come.

pease porridge

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What's All This Fuzzy Logic Stuff, Anyhow? (Part V)

Okay, I showed you a Paper Study in the last column (ELECTRONIC DESIGN, *Nov. 6, p. 146*). It was a schematic diagram of a servo controller that I hadn't yet built. I asked you to save that column because you'll need it this month. I told you it was pretty likely to work, and work well. Did it? Yes, it worked very well. Almost perfectly.

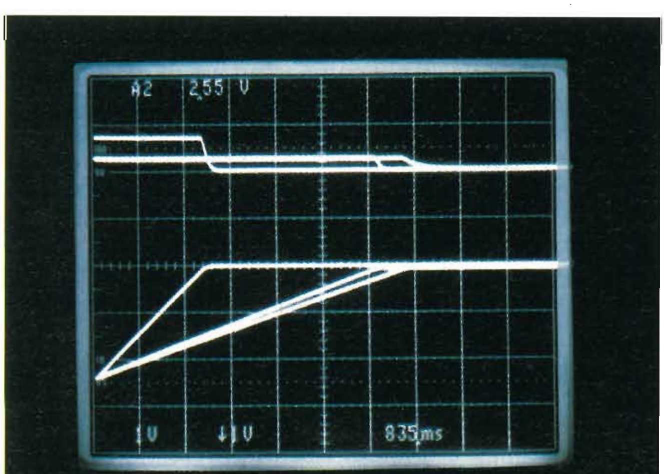
First, I built the "model" of the truck *(Fig. 2 of the previous column)*, and by turning the pots, I could make the "truck's speed" increase (by "stepping on the gas") and decrease, as expected. Hey, a truck trying to pick up speed is JUST like an integrator. (Well, like a *leaky* integrator, because the faster it goes, the less it's able to accelerate fast. And if you take your foot off the gas, it tends to slow down.)

Then I built the main PID servo *(Fig. 1 of the previous column)*. With the integrator disconnected, I connected it up to the "truck model" and started it up. The P and D terms alone made a surprisingly crisp servo. All I had to do to get fast settling and no overshoot was to set those two pots at 100%. Swoop, the output "accelerated" right up to "53.4 mph," ±0.5 mph, and held there with no overshoot *(Scope photo 1)*. The vertical scale factor is 2 mph per division, at ≈0.835 seconds per horizontal division. Looking at the three lower waveforms, the one on the left shows the "speed" of a lightly loaded ("8-ton") truck with fast acceleration, and the middle one reveals a heavily loaded ("40-ton") truck, accelerating at a slower rate. The right waveform shows the "8-ton" truck on an "upgrade." You can see that the limiter is stable for all kinds of loads and biases. The upper waveforms are just the outputs of the differentiator. In a short while we'll discuss why it worked so well, and why I picked the R and C values that I did.

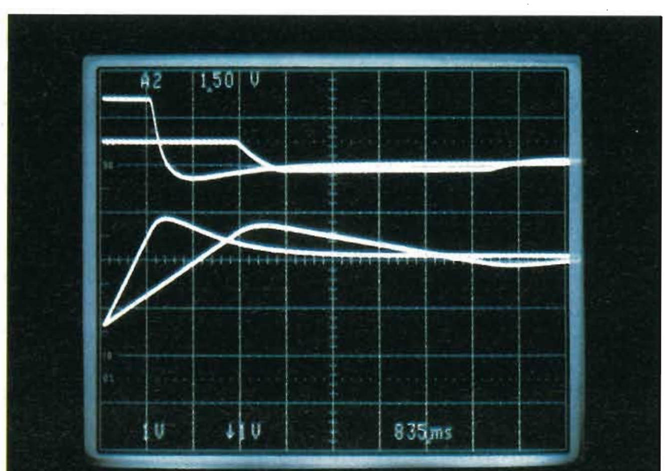
Now, with just the P and D amplifiers connected, the gain was not infinite. The proportional path had a gain of about 5 × 16 = 80. Therefore, if one was "driving uphill" as fast as it would go on a steep upgrade, there would be a little error, perhaps –0.3 mph (i.e., 53.1 mph), which was necessary to let the throttle go nearly wide open (–7 V). Conversely, if the "truck" was on a "downgrade," the speed error might be +0.3 mph, because the main servo path had to pull the gas pedal "up" until it was nearly off (–0.2 V, e.g.)—even if the driver kept his foot FLOORED. Some people might say that ±0.3 mph with no overshoot is pretty good. It's acceptable to many truck drivers. But I wanted to make it much better. (Have you ever seen any Fuzzy Logic (FL) controllers that had accuracy better than that on upgrades and downgrades?)

Next, I connected up the integrator stage. Sure enough, the integrator would "wind up" and cause a 1.8-mph overshoot as the speed limiter was starting to cut in—up to 55.2 mph—exactly as I had expected. See Scope photo 2 with the same two "trucks." But after it settled, the integrator would trim the error to *exactly* 53.4 mph, as desired. Not too bad!

Then I added the anti-wind-up circuit. Son of a gun, that worked, too! It kept the integrator's output at 0 V until the speed limiter began to cut in. Now, the speed would rise right up to 53 mph ±0.2 mph, and promptly settle out to 53.4 mph, exactly, within better than 0.1 mph. That's what I expected

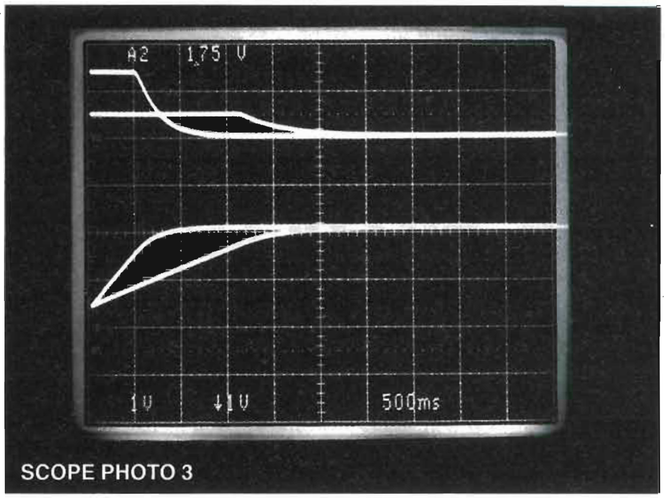


SCOPE PHOTO 1



SCOPE PHOTO 2

(Scope photo 3).



SCOPE PHOTO 3

I fooled around with higher gain and lower gain, and things worked as expected. I fooled around with *heavier* versus *lighter* trucks. I even got data (and a scope photo) on an "88-ton truck," but we decided not to print it because it was very well-behaved and *boring*. The control was always well-behaved. I tried cutting back on the gain for the D term and got some slow overshoot. It wasn't really BAD, maybe 0.5 mph. That's what I had anticipated. Then I set that gain back to 100%.

I varied all of the gains for the integrators AND everything else. The response was pretty clean in every case. I didn't have to make any major or minor adjustments to get the response to be well-behaved. Even when I changed the truck's gear ratio, it was well-behaved. You may notice, though, that the settling of the limiter wasn't quite as "crisp" when the integrator was added, compared to Scope photo 1. There's a little "settling tail." Maybe the PID system isn't perfect, but it's pretty good, and it settles well inside 0.1 mph error in just a couple of seconds.

What components did I change in Figure 1 of the previous column? All three pots wanted to be up near 100%. The input resistance for the integrator worked slightly better at 200 kΩ than at 1 MΩ. The input resistor for the P term still worked well if I paralleled it with another 200 kΩ. That means I had a lot of safety margin, but I left it at 200 kΩ. I didn't have to change the basic differentiator much. But the resistor from the D term to the output wanted to be changed from 27 kΩ to 56 kΩ, so that the differentiator couldn't overpower the other terms and turn off the anti-wind-up too early. In the anti-wind-up circuit, the 1-µF capacitor in the detector that fed the limiter worked slightly better when changed to 0.1 µF *(Fig. 4 of the previous column)*.

In fact, I know one guy who started out his planning for an FL system by building an analog system, which is easy to get a feel for.

I set up some more experiments with and without the anti-wind-up circuit. If the anti-wind-up circuit wasn't provided, it sure did overshoot significantly—not bad enough to fail a test, but bad enough to look crummy.

Some proponents of FL have stated flatly that it would be impossible for any conventional controller, such as a PID type, to cover such a wide range without oscillating. But you just witnessed how it worked well in two worst-case conditions: heavily loaded, and lightly loaded. It also worked at in-between values.

Some FL experts claimed that a conventional or PID approach couldn't possibly work well if the controller wasn't linear. I built some nonlinear circuits in the controller, so the gain at the controller input could be halved or doubled at low throttle settings or at high. It was impossible to see any difference in the results.

Now, that circuit I showed in the previous column was designed to be very versatile—and it was. But it was also quite complicated. So, my plan was to determine the correct coefficients of gain in *that* circuit, and then execute that function with a much simpler circuit *(New Fig. 1)*. This controller is to be hooked up to the basic Figure 2 of the previous column. I engineered this to work the same as the old Figure 1, but with simpler capabilities and less expensive parts.

Note that this circuit is definitely simpler. Instead of using four op amps to make the null amplifier and PID controller, this circuit only requires a dual op-amp. Rather than employing four op amps to make a detector and anti-wind-up circuit, I used a couple of transistors and 1/4 CD4066 to reset the integrator and keep it from causing any errors.

Will this circuit work well under all road conditions with all loads? I'm sure it will. Just because I haven't yet built it does NOT mean that it's NOT certain to work.

Next hack: could we use this controller to act as a speed limiter for a high-performance car? How about a vehicle like a Corvette or a hot Mustang that could accelerate at around 0.5 G even at 50 or 80 mph? Perhaps. But obviously, the input to the throttle controller wouldn't work well with 0.3 seconds of lag. It would require more like 0.1 second.

I COULD chop the 1-µF feedback capacitor in the vehicle's model to 0.1 µF to simulate a high power-to-weight ratio. Plus, I could cut the lag of the controller actuator and run this in real time.

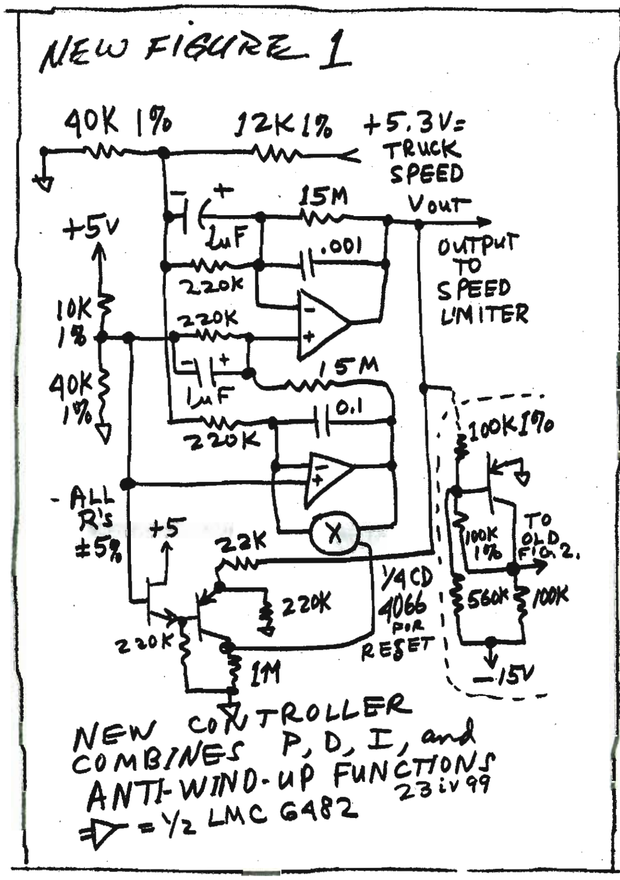
But I actually decided that this is an analog computer, and to simulate a car 10 times faster, I would just declare the time scale changed by a factor of 10. I had proven already that it worked, so I didn't have to rebuild the circuit. This was reasonable, especially because nobody wants to buy such a speed limiter.

In conclusion, when an EXPERT on FL claims to have a scheme that's much better than any *conventional controller*, he may not know that he's only comparing his FL system to a mis-applied or far-off-optimum conventional circuit or system. For years,[1,2,3] I have been saying that in most cases, if you find out how the comparison is made, you may be able to show that a conventional (PID or similar) controller or system can actually do better than the best available FL-based system.

This is partly because it's sometimes not easy to optimize a FL system. It might take a lot of work to get the FL system working well, especially if things are complicated or nonlinear. If an FL controller has P and D terms but not any I term, then it might have trouble competing with a well-designed PID system because it doesn't have infinite gain at dc.

I also have said previously that I often agree that some systems based on FL are excellent, compared to conventional systems. BUT—not the one in the article that raised all of these questions.

Furthermore, it's true that FL may provide advantages if there's a lot of nonlinearity in the system, or if the controller will work better if it is nonlinear. In that case, the FL system might work quite well—after a lot of study and work. Just don't forget that the conventional system also can have nonlinearities built in.



How well does my PID controller respond when you ask it to respond to an upgrade or downgrade? Does it respond as smoothly and precisely as the FL controller? I would love to plan some comparisons. I have yet to connect my controller to a real vehicle. But at least the model of the truck worked well, with plenty of gain to hold negligible error on "upgrades" and "downgrades."

Plus, I didn't need many trims or adjustment to go from one kind of "truck" to another. My standard controller was well-behaved in each case, even if the "actuator" was nonlinear with steeper gain at some settings and less at others.

Now, do you have to purchase op amps and 1-µF capacitors in order to take advantage of my best controller scheme? Heavens, no. You could execute my PID with anti-wind-up with any number of PID controllers. It could be executed with analog circuits, straight digital, DSP, or even FL. But if you want it to work well, you need to *understand* the signals, the circuits, and the principles behind the analog circuit. If you don't understand all of that, then you might say something foolish, like: "Conventional controllers are OBVIOUSLY inferior. They couldn't POSSIBLY perform this task, so we won't even try one. We'll just build an FL controller." Bad idea!

In fact, I know one guy who started out his planning for an FL system by building an analog system, which is easy to get a feel for. Then he took the best analog system and added refinements, nonlinearity, etc.—and executed it all in FL.

Am I going to put a speed limiter on my Beetle to keep it down below 72 mph? Heck, no. That wouldn't be safe. I have better ideas.

So, what's my point here? As I often say, "The sudden cessation of *my* stupidity is worthy of some note." And if you see FL Experts claiming that they can do things that nobody else can, QUESTION AUTHORITY.

Is it just possible that they have an "excellent system" that's excellent only in comparison to a mis-applied "conventional" controller? Is it possible that they have designed a steam-pressure controller that won't regulate pressure when you begin drawing steam? Is it possible that they have designed a truck-speed controller that will hold the speed constant only until it comes to an upgrade?

Oh yeah, I was going to explain why I picked the components that I did. The "truck" acts as an integrator with unity gain at 3 mHz from the "gas pedal" to the voltage that represents the speed. If I add a gain of 80, it would make the loop have unity gain at 240 mHz. Then there's a lag of 0.3 seconds (estimated) added into the controller path.

That's seen as a lag at a frequency of 0.5 Hz. If I can keep the loop closure below 0.24 Hz, that shouldn't be too close. It might cause a bit of ringing, but I can tweak that out by adding the differentiator.

The lightly loaded truck now looks like an integrator (i.e., just like an op amp) with unity-gain crossover at 0.24 Hz, plus an extra lag at 0.5 Hz. If the main feedback path is a gain of 80, it would be wise to add a lead (gain boost) at frequencies above 0.5 Hz, which means a differentiator with a gain of 80 at 0.5 Hz. That's what you get with a preamp gain of 5, feeding a differentiator at 3.3 seconds. The effective differentiator is at 16.5 seconds, or 60 milliradians/s, or 9 mHz. When will this gain get up to 80? At about 720 mHz. Not bad! That's what I chose from scribbling on the back of envelopes. It worked the first time with no overshoot. This is for the worst case, with a lightly loaded truck. For a truck loaded much heavier, such as five or 10 times heavier, the integrator has a unity-gain crossover at 0.048 or 0.024 Hz. This kind of "op amp" or "integrator" is even easier to close the loop around. It's even more stable.

All for now. / Comments invited!
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1. Pease, Robert A. "What's All This Fuzzy Logic Stuff, Anyhow?" *Electronic Design*, May 13, 1993, p. 77.

2. Pease, Robert A. "What's All This Fuzzy Logic Stuff, Anyhow? (Part II)," *Electronic Design*, Nov. 1, 1993, p. 95.

3. Pease, Robert A. "What's All This Fuzzy Logic Stuff, Anyhow? (Part III)," *Electronic Design*, Nov. 11, 1993, p. 105.

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What's All This Floobydust Stuff, Anyhow? (Part 9)

Well, it's getting close to the end of the year again, so this is a good time for another Floobydust column. In these columns I put some of the interesting tidbits, follow ups, and miscellaneous items that I gathered throughout the previous year.

Platinum-powered cars? Refer back to "Platinum (Chloride) Stuff," *(*ELECTRONIC DESIGN*, Dec. 6, 1999, p. 173)*. Many people asked me if I wasn't doing "water injection." No, because the amount of liquid wasn't being depleted except to the extent of only a few grams per 1000 miles. They asked if I wasn't just *leaning out* the mixture. No, because the bubbles were just adding a couple ppm of air more than normal. So, this was insignificant.

After a year, my Beetle is still getting an 8% advantage from the Platinum Injection, and my friend is still getting 15% in his 1986 Dodge. Almost zero readers have said that they tried it. One guy claimed that he put this into a Falcon many years ago. This should have made at least a 10% improvement—but that guy said it did not.

The advantages of this Platinum Injection are confounded by the decision of the platinum people to increase the price by several dB. They obviously looked at consumers' rage about the cost of fuel and figured the price could be raised about from $99 to $177.

Still, I will recommend that this can provide a good ROI for any old carburetted car. I specifically DIS-recommend it for any modern fuel-injected, computerized car. It won't help there.

If you're going to buy this kit for $177 or whatever, be sure to calibrate your gas mileage carefully, on a standard route, at a standardized speed, etc., BEFORE you take out your credit card and buy the "platinum." Then, if it doesn't make a distinct improvement, send it back promptly within a month on the money-back warranty. If you drive a lot and burn more than two gallons per day, this will have a fairly good payback.

Hybrid cars: Most of the hybrid cars currently on sale significantly depend on gasoline, using a fairly large engine. I was proposing back in "What's All This Electric Car Stuff, Anyhow," *(*ELECTRONIC DESIGN*, Aug. 8, 1994, p. 107)* to use a very small gasoline or diesel engine, perhaps 5 hp. That's just big enough for the car to limp along at 50 mph. Ideally, this car would be very clean for normal commuting—because for normal best-case commuting, I could make it from home to work without using any gasoline. I'd start with the batteries full and arrive at work with the battery charge fairly low. I'd charge it up from line power when I got to work, and also when I got home. Only in bad-case conditions would I have to start my gasoline engine, as a "reserve," to get home, or in case the battery got lower than normal, or for long trips.

But now, most hybrids seem to use the electric motor only in special cases, as a "boost" for upgrades or for acceleration, or for around-town stop-and-go driving. The gas engine is okay for cruising at highway speeds for long distances, but it isn't my preference for best economy while commuting.

What mode? Here's a related problem that nobody has addressed. Let's say that I'm driving a hybrid (gasoline-electric) car down a long hill. Do I want the car to be charging the battery? If the battery is low, should I turn off the engine, or keep it running to charge the battery? I do not necessarily know.

Let's consider the case where I get halfway down the hill and then decide to take a route that goes back UP the hill. In that case, using the downgrade's energy and the engine's energy to charge up the battery on the downgrade is wise, because I will soon use that energy to go up the hill.

But what if, halfway down the hill, I decide to take a route that continues down the hill? In that situation, charging the battery a lot isn't such a good idea because it may already be full, or it will *soon* be full.

I don't think any car can be "smart enough" to guess what I will want. A very wise car might ask me what "mode" I would like to run in, what strategy I would like to use.

Which route would I take? Heck, the car cannot know if I don't know, and I may not know until I see the traffic situation. I might not know until I arrive at the decision point. So I certainly can't demand that the car's computer must "do the right thing" in cases where I myself don't know where I will be going. I don't think any car can be "smart enough" to guess what I will want. A very wise car might ask me what "mode" I would like to run in, what strategy I would like to use. Should I keep the battery full? Or, should I let it run low? If I knew, I could tell the computer which strategy to use.

I must say, a lot of cars commute to Silicon Valley on old Route 17. There's a descent of 1000 ft. coming down to Los Gatos. Could you come down that hill and save a LOT of energy in a battery? I doubt if you could save up one third of that energy. So, it's not too efficient a deal.

Electric cars and hybrids do not just

get good "mileage" because they regenerate lots of energy into the battery. They get good mileage because every aspect of the car is engineered for good efficiency—tires, weight, friction, transmissions, etc. If you had to commute over a big hill, I would be very skeptical that an electric car would be efficient or cost-effective. I suspect that they will be efficient mostly in flat country, and for some stop-and-go driving.

Flashlights: When we go to Nepal for my 35-day trek, we're only going to bring our two $20 PALight flashlights (*www.lightechnology.com*) with the white LEDs, and one spare 9-V battery. I don't plan to do much hiking at night. The moon will be full as soon as we get to Namche Bazaar, and when the moon is full again, it will be time to turn around and head for home.

I have gone window-shopping at *www.glow-bug.com* to see if there are any other good LED flashlights that I should try out. Unfortunately, while this site tries to provide comprehensive information on a large number of LED flashlights, it seems to be a little deficient as it offers zero serious information for an engineer, or a backpacker—the power drain, expected battery life, flashlight weight, or light output.

The Web pages of the Action Light, *www.hdssystems.com/ActionLight.htm*, provide good engineering information on the design of the company's excellent product. But for $280, only people who have too much money, or are astronauts, or are Everest climbers, or are people who go on serious caving expeditions will buy them.

But then I realized that there were some annoying half-truths to the company's information on batteries. They recommend a lithium/sulfur-dioxide battery, SAFT L026SX, claiming that this puts out 7.5 Ah at an average of 2.8 V, or 21 Wh. A single alkaline D-cell weighs 5 ounces and can put out 15 Ah at 1.2 V (average), which is 18 Wh—not bad for $1. Yet the Web pages claim that their lithium can replace 2.5 alkalines of the same size. That's not so. They do have an advantage of almost two times in energy per weight, but also a 14: or 17:1 disadvantage in price per watt-hour.

I thought about this some more. Why do these guys recommend a nonrechargeable lithium battery for their flashlight system, when camcorders use rechargeable lithiums? Why don't these guys recommend a rechargeable battery?

I wouldn't go on a serious expedition with one type of rechargeable battery for my camcorders, and an incompatible nonrechargeable (or rechargeable) battery for my flashlights. (Each one is comparable in watts and watt-hours.)

HEY! I'm carrying three good old NiCads on my trek for my camcorder, and each is good for 2 Ah at 6+ V. Why don't I rig up some white LEDs with a current regulator for them? So I did. I specifically made the circuit "inefficient" so it would stop drawing current when the battery went down to 6 V—and not over-discharge the battery. I used the basic current-regulating circuit from "Current Limiter Stuff" (ELECTRONIC DESIGN, *Sept. 5, p. 187)*.

Halogens can't be throttled back by just going to low voltage or low power—but LEDs become more efficient at low currents. So the day of the white LED isn't just coming—it's here.

But I only put the LEDs in series with the power-supply lead, not in series with the pnp's collector. I put in five LEDs in parallel, each running at about 20 mA, with a little 12-Ω sharing resistor for every LED, and a 0.66-Ω resistor in the SENSE path of the LM334. Now I can read a book or go to the latrine at midnight and never use any nonrechargeable battery. Or if the sunlight has been in short supply and my NiCads are low, I will refuse to use them. It's good to have compatible battery systems, and this light is quite bright!

A friend pointed out that white LEDs can put out 15 to 18 lumens per watt at their high output level of 20 mA per LED. That's just about the same as the efficiency of a 100-W bulb (1690 lumens per 100 W). Now, halogen bulbs can put out twice the light output as conventional incandescents, at large power outputs. But halogens and all incandescents are much less efficient (less lumens per watt) at smaller output levels, because the filament's heat losses are relatively poor. Halogens can't be throttled back by just going to low voltage or low power—but LEDs become more efficient at low currents. So the day of the white LED isn't just coming—it's here. If you need a good long-life flashlight, I think you'll like these white-LED flashlights.

BABES with AXES? All of you folks who enjoyed the music of "Babes With Axes," that I mentioned in "Obsession Stuff" (ELECTRONIC DESIGN, *June 8, 1998, p. 179)* will like the CDs *Corduroy* by Laura Kemp and *Ghosts Of Dreams* by T.R. Kelley. These women are two of the "Babes." (The cost is about $16 each. Send your check to Debbie Diedrich, P.O. Box 12178, Eugene, OR 97440.) I'm slow to catch on, but there's some great music in there.

Fascia boards: Many people wrote in to remind me that the vertical board "F" in my Sketch 2 for "Sudden Cessation of Stupidity" (ELECTRONIC DESIGN, *Aug. 7, p. 134)* is called a "fascia board," and if that board weren't extended lower than the adjacent horizontal boards (soffit covers), then of course I would have trouble with water running over to the house. I had to reply that my sketch was a little sloppy, and the fascia board really *did* extend down a little (0.25 to 0.5 in.) below the soffit boards. But that isn't enough! So I will be adding quarter-round strips at the bottom of the fascia boards too for a double-barreled defense and stop water from running uphill!

More Fuzz? I was ambling through a pharmacy and checked out the blood-pressure instruments sitting on the shelf. Some were $39.95, while others were $99.95, as you would expect. I suddenly noticed the name OMRON—people who have long promoted Fuzzy Logic. Did this top-of-the-line one have FL? I picked up the box. Did it brag of its use of FL? NO! This one had "Intellisense." I laughed—now Fuzzy Logic cannot be confused with Hairy Logic or Furry Logic. It seems that when it's a consumer product, they're calling it "Intellisense." More grist for the Floobydust mill....

All for now. / Comments invited!
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Bob's Mailbox

Hi Bob:

During heavy rain, water drips from the underside of my dashboard onto my left leg. I often cannot move my leg out from under the drip as the leg is busy operating the clutch during my commute in traffic-congested downtown Boston. Very annoying.

So where's the sneak path in my '93 Jeep Wrangler? Well, I've traced the path of the water up to the windshield frame. Sometimes the frame accumulates so much water that when I take a sharp turn, it sounds like a small babbling brook is flowing through my dashboard! I haven't been able to figure out how the water is making it into the frame, though. The windshield has been replaced twice due to stone chips, but the seal looks good, and it passes the garden hose test. What next? There also are windshield wipers and roof hardware attached to the window frame. Perhaps I'll have another go at it with the garden hose.

Anyway, I have 21 or so years and $250+ dollars to spend to find the root cause and still be a step ahead of you!

Steve Rideout
via e-mail

Steve, here are a few approaches:

(A) Ask the Jeep guys what's going on. They may know.

(B) Ask the windshield guys. This is not rocket science. It's their specialty. They have to know what's causing the problem.

(C) For free (on warranty) or for $$, either way, ask them to fix it. They can glue the BEJEEZUS out of it to end that problem. I put goo on my old Beetle, and that fixed it pretty well for a couple of years.

(D) Drill a hole in that frame and siphon all of the water out!!—RAP

Hi Bob:

I would like to add to what Mike Cozza from Fender had to say about the sound of tube amps versus solid state (ELECTRONIC DESIGN, *May 29, p. 120*). I think that it all depends on whether you're trying to produce or reproduce a sound. If you're reproducing a sound with your hi fi, then yep, I think solid state is the way to go. If it sounds the same as the original, then it sounds right. But if you're producing an original sound via an amp/guitar combination, then a tube amp is often the way to go. The combination of the two is the musical instrument, not just the guitar by itself. If you get the sound that you want, distorted or not, then it sounds right.

Graham Pratt
via e-mail

Of course! Very well put. Thanks for writing, Graham.—RAP

Hi Mr. Pease:

I was referred to you by someone who thought that you might be able to answer my question. I'm looking for the producer of the first operational amplifier, and the specs for this chip. He thought that Bob Widlar of National might have designed it. If you happen to know—or know where I might be able to find it—I'd appreciate any info that you could offer. Thanks a lot!

Tara Calabrese
Catholic University of America
via e-mail

Hello, Tara. The first 300 solid-state operational amplifier designs were not "chips." They were op amps made out of 10 or 20 discrete transistors. I designed several of them. Those designs were made by Zeltex, Burr-Brown, Nexus, Philbrick, and over a dozen other companies. Hybrid designs were crafted by Fairchild, National, and a bunch of others that are hard for me to remember now.

For about 20 years before that, there were op amps made out of four, eight, or 14 triode vacuum tubes—or pentodes. Also, some were even built from the parts of a cheap Japanese seven-transistor radio. I can document that—7 GERMANIUMs.

The µA709 from Fairchild was the first real op amp made as a chip, in around 1967, long after the other 300 designs. It was designed by Bob Widlar, but not when he was at National. He was at Fairchild, then. You can look up the chip's specs on the NSC LM709 data sheet, which is located on NSC's Web site at www.national.com. Just ask for LM709.

The µA702 from Fairchild was the first "op amp" made as a chip, in about 1966. But, it was a special-purpose junker that could only run on +12 V and –6 V. Its specs were awful. It had almost no output drive. The input base current was a lot of microamps. Maybe 20? It had no specs to speak of, and they're out of print, as the '702 has been out of production for over 10 years.

It was characterized very thinly. The µA702 went to the moon. Every time the audio systems went silent, the guys who designed the '702 into the lunar landers gasped, because they were terrified that the 702s were DYING—again. It wasn't a very sturdy or robust IC. In fact, its lousy robustness was exceeded only by its poor performance.

There were some TI amplifiers, such as the SN5224 and SN5226. (I know those aren't the correct numbers, but they were something like them). Yet, while TI called them op amps, they were not. They really were differential-in, push-pull out (differential-out). So, they were barely able to make an output swing of 1 V p-p. Plus, they too had poor Z_{IN} and poor I_{BASE}.

The µA709A actually had a base current of 0.5 µA, and it sold for $75 in 1968. Its gain was 25k. We made good op amps at Philbrick, with I_B of less than 0.005 µA and gain above 200k, that could put out ±20 mA at 1 MHz. But they cost a lot to make. As soon as Fairchild got their yield up, the days of the discrete-transistor op amp were numbered.—RAP

All for now. / Comments invited!
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What's All This Transimpedance Amplifier Stuff, Anyhow? (Part I)

One of the first things you learn about operational amplifiers (op amps) is that the op amp's gain is very high. Now, let's connect a feedback resistor across it, from the output to the –input. When you put some input current into the –input (also known as the *summing point*), the gain is so high that all of the current must go through the feedback resistor. So, the output will be $V_{OUT} = -(I_{IN} \times R_F)$. That's neat *(Fig. 1)*. While we used to call this a "current-to-voltage converter," which it is indeed, it's also sometimes referred to as a "transimpedance amplifier," where the "gain" or "transimpedance" is equal to R_F.

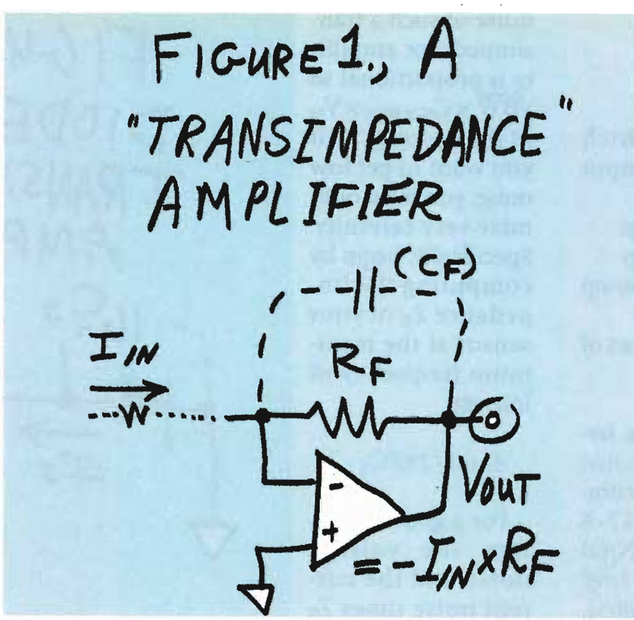
There's a whole class of applications in which this configuration is quite useful and important. An important case is when you need an op amp to amplify the signal from a sensor, such as a photodiode. Photodiodes put out current at high impedance (high at dc), but often they have a lot of capacitance. If you just let the photo diode dump its current out into a resistor, there are two problems *(Fig. 2)*. If the sense resistor is large, then the gain can be fairly large, but the response will be slow and the time-constant will be large: $\tau = R_L \times C_S$. But if you choose a small sense resistor to get a small τ, the gain will be low. The signal-to-noise ratio (SNR) may also be unacceptable. How can you avoid poor gain and/or poor response? Kay garney? (That's Nepali for "What to do?")

To avoid this terrible compromise, it's a good idea to feed the photodiode's output current directly into the summing point of a transimpedance amplifier *(Fig. 3)*. Here, the response time is not $R_F \times C_S$, but considerably faster. Plus, the gain can be considerably larger, because now you can use a larger R_F. This helps improve the signal-to-noise ratio too!

When you connect up the diode like this, the first thing you realize is that the darned thing is oscillating! Why? Well, it's well known that the input capacitance of an op amp (and its circuitry) can cause instability when the op amp is used with a feedback resistor. You *usually* need to add a feedback capacitor across R_F to make it stable. In the old days, it was stated that:

$$C_F \times R_F = C_{IN} \times R_{IN}$$

So if you have a unity-gain inverter with $R_{IN} = R_F = 1\ M\Omega$, and the input capacitance of the op amp is 10 pF, then you're supposed to install a feedback capacitor of 10 pF. That's what people said for *years*. The LF156 data sheet stated this, and it still does. But that's not exactly true. A complete explanation is a bit beyond the scope of this column, but in practice you can usually get away with a much smaller feedback capacitor. In many cases, you can get a response that's improved by a factor of five or 10, and still not get excessive (more than 5% or 10%) overshoot. In practice, you have to *tweak* and optimize the feedback capacitance as you observe the response.



The formula for the optimized amount of C_F is, if:

$$\left(\frac{R_F}{R_{IN}} + 1\right) \geq 2\sqrt{GBW \times R_F \times C_S}$$

then:

$$C_F = \frac{C_S}{2\left(\frac{R_F}{R_{IN}} + 1\right)}$$

but if:

$$\left(\frac{R_F}{R_{IN}} + 1\right) < 2\sqrt{GBW \times R_F \times C_S}$$

the feedback capacitor C_F should be:

$$C_F = \sqrt{\frac{C_S}{GBW \times R_F}}$$

Now, whenever you have an op amp with a large C_S, a large R_F, and a small C_F, the noise gain will rise at moderate frequencies. The definition of noise gain is the reciprocal of the attenuation from the output back to the –input. In other words, if the attenuation is $Z_{IN}/(Z_{IN} + Z_F)$, then the noise gain is $1 + Z_F/Z_{IN}$.

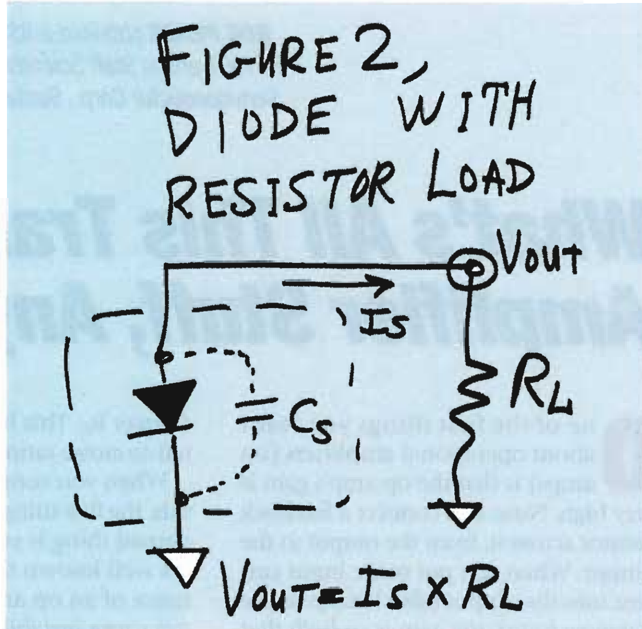
At moderate frequencies, the Z_F is determined by R_F, and Z_{IN} is established by C_S. So, the noise gain will rise until the frequency where the impedance of C_F becomes equal to R_F. Then the noise gain flattens out, typically at a large number, such as 20, 40, or 80. We do this because if the noise gain kept rising at 6 dB/octave while the op amp's gain is rolling off at 6 dB/octave, the loop is going to be unstable, and it will oscillate. The reason that we choose a small value of C_F is to make the noise gain flatten out, make the loop stable, and stop the oscillation and ringing *(Fig. 4)*.

If you make $C_F = C_{IN}$, you can get the noise-gain curve to stay flat as in line A-E. It will be very stable but have a very slow response. If you add no feedback capacitor, the noise gain will tend to rise as per line A-B-C. This will cause instability. Selecting a suitable small value for C_F can get the smooth results shown by line A-B-D. Yeah, it's as easy as ABD to get fast, stable response by picking a small C_F. So, we have made the feedback capacitance big enough to stop the oscillation and minimize the overshoot. Now what?

There's a pretty good book by Jerald Graeme (ex-Burr-Brown) on the topic of the transconductance amplifier: *Photodiode Amplifiers—Op Amp Solutions*. Jerry and I have definitely come to the same basic conclusion. When you want to optimize a transimpedance amplifier, everything interacts. Therefore, every time you compute the response and the noise, and change any factor, the computations may change considerably. There's no simple or obvious way to compute or optimize the performance. The performance, in terms of response or bandwidth, in terms of peaking or overshoot, and in terms of noise or SNR, is an extremely complicated, nonlinear, and highly interacting function of:

- the feedback resistor
- the source capacitance
- the feedback capacitance
- the desired bandwidth
- the desired gain factor (which does predict the full-scale output voltage)
- the voltage noise of the op amp
- the current noise of the op amp
- the input capacitances of the op amp
- and the gain-bandwidth product of the op amp.

Jerry and I certainly agree on that. Jerry's book is well written, and for just $55, it's pretty much a bargain. I recommend it: ISBN = 0-07-024237-X *(www.amazon.com/exec/obidos/ASIN/007024247X/o/qid=968200121/sr=8-1/ref=aps_sr_b_1_3/002-6674439-7948805)*.



But I also have worked on this general problem many times over the years and have several suggestions that go beyond Jerry's book. More on this later.

There are several basic rules of thumb that Jerry and I agree upon:

(A) You want to avoid an op amp with high voltage noise (nV/√Hz).

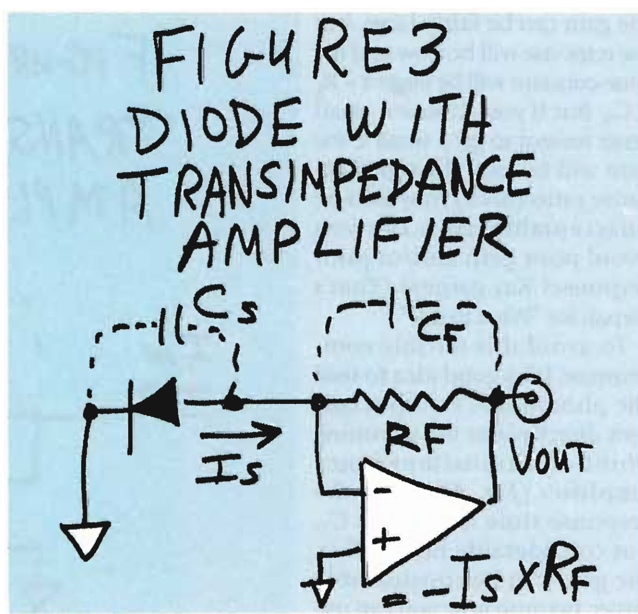
(B) You want to avoid an op amp with high current noise (pA/√Hz). (Most bipolar op amps have much higher current noise than FETs.) It's a rare case when an op amp with bipolar input transistors is better, except when R_S is very low or resistive (or in cases where the input is capacitive but the bandwidth is narrow).

(C) You usually want to avoid an op amp with large input capacitance. Unfortunately, most data sheets don't properly specify the op amp's input capacitances, neither differential-mode nor common-mode. But it's fair to assume that most "low-noise" op amps have a larger input capacitance than ordinary op amps. You may want to ask the manufacturer, or you might just decide to measure it yourself.

(D) Much of the noise of such a transimpedance amplifier is proportional to $\sqrt{BW} \times C_{SOURCE} \times V_N$ of the op amp. So if you want to get low noise, you must optimize very carefully. Specifically, begin by computing the impedance Z_S of your sensor at the maximum frequency of interest:

$$Z_S = 1/2\pi F C_S$$

For a good amplifier, the voltage noise and the current noise times Z_S should both be as small as you can get. If one of these noises is much larger than the other, then you're probably far off optimum.



(E) If you have any choice of what sensor you employ, try to find a lower-capacitance sensor. Furthermore, make a low-capacitance layout between the sensor and the op amp.

If you want to get fast response, low noise, or wide bandwidth, Jerry's book offers some pretty good advice. More on that later.

But Jerry didn't include a list of good op amps that have low voltage noise, and/or low current noise, and/or low input capacitance. Because some are better than others, I bet you can use Paul Grohe's selector guide to find some low-noise op amps. See *www.national.com/selguide* for free "Selguide" software that can run on your PC to help you select a good, low-noise, inexpensive op amp.

Also, Jerry neglected to mention that you can design your own op amp with better, lower voltage noise and better bandwidth. I mean, op amps that you can buy off the shelf cover a wide array of cases where they are optimized for low V_{NOISE} and low I_{NOISE}, wide bandwidth, low power drain, and so on. But you can "roll your own" surprisingly easily and accomplish even better performance for a specified application! I'm not proposing that you design a complete op amp, but it's simple to just add a new low-noise front end ahead of a suitable op amp.

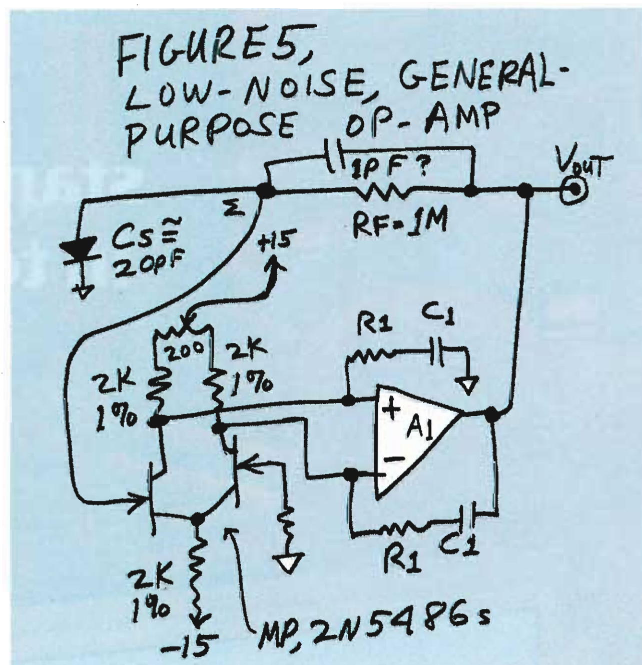
The basic idea is to add a couple of good low-noise FETs in front of an existing op amp. Most op amps don't operate the front-end transistors as rich as the output. Yet in a case like this, there's no reason at all not to run more current through the front end than in the rest of the op amp. My first pick is the 2N5486, which has less than 1 pf of C_{RSS}, but has a lot of g_{ms} (4 millimhos) and low voltage noise (at I_S = 3 mA). So for my first design, I'll just put a matched pair* of 2N5486s in front of a decent wideband op amp, such as the LM6171 *(Fig. 5)*. What's the voltage noise of this amplifier? We may be able to get an average of 3 nV/$\sqrt{Hz}$, out to 10 kHz.

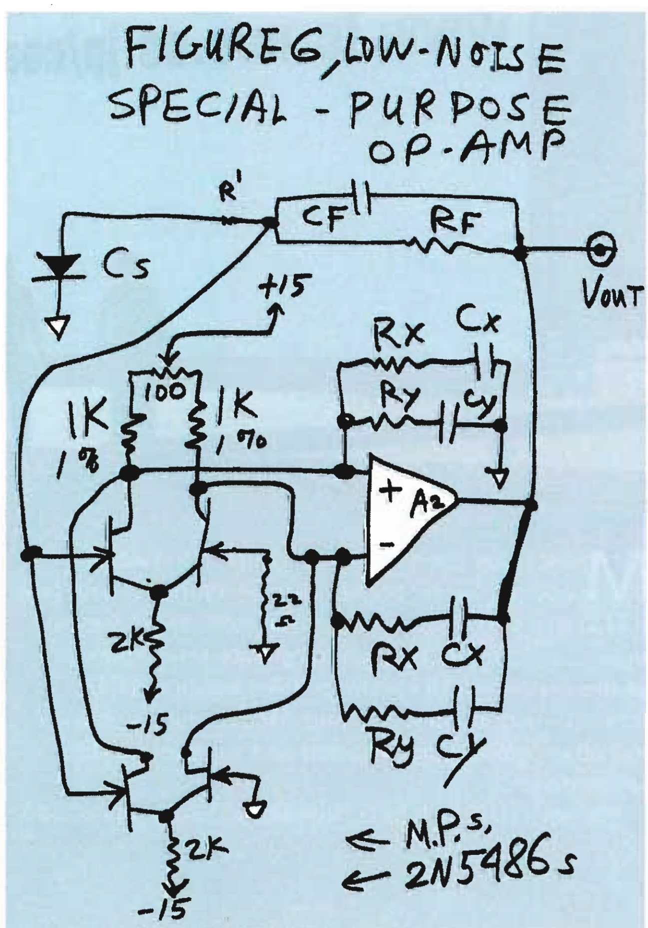
When you're designing an op amp, remember this: adding gain is one of the cheapest things you can add. You only need to be careful about how to give that gain away—to roll it off.

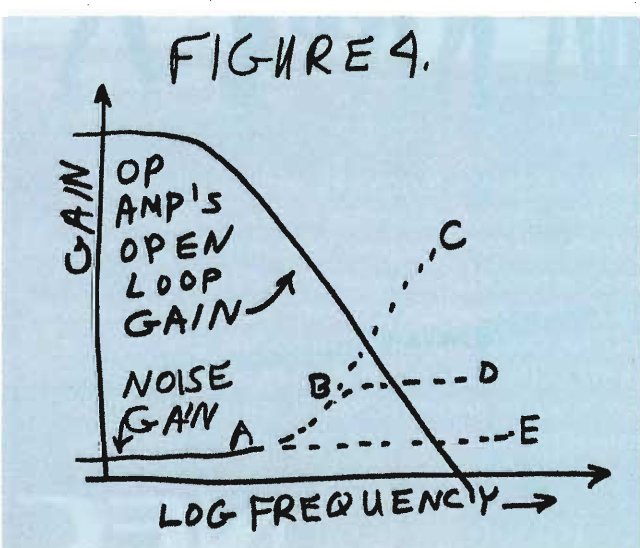
In this case, it's easy. The R1-C1 network in Figure 5 just rolls off the gain for a fairly smooth frequency response. To achieve 2 MHz of bandwidth and a fairly good, smooth 6-dB/octave rolloff, I suggest R1 = 75 Ω, and C1 = 100 pF as a good place to start your design.

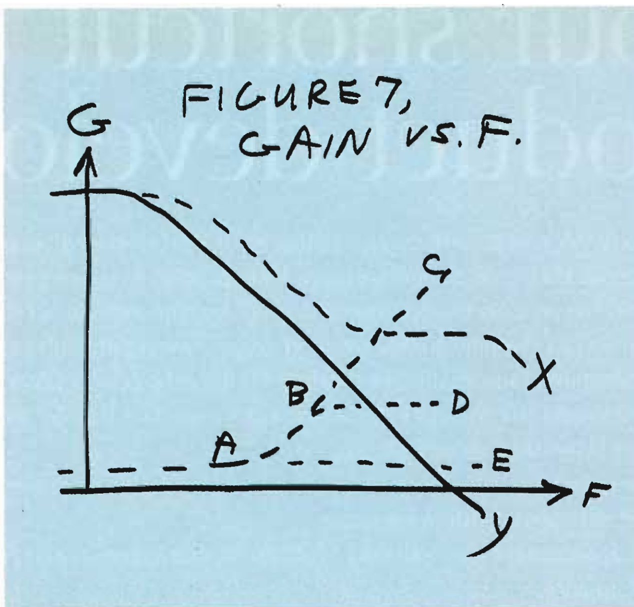
But now, look at the refinements in Figure 6. We can roll off the amplifier's gain simply in two swoops. The low-frequency gain is rolled off by R_X and C_X. Then after the gain rolls off flatly, we roll it off some more by R_Y and C_Y. When we are finished, it should look something like curve X in Figure 7. This isn't exactly rocket science. We just want to make it a practical design. But this is a whole system design. You can't very well design and optimize the op amp alone. It's the op amp, the feedback system, the noise filters, and the post-amplifiers that have to be considered and optimized all together. My first-hack proposals for these damping/stabilization components are:

R_X = 5.1 kΩ, C_X = 50 pF









R_Y = 330 Ω, C_Y = 7.5 pF

The whole point behind making your own op amp is that you do not have to just build an op amp with a smooth 6-dB/octave rolloff, all the way out to a few megahertz. You can roll off the gain at a 6 dB/octave out to some intermediate frequency, and then flatten out the gain. Then, at a higher frequency, let it roll off some more in some vaguely controlled way. This would make a lousy general-purpose op amp, but it might be ideal for a case where the noise gain is rising, such as in a transimpedance amplifier. (Look at the old LM709. When you choose the correct damping networks, it can provide a gain of 1000 out to some high frequency like 1 MHz.)

Also note that I added a second pair of 2N5486s to improve the voltage noise. Yes, this will approximately *double* the input capacitance. But if your C_S is already large, this may easily improve the signal-to-noise ratio. If it's good to have two, will three be better? I'll let you figure that out! But, yes, four or five may provide definite improvements... or that might not be the case.

I won't recommend that you design your own op amp if you can buy one that does the job. But if the best one you can buy isn't good enough, then there's some hope here. Designing your own composite op amp is not that hard, and not that expensive, even if you are going to build one or 10 or 1000. The post-amplifier can be inexpensive. Of course, all of the basic designs will be somewhat different if you are running on ±5-V supplies, or ±15-V supplies.

Either way, it's not that difficult, but the design compromises are slightly different. Here, I just showed a couple of ±15-V applications. (The ±5-V designs differ mostly by using a low-voltage, rail-to-rail-output op amp.)

In future columns on this topic, I will comment on other aspects of design and optimization for transimpedance amplifiers.

Meanwhile, try to avoid Tee networks in the feedback network. They often cause poor signal-to-noise ratios. Next time, I'll explain that completely. Yes, a Tee network might help you avoid buying 1000-MΩ resistors, but that's only okay when you have proven that the noise is okay.

All for now. / Comments invited!
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*For this case, grade a good number of 2N5486s into 20-mV bins of V_S, with V_{GD} = 7 V, and I_S = 3.8 mA. Take units out of the same bin for good matched pairs.

P.S. If you design in an op amp, try to avoid relying on nonguaranteed characteristics, such as noise, which is rarely guaranteed.

P.P.S. I neglected to mention that any resistor may have a built-in capacitance of 0.3 to 0.8 pF. If you add that to any imperfect layout, the capacitance could be so big that you wish it were smaller. Good layout and good engineering can easily cut the C to less than 0.2 pf. For example, make the feedback resistance out of three or four resistors in series, and install a shield land between the ends of the resistor. More later. /rap

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

pease porridge

Bob's Mailbox

Mr. Pease:

You inserted a comment into the letter by Dan Conine (ELECTRONIC DESIGN, *Aug. 21, 2000, p. 136*) that demands an informed response. In your insertion, you stated "I might like some of those better than military technicians who are mostly only trained to follow cookbook troubleshooting procedures. Are they educated in theory? I doubt there are many who are." *(As you point out below: MY DOUBTS were not well-founded. I'm delighted that you have proven me wrong./rap)*

I attended the Air Force's Microwave Radio Maintenance school at Keesler AFB, Miss., from May to December, 1983. The first five months of that training consisted of device and circuit theory. We covered everything from discrete devices to transceivers, from ac theory to digital truth tables. Interwoven with all this theory was a continual emphasis on troubleshooting. Frequently the question was asked: "What would happen to this circuit if this component opened/shorted/broke into oscillation?" This practice of having us continually thinking in terms of "what would happen??" continued into our specialty training. *(That sounds pretty good—a good combination of theory, practice, and Troubleshooting. /rap)*

There we encountered practical troubleshooting. Our instructors kept a stock of bad components available that were used to "break" the equipment. We were then told what the equipment was or wasn't doing, and were told to fix it. No cook-book there. You were expected to find and fix the problem within minutes, while having an instructor watch over your shoulder. It was quite nerve-racking, but taught us to think quickly and efficiently to find problems. *(Darned few schools will teach you THAT. But are the USAF programs STILL done that way? Do you know? Many other good educational programs have changed a lot./rap*

A great many of us who graduated from these schools have various careers in the electronics industry. The training that I received enabled me to obtain both an Amateur Radio license, and an FCC General Radiotelephone License, with virtually no studying. In fact, most of the people who took the FCC test with me were military members. I'm employed as an electronic troubleshooter at a broadcast facility, and am quite successful despite having had no broadcast training. The broad depth of knowledge that I obtained in the military allows me to work in virtually any electronic specialty.

With most colleges not even offering courses in analog electronics, RF, or antenna theory, military school graduates are the best source of highly knowledgeable and experienced technicians available. By the time an employer sees a military person, they're getting someone who has had both an in-depth theoretical education and years of hands-on field experience.

Perhaps you could revisit this issue. I think you'd see your perception of military technicians is false.

Bill Lazure, CET
Broadcast Engineer
WSTM TV, Syracuse, N.Y.
via e-mail

Thanks for writing. A few other guys tweaked me on this, but your explanation is about the best. I'm just curious, though, why didn't I run into some of these guys? Maybe here is Silicon Valley, there aren't so many of them.—RAP

Floobydust Extras

There wasn't room in my last "Floobydust Stuff, Part 9" (ELECTRONIC DESIGN, *Dec. 4, 2000, p. 141*) to fit in all of the items that I had prepared, so here are the leftovers:

How bit?? How big is a "drop" of water? You can try to look it up in an encyclopedia, or an almanac, or a dictionary—or in a handbook of physics. But these books don't usually tell you the size of a "drop." The other day, I needed to know, and I asked around. I go no answers, so I took some data. I counted 100 drops of water from a faucet to fill up a Tablespoon (1/2 ounce or 14 grams). Thus, such a drop is about 0.14 grams. Then I counted 100 drops from a small medicine dropper to just make 1/4 ounce or 7 grams. That's 0.07 to 0.14 grams per drop, or about a factor of 2 difference. That sounds pretty VAGUE. But hey, a facto r of 1.26 in a linear dimension of a "drop" gives a factor of 2 in volume. So we know the size of a "drop" within a fairly reasonable span—about ±12% in a linear dimension—and we know that not all "drops" are the same size. And now you can write into your dictionary that one "drop" can have a diameter of 0.6 cm, ±12%, and a mass in the range of 0.07 to 0.14 grams.

Timers: Our Coffee Gal was starting to get reprimands and warnings because the coffeepot would sometimes be left on all weekend. On a Saturday afternoon, security would smell the stink of scorched coffee and leave her nasty notes about generating fire hazards. (A fire in 5 grams of coffee dregs in a pyrex coffeepot could hardly cause any real fire—even though it would sure make a stink.) I wanted to find a timer—not just a 24-hour timer, but a seven-day, 24-hour timer—so the coffeepot would stay OFF on Saturdays and Sundays.

Fry's didn't have one. Radio Shack didn't either. But Home Depot did. Problem solved. Of course we had to wire it up, as it didn't come prewired to plugs and sockets.

All for now. / Comments invited!
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What's All This Battery-Charging Stuff, Anyhow?

On October 4, at noon, I sat down at my breakfast table, and plugged in my soldering iron. I was going to build the circuit shown in Figure 1. I had one hour to put it together, which was enough time, and then I was going to drive down to the airport to fly to Kathmandu.

As the soldering iron was warming up, I looked for the collection of parts that I needed for this circuit and had shoved into an envelope. Rats! Where were they? I knew I had left the parts in a safe place. I searched in every reasonable spot, every pocket of my briefcase, and all around my house. After 10 minutes, I gave up and unplugged the soldering iron. (Later, 10 miles up the trail above Namche, I found the parts in an envelope in my trousers' left front pocket, which, of course, was a "safe place.")

Fortunately, the circuit that I was going to build was just a spare, a back-up, and we never needed it. So, it wasn't a big deal that it didn't get built.

About eight years ago, I explained in "What's All This Battery-Powered Stuff, Anyhow?" that I used a gear-motor with a hand crank, at about 40 RPM, to charge up the batteries for my new Sony camcorder when I was off backpacking or trekking. That was better than nothing. But the gear-motor's maximum output—barely 2 W!—was limited NOT by the motor, nor by the strength of your arm, but by the gears' maximum allowed torque, which was NOT a lot. So a couple of years later, I bought a small solar panel that could put out much more charge on a typical sunny day. Next, I bought a bigger, yet lighter panel. Then when I was in Kathmandu, I discovered that one of my panels had apparently quit (really, it hadn't), so I bought another panel from Lotus Energy *(see the table)*.

Because my camcorder batteries have been mostly NiCads, I used a simple circuit and just let the solar panel's photocurrents flow into my batteries. The circuit shown in Figure 2 is merely a simple scheme with a Schottky rectifier to connect the solar panel's output to the battery, plus a detector to show if the battery isn't connected. If the battery is below 8 or 9 V, the LED will NOT turn ON, and that's GOOD. That means the battery is getting charged, and holding the voltage low. But if the voltage is above 10 V, the LED will turn on, indicating that the battery is NOT getting charged. This is a bad thing, so the LED signifies bad news. It's time to re-adjust the rubber bands! I mount the LED right near the banana plugs, which I keep outside of my pack's back pocket, while the battery rides inside the pocket. The solar panel is lashed on top of my pack.

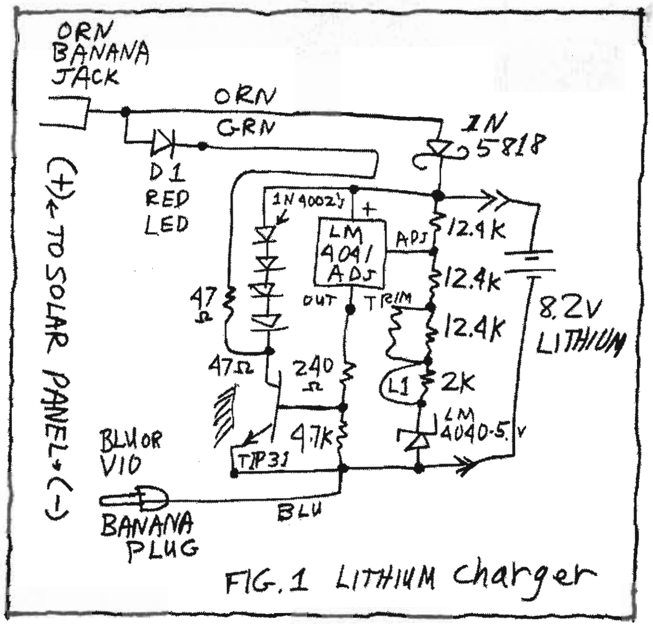


FIG. 1 LITHIUM Charger

The number of 1N4002s in series at D2, D2.5, D3, D3.5 should be perhaps two or three, but maybe more, depending on your actual battery. I recently found that one of my batteries has six NiCad cells in it, not the usual five, so I had to use a couple of extra diodes in series, or the LED wouldn't have gone out!

Many SONY and RCA camcorders have a simple flat interface to the battery, where it was easy for me to set up a couple of small blunt bolts or pins, to be pressed against the recessed terminals of the battery. The connector should be arranged and keyed in such a way that it cannot be applied BACKWARDS to the battery. The sketch of how I did mine is shown in Figure 3. I used tin snips to cut copper-clad 1/16-in. epoxy material into thin strips, such as 3/8-in. wide. And I used a hacksaw blade to saw a dozen gaps in the copper. I soldered three of these thin strips (at the places marked with S) to make a triangular frame, which is easy to strap to the battery with a few rubber bands. I used the isolated foil areas to solder up circuit nodes, such as the LM334 and various diodes.

How do I know how much charge to put into a NiCad battery? I have several two-hour NiCads (2000 mA-H). If the battery gets low, and the camcorder shuts off because it's low, then I can put in well over 1 A-H, or 0.3 A × 3 or 4 hr., before I need to taper off. Usually, if I'm charging up one battery, I'm using another one to

SOME AVAILABLE SOLAR PANELS

	Weight (lb.)	L × W (in.)	Output	Price	Supplier
#1	1.5	12 × 13	0.30 A × 20 V	$140	Backwoods Electric
#2	1.0	10 × 20	0.40 A × 20 V	$110	West Marine
#3	1.4	10 × 16	0.40 A × 14 V	$105	Lotus Energy
#4	1.0	10 × 20	0.40 A × 20 V	$100	West Marine

Of course, #3 can't charge two 8-V batteries in series. But OK.

record with, so rather than worry about EXACTLY how full it is, I just swap batteries and fill up the one I was using.

What if I'm going to leave camp and leave my battery charging in the sun? I will usually put the solar panel in a sunny place, and lay it out at an angle so that the solar radiation will get more oblique as the day goes on, and the rate of charge will taper off. I might just put the panel FLAT on the ground. At noon, the sun will come booming in, but in the afternoon, the panel's output will drop a lot. If the panel's output falls to 0.2 A, a 2-A-H battery can take that much current in for a long time with no harm (C/10 rate). My panels can put out about 0.4 A, which is NOT a horrible amount.

Many modern camcorders have a gauge to tell you if the battery is nearly full, or what. (Some batteries come with a "fuel gauge," and most of those are rather optimistic; after one-half hour of charge, they say that the battery is full, which is obviously malarkey!) Of course, the correct way to terminate charging on NiCads is to detect when the battery has a rapid rate of rise in temperature. But I have never had to do that when hiking. For a fixed installation, I would probably set one up.

One of my trekking friends had NiMH batteries for his newer camcorder. I checked it out, and NiMHs like to get charged the same way as NiCads. Just push in the amperes until the battery is nearly full, but be sure to taper off to C/10 when it gets full. I told him to do exactly what I was doing, and he made similar adapters.

But a couple of my trekking friends had new camcorders with lithium batteries. I knew that you have to be very careful with them, because overcharging a lithium battery can lead to RAPID DISASSEMBLY. Most of you guys know what that is...or you can figure it out.

So, it's important to have a reliable regulator that will charge your lithium battery up to 8.200 V (or 8.400 V) and no higher.

NSC makes two nice little ICs that can do that, the LM3420 and LM3620. These are nice, accurate series regulators, but they're NOT easy to turn into shunt regulators. I want a shunt regulator, and here's why:

A solar panel is a current source. It puts out an approximately constant current into any load that you connect to it—even a short circuit. Plus, even if you leave its output open-circuited, it isn't unhappy. When you think about it, it's fundamentally different from any ordinary voltage source. (For further notes on 50 good current sources, see the Web seminar I gave on Dec. 6, 2000, in the archives at *www.netseminar.com*.)

When I put the output of a 20-V solar panel into an 8-V battery, some power is wasted, but that's not a big deal. The battery and the solar panel are both happy about this situation.

If I want to get all of the energy possible from that solar panel, I feed that current into a series stack of two 8-V batteries. To do that, you need current-mode charging, and you need *shunt* regulators, not series regulators. Then if my batteries are low and I'm just coming into a period of sunshine after a long spell of clouds, I can simply stack two of them in series and shove the current through BOTH of them. Best of all, these batteries, with their shunt regulators, are mix-and-match, so I can stack any two in series. I can charge up one of my NiCads in series with an 8.2-V lithium, or a NiMH in series with an 8.4-V lithium, and the solar panel just kicks the charge into both. If one of the lithiums gets full, the charge is shunted through the power transistor and it keeps flowing through the other battery, so charging continues. This wouldn't be possible with a series regulator. Because we had about 12 batteries, four solar panels, and about 10 regulator modules on our trek, we weren't only self-sufficient, but we were inter-operable. As a result, the loss of any one regulator or any one panel wouldn't stop us. It would barely slow us down.

Could I use a switching regulator to convert 20 V at 300 mA into 8 V at 700 mA? YES, in theory I could. But I don't usually need quite that much efficiency. I built one, once, and it did work, but it wasn't a winner even though it weighed only 1 ounce. Usually, it's just fine to stack the two batteries in series. Simplicity is a great virtue—even though I have to carry around two batteries that tend to get a bit heavy!

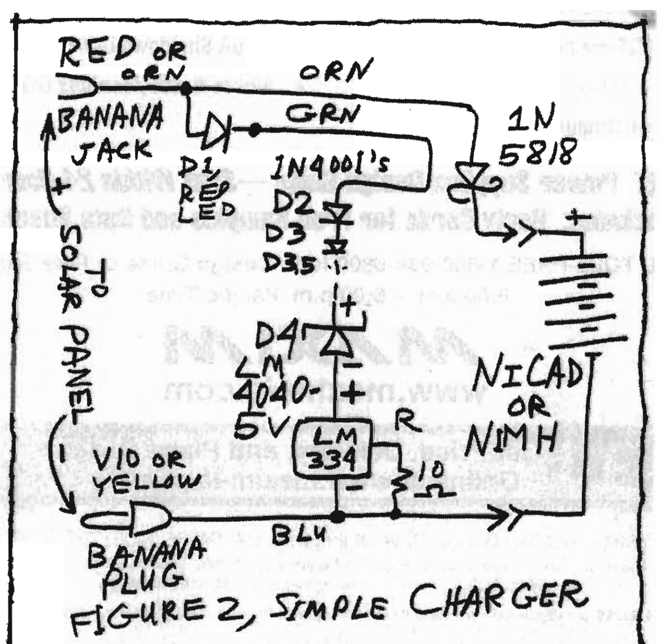


FIGURE 2, SIMPLE CHARGER

Connectors

We have all seen power systems using fancy connectors. When they get banged up, they're impossible to repair. Our Head Porter had a solar panel that *he* carried on his back every day, thus making five of us solar guys on this trek. His panel fed into the batteries that he used to run our fluorescent lantern. But his connectors were RCA phono plugs, and when they got abused, they were not only unreplaceable (Namche Bazaar has a few radio repair shops, but had ZERO pieces of RCA plugs/jacks that could be bought or scavenged for repairs), but they were nonrepairable.

For nine years, I have used as my *standard convention*, that the + wire from the solar panel has an orange (or red) banana plug, which mates with an orange (or red) banana jack, and an orange (or red) wire going to the battery. The – side is reversed in gender: a violet (or blue or yellow) banana jack from the solar panel, and a violet plug tied to the battery. This makes it easy to connect two batteries in series. (Yes, I know it looks funny when the two batteries are connected in series by plugging a yellow plug into an orange jack, but it's perfectly OK, and nothing can go wrong.)

Further, there's hardly ANYTHING more repairable than a banana plug (which works great with no solder) or a banana jack (wrap the wire around the tab and crimp it or put on a minigator clip). We had zero trouble on the trek with our wires or connectors. (When the porter's RCA plugs failed, we managed to coyote them up—lashed them in parallel—and the lamp kept working every night.)

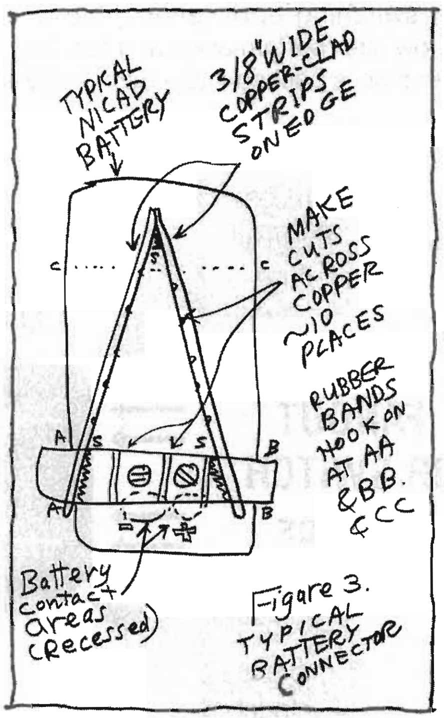


Figure 3. TYPICAL BATTERY CONNECTOR

Now let's look at the circuit of Figure 1, the critical one for Lithium batteries. The LM4041-ADJ is basically OFF if the battery voltage is below 8.2 V. The circuit draws only 140 µA. This means that all of the current from the solar panel flows into the battery. When the voltage gets up to 8.2 V, the LM4041 sees 1.24 V at its ADJUST pin, so it turns on, and it turns on the big NPN to shunt off all current necessary to hold the battery voltage at 8.2 V. When this happens, there's enough current to turn on the red LED. So, if the battery is fully charged, the red LED turns ON and tells you this. Or, if the battery isn't connected, the red LED will also turn on. You may have to check your connections to tell which is happening. Still, it's a good two-mode indicator. It only wastes 10 mA in the LED when the battery is NOT getting charged. But the big NPN has to carry as much as 400 mA, and it can get hot, so be sure to provide an adequate heat fin.

This circuit is set up to be trimmed to 8.2 V, but if you disconnect the link L1, the voltage goes to 8.40 V. Which one should YOU trim for?

Connect a couple of small wires to your lithium battery's terminals, and monitor the voltage with a DVM as you charge it. If it stops at 8.2 V, that's what you need. One of our guys had an 8.2-V battery in his Canon Elura. The other guy had an 8.4-V lithium in his Sony. Most people would set up the regulator for just their battery. The circuit of Figure 1 was going to be trimmed for BOTH voltages, with a link to snip to get the higher voltage. How do we know for sure? We brought two DVMs to Kathmandu, and then we brought the lighter one along on the trek. We just trimmed the basic circuit of Figure 1 to 8.2 V by adding various high-value resistors across the 12.4 k in order to get the voltage to 8.2 V ± 0.25%. Then if we needed 8.4 *(see the table)*, we would just undo the link. (Because we had low-temperature solder from Radio Shack, we could reconnect any wires using a match for heat.)

The 8.2-V battery for the Elura clipped onto its regulator by rubberbands. The 8.4-V battery for the Sony had two small sockets set into the battery, and a couple of MINI banana plugs matched those sockets perfectly. I used to be nervous about lithium batteries, but now I'm perfectly comfortable with them. When you charge the battery with this circuit, it pulls the battery right up to 8.2 V, and then it keeps it at a full state. The LED tells you that it's full. Even if something FALLS OFF, the battery cannot be over-voltaged or overcharged.

What's the right way to charge lead-acids? *(Fig. 4)*. That circuit can put out 14.4 V to bring a "12-V battery" up quickly. But after it gets up there, hysteresis is added through the 18 k, to bring the voltage down to a float voltage of 13.4 V. This circuit does have temperature compensation, because on a hiking trip or trek, you could easily have a working temperature range between +120°F and 0°F. You wouldn't want to over-charge the battery when hot, and you wouldn't want to under-charge it when cold, which is what would happen if you charged it to a fixed 13.4 V at all temperatures. (The other types of batteries don't need temperature compensation.)

So trim that pot to get 13.4-V DC at no load at 25°C, and (13.4 V – 22 mV/degree) at temperatures away from +25°. In this circuit, the LM334 is NOT used as a current-source, but as a low-voltage comparator. This circuit is a series regulator because you won't be stacking two of these!

(The town of Namche Bazaar has good reliable 220-V AC power. But some of the innkeepers have learned to charge tourists and trekkers high prices—as high as $4 to $7 for charging one battery. When they get you over a barrel, they really know how to get you! Also, above Namche, there isn't a lot of reliable electricity available. Therefore, it would be very hard and/or expensive to bring a group of batteries and only record a LITTLE. By bringing my own charging equipment, I had no trouble recording 23 hours of video in 35 days on the trail. Of course, it took up a lot of my Christmas vacation to get all of the video listed and ready to edit down to a few one-hour tapes!)

Several people along the trek asked why we were carrying these solar panels, and we explained. Some of them said, "Hey, that sounds like a really good idea. I left my camcorder at home because I couldn't figure out how to charge its batteries. Let me know when you can tell me how to do it!" Well, that's what this column is about.

The flashlight that I hooked up to a battery can be seen in Figure 5. The LM334 and 2N3906 form a 100-mA current source. When you unplug the solar panel and plug in this flashlight, it's a pretty good little light. Normally, you wouldn't want any discharge path if you shorted the orange and violet terminals together. But because this is just a regulated 100 mA, the battery won't be abused. The components of the little current regulator are easy to mount inside of one of the A-frame members. You might switch out one or two of those 2-Ω resistors to adjust the brightness.

I arranged the LEDs (Digikey Part CMD333UWC-ND, about $3) in a fan array, to make it easy for reading. You can point them anywhere you want, though. The current source shown here isn't as efficient in voltage as the one I showed back in the September 5 issue. I did that on purpose, because I wanted this circuit to quit drawing

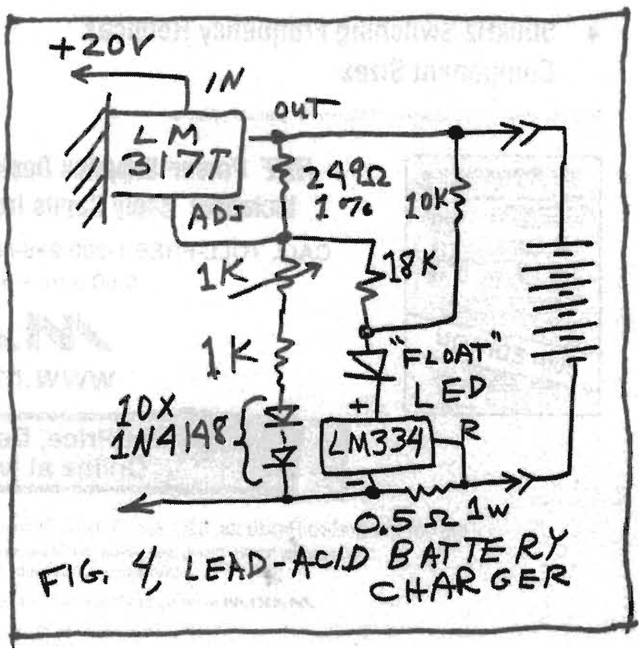
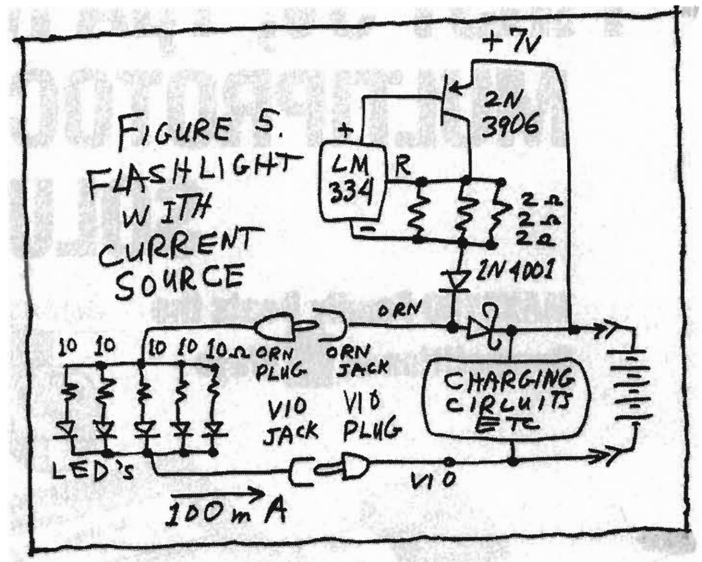


FIG. 4, LEAD-ACID BATTERY CHARGER



current if the voltage supply gets down to 6 V to protect the battery. This circuit does have the advantage that it connects to the load and the battery with just two wires, rather than four. Therefore, the wiring is much easier and safer. Now my best flashlight is easy to recharge! A solar-powered night-light!

These are some of the circuits and procedures, the tricks, and the connectors that kept us running with plenty of charge for over a month. Did our batteries ever get low? Yeah, after three days of gray weather. That's why we like to keep our batteries charged up pretty full, almost all the time!

All for now. / Comments invited!
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pease porridge

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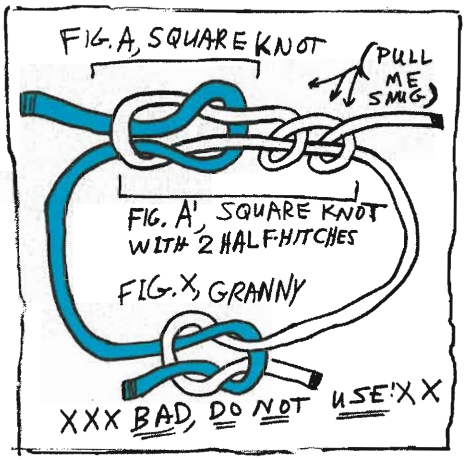
What's All This Knot Stuff, Anyhow? (Part I)

Let's get the ball rolling with square knots and half-hitches. When I was a lad, a mere tenderfoot, I was learning the lore of the Boy Scouts. I still have a lot of respect for them, even though I don't happen to agree with 100% of their ideas.



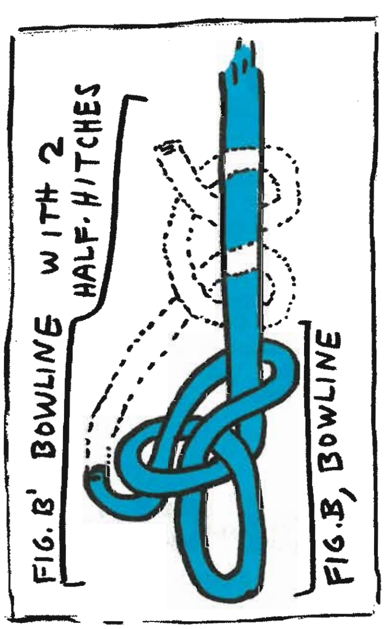
I remember the old story of a young Boy Scout who had just shown up at the scene of a crisis. A steeplejack was stranded high up on a tall chimney, and a crowd of 100 people stood around as he pleaded, "Does anybody know how to tie a square knot?" Apparently he had some ropes dangling down to the ground, and if any person knew how to tie a square knot, the steeplejack's life would be saved. If a "granny knot" or "false granny" were tied, he would probably fall to his death. And, nobody in the crowd was really confident about knowing how to tie a square knot.

This young scout had just passed all of the relevant tests. He spoke up with as clear, confident a voice as he could, and asked, "Where should I tie the knot?" After receiving the correct instructions from the guy on the chimney, the scout correctly tied the knot, and the steeplejack let himself down safely. The cheers of the crowd went to applaud the young Boy Scout. As we old scouts often say, "Shucks, Ma'am, 'twarn't nothin'..."

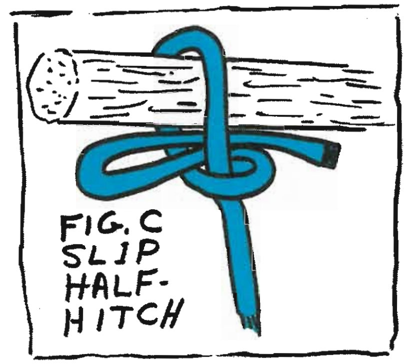
Tying knots used to be a standard set of tasks for young scouts. Making a display board of knots was, too. I never made a board to display all of the knots I knew. But I sure made a lot of knots. I still do today.

First of all, a square knot is much better than a granny knot, but I would never trust it for my life. A square knot with a half-hitch or two is much more reliable and trustworthy than a square knot alone. So, if a guy up on a chimney said I had to be sure to tie a square knot safely to save his life, I would request permission to put a couple of half-hitches on each side to be safe. See Figures A and A'. You should never make and use a granny knot, as shown in Figure X, as it's likely to either jam up or slip. But you should recognize it when you see one.

The square knot is similar to the familiar knot for shoelaces (not shown), which could properly be called a slip square knot because pulling on either one of the loose ends will untie it.



Similarly, a bowline, as shown in Figure B, is pretty good for making a loop at the end of a rope. But a bowline with a couple of half-hitches is better, and more trustworthy, per Figure B'. Note also that the slip half-hitch in Figure C isn't *per se* a good or trustworthy knot. But it can be used as part of a good knot,



if you take good care of its loose loop and make it secure, as we will see later.

I have read that more people have died when a square knot slipped or failed than from using any other knot. So, a square knot with a couple of half-hitches is definitely trustworthy. Also, most knots have a tendency to get looser when you jiggle them. I tied some cords onto the door handle of my car using these knots, not tight, but just waving in the wind. After five months, the knots seem as good as ever. Coming up later: binding a bulky load onto a knapsack—or a truck.

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Bob's Mailbox

Dear Robert Pease:

I enjoyed your Parts IV and V of "What's All This Fuzzy Logic Stuff, Anyhow" series (ELECTRONIC DESIGN, *Nov. 6, p. 146; Nov. 20, p. 159*). Wow! What a claim from the "Fuzzy People!" I worked with Navistar International on an advanced electronically controlled diesel engine back in 1991. I guess we were just too uneducated to realize that a PID controller wasn't up to the task of speed control! *(Yeah, you guys were REALLY stupid! And, ignorant too. /rap)*

I'm going to go back and find out more about this book that said this was impossible. *(Did you ever invent an automatic pilot for bumblebees? They can't fly either. I read it in a BOOK. /rap)*

We even used the same PID controller as the engine governor. That design was implemented in a digital controller, but it included everything you described in your two articles. *(Check. /rap)*

We limited the integrator error input term to prevent windup and our controller worked/works very well. And this application IS on trucks! *(Yeah, but you can only use it on light trucks, or heavy trucks, but not both—right? /rap)*

Real-world controller designs require the engineers to not only understand the technology they're working with, but the systems that the controller is applied to. *(Check. /rap)* And as you noted, not just the steady-state conditions, but also transient and even error conditions! *(Check! /rap)*

You have to use the right tool for the job, and know how to use that tool.

Steve Zavodny
via e-mail

RAP:

I have followed your discourses on (or against) fuzzy logic over the years. I, with you, fail to see where in most control systems fuzzy logic affords any advantage over a good analog design, or even digital implementation of an analog design. *(One of my major problems is that the FL guys say, "Isn't this a great solution for a simple system?" like the Mamdani steam pressure controller. They expect me to trust them when they have a whole lot of variables for a more complex problem. But when I check into it, I find that they're exaggerating all of their advantages in the simplest problem. So how am I supposed to trust them for big or complex systems? /rap)*

Having said that, I must say that fuzzy logic works where the logic is fuzzy—when a person has to describe an event in terms of "sort of," "about," "kinda like," etc. I see no other conditions where it does any good. *(It may apply for a really nonlinear problem. You could look up the U.S. patents of Marco Boccadoro. /rap)*

I saw an advantage in sensor fusion for intelligent process control. About seven years ago, I did some R&D on using multiple sensors for controlling the stoichiometry and other qualities of tertiary compounds in edge-defined crystal growth. My company decided it didn't want to be in that business before I could cut hardware. However, as there were multiple sensors trying to control multiple parameters simultaneously, and the edges between the conditions were "fuzzy," fuzzy logic seemed the simplest implementation. Simulations worked, but that was pulling one's self up by one's boot strap.

Ralph Reinhold
via e-mail

I agree. There are many complicated systems in the world. When they're hard to model, or hard to simulate, things get messy. But think about SPICE. Electronic things are often EASY to model—and SPICE still gives stupid answers sometimes! /rap

Bob:

I have been watching your comments on electric and hybrid cars. Years ago, I started preaching to my coworkers that the "all electric" vehicle wasn't the way to go. I proposed hybrid cars, but not like the hybrids showing up now. *(They're pretty good—and much better than electric cars. /rap)*

Most automakers' models retain the mechanical transmission and like you said, use the electric motor only for assisting the gasoline engine. My hybrid version would use a small internal combustion engine driving a generator used to charge the batteries. The output of this pair would have to be the average power used by the vehicle. At constant load and speed, this should be a more efficient way to use the gasoline.

(Yes, that's a better way. I wonder why almost nobody does it! Maybe it's because that would be less like a conventional car. By making something and calling it a "hybrid," they can pitch that they're selling a very "green" product even though it isn't much different from ordinary gas cars. /rap)

The batteries would carry the peak load. Range would be greater than that which can be supported by batteries alone. The motor generator set could even run after the vehicle stopped to fully charge the batteries.

(Check. And if you're going on a moderate trip, such as a 30-mile commute, you can charge up the battery before and after the trip, and never even start your engine unless there are special circumstances. /rap)

Dynamic braking can also recharge the batteries. Each wheel would have an electric motor directly driving the wheel. A processor (not using Fuzzy Logic!) would control the power to each motor, resulting in all-wheel drive and no-slip traction. *(I don't really care if the motor drives a gearbox or not. That's not a bad way. /rap)*

Jim Jansen
Dallas, TX
via e-mail

We tend to agree on electric cars, but I'm waiting for the flywheels. /rap

All for now. / Comments invited!
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What's All This Southern Crossing Stuff, Anyhow? (Or: The Law Of Unintended Consequences)

A couple of months ago, the San Francisco *Chronicle* printed a big headline on page 1: "Feinstein Endorses Southern Crossing." Many years before, arguments had erupted over whether or not the state should invest a few thousand million dollars on a new bridge across the San Francisco Bay.

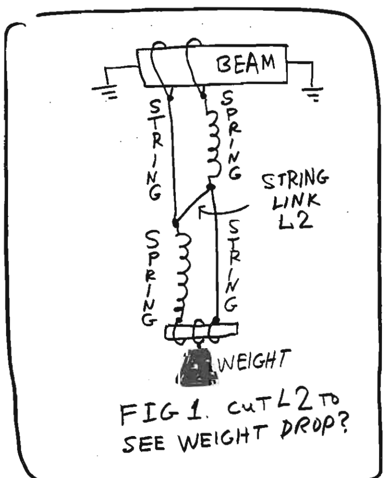
This bridge would be situated several miles south of the SF-Oakland Bay Bridge, and north of the San Mateo Bridge, perhaps landing in San Francisco near Candlestick Park. Even though this route hasn't been fully engineered or located, it has been called "the Southern Crossing." The debate had died out and nobody had raised the issue for several years.

But then Senator Dianne Feinstein went over and poked a sharp stick at the sleeping lion, which stirred up much howling and caterwauling again. Some Developers nodded that this was a GREAT idea because the existing highways were filling up too fast (even during late evening hours), and new ways were necessary to get taxpayers, shoppers, and employees into and out of the city. Conservationists, on the other hand, bleated that any new roads would become over-crammed as soon as they were opened.

Nobody asked the engineers. But I wrote a letter to the editor of the *Chronicle* (which was ignored), pointing out that opening up a new road could not only fail to make traffic better—it could actually make traffic worse.

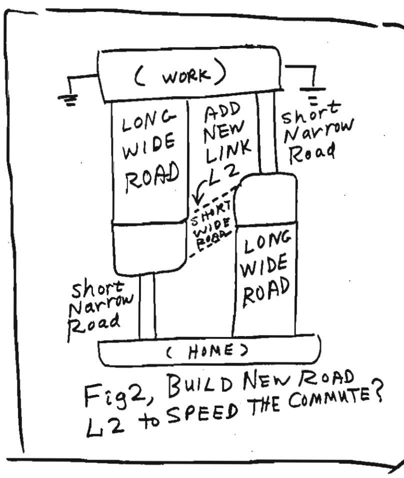
Meanwhile, the citizens down in San Diego were screaming that energy rates had risen horribly. The recent laws had deregulated the cost of electricity in such a way that they *expected* the electricity prices to go down, but that wasn't happening. How come? The Law of Unintended Consequences seems to apply here: "Be careful what you ask for: You might get it."

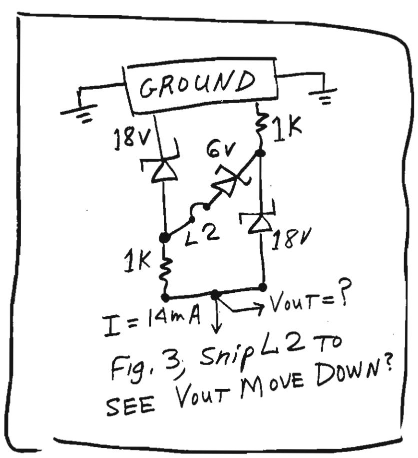
Let's build the "circuit" of Figure 1, using rubber bands or springs, and strings. I select *just* the right amount of weight and suspend it from this simple network of strings and springs. I volunteer to cut a string at L2. Do people think the weight will rise up, or fall down? Of course, everybody says that when I cut the fixed link, the weight will *descend*. I cut the string—and the weight does what it does.



So, when there are a number of roads, wide and narrow, leading from point W (Work) to point H (Home), as shown in Figure 2, and a new path is opened—Link Road L2—of course the typical commute speeds and times will be improved, right? Yeah, sure... Not a perfect analogy, but a good one is the electrical analogue shown in Figure 3, made of resistors and zeners. If I break the link L2 that connects up the 6-V zener, will the negative output voltage rise or fall? Of course, it must go down. Just run this in Spice. Or build the circuit, and snip the link going to the 6-V zener.

The mistake they made in San Diego was to *assume* that the laws of Supply and Demand would benefit the consumer in the most generous way. Every time a new technique was found to generate electricity cheaply, the net cost to the consumer declined. Great theory. As long as electricity usage was decreasing, the price of the cheapest source tended to decrease. But the law was written so that was just one possibility of what would happen on the curve of supply versus demand. Every time the demand increased enough to bring in a new high-priced supplier of electricity, the price for ALL suppliers—even those that could make electricity cheaply—



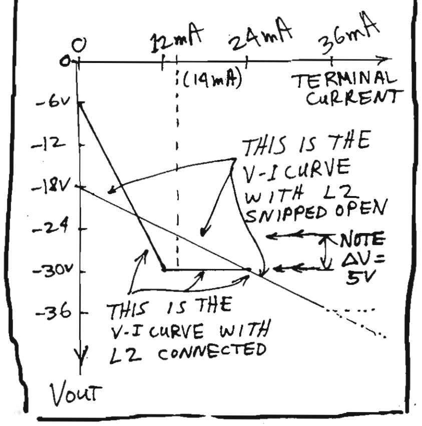


went UP, UP, UP. The average wasn't held down. Thus, the law-makers who expected these laws to lower the average price actually achieved the opposite result: the price for all suppliers rises to that proposed by the highest seller. Although that's not what anybody wanted, except maybe the power-generating companies, that's what they got. It will take a while before they can talk their way out of it, too.

Yes, the weight in Figure 1 will go UP when you cut the string. (This assumes that you choose the "right" weight, and correctly pick the lengths of the strings versus the lengths of the stretched springs. This jump UP is most noticeable when there's a maximum tension in link L2 and only a minimum tension in the long strings.)

Also, the commute time in Figure 2 will probably get worse when the new road is opened. (This presumes that the average speed on a narrow road decreases when you try to shove a lot of traffic onto it, as we know is frequently the case.)

FIG. 4. V-I CURVES



Finally, the size of the output voltage will decrease when the 6-V zener is disconnected. Refer to Figure 4. When the current applied is 14 ma, disconnecting Link L2 will cause the output voltage to *shrink* by several volts, as if there were a negative resistance. Yet, no active elements are present to cause a negative resistance. Analogues are analogous when Figures 3 and 4 are compared to Figures 1 and 2. Are you smart enough to avoid the Law of Unintended Consequences?

All for now. / Comments invited!
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Bob's Mailbox

Dear Bob:

Do you know of any stash of MM5369/8 chips that may be around? I am looking for however many I can get for a couple of one-off projects. (These were really neat chips.) I have not used them in years and only recently found-out that they have been out of production since '97.

Jim Prince
via e-mail

I called up Halted Specialties, which is one of the best surplus stores for miles. They had none. I think you better use something else! Myself, I never used one or held one in my hand.—RAP

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Dear Bob:

About your reference to coffee timers (ELECTRONIC DESIGN, *Jan. 22, p. 127)*: we too have been threatened by our security guards for leaving our coffee pots on. So, I purchased a couple of timers for coffee pots to use both at home and here at work. I got the kind with the plastic inserts you can move around to set the on and off times. Then, I completely removed the "on" inserts and now just use the "off" inserts. That way, I have to manually turn the pot on, and the timer turns the pot off.

I tried to convince our security guards that this system was highly reliable, but their regulations state that timers on coffee pots aren't allowed. My solution was to put the timer in a place where the guard couldn't see it—end of problem, end of the nasty notes.

Chuck Neal
via e-mail

I have to say, that's a cute and elegant scheme! I like it! (Not that my timer is bad.) I'll have to think of some cases where my scheme does things better than yours (if there are any instances). But yours probably works better on a holiday.—RAP

Hello Bob:

I noted in your column that although you had satisfied your need for a coffeepot timer, you had to "wire it up." I've had a timer on my copier for years, which was made by Intermatic. You can set the on/off times for each day of the week. It's called their Time All Scheduler, Model SB911 (Rated 15A, 1/3 hp). Once plugged in, you only need to set it, plug in your appliance(s), and program it by moving sliding actuators.

By the way, because I'm involved in the electrical product safety compliance trade *(www.safetylink.com)*, be certain that the coffeepot you're using isn't "Rated for Household Use Only"—as are nearly all appliances available in the mass marketplace. You will typically find this notice adjacent to the safety agency's markings.

It's not unusual, in my experience, to find home-rated appliances in restaurants, offices, church kitchens, and other workplace environments. These appliances aren't rated for commercial duty and shouldn't be employed in the workplace; to do so is a misuse of such appliances. Electrical appliances used in a workplace should be rated for commercial usage and bear the mark of a nationally recognized testing laboratory (NRTL), among which the more familiar are UL, ETL, and CSA.

Art Michael
via e-mail

Ours is an industrial-rated BUNN-omatic and is marked UL.—RAP

Howdy Bob:

I started out as an electrical power engineer at the University of Idaho. I have been working for the Navy for about 25 years and I learned analog engineering on the job, with a lot of help from your design articles. I did pass the P.E. exam a while back and haven't used it much, but I have kept an eye on the electric industry. We have been blessed with relatively cheap energy, until now.

Some of my friends here at China Lake studied ways to reduce energy consumption of fractional horsepower motors back in the Carter Administration energy crisis, but their solutions were ignored when the crisis passed. They published "Naval Weapons Center Technical Memorandum 4552" in July 1981. It showed their investigations and recommendations to retrofit fractional horsepower motors (1/3 through 3/4 hp) and turn them into two-phase motors by using an ac capacitor across the start (speed) switch.

This way, the start winding is used as a second-phase winding during running. At stop, the switch is closed and the capacitor is safely shorted. When the motor gets rolling, the switch opens and the capacitor phase shifts the line current to use the start winding to help push the rotor. It takes about 35 µF for a 1/3-hp motor, about 45 µF for 1/2 hp, and about 55 µF for a 3/4 hp. Again, these are ac caps with at least a 350-V ac rating. I got my caps from C & H Sales in Pasadena, Calif.

I'm going to retrofit my private well pressure pumps and my evaporative cooler motors so that the "wheel of fortune" doesn't gig me any more than necessary. Of course, the wiring has to be done safely, although the savings are on the order of 20%, if all is done properly. The motor pulleys need to be properly sized, and the minimum current point must be determined with a clamp-on ammeter, as the capacitor values are tried.

A second benefit is that the run winding with the start winding actually runs cooler than just the run winding alone. That should help the motor last longer. This TM 4552 isn't available in electronic form at this time, but I can send a copy to you with my added notes, if you're interested. (Note: this isn't a simple power-factor correction, but a conversion of the motor into a two-phase unit.)

Ed Tipler
via e-mail

Hello Ed. This seems kind of neat. It sounds like the sort of thing that is ignored. Yes, please send it to me.—RAP

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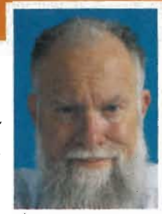
NEXT TREK: If you're a strong, careful mountain biker, you might want to inquire about our next trek in Nepal, bicycling around the Annapurna Circuit, Oct. 12 to Nov. 3. It's only 23 days, and it's never higher than 18,000 feet. Just e-mail *rap@transtronix.com*.



BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

pease porridge

What's All This Finite-Gain Stuff, Anyhow? (Part I)

I have been asked, "Why is it so hard to measure temperature?" I point out that 100 years ago, any attempts to make precision voltage measurements weren't done by a DVM or voltage meter, but by a big voltage divider (potentiometer) and a voltage null meter. Even as recently as 30 years ago, this was done for the best precision.

Likewise, for most of the last 100 years, precision temperature measurements were made by comparing an unknown temperature to that on a "temperature divider." The ends of the "temperature divider" were held at known, precisely calibrated temperatures, and the temperature along the big temperature divider was proven to be a linear function of the position.

I came home last night and opened up all of my junk mail. (Last year, I received 746 mail-order catalogs, weighing 242 pounds, plus *thousands* of advertisements, and *thousands* of requests for charitable giving. It's too bad I don't have a wood stove to burn them in and keep my house warm. But I do recycle all of that paper.)

I was throwing out a lot of useless paper when I noticed some phrases enclosed with the PG&E bill. (I'm sure you know how Pacific Gas & Electric, also known as "Pigs, Greed & Extortion," is notorious for all of its problems.) The little fly-sheet advised us, "Be sure to set your thermostat no higher than 64° in the winter, but set your air conditioner's thermostat to 78° in the summer." That sounds like good frugal advice, but it doesn't sound like we're going to get very comfortable until energy prices come down a lot.

But I got a rule-bender, good for the summer. Let's put my computer table near the window where my air conditioner is running. I can arrange some ducts or drapes to send the cool air right to my legs. I'll put some drapery over the table, down to the floor, to keep the cool air around my legs. Then I will arrange things so that the air wafting out from under the table will flow past my arms and head. Even when I set the room's thermostat at 80°F, the room might run around 79°, but I can be cool and comfortable at 68°F or 66°F, or as I prefer.

What I have done is to locate myself at a good place in the servo loop, in the thermal divider, part way between the source of cool air and the thermostat. It's not cheap to cool the whole room to 66°F, but I can make sure that I'm in the region where the temperature really is as cool as I like.

If I really have to cool off the whole room so that everybody is comfortable, then this scheme doesn't help much. But at least I can make sure that only the room where I'm located will be cooled. Letting the rest of the house stay hot may be acceptable, and more comfortable—and save a lot of money!

Hey, when I was a kid, most people heated just two or three rooms of their houses. Bedrooms and other rooms were mostly left unheated in cool weather. Nobody assumed a right to affordable energy to keep every room toasty warm in winter—or cool in summer. Maybe we're headed back there.

Here in San Francisco, we get natural air conditioning on many days, so I have never bought an air conditioner. But the summertime weather does run cool. The claim that "The coldest winter I ever spent was a summer in San Francisco," is a great line, and partly true.

Okay—now that summer's cool weather is here, I will put my computer table right in front of the hot-air duct. I'll drape some fabric all over the tabletop, down to the floor, to hold the heat. I can set the thermostat at 63°F, but because I'm closer to the heat source, I can be comfy and warm even when the rest of the room is chilly. I can stay much warmer than the thermostat setting because I'm putting myself at the right place in the "thermal divider."

In fact, if natural gas prices continue to go up, I might just buy an air conditioner. Of course, I will only want to run it as an air conditioner, one or two days in a summer, or more likely, in the fall, when we get most of our warm weather. But during the winter and the rest of the year, I will mount it backwards in a window. I'll need a special mounting so the controls and front panel won't get wet, but that's not hard. I'll just let it run as needed, pumping cool air outside, and pumping heat into the house.

If I apply 1 kW to any resistive space heater, I can't get more than 1 kW of heat into my house. If I generate 1 BTU/second, I only generate 1055 W. If I burn one "therm" of gas in an efficient furnace, I may get better than 90% of those 100,000 BTUs to warm my house. But if I run 1 kW-hour of electric power into my backwards air conditioner, I can get 3 or 4 kW-hours of heat pumped into my house. If the inside air and outside air are only 5°F to 15°F apart, I might even get more than a gain of five—to be determined. If the outside temperature is more than 30°F or 40°F below the house's temp, the gain still may be better than two! This gain might vary a lot, depending on the model or type of the air conditioner. Still, when the cost of energy gets ridiculous, spending $200 for a good air conditioner could be a good investment. More shortly—in two weeks.

All for now. / Comments invited!

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What's All this Finite-Gain Stuff, Anyhow? (Part 2)

Back in around 1963, we had a whole bunch of controversies at Philbrick Researches. We were getting a bunch of new solid-state operational amplifiers, some with high voltage gain, and others with moderate gain. A lot of debates and arguments erupted. One guy even argued that an op amp with low input impedance was better than high impedance. I didn't quite agree with him on that.

Also, most of these op amps had a collector-loaded output with high output impedance, quite different from the low output impedances of the cathode-followers of our older vacuum-tube amplifiers. Even though these op amps didn't have terribly high voltage gain at full load (such as A_V = 50,000 at R_L = 5 kΩ), the gain would rise by a factor of 10, if you only had to drive a light load. So, a user could achieve better precision with light loads—a nice feature.

(A while ago, there was an engineer who liked to argue that an ordinary op amp with a high dc gain, such as 2 million, didn't have any better useful gain because you could only use this gain at frequencies below 1 Hz. He refused to hear my point that if you asked this amplifier to amplify a square wave at 100 Hz, the op amp with high gain would settle (in much less time than 0.1 ms) to a 10-times better accuracy than an op amp with a mediocre gain, such as 200,000. He was wrong, and he didn't want to hear about it.)

One Philbrick engineer ran a full analysis with equations. Using a big flock of them, he showed that an op amp with high output impedance didn't suffer appreciably in ordinary applications. They're the same equations as the ones I worked out again last week, below.

It's been well known for years, even before 1960, that the gain of an op amp in a typical case is:

$-V_{OUT}$ = Ideal Relationship × Error Factor

where the Error Factor is:

$$[1/(1 + 1/A_V \times \beta)]$$

For example: the ideal relationship for a simple inverting amplifier is:

$$-V_{OUT} = V_{IN} \times R_F/R_{IN}$$

and the Error Factor is:

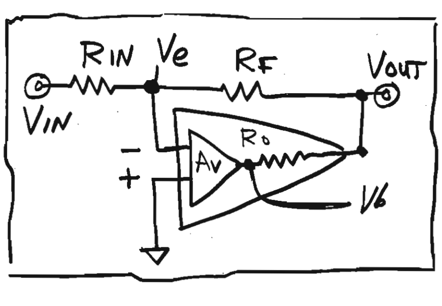
$$\{1/[1 + (R_F + R_{IN})/A_V \times R_{IN}]\}$$

Further, that Philbrick engineer defined the Relative Error, R.E., as:

$$R.E. = V_{OUT}\,(1 - \text{Error Factor})/\,V_{OUT} \times \text{Error Factor}$$

But, this all assumes that the voltage gain, A_V, is largely invariant of output load. If the amplifier's output resistance, R_O, isn't low, then these assumptions aren't valid. These engineers used a few pages to show this *(see Equation Listing)*.

I checked out the equations. It looked like fun! If I chose the right values, I could make this equation blow up! I went out in the lab and built up a unity-gain inverter. I picked a couple of *appropriately selected* resistors, and plugged in a couple of *appropriately selected* op amps. These were experimental op amps with A_V = 50,000 specified at a light load of 100 kΩ—but a much lower A_V when R_L was 5 kΩ. I ran some measurements, then went over to the design area and declared, "This equation blows up, and the Relative Error is—infinity!"



The engineers said, "No, that can't be." But I declared that I had measured these op amps as unity-gain inverters, and the Relative Error was infinity! That's much higher than 1000! In fact, using these new experimental amplifiers, the signal gain of the unity-gain inverter was zero!

The engineers couldn't believe this, and they spilled out of their offices to see what I was doing wrong. I showed them that V_{IN} was a certain amplitude, several millivolts peak-to-peak (p-p), and on the same scale, the output was 0.0 mV p-p. They were horrified (and very skeptical). But I showed them that our standard P65As didn't have this kind of problem. Their gain was pretty good. What was going wrong? They asked me to show them the schematic of what I was doing. Fine *(see the figure)*.

So I showed them the math, that when the R_F is very low, the Error Factor can fall rapidly toward zero. Then, too, the Relative Error could be outrageously bad (large) just because the signal gain became about zero, and the output signal was thus—about zero. I pointed out that maybe the "Relative Error" wasn't a very good or useful parameter if it behaved so badly!

I showed them that the Error Factor becomes 0.0 when $R_F = 1/g_m$, where "g_m" is the transconductance of the op amp, or ΔI_{OUT} per ΔV_{IN}. Effectively, the voltage gain of the op amp is:

$A_V = g_m \times R_L$, (or to be more precise: × R_L parallel to R_O parallel to R_F)

In this case, the g_m of the little experimental op amp was barely 1.11 mho.

EQUATION LISTING

$$\frac{V_{IN} - V_e}{R_{IN}} = \frac{V_e - V_{OUT}}{R_F} \qquad (1)$$

$$\frac{V_{IN} - V_e}{R_{IN}} = \frac{V_e - V_b}{R_F + R_O} \qquad (2)$$

$$V_e = \frac{V_b}{A_V} \qquad (3)$$

where: $V_{OS} \cong 0$, $I_B \cong 0$, and A_V is NEGATIVE

First, regroup Eq. 2:

$$\frac{V_{IN}}{R_{IN}} + \frac{V_b}{R_F + R_O} = \frac{V_e}{R_{IN}} + \frac{V_e}{R_F + R_O}$$

This becomes, when you insert $V_e = \frac{V_b}{A_V}$,

$$V_b = -V_{IN}\left(\frac{R_F + R_O}{R_{IN}}\right)\left(\frac{1}{1 - \frac{1}{A_V}\left(\frac{R_F + R_O + R_{IN}}{R_{IN}}\right)}\right)$$

$$\text{and: } V_e = \frac{V_b}{A_V} = -\frac{V_{IN}}{A_V}\left(\frac{R_F + R_O}{R_{IN}}\right)\left(\frac{1}{1 - \frac{1}{A_V}\left(\frac{R_F + R_O + R_{IN}}{R_{IN}}\right)}\right)$$

Now, rearrange Eq. 1:

$$\frac{V_{OUT}}{R_F} + \frac{V_{IN}}{R_{IN}} = V_e\left(\frac{1}{R_F} + \frac{1}{R_{IN}}\right) = V_e\left(\frac{R_F + R_{IN}}{R_F \times R_{IN}}\right)$$

Substitute in V_e:

$$\frac{V_{OUT}}{R_F} = -\frac{V_{IN}}{R_{IN}} - \frac{V_{IN}}{A_V}\left(\frac{R_F + R_{IN}}{R_F \times R_{IN}}\right)\left(\frac{R_F + R_O}{R_{IN}}\right)\left(\frac{1}{1 - \frac{1}{A_V}\left(\frac{R_F + R_O + R_{IN}}{R_{IN}}\right)}\right)$$

$$\text{so: } V_{OUT} = -V_{IN}\left(\frac{R_F}{R_{IN}}\right)\left[1 + \left(\frac{R_F + R_{IN}}{R_{IN}}\right)\left(\frac{R_F + R_O}{R_F}\right)\frac{1}{A_V}\left(\frac{1}{1 - \frac{1}{A_V}\left(\frac{R_F + R_O + R_{IN}}{R_{IN}}\right)}\right)\right]$$

Thus, while we usually say:

$$V_{OUT} \cong -V_{IN}\left(\frac{R_F}{R_{IN}}\right)$$

$$\text{Actually, } V_{OUT} = -V_{IN}\left(\frac{R_F}{R_{IN}}\right) \times \text{Error Factor}$$

$$\text{where: Error Factor} = \left[1 + \frac{1}{A_V}\left(\frac{R_F + R_{IN}}{R_{IN}}\right)\left(\frac{R_F + R_O}{R_F}\right)\left(\frac{1}{1 - \frac{1}{A_V}\left(\frac{R_F + R_O + R_{IN}}{R_{IN}}\right)}\right)\right]$$

Don't forget that A_V is a *negative* number!

So if $R_F \cong \frac{R_O}{A_V}$, the Error Factor approaches ZERO!

So, the equations bear out the results that you get when you wire it up. When $R_F = 0.9\ \Omega$, the signal gain will be zero, no matter the ratio of R_{IN} to R_F. The Error Factor will be zero, so the output will be zero, and if the Relative Error is defined as (Error in V_{OUT})/(V_{OUT}), then the Relative Error will be—infinity!

Even though my example was aimed to provide ridiculous results, it indicated that an amplifier with low g_m is likely to give relatively poor gain accuracy in ordinary applications. The op amps with poor g_m and poor voltage gain, even at loads as heavy as 5 kΩ, were largely discredited. From then on, a minimum gain of 20,000 was tolerated only for the cheapest op amps, and all new general-purpose designs had to do 50,000 minimum, with a 5-kΩ load. So the g_m was at least as high as 10 mhos.

(A way to look at this example is that op amps with low R_O can provide better gain accuracy with heavy loads. They can be said to have better g_m. Most modern high-performance op amps have emitter-follower outputs and, thus, lower R_O and higher voltage gain with any reasonable load. Although many rail-to-rail op amps don't have follower outputs—they get their precision in other ways—not all available op amps have very good gain accuracy with heavy loads.)

In the future (in several months), I'll talk more about the transconductance (g_m) of op amps. It's not always the best way to analyze a circuit, but it can provide some very good insights!

All for now. / Comments invited!

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Note: I really wanted to print this column on the *theoretical* aspects of finite gain first, but it was more important to first print last month's *practical* column about finite gain *(April 30, p. 95)*. Also, concerning last month's column, Bob Milne suggested that an air-conditioner's normal thermostat wouldn't work very well if the *outside* temperature varied while you were only trying to hold a reasonably stable *indoor* temperature. Of course, he's right, but it wouldn't be too hard to swap in a suitable thermostat to control the indoor temperature. /RAP

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

pease porridge

Bob's Mailbox

If any of you readers don't know why it's important to stand far away from taut cable or rope, here are the reasons! /rap

Dear Bob:

Would you believe I just got the latest issue of *Electronic Design*? The first thing I did was find your column to read. Much to my surprise, it was about knots (ELECTRONIC DESIGN, *March 5, p. 156)*. This stirred up a painful memory for me.

It was a Friday morning in February, 1976, on the Columbia River Bar, just outside of Ilwaco, Wash., at the USCG's Motor Lifeboat School. There were about six of us on a 44-ft. MLB practicing towing a disabled boat through the breakers just off of Jetty "A." The boat that we were towing was a 25-ft. surf boat used by the Coast Guard to get close to the beach. Attached to the surf boat were a 1.5-in. (diameter) double-braided Samson (nylon) line, about 20 ft. long, plus a 3-in. double-braided Samson, about 80 ft. long. We used a sheet bend to attach the two lines, using the 3-in. line as the bight.

Myself and one other person were outside of the relative safety of Cox'ns flat, toward the stern. The Cox'n did a good job of powering through a 12- to 15-ft. breaker. I turned back to watch how he would do pulling the surf boat through the same breaker. I saw the bow of the surf boat start through the backside of the breaker about 100 ft. behind us, when the sheet bend let go. The sight of a 3-in. line whipping at you is not fun! The line didn't even touch the water before hitting us.

I caught a bight of that line on the right side of my face. The other guy got hit in the back with a bight of line. You could see the individual threads of the braid in the welt on his back. My nose and right eye immediately swelled up so that I couldn't see from that side, and my left eye was very watery. All 80 ft. of the 3-in. line was draped across the beam of the boat and in the water on both sides. At the board of inquiry, it was decided that two half-hitches should have also been employed. From then on, the USCG's MLB school has taught to use two half-hitches along with the sheet bend. As for my nose, there's a small bump on the right side.

Terry L. Kerr
via e-mail

Wow, Terry, the concept of "seeing the bullet that hit me" is frightening. It must be pretty scary to see the hawser headed right at you, knowing what's coming next. At least it wasn't a steel cable. I guess there's never too much safety when it comes to standing in a safe place, far from the danger of the taut hawser—and adding those half-hitches.—RAP

Dear Bob, My Man:

I thoroughly enjoyed your piece on knots in the March 5 issue. 'Tis nice to step out of the lab once in a while, isn't it? If the length of your beard is any indication, you certainly remember the good old days of waxed lacing cord, used in nigh every piece of precircuit-board electronics equipment—and even some post-pc-board applications. *(I have seen people who were required to use it, but I never considered that as the best way to make reliable circuits. I never had to use it myself, and usually my technicians didn't have to either. /rap)*

I remember the *ARRL Handbooks* from that era had an extensive section on wire lacing and the proper way to tie the hitches. If you did them incorrectly, one tug would unwind a week's worth of intensive labor on your latest Heathkit! Well, all of that had become a lost art with the advent of nylon Ty-Raps and other clones—or so I had thought.

For a few years, I worked in a telco central office, wired together with all of the latest and greatest fastening technology. Crawling around the equipment racks all day, I would usually emerge with my arms looking like they had been through a meat grinder. No matter how flush you cut a Ty-Rap, you would always have those sharp edges.

A couple of years ago, we expanded our telco operations and enlisted the help of a Canadian telco firm to assist with the substantial move. Lo and behold, these old geezers wired up the telco office with—you guessed it—waxed lacing wire! The result was nothing short of beautiful, and they were every bit as fast as I was with my newfangled Ty-Rap gun. Best of all, the bundles were smooth! I didn't carve up my forearms fishing wires through bundles. I could emerge from close encounters of the telco kind with nary a scratch! There must have been 900,000 knots tied in that installation, and every one was correct and perfectly evenly spaced. As a result of this, I have ejected my Ty-Rap gun from my workbench and retaught myself the fine art of wire-lacing. From one old knot to another.

Eric Nichols, KL7AJ
via e-mail

Thanks for writing, Eric. I'm not a big Ty-Rap fan either. Best regards.—RAP

Dear Bob:

In your column on knots, you say, "You should never...use a granny knot...as it's likely to jam up or slip." "Jam up" and "slip" are polar opposites. If it jams, it won't slip. So I would think that a granny is a safer knot than a square knot.

David Hadaway
via e-mail

Hello, David. No, the condemnation of the granny is because it may hold, or it may slip, or it may jam. You can't be sure what's going to happen. In other words, if I added three half-hitches to a granny so it couldn't slip, it would probably jam and be very difficult to untie.—RAP

All for now. / Comments invited!
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pease porridge

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Mailbox

May 21, 2001

Analog Debate
Roger Caffins' letter, was spot-on. Unfortunately, the problem he highlights is only the latest symptom of a much wider problem. Many of your readers have followed Bob Pease's articles about fuzzy logic, and I think this is another manifestation of the same syndrome. Why? Because fuzzy logic in the vast majority of its applications is nothing more than a crutch for those who don't understand control theory and control systems engineering. Perhaps even worse, it has become a marketing tool that's driving its use in many products. So in these cases, it's a fashion accessory—there to catch the eye, not for any practical reason (let alone those quoted). As consumers we all know this will happen, but as engineers we should know the difference.

Trickle-Down Benefits
I can't believe that your magazine would print such an article as , unless the magazine was looking to spur a lot of letters to the editor.

Mr. Kamm obviously forgets that, since its inception, the manned space program has continuously provided "trickle-down" benefits in many areas of life, especially with regard to the medical field. Remote monitoring of human vitals, treatments for disease, and advanced prosthetics (to name only a few) can all follow short trails directly back to the manned space program.

As a lawyer friend of mine likes to say, "You can buy an expert witness to testify anything you want the court to hear for the right price." I would expect to see such drivel as this column in a left-wing political magazine, not in one read by the very people who developed the tools that are saving lives today. It's irresponsible for any magazine to take potshots at a branch of engineering that is so responsible for the improved lives of innumerable people.

Respond As An Engineer
Lawrence Kamm's indictment of the manned space program is regrettable in raising the tired strawman of the "biggest porkbarrel in history." This program has cost almost nothing compared to the benefits it has produced. The unmanned space program he lauds wouldn't exist without it. Its stimulation of the imagination in this country, and creation of prestige for this country from outsiders, makes it more worthwhile than almost any other government project.

The Soviet Union, which everyone amuses themselves by lambasting, knew better than anyone the value of prestige. Its launch of Sputnik spurred us to achieve something far beyond the ordinary. The purpose of government spending is to purchase what's needed but couldn't or wouldn't be paid for by individuals. Hopefully, President Bush won't throw away this jewel of our national imagination.

In another vein, Paul Schick's editorial response to the California energy crisis was odd indeed. The letter suggested that we do nothing except build until there's no green left and wait for the inevitable energy war. That's hardly the response of an engineer, someone who should solve problems with what's at hand. We have an astounding amount of wasted energy that could be "unwasted," which I suppose is equivalent to the dirty word "conserved." It's high time engineers realized that products and services aren't well engineered if they waste resources.

Light Pollution Crisis
Lack of quality control for outdoor lighting is having a significant impact on environmental quality. An odd note of interest is that public agencies are fostering light-pollution problems through their own programs. For example, shoreline lighting practices on waterfront structures permitted by the Army Corps of Engineers, state agencies, and local wetlands boards are causing adverse impacts to the wildlife habitat they're supposed to protect.

These same shoreline lighting practices are compromising boating safety at night. Boat operators must navigate waterways using the universal channel markers that can't be seen at night due to the excessive glare from shoreline lights. This causes groundings and accidents. The U.S. Coast Guard and local marine police all agree that shoreline lights are a safety nuisance. They point the finger at local governments as being responsible for regulating shoreline lights. Local governments point the finger back and say it's the federal and state agencies' fault because they regulate boating safety.

The bottom line is that all of these environmental and boating safety agencies recognize the problem but aren't doing anything about it.

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What's All This Tee Network Stuff, Anyhow?

A few dozen years ago, somebody asked me how to compute the transform between a *TEE* (or *WYE)* of resistors and the *DELTA* of resistors shown in the figure. I did all of the calculations and posted a copy of them inside a cabinet. The equations stayed there for over 10 years, until I neglected to transfer them to my new cabinet. Now, because somebody asked me to, I must do them again. Note that I show a tentative connection among the three legs of each network, as if to summing point, ground, and V_{OUT}, which is typical. But these resistor networks can be connected to any circuit.

If you tell me your values for a Tee (or Wye), I can choose the right R values and make a Delta, and the resistor networks will be perfectly equivalent for their resistance. You won't be able to tell them apart (except perhaps for their capacitive strays). Conversely, if you have a Delta network of resistors, I can make a perfect equivalent with a Wye. So why would anybody use a Tee (or Wye) instead of a real resistor?

You might not have a 100-MΩ resistor lying around if you need a 100-MΩ feedback resistance for an op amp. But if you did, it might have poor quality and a poor tempco. With a decent RN65D 10-MΩ film resistor, you could put that in a Tee as R1, with R2 = 9 kΩ, and R3 = 1 kΩ (both RN55D, ±1%). We'll call this Case 1, and it will give you a feedback resistance, R_C, of 100 MΩ, with pretty good stability and tempco. (The equations for R_C below would indicate 100.01 MΩ, but that's not a significant discrepancy.)

If you need to do some *really* high-impedance work, you could go out and buy a 10^{10}-Ω resistor for R1 and use 10 kΩ/100 Ω as R2/R3 to get a feedback resistance of 10^{12} Ω (Case 2). Sometimes a 10^{10}-Ω resistor has better tolerances, better tempco, and better stability than a higher value, such as 10^{12} Ω. Alright, this sounds like a great invention, so why not just do it?

The reason is because the output accuracy and stability are degraded. Let's go back and look at Case 1. A good op amp's output may still be pretty stable, but it's likely to be 10 times more drifty or noisy than if you used a *real* 100-MΩ resistor. The increase in the noise gain is the problem. One way to look at this is that you must get a feedback resistance of 100 MΩ, but the R_B of about 10 MΩ to ground causes the noise gain (ratio of V_{OUT} per V_{OS}) to rise to at least 10 (maybe more). Every 1 mV of the op amp's V_{OS} causes 10 mV of offset on the output. Every microvolt of noise causes 10 µV of noise at the output.

In Case 2, the noise gain is up considerably, from 1 to 100. So in many cases, using a Tee network for the feedback resistance of an op amp is tolerable only if you can convince yourself that the excess noise and drift (as well as the decreased bandwidth) are acceptable. When *is* a good time to use a Tee network? A few situations come to mind:

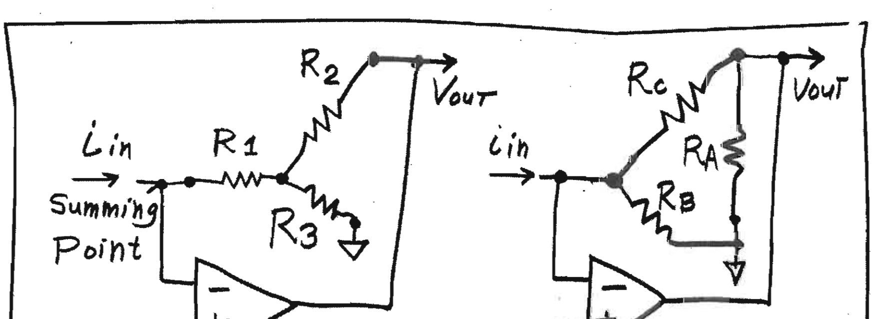
(A) If you only need to use a noise gain (= 1 + R2/R3) in the range of 1.2 to 2, to let you trim the gain, using a pot.

(B) When you're only going to use a noise gain of about 1.5 to 2 or 3, to let you adjust the feedback resistance (the gain) to the value you need, that's not a standard R value, such as 3,141.6 MΩ.

(C) If you're trying to get broad bandwidth, and the lower value of R1 provides higher frequency response because your value of R1 is lower than the feedback resistance—given a fixed amount of capacitance across R1. That may help your response, but keep the noise gain to a fairly small value—usually less than 5 or 10. Still, you should implement good layout to minimize the capacitance across R1.

(D) When you want to engineer the R2/R3 ratio with a special tempco, to compensate for a poor tempco in R1. *(See "What's All This Thermistor Stuff, Anyhow?"* ELECTRONIC DESIGN, *Jan. 6, 1997, p. 171.)*

Other than that, it's *usually* a poor idea to use a Tee network with R2/R3 greater than 2 or 3, unless you can prove that the advantages are good and the disadvantages acceptable. My reply is directed to the reader who asked, "What's wrong with using a Tee network, anyhow?"



How to compute the R values for the Wye-Delta Transform: If you just read the open-circuit voltage at the "input" node and apply a voltage between V_{OUT} and ground, you can easily see that R2/R3 = R_C/R_B, or R2 = R3 (R_C/R_B). If you ground both the V_{OUT} and the ground, it's easy to see that the conductance from the input to ground is:

$$(1/R_B + 1/R_C) = 1/(R1 + R2||R3)$$

Substitute the first equation into the second equation to get:

$$R_C = (R1R2 + R1R3 + R2R3)/R3$$

Similarly:

$$R_B = (R1R2 + R1R3 + R2R3)/R2,$$
$$R_A = (R1R2 + R1R3 + R2R3)/R1$$

Likewise, one can compute the reverse transform:

$$R3 = R_AR_B/(R_A + R_B + R_C),$$
$$R2 = R_AR_C/(R_A + R_B + R_C),$$
$$R1 = R_BR_C/(R_A + R_B + R_C)$$

So now you too can paste a copy of these equations inside your resistor cabinet, and now you know why Tee networks won't give you something for nothing!

All for now. / Comments invited!
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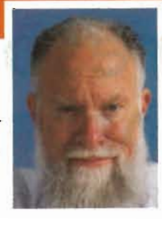
Mailbox Bonus

Hi Bob:

I took a course in motor controls a few years ago, and I remember the instructor vaguely touching on the concept of an eddy brake as a method of inexpensive low-end speed control. Unfortunately now that I have a need for such an item, I can't find any information on it. Could you shine any light on this concept? Thanks.

Dan Slaughter
via e-mail

I don't think I have this in any book I know. Have you tried the Web? Or a good library? Sliding a piece (or rotating a disk) of aluminum through a strong magnetic field generates a lot of "drag." I'm sure this would work well with an electromagnet, as well as with a permanent magnet. Obviously you can't turn an electromagnet on or off very fast, but this will work, if clean friction is what you need. Have fun!!—RAP



BOB PEASE obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.

Bob's Mailbox

Dear Bob:

I have a question for you. Can you give a simple description of the differences between commercial, industrial, and military temperature grades of the same chip? Are they the same silicon, just with looser specs for the wider temperature ranges? Are they the same silicon, but tested to prove that they meet specs over the wider temperature ranges? Or, is the chip design/manufacturing process different for the different grades? *(Almost never! See below. /rap)* If so, what are the differences, in nonspecialist language?

Stewart Cobb
via e-mail

For openers, not all ICs are the same. Some get different kinds of testing. Some ICs have good yields to MIL grades, while some have poor yields. We try to not let that happen, but sometimes despite our best plans, it just happens. Sometimes the demand for MIL-grade parts or A-grade parts just goes sky-high. An LM101A, an LM201A, and an LM301A are all the same chip. In almost all IC examples, the MIL grade and the commercial grade are all the same chip. (But the LM3876 is a completely different circuit than an LM2876, which also is a completely different circuit from an LM1876, so beware of these cases!)

In most cases, a MIL-grade chip (1xx-grade) is a selected part, with low errors at room temperature. So it starts out as an A-grade part and then gets extra testing to make sure it's well-behaved at high and low temperatures. This usually involves 100% testing at hot and cold (125°C and –55°C) to show that the part works well at extremes.

An LM2xx that's rated for the industrial range may be the same kind of selected best-grade part, but it may or may not get tested at 85°C or –25°C. It won't need that if it gets high yield. We can usually correlate the performance at 85°C or –25°C with some test results at room temperature. Most people love that because it helps to drive down the manufacturing costs and end-user prices.

In the old days, we brought out 100, 200, and 300 grades for many, but not all, parts. Recently, most of the older 200s were discontinued, as there wasn't a large market demand. These were mostly LM2xxHs in a hermetic package. In the last couple of years, many ICs have been brought out with just the industrial grade because that's what a lot of people want. These almost entirely come in plastic packaging, which makes quite a difference!

If you buy a 300-grade part, is it a part that flunked an LM1xx test at room temperature? Maybe, but maybe not. Is it a part that flunked an LM1xx test, hot or cold? Possible, but not likely. If we screen for good parts and sell 1000 parts a week of MIL parts, and reject 600 parts, hot and cold, these may be rejects for some very tight specs. Plus, these 600 "rejects" might be salted in with 20,000 good LM3xxs, on a typical week. So the number of LM1xx rejects in a batch of LM3xxs might be pretty small.

What are the chances of getting an LM3xx that actually meets LM1xx specs? In many cases, they're quite high. Maybe 30% or 60% of these 3xxs might meet the 1xx specs—or in some cases, 3%; maybe 90%; maybe 0%. I recall when I designed the LM333, the 3-A version of the LM137, that we selected out the better grades at room temperature—these were basically the LM333A grade parts—and sent 200 pieces through the hot and cold tests. When we got back the test results, the yield was 99%. The two parts that didn't pass might have been due to handler or contactor failures. This 99% yield isn't true for all parts.

Now you might ask, "What's the chance of an LM3xx working really badly at hot or cold temperatures?" It turns out that in many situations, the chances are less than 1%. An LM3xx might go slightly out of spec, but if its usage is in a not too critical circuit, then you may never see improper operation. For example, an LM324 might have 5 mV of V_{OS} at room temperature, and 7 mV at 125°C. But that's not going to cause any significant failure in most applications. On the other hand, the LM368H-2.5 was released to production, even though we couldn't make an LM168H-2.5; the part would oscillate at some cold temperatures, but we let it go anyway. We decided that it wasn't worth the effort to cure the oscillation. You certainly wouldn't want to use that over a wide range! There may be some parts with big problems like that, although I don't know about very many, and that's okay with me. I don't have to be an expert.

Of course, some people want to use an LM3xx in cost-sensitive industrial systems, like in a traffic-light controller where the temperatures are quite hot and cold. We caution them that they can't get mad at us if some LM3xxs don't work perfectly, hot or cold. They should comprehensively evaluate at least their first 20 systems at all temperatures, sweeping from hot to cold. If the systems still work, and they keep working at even hotter and colder temperatures than the needed range, then that's pretty encouraging. Then we caution them to test at least a sample of their systems—5%, 10%, or 20%—at good hot and cold temperatures, to make sure nothing bad is getting in. In many cases, this probably works well—so long as you aren't putting in LM368H-2.5s!!!

I can't speak for every other IC manufacturer. Many may make parts that are just fine, hot and cold. I suspect that others make parts that are really bad outside of their rated range, but I don't know much about that. I would guess that many other IC makers do tests that are comparable to what we do, and if you ask them, they ought to tell you. I hope that's a helpful answer to your question.—RAP

All for now. / Comments invited!
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pease porridge

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Mailbox

June 18, 2001

They're Knot Fooling Around
I read Bob Pease's article with great interest . I have always liked a really good knot. Loading the ol' xmas tree on the roof of the '55 Chevy was always a task. Knowing a good knot to hold the lumber from sliding off the roof of the '70 Plymouth was a concern. So I had studied several knots, and used them quite successfully.

One of my coworkers is an Eagle Scout and an active scout leader in Troop 463 in Northford, Conn. He sent me this site on the very subject of knots. In fact, they're animated too:

As a convinced bowline-tier for close to 50 years, I'm happy to see you give my favorite knot some good words. Apart from its useful features of being both nonslip and easy to undo, the bowline has other virtues.

The strength of a rope is adversely affected by tying knots in it, and the bowline does better than most by maintaining about 85% of the original rope strength. (This was the result of a series of tests made on nylon climbing rope with an engineering-school tensile testing machine, a fine application for this equipment. Note that the result is likely to depend on the construction and material in the rope, because knots tend to damage ropes by "choking" the line, and this will probably be material-dependent.)

But probably the best feature of the bowline is that you can tie it neatly around yourself with just one hand, a trick which is highly recommended to the steeplejack (or mountaineer) who is hanging on grimly with one hand and both feet, while dropped a line from above and asked to tie it around his middle. I've even used this for real a couple of times. If you haven't seen it done, tell me and I'll make a sketch.

I wonder how many other e-mails you have received telling you that the bowline you pictured is not a regular bowline, as the end is outside the loop instead of inside. What you have drawn is often referred to as the ring or stopper bowline. However, as Geoffrey Budworth, IGKT, says, "Knotting ventured, knotting gained."

Maybe Money Isn't Everything
Regarding , that's not always the case. Was Vietnam richer than the U.S.? I don't think so. The U.S. was fighting the wrong war. The people that U.S. soldiers were trying to prop up weren't wanted by the majority of Vietnamese. They couldn't put enough soldiers in the field to defeat the Vietnamese on the ground, and there wasn't enough fuel in the world to defeat them from the air.

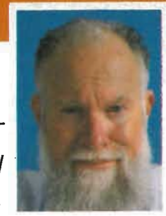
Perhaps the nature of anti-aircraft missiles has changed to such an extent that agile fighters, such as the Harrier, which can fly backwards to some extent, are no longer important. But their agility certainly was important to the British victory in the Falkland Islands, as it enabled them to dodge missiles which would otherwise have destroyed them.

The best manuals I have seen in the recent past came from Morphy Richards (breadmaking machine) and Rigaku-Denki (automated crystallographic x-ray spectrometer).

At the height of the "fuel crisis" of the 1970s, my wife and I got lost on the way from Cambridge, England, to Edinburgh, Scotland, at night. We drove to the top of a hill and looked to see if we could see our way better from up there. What we saw astonished us. At a time when our government was imploring us to save energy at all costs, at 3 a.m., as far as the eye could see, it was a sea of light—and bright light. Why didn't we install street lights that come on when something near them moves? The technology is there, and I'm pretty sure it would save its cost in very little time.

A Good Read On TZAs
I just added Bob Pease's excellent article on TZAs to my collection . I also have the Graeme book and a new book by Philip Hobbs, . Have you seen this one? In my opinion, it's very good, and Chapter 18 was one of the most intuitive treatments of TZA tradeoffs and tricks I've seen. I have no connection or stake in it other than the fact that Philip once helped me, gratis via e-mail, with some opto-electronic design problems I had.

Note Of Appreciation
I wanted to write a lot sooner but did not manage. I wish to express my appreciation over your article . It feels good to read articles like this. I shall preserve it for a long time and show it to people I like.



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What's All This Floobydust Stuff, Anyhow? (Part 10)

People have asked me about some good new books, such as those that I mentioned and recommended at the recent Linear Seminars. So here is a list. Most of these books are available at Amazon.com. But even if you decide not to buy a book there, you might want to visit the site and read what other people say about the book...but I like to buy my books from Amazon.com.

National Semiconductor 1980 Audio-Radio Handbook, reprinted in April 2001, ISBN 1-882589-35-4. This $19 book is not published or sold by NSC, but rather by Old Colony Sound Labs, 305 Union St., P.O. Box 876, Peterborough, NH 03458-0876. You can also order it from *www.audioXpress.com*, or by phone at (888) 924-9465. Many people are nostalgic about this classic book, and now you can get a clean new copy. Note: this is the book that first brought you "Floobydust" (= "Miscellaneous").

Hot Air Rises and Heat Sinks: Everything You Know About Cooling Electronics is Wrong, by Tony Kordyban, ISBN 0791800741. It costs about $40. This little book cleverly debunks many old myths concerning thermal management for circuit boards and rack-mounted equipment. If you like my writing, you'll enjoy his because he's a great storyteller.

This book *literally* won't be much use for an engineer designing an IC. But it will be of great use to the IC applications engineers who have to help customers get the ICs built up on boards, and get the heat out. I recommend this book to anyone who builds circuits on pc boards, even if they only get a little warm. This book is especially good for educating young engineers who haven't learned this thermal stuff in school. Kordyban uses computers—yet doesn't just trust them. He checks the computer results with sanity checks, calibration tests, and sample problems. This is an excellent piece of technical writing and fun to read. Good man!

Building Electro-Optical Systems: Making it All Work, by Philip Hobbs, ISBN 0471246816, priced at approximately $125. Several people recommended this great new book to me after reading my column on "Transimpedance Stuff." I went to ask my librarian to buy it, but she had it already.

I like this guy's attitude. He points out how most scholars propose an experiment and mention their experimental apparatus. Then they write a whole technical paper about the data, the analysis, and the conclusions, but never write about the troubles they had getting the apparatus to work right, or the changes they had to make to get valid data. Mr. Hobbs talks about exactly that. Good man. As with some other books that aren't cheap, if you work in this field, you ought to buy this book. If you don't work in this field, then you should still read it. So ask your librarian to buy it. You should be on good terms with your librarian, as you want to have pull on new book purchases. Also, check out good reviews at Amazon.com.

High-Speed Digital Design—A Handbook of Black Magic, by Howard Johnson, 1993, ISBN 013395724. About $85, it's a classic for anybody who has to learn modern digital design and layout. See good reviews at Amazon.com.

Analog Circuit Design, by Dennis Feucht. I recommended this book on paper, a few years ago, but it ran out of print. Now on CD, it's updated and expanded slightly. It runs for around $64. Inquire at *dennis@innovatia.com*, or visit *www.innovatia.com*.

Passive Components, by Ian Sinclair, Butterworth-Heinemann, 2001. I recommended this $38 book too a few years ago, but it went out of print. Now it's back in an updated version, ISBN 075064933X.

Noise Reduction Techniques in Electronic Systems—Second Edition, by Henry Ott, ISBN 0471850683, running approximately $95. This is a good general book on how to avoid noise problems.

Some people have asked about the German, Dutch, and French translations of my *Troubleshooting* book. These are, respectively:

Troubleshooting in Analogschaltungen, Ursache-Wirkung-Felhlerbeseitigung, ISBN 3-89576-059-5, *www.elektor.de/books/books.htm*.

Voorkomen is beter...Over foutzoeken in analoge schakelingen, ISBN 90-5381-088-9; *www.elektuur.nl/books/books.htm*.

Un coup ça marche, un coup ça marche pas Heur(t)s et malheurs des circuits analogiques, ISBN 2-8661-090-3, *www.elektor.presse.fr/books/books.htm*.

The Russian translation of this book is presently at the printers. More info will come shortly. Watch this space.

The original *Troubleshooting Analog Circuits*, Butterworth-Heinemann-Newnes (1991), now in its twelfth or thirteenth printing, ISBN 0-7506-9499-8. Send a check for $36.95 to Robert A. Pease, 682 Miramar Ave., San Francisco, CA 94112-1232

How To Drive Into ACCIDENTS—and How NOT To, Pease Publishing, 1998. Send a $21.95 check to Robert A. Pease (address as above). For further info see *www.transtronix.com*. (Both of Pease's books have a discount price of $54.)

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pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Note: *When I was on the road, a guy told me about some special software called "CP COOL" that's supposed to significantly slow down your CP clock when you're just typing, and thus considerably prolong a laptop's battery life. I tried searching for this on the Web, as the guy suggested. But for some reason, it wouldn't show up for me. Can anybody tell me where to find this? I'll let you know if it's any good.*

Hello Mr. Pease:

Not so long ago I realized the reason why my shoelaces got loose so often. I have used something like a "granny slip knot" to tie them. Afterwards, I noticed that this was the case with those of my friends who had the same "problem." Even though I am now very familiar with all kinds of knots used, like in maritime traditions, it seems hard to recognize some bad habits that I learned 40 years ago. Thank you for your interesting articles.

Hannu Mikkola
via e-mail

I don't think the "slip granny" is your problem. Usually, I'm careful to tie my shoelaces with a slip reef knot, and careful to not use a slip granny. But recently, I tried a "slip granny," and it doesn't flop apart all day. So I think the knot isn't the problem.

Rather, your shoelaces don't like to stay tied—they're too slippery, and hard or stiff. It's like comparing nylon or polypropylene rope to cotton or hemp. Some ropes and some cords just do not like to stay tied, no matter the strength of the rope. Old cotton and hemp do like to stay tied. Try some cotton laces, and you'll see the untying problem go away. Let me know how this experiment works out! If you buy nice cotton laces, they will probably stay tied much better than those that came with your shoes. I often throw away (or retire) the laces of a new pair of shoes if they refuse to stay tied.—RAP

Hi Bob:

Concerning the recent Bob's Mailbox (ELECTRONIC DESIGN, *March 19, p. 136)*, what's the fuss about hybrid vehicles? This isn't new earth-shattering technology. Railroads have been successfully using hybrid diesel/electric traction systems for many decades.

Ira A. Wilner
via e-mail

Ira, these are new hybrid cars of types not seen much before. Some of the time they run on batteries, sometimes on gas engines, and sometimes they run on both. Diesel-electrics have been around for a long time, but they're not "hybrid" in that sense, as they never run on batteries alone!—RAP

Bob:

I didn't read "What's All This Knot Stuff, Anyhow?" (ELECTRONIC DESIGN, *March 5, p. 142)*, but I saw the feedback on it in "Bob's Mailbox" (ELECTRONIC DESIGN, *May 21, p. 99)*. Let me add this account to *Why It's Important to Stand Away from Taut Cable*. I'm talking about taut steel here.

From 1969 through 1973, I worked as a radio engineer at WWJ in Detroit. The guy there who got me the job was a great big hulk, sometimes referred to as a "human crane." One day he recounted for me how, always having been big for his age, he could successfully lie about his age. Thus at 16, he was able to attain a job on the Detroit waterfront, unloading coal barges. Each day with a lunch packed in a bag, his mother drove him down to the dock, where the coal barge would be moored. To unload the barge evenly, it was winched back and forth by pulling or releasing steel cables from each end, so that the appropriate hatch would be brought to the unloading machinery. This required coordination of the two winch operators, one at each end of the barge.

One day when he arrived, the unloading activity had been suspended and there was a commotion on the dock. He quickly found out that the winch operators had crossed their signals, each winching his end in until one of the steel cables snapped and whipped down the dock. As he approached, they were just hosing down the area where the recoiling flying cable had cut a man in two and killed him.

I can't remember just what stimulated big Jim's recall of this incident on that particular day. A few of us in the radio studio were sailors and we probably were talking about winching in sheets, halyards, and cable tensions in strong wind. I will never forget that story.

Frank Laperriere
via e-mail

I doubt if I can forget it either, and I wasn't even there! Best regards.—RAP

Dear Bob:

Your note about air conditioner thermostat efficacy and system gain brought this to mind: when the new wing was built for our labs (~1981), there was great difficulty in getting the HVAC system to stabilize. It was cold outside, the building was very cold in the mornings, and the heat would cycle wildly. Several attempts to fix or patch the system failed. Finally, the problem was found. This advanced HVAC system had an outdoor temperature sensor, which was used as an "anticipator" circuit to start the furnaces early on cold mornings. The outdoor sensor had been carefully installed *inside* the building! Once the sensor was moved outside, we had warm, stable (temperature-wise, anyway) offices.

Ken Welles
via e-mail

Lovely!!! Hilarious! A tiny error like that can screw you up for months!—RAP

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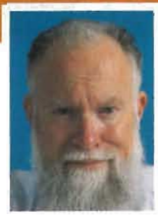

What's All This ROI Stuff, Anyhow? (Part I)

Due to my recent comments on Ed Tipler's proposal (ELECTRONIC DESIGN, *April 16, p. 109*) for improved efficiency of ordinary (capacitor-start) electric motors, several readers wrote to criticize, question, or doubt me. Some were very skeptical that an improvement of 20% could be achieved. They thought perhaps I was fooled by a 20% improvement in the IN-efficiency. But the data I saw indicated that a real improvement is likely. There will be considerably less amperes* flowing through the motor. Ask me for a copy of the information.

But one reader really got on my case because he thought I was confused about the return on investment (ROI) of the improved motor efficiency. He pointed out that a 20% efficiency improvement on a big amount was a big deal, and that a 20% improvement on a small matter would really be a very small deal.

I replied that I certainly agreed with that generalization. He implied that I hadn't considered the ROI, which was going to be lousy. My general comment on this was, "Do they really not teach about ROI in school?" Then I began to think that maybe they don't teach this in school. So I decided to write about this topic. Also, I sat down and computed out the actual ROI on the back of an envelope, which I had not done before. More on this later.

I recently read in my local newspaper about a Vermonter who was very proudly ecology-minded. She went out and bought a new hybrid car that got very good energy efficiency—very good mpg—AND THEN SHE DROVE IT AS LITTLE AS POSSIBLE!

How sad! If a person can drive as little as 20 or 40 miles/week, that person should buy a good old gas-guzzling car, because for that amount of driving, the mediocre mpg that person is getting is not a big deal. The best way to cut down on smog (and gas consumption) is to have people who drive many miles buy modern cars and replace their inefficient and *smoggy* old cars. Then, people who don't drive much should purchase these old cars cheaply. There's no point in throwing away an old car if it runs well and will also keep you dry in the rain!

(One of the cheapest ways to cut down on smog is not to decree that all new cars must have their emissions cut to nothing. Instead, buy up old smoggy cars and GIVE those drivers modern low-smog cars. This may not happen, but you have to think about what's going on. Is it reasonable to flog a car maker to spend all of its money to make cars with the lowest possible pollution emissions, while 100 such high-tech cars might not cause as much pollution as one old car? I'll let somebody else worry about that.)

This reader also observed that, rather than worrying about motors, I should consider getting a more efficient car. The savings there would be much more important, he argued. Okay, let's do some ROI computations. On average, I drive about 54 miles/day at around 27 mpg, which equals about 2 gallons. At $1.90/gallon, that costs around $3.80. If I could trade in my old car for a car that would really get 33 mpg, it sure would be nice to save 70 cents/day on gasoline. This would save me more energy costs than 11 half-horsepower motors! (And I don't even own 11 such motors.)

But what investment would I have to make to realize that savings? If I bought a good $8000 car on three-year terms, it would cost me at least $9 or $10/day. That isn't a great investment to make to save only 70 cents/day. I refuse to do it. Certainly, I can think of better places to invest my money!

But how about the environmental cost of getting a new car made? If I spend $8000 on a car, doesn't that cause some damage to the environment, with the smoke and carbon dioxide caused by steel-making and all of the scrap involved in making a new car? I really think I'm better off staying with my old car.

Additionally, the reader tried to chide me about the environmental costs. He even wanted me to count in the cost of buying a new pulley for the motor, and the environmental cost of throwing away an old pulley. But the scheme of adding a capacitor won't require any change in pulley size, so that was a specious problem.

Every month, many newspapers and magazines (as well as newsletters from your power company) recommend that we all replace old incandescent light bulbs with fluorescents. Sure. But while there are great potential savings if you replace an ordinary (incandescent) 100-W bulb with a fluorescent bulb, it would not save you any money for a terribly long time if you're replacing a bulb that's only run for a few hours per week. Next month I'll talk about ROI on electrical stuff, including Mr. Tipler's proposal. So stay tuned!

All for now. / Comments invited!
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*Ask me for directions on how to find the *very good* Museum of Electricity, dedicated to Andre-Marie Ampere, in Polymieux, France, just 12 km northwest of Lyon.

pease porridge

BOB PEASE *obtained a BSEE from MIT in 1961 and is Staff Scientist at National Semiconductor Corp., Santa Clara, Calif.*

Bob's Mailbox

Dear Bob:

A few days after I read your article on wind-up error in my stack of delinquent reading (ELECTRONIC DESIGN, *Nov. 6, 2000, p. 146)*, I encountered an ad in a mechanical rag mentioning wind-up. My interest was sparked.

I haven't done a motion servo for at least 15 years. But I ran into a virtually identical problem with a 100-kW medical MRI gradient coil driver and a similar-size HV supply for a medical CT scanner a few years ago. Ultimately, output E/L limited the coil driver slew rate, and I/C limited the HV supply. A position or velocity servo is typically limited by force/mass or torque/moment of inertia. The medical coil driver and HV supply were absolutely unforgiving of discontinuities in the settling response or resultant overshoot.

Wind-up error results from accumulated charge in the error integrator when the output can't keep up with the demand. The ultimate solution was to keep the loop closed by rate-limiting the demand voltage to just below the natural slew limit of the system. The modified system slewed slower, but closed on equilibrium much faster—i.e., "slower is faster," or, "if it hurts to do that, don't do that."

Ron Bax
via e-mail

Hello, Ron. I agree with your "slower is faster," or, "if it hurts to do that, don't do that." But for a truck with variable mass, one cannot foresee what may be the natural slew rate of the system. The acceleration rate on an upgrade will greatly differ from that on a downgrade, so you just about have to use anti-wind-up!—RAP

Dear Bob:

I found your "What's All This Tee Network Stuff, Anyhow?" column interesting (ELECTRONIC DESIGN, *June 4, p. 113)*. Like you, I learned the wye-delta, delta-wye transforms as an EE student over 30 years ago. My professor made an interesting observation, which he taught us. It has allowed me to remember how to do them over the years from memory. It is as follows: If you want to do the wye-delta transform, rewrite the impedances (resistances) as admittances (conductances), and the form of each transform expression will be the same as for the delta-wye direction. For instance, using the labels of your figure:

$G1 = 1/R1$, $G2 = 1/R2$, etc. Now:
$G_C = G1G2/(G1 + G2 + G3)$
$G_A = G2G3/(G1 + G2 + G3)$ and
$G_B = G1G3/(G1 + G2 + G3)$. Then:
$R1 = 1/G1$, etc.

It's easy to remember to use admittances because Y is the symbol normally used for those quantities. The beautiful symmetry between series and parallel circuits makes this possible, no doubt. I teach this to my electronic instrumentation students through the example of calculating the transfer function or voltage-gain expression for an op-amp circuit with a Tee network in the feedback path, as in your example.

There are several ways to obtain the solution. But if you use the wye-delta transform to calculate R_C, and recognize that the "–" op-amp input is a virtual ground, you can get the inverting voltage-gain expression as R_C/R_{IN} (not shown on your diagram). I have also used the expressions that you derived in a previous article to show the effect of finite open-loop voltage gain upon closed-loop voltage-gain accuracy.

Elvin Stepp
via e-mail

Thanks for the comments, Elvin!—RAP

Bob:

In the second paragraph of "What's All This Tee Network Stuff, Anyhow?" you stated something that has always been my belief, too: "You won't be able to tell them apart (except perhaps for their capacitive strays)." But as I read further, I realized that you have found a way! Imagine this. Build a test jig that consists of the circuit shown in the figure in a box with three terminals on the top of the box. Bring out the nodes where the R1, R2, R3 network connects to the circuit. Use a noisy op amp for convenience in measuring noise levels. Then, connect either the Tee network or the delta network. Using the values in your first example, the output noise will be 100 times greater *(Nope. /rap)* when the delta network is connected, which should be easily distinguishable.

Rodger Rosenbaum
via e-mail

Not at all. The noise gain and the noise will be exactly the same for both cases. Go ahead and try it!—RAP

Dear Bob:

I've made two AA-cell red LED "night-vision flashlights" over the past six years for sailing friends. I removed the glass incandescent element from the bulb base and mounted the LED and a 47-Ω series resistor in its place.

I just installed my homemade LED anchor light on my sailboat. It uses 12 white (5600 mcd) LEDs connected in four groups of three, which are in series, driven by the LM317L current source at 20 mA. The total consumption is 80 mA, for a consumption of 1 W at 12 V. The normal anchor-light lamp is 10 W. The four panels are mounted vertically in a square, and the three LEDs are angled 30° apart (/|\). This covers the full visible circle with the 12 LEDs. It may not be visible for the legal one-mile range, but it sure looks effective in the dark.

Greg Mansfield
via e-mail

Thanks for the notes, Greg!—RAP

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pease porridge

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What's All This ROI Stuff, Anyhow? (Part 2)

I'm sitting here typing at 11 p.m. by the light of a 100-W incandescent bulb. Not a fluorescent? No, *not* a fluorescent bulb. Why not? Because I am definitely willing to pay a penny per hour for good quality of light to make my job easier and my life better. Let's look at the return on investment (ROI). If I invest $4 in a new high-efficiency light bulb, what's my ROI? If I replace a cheap incandescent 100-W bulb with a 22-W fluorescent, I can save 1.872 kWh/day, and at 10 cents/kWh, that's 18.7 cents/day. That high-efficiency bulb can pay for itself in 22 days.

That's fine—if I'm running the light 24 hours/day. On the other hand, if I'm running it just 1 hour/week (and many of the lights in my house run only that amount), then the bulb will pay for itself in about 10 years. I'd consider that a lousy payback, a poor ROI, and I wouldn't do that.

In the real world, many other factors exist. If a fluorescent light is turned on and off a lot, its life will be shortened. In such cases, a fluorescent might not save nearly as much as expected, because its life will be degraded. I've heard that a fluorescent light may last 20,000 hours minus five minutes every time the lamp is turned on. A cheap incandescent bulb might last 1000 hours minus 0.1 second every time it's turned on. You figure it out. If a lamp is located in a fixture that makes changing it difficult, the cost of labor for replacing bulbs could be significant. Not all of these computations are simple and objective. Some aspects might be quite subjective.

Lastly, let's get down to Mr. Tipler's proposal (ELECTRONIC DESIGN, *April 16, p. 109*). Is there any motor in my house that runs more than 10 hours/day? No. There aren't any 0.5-hp motors running even 1 hour/day. But if your job involves motors that run more than 6 hours/day, such as in the air-conditioning, heating, ventilation, or pumping areas of your company—and there might be dozens or hundreds of them—then this may get interesting.

For example, let's presume that you have several 0.5-hp electrical motors that are several years old. Admittedly, it's not easy to find data on this motor. You may have to take your own data to be sure of the savings factors. If this motor runs around full power for about half the time (about 12 hours/day), it will use around (at least) 500 W × 12 hours, or 6 kWh/day. Let's make some simple assumptions—there's some possibility of: (A) a 10% improvement in efficiency; (B) 12 hours of operation/day (or more); (C) electricity costing 10 cents/kWh.

Under such conditions, a 0.5-hp motor will use 6 kWh, or 60 cents/day, and the savings could be 6 cents/day. Fine. You could save $22 a year, which is enough to pay for a good 25-µF, 400-V ac-rated capacitor that can be used to accomplish these savings.

Is this a good ROI? Well, it's in the right ballpark. If you can invest $22 and get a $22 savings within a year, that's a fairly good ROI. Next year, you may save another $20! So we're headed in the right direction. But if that motor only runs 1 hour/day, then the ROI will be decreased by a factor of 12.

On the other hand, if the cost of energy rises by a factor of two, the time for payback will be decreased by a factor of two. If the motor runs 24 hours/day, there's an additional factor of two. If the real improvement isn't just 10%, but rather 20%, then that's another possible factor of two.

I want all of you readers to grasp the idea that we're working with some fairly crude areas of uncertainty. It would be great if we could make these estimates with 30% uncertainty. Some people like to rely on spreadsheets with 0.01% resolution. Even the tiniest improvement would be great. Yeah, sure. (I don't like computerized spreadsheets, anyhow.*)

In the real world, 10% or 20% improvements are hard to pin down, and the uncertainties are bigger than that. What if the price of energy doesn't go up by 2:1? What if it does? My main point is that if there's a big percentage of improvement in a very small item, then I agree with my grouchy friend—that isn't significant. But you have to look at the whole picture. What about the cost of labor for connecting the capacitor and installing it in a safe housing? If an electrician had to convert 100 such motors, could he do it for a labor cost of less than $20 each? Maybe.

Another factor is that the motor seems to run cooler, as it draws less power and less current. So the motor may last longer, and that's a good feature. This might be quite important and not easy to quantize.

Based on the data in the report, I wasn't able to see the exact improvement in watts. But it seems to indicate that if a motor runs at less than 100% of rated power, the power savings (by adding the capacitor) is probably about the same 6 cents/day and does not decrease as a fixed percentage of power drawn. So, you don't have to consider this only for motors run at full rated power.

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*Refer to "What's All This Spreadsheet Stuff, Anyhow?" (ELECTRONIC DESIGN, *August 20, 1992, p. 73*).

pease porridge

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Bob's Mailbox

Dear Bob:

Re: "What's All This Motorcycling Stuff, Anyhow?" (ELECTRONIC DESIGN, *Feb. 9, 1998, p. 141*). I just ran across it and I have a theory for why the front brakes on bikes would be controlled by the left hand. Because most people are dominant with their right hand, they would squeeze harder with that hand, particularly under duress. When you slam on the front brakes, you're more likely to flip your bike. Therefore, they put the front brake on the left, the weaker side for most people.

Besides, you want the back brake on the right so that you can really clamp down on the brake when you want to skid out and leave black/blue marks up and down your parents' driveway. *(I do that in low gear! /rap)*

Adam J. Tolman
via e-mail

My right hand is definitely stronger than my left hand, and I can use it to hold on the front brakes at the desired level and servo the rear wheel just about on, or just barely off, the ground. You can't slow down any faster than that. My left hand isn't strong enough to do that with ease. So, the first thing I did when I bought my new mountain bike was to have the bike shop swap the brake levers and their cables. Now, my right hand works the front brakes—as all imported bikes used to 30, 40, and 50 years ago.—RAP

Hello Bob:

A few remarks on knots (ELECTRONIC DESIGN, *March 5, p. 142*): The square knot isn't intended to be used to tie a rope to something, nor to tie two ropes together, as you imply in your article. The square knot, also called the reef knot in sailing, is used for lashing something to its place, like a sail to its boom (that's reefing), or like tying your laces. It should never be in a situation where it can be juggled around by wind, water, or whatnot, as it will slip. *(Can you name a knot that will not slip in this situation? Can you name any knot better than a square knot with two half-hitches, on each tail end, for this situation? Do you think a sheet bend is much better? You still have to put the half-hitches after the sheet bend. /rap)*

As for the bowline, your drawing represents a left-hand bowline, which is insecure in comparison to the normal bowline. *(Yes, I have heard that's called a Dutch bowline. My goof. /rap)* The bowline's main characteristic (other than the difficulty to get it right for future sailors) is an extremely reliable hold under all conditions, and yet it's so easy to untie. *(I don't find it terribly easy to untie. /rap)* As for the granny knot, you correctly state that it's downright dangerous.

Knots, like most things in life, must stay simple. Adding half-hitches here and there messes them up and increases the difficulty of untying them. *(Yeah, but you still have to name a knot that's better than my mediocre square knot with two half-hitches. /rap)* And believe me, if tying a reliable knot is of the utmost importance, being able to untie a knot also can be a lifesaver!

Adrian Corfield
via e-mail

That's true. I'll cover this in Part II of Knot Stuff.—RAP

Hi Bob:

The e-mail that you received from Dan Slaughter about the eddy brake (ELECTRONIC DESIGN, *June 4, p. 113*) reminded me of a demonstration on this principle in physics class during my undergrad days. The setup was an aluminum sector that was swinging back and forth through the gap of an electromagnet. Then the professor energized the electromagnet, and the piece of aluminum seemed to stop moving instantaneously! *(Actually, it should slow down a lot. But it shouldn't necessarily stop instantly—not if it's at the peak of the swing. /rap)* It was pretty amazing!

On a completely different note, with the energy crunch we're having in California, have you noticed LED-based traffic lights replacing incandescents up there in the Bay Area? We're seeing quite a few here in Southern Cal. First it was a few red lights, then green ones here and there, and now even the yellow (amber, as some call them) are showing up all over the streets. Sounds like a great idea to me. The efficiency has to be much, much greater, and they probably last almost forever. Even if a few LEDs burn out, it's still functional. *(It will be interesting to see the pattern if one LED goes bad! /rap)*

Jim Ford
via e-mail

In Sunnyvale, the red lights have been changed over to LEDs for a couple of years. Plus, when the light turns red, it blinks red for about 1/4 second with increased intensity. Then it goes out for 1/4 second, and then comes on and stays on at red. That blink is a great attention getter!—RAP

Dear Bob:

Our agency coordinator remembers a piece of test equipment that he used at UL called a "Seely" box. It allowed the user to measure changes in coil resistance in a solenoid, or motor, without the need to remove the ac source. The resistance, he says, was measured with a bridge. The box was filled with capacitors. There was a two-pole switch, for "measure" and "run," but the device still worked while the measurement was taken. How do you think it worked?

Bill Shaw
via e-mail

Bill, I have no idea. I don't think that you gave me enough information to tell. Perhaps some of our readers can shed some light on it.—RAP

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October 01, 2001

What's All This Algebraic Equation Stuff, Anyhow? (Part 1)

You guys may have noticed that recently, I have been showing you a lot of algebraic equations. I really don't like to use, or generate, algebraic equations. Sometimes they're much messier than just doing numerical evaluations.

For example, to evaluate the re-sponse of a filter, I usually like to plug in the R and C values, and simplify as much as possible before I do the full analysis. I just prefer to get the numbers into number form as early as possible. But sometimes to generalize properly, it really makes sense to write down an equation.

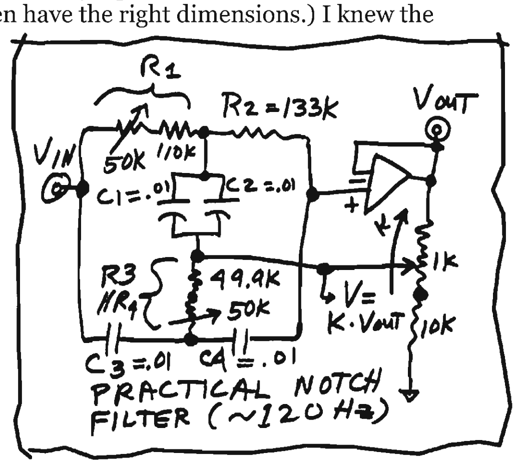
For instance, I gave you the Wye-Delta and Delta-Wye transforms in "Tee Network Stuff" Electronic Design. I listed a big equation in "V_{BE} Stuff" Electronic Design and set up some equations in "Transimpedance Stuff" Electronic Design. So it's not that I can't do algebraic equations—I just prefer not to, usually.

Recently, I had planned on going to an excellent museum. But I wanted to correctly finish the derivation of an equation that had been giving me trouble and wasting a lot of my time, as I had obviously been making errors. This just happens to be the circuit shown in the figure.

I knew what the solution had to be like, but I was getting stupid answers and messy equations that made no sense. So I knew that I had to stop making dumb errors. (The solution I had didn't even have the right dimensions.) I knew the solution had to look very much like:

$V_{OUT} = V_{IN} \times [1 + 0 \cdot pRC + (pRC)^2]/$

$[1 + K1 \cdot pRC + (pRC)^2]$



where K1 is some function of , and pC is the reciprocal of the impedance of a capacitor: $pC = j \times 2\pi fC$. We also are going to assume that C1 = C2 = C3 = C4 = C, exactly, and that R1 = R2 = R3 = R4 = R, exactly. (Later, we will discuss how to fix things if the Rs and Cs aren't perfect.) We're assuming that the gain and CMRR of the amplifier are plenty high too (and that the gain errors and CMRR errors are small enough and linear enough) at the frequencies you're interested in. Or, if they're not quite small, we will assume we can trim them out.

I wish I could tell you that trimming R1 will trim the center frequency, trimming R3 will trim the depth of the notch, and trimming will trim the Q, with no interaction. But I can't tell you that, as there's considerable interaction. Still, it's not hard to trim to get good depth and a good center frequency. It may be nice to use 5% capacitors, and it's always reasonable to use 1% film resistors. But nothing fancy is required. In the case where you want 120 Hz, just get 0.01-µF mylars or polypropylenes for Cs, and use R ≅ 135 kΩ.

This works much better than most forms of notch filter. If you need one, this is worth building. I have some other tricks up my sleeve, too. So it's not that I can't do algebraic equations, I just prefer not to—usually. But when it's important, I know how to do them, and I can show you how as well.

I sat in my car in the museum's parking lot, sipping some beer and crunching along on about seven pages of scrap paper. Finally, I came up with the right answer. The above formula was exactly right, and the correct function for K1 turned out to be: K1 = 4 (1 –).

This means that if is very close to 1, K1 gets very small, and the Q of this filter is very high (very good). This is much easier to see, in the general case, by using the algebraic equations than by just plugging in the component values. It means that if you have gotten a good notch filter, with the right depth and the right center frequency, you can use the pot at to trim to get any Q you want without significant interaction. Next time, I will show you how to do the math.

pease porridge

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What's All This Algebraic Equation Stuff, Anyhow? (Part 2)

As I said in the last issue, I wanted to derive the equations for a network of Rs and Cs—which just happens to be an analog filter *(see the figure)*. Let's just look at the principle here. We will assume that there's an output voltage V_{OUT}, and that there's a current I1. What is V1? $V1 = V_{OUT} + I1 \times R$. If we know V_{OUT} and $k \times V_{OUT}$, then there's a current $I2 = [V_{OUT} + I1 \times R - k(V_{OUT})] \times 1/(2pC)$.

Now, we know that I3 = I1 + I2, so V_{IN} must be a nice linear function of V_{OUT} and I1, namely:

$$V_{IN} = F1[V_{OUT} + F2(I1)]$$

where F1 and F2 are functions of R1, R2, C1, and C2—and of frequency. We derived that equation just by studying the currents through R1 and R2, and C1 and C2.

Similarly, we can derive that V_{IN} also is a linear function of V_{OUT} and I1, and of R3, R4, C3, and C4—and of frequency:

$$V_{IN} = F3(V_{OUT}) + F4(I1)$$

where F3 and F4 are functions of R3, R4, C3, and C4.

Now, let's try turning around that second equation for V_{IN}, so it reads in terms of I1:

$$I1 = (1/F4) \times [V_{IN} - F3(V_{OUT})]$$

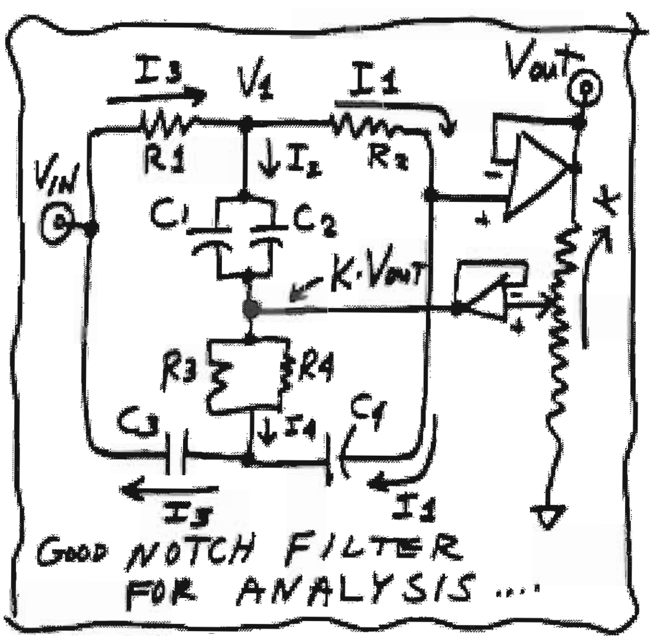
If we simply substitute that expression for I1 into the first equation, we have a messy (but conceptually simple) equation that's only in terms of V_{IN} and V_{OUT}:

$$V_{IN} = F1[V_{OUT} + F2(I1)]$$
$$= F1\{V_{OUT} + (F2/F4) \times [V_{IN} - F3(V_{OUT})]\}$$

You only have to rearrange all of these terms to get the ratio of V_{IN} to V_{OUT}. The result comes out as I showed it a couple of weeks ago.

$$\text{Gain} = [1 + (pRC)^2]/[1 + 4(1-k)pRC + (pRC)^2]$$

Of course, manipulating all the terms of all the equations isn't too simple. And you really want to avoid making sloppy errors, or you will get very discouraged. It's very helpful to know what the answer is supposed to look like so you will know when to stop. Additionally, it's good to have several large pieces of paper, 11 by 17 in. or similar, to simplify what you carry along and write down.



Comments on the actual filter: If you set $k = 0$ and just connect the bottom of the RC network to ground, you get a nice simple filter. But the Q is lousy, about 1/3. Thus, if you wanted to notch out some 120-Hz noise, you would also badly attenuate any signals at 50 or 100 Hz, and at 150 or 250 Hz. In many cases, that would be unacceptable.

So by merely adding the op amp, you can get k up to 99%, which gives you a Q of about 9. Therefore, frequencies below 100 Hz or above 140 Hz will get less than 1 dB of attenuation. Note that if k is very close to 1, it isn't important to have the second follower. You probably won't even need it, as the impedance of the output attenuator will be quite low. That makes a pretty good notch filter, and it's simple.

Next time, I will walk you through the derivation for the response for the simplest kind of RC filter, a basic Sallen-Key low-pass filter. Then if you ever have to do it yourself, you will know that it's not so hard.

I can't say that the equations above are really easy, but I think I've indicated how, by approaching it the correct way, you can get there. The same is true for other filters.

All for now. / Comments invited!

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P.S. Before putting this story to bed, I decided to be a real sport and build this notch filter again, and it worked exactly as I claimed. /rap

pease porridge

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Bob's Mailbox

October 29, 2001

Dear Bob:

I just read your article on knots with great interest (ELECTRONIC DESIGN, *March 5, p. 142*). As an outdoorsman (hunter, fisher, hiker, climber), I'm very interested in knots as well. One knot in particular seems to be a do-all for me. This knot is the basis for all climbing activities. It's the Figure-8 knot. You can tie this knot to create a bight (loop). You could then connect two ropes together. This knot is very safe, and even after being weighted, it's easy to untie. The only true downside is that it's rather bulky and prone to hang up if dragged over an edge.

Daniel Nesthus
via e-mail

Several other people also showed me the Figure-8 with the bight, which looks pretty good. Ashley does list this as #531.—RAP

Dear Bob:

I'm a regular reader of Pease Porridge and I remember reading various articles in which you had written about generating electricity while out backpacking (to charge batteries, etc.). When I saw this flashlight, I thought that you might find it interesting. Here's the link: *www.shakelight.com/revamp/*. It looks like an LED flashlight that's powered "dynamo-electrically" by shaking. The design looks pretty cool (especially the magnetic "springs") and very robust. Unfortunately, it doesn't appear to be as bright as a real flashlight.

From what I have read in your articles, this seems like the type of device that you may have already investigated. If so, please refer me to the issue in which I might find your comments. If this flashlight is new to you, I would love to hear your opinion of the device.

Joe Miguel
via e-mail

I first heard about this flashlight a few months ago. It has some nice features, but you can't bring it near magnetic tape. I would never have this near my knapsack or my home, as the chance of it erasing my videotape are just too horrifying! It's a neat idea, but obviously to keep it small and light, they didn't put much material into shielding the dc or ac magnetic fields. This isn't for me! Thanks anyhow!—RAP

Hello Bob:

Just recently discovered your series of "What's All This..." articles! Good stuff. In "Floobydust (Part 9)" (ELECTRONIC DESIGN, *Dec. 4, 2000, p. 141*), you were wondering why the Action Light guys recommend lithium/sulfur-dioxide batteries instead of alkalines or rechargeables. You might have missed this page, where they go a little more in depth about it: *www.hdssystems.com/ActionLightTechnology.htm#BatterySystems*.

From their table, it looks like alkalines would be a great choice if you plan to never run their light above its medium power setting. Alkalines are a terrible battery technology for high-current applications due to relatively high internal resistance. But they can be very good when asked to deliver low to medium currents. They also seem to want to sell their light as an "anywhere, anytime, no-maintenance" device.

Nonrechargeable lithium cells are great for this purpose because of their extremely long shelf life. Additionally, the particular chemistry they choose will operate over a very wide temperature range (−60°C to 80°C). Finally, the Saft LO26SX has an internal circuit breaker to protect the battery from an external short circuit.

They give you the choice to optimize for your use, though. It looks like you can buy an all-in-one flashlight with space for a single D cell (in which case you *must* use some kind of lithium chemistry. Otherwise, you won't have enough voltage to run the thing). Or, you can buy a light module with some terminals for hooking up a dc power source. They supply one- and two-cell battery holders and cords for use with this version of the light. In fact, the two-cell holder comes with a pair of alkalines. I suspect another motivation for single D-size lithium on the all-in-one unit is keeping the weight to an absolute minimum because the designers originally wanted to build a light for mounting on a caving helmet.

Tim Seufert
via e-mail

Tim, I still say that nonrechargeable lithiums are too expensive, good for astronauts and Everest climbers. Alkalines are cheap and available everywhere. At 1/20 the price of lithiums, they provide 50% of the energy, per ounce, for most uses. Not terrible. Rechargeable lithiums are fine for camcorders and LED flashlights.—RAP

Hi Bob:

I think the basic problem is that energy is too cheap in the U.S. Therefore, it's easy to calculate that it doesn't make any sense to invest in environmentally friendlier stuff. Anyhow, the damage made by cars, power plants, and so on will have to be paid in the future. I don't know *who* will pay, but I'm pretty sure that one won't have any opportunity to choose.

Heinz F.
via e-mail

Actually, the energy cost is about the same. It's just that in Europe, the politicians have decided to put high taxes on the energy. Now, did these politicians ever give you a chance to vote on whether or not you would like to have high taxes on energy? Or, did they just do it and assume that you would be happy? Our politicians put high taxes on gasoline and energy, even higher than on many of our other consumer goods—just not as high as your taxes.—RAP

All for now. / Comments invited!
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What's All This Algebraic Equation Stuff, Anyhow? (Part 3)

As we were saying, it can be tricky to figure out a filter, yet not impossible. Let's take the example of a basic Sallen-Key filter—the low-pass one in the figure. Do we have to worry about R3 and C3? No, they're only needed to prevent bad offset due to the bias current of a bipolar op amp. For any decent FET op amp, R3 should be 0 and there is, of course, no need for C3. They have no effect on the response anyway.

Let's say we acknowledge that when the input signal moves, there will be currents (such as I1, I2, and I3) flowing, and voltages (such as V1 and V2) moving. How can we analyze this to see the overall response of the filter? If you just start writing equations, it's easy to crawl into a morass that does not lead to an answer—which I have done many times. But here's an approach that I've used many times successfully.

In this case, let's assume that we know V_{OUT}, and work back to the front of the circuit. If we know V_{OUT}, then it's reasonable to assume that $V1 \cong V_{OUT}$, given a finite bandwidth for the op amp, so the bandwidth is much more than F_{3dB}. (If that's not the case, I will let you factor it in, that $V1 = V_{OUT} \times (1+p/\omega h)$.) Then the current I1 will be $V_{OUT} \times pC2$, where 1/pC2 is the impedance of the capacitor and p is the derivative operator *d/dt*. (Later, we may substitute in that $p = s = 2\pi jf$ (or $j\omega$).)

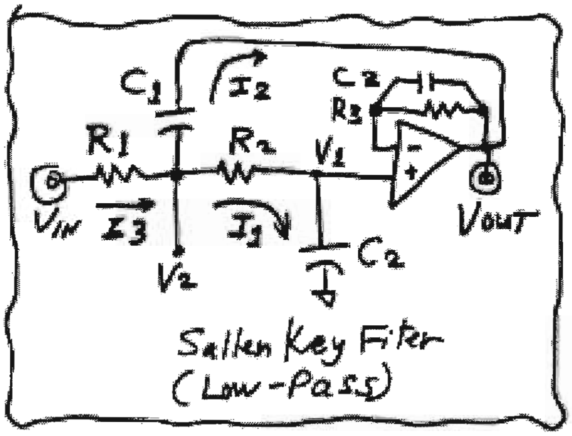
If we know that $I1 = V_{OUT} \times pC2$, then we know that V2 is I1 × R2 higher than V_{OUT}, so $V2 = V_{OUT} + I1 \times R$, or $V2 = V_{OUT} + V_{OUT}(pC2R2)$. That's good information because now that we know V2, we can compute that:

$$I2 = (V2 - Vout) \times pC1 = V_{OUT} \times p^2C2R2C1$$

Now that we know I2, we know that I2 + I1 = I3 , and the input voltage V1 will be (I1 + I2) × R1 bigger than V2. Let's stuff this all into a big equation:

$$V_{IN} = V_{OUT} \times [1 + pC1(R1+R2) + p^2R1C1R2C2]$$

The result is that $V_{IN} = F \times V_{OUT}$. This shows that the V_{IN} is normally bigger than V_{OUT} by that factor. So the useful result is:



$$V_{OUT}/V_{IN} = Gain = 1/[1 + pC2(R1+R2) + p^2R1C1R2C2]$$

Now we have shown that it's possible (I never said it was easy) to compute the frequency response of a simple RC filter with two Rs and two Cs.

This indicates that it would be possible to compute the response of analog filters with three or more Rs and three or more Cs. Not a big deal. You may use several sheets of paper, but you can get there, if you are meticulous. (In the previously noted filter with the twin Tee, there were about 16 terms, each with an average of six items, so the number of places where you can goof up is not small, but you can do it.)

If you maintain the product of R1C1R2C2 constant, the f_{20dB} and high-frequency rolloff will stay about the same. But increasing C1 while decreasing C2 can cause peaking in the frequency domain, overshoot for step response in the time domain, and even ringing. This is especially true for $C1(R1+R2) > 1.4\sqrt{R1C1R2C2}$. Fool around and see for yourself! More on this later in Part 4.

Should you have the same quality of C for C1 and C2? Nope. C1 should be a pretty good capacitor; mylar or metalized mylar may be suitable. But C2 has to be a low-leakage type, such as polypropylene. (C1 does *not*.) So C2 should be of good quality, and C1 can be cheaper. There's never any dc voltage on C1. Its leakage characteristics are not important. Neither is its soakage.

Beware of using any LM324 output stages. That can cause poor linearity and poor rejection. A preload could help. Most LM324 computer models don't tell the truth about this.

This isn't the only filter in the world, but there are many filters just like it and they have the same shape. This filter has no need for precision resistors, as they don't affect the gain. However, CM slew and CMRR nonlinearities and CM input impedance (capacitance) aren't always trivial matters. But many people like this, as I do for many cases.

All for now. / Comments invited!
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Bob's Mailbox

Dear Bob:

Your article on ROI was very interesting (ELECTRONIC DESIGN, *Aug. 6, p. 97*). I know that many people get caught out by great offers in savings on energy-efficient devices. One thing that bothers me is that the bigger picture doesn't look as good if, for example, we examine how much more energy is involved in making these energy-efficient devices in the first place. Like electric cars, which are supposed to reduce pollution, in many cases, they will just move the pollution back to an inefficient power station. Anyway, thanks for the many articles untangling jargon. Someone at S.L.A.C. once told me that jargon is something you use to find out what somebody else doesn't know, so you can snow them with it.

Robert L. English
via e-mail

Not to mention the expense and the large amounts of energy that will go into making the batteries and all the other expensive parts. Plus, the batteries have to be replaced every couple of years at a significant cost in money, energy, and pollution to the environment. Most people don't think about that. Cost to the environment doesn't always correlate with dollars saved. In many cases, it's close enough.—RAP

Robert:

Just read your "Mailbox" (ELECTRONIC DESIGN, *Sept. 17, p. 100*). Looks like Adam was going through some back issues to find the article on bicycle-brake set up (ELECTRONIC DESIGN, *Feb. 9, 1998, p. 141*). In any case, I just thought you might like to know that nearly *all bikes*—motorcycles and bicycles—used to have the front brake on the right. In 1975, the CPSC (*www.cpsc.gov*) turned its attention to bicycles (under the Federal Hazardous Materials Act, believe it or not). The problem was that they weren't cyclists themselves and considered bicycles more as toys than as transportation. That didn't stop them from making up a bunch of rules that covered *all bicycles* and not just "toy" bicycles. *(I didn't know this. Those blankety-blank bureaucrats. /rap)*

Among the most grievous errors they made was deciding that front brakes are inherently dangerous, and that the cure for this was to move the front brake to the nondominant hand. (I guess left-handers are either smarter about these matters or expendable.) The only bicycles currently normally set up with front-brake-right (in North America, at least) are cyclo-cross bikes (*www.cyclo-cross.com*). A lot of bicycle riders who also ride motorbikes set their bicycles up front-right too so that the controls are as similar as possible.

Unfortunately in North America, this front-left/rear-right stuff is so ingrained that it's probably impossible to correct now. *(Well, I have been using RH levers for the front brakes for so long that I'm impossible to cure too. /rap)* By the way, besides being a research scientist, I am a member of:

- The Bicycle Transportation Alliance
- The Washington County Bicycle Transportation Alliance
- The Beaverton BIKE Task Force
- Team Oregon
- Oregon Bicycle Racing Association

I own four bicycles personally—road, mountain, track (velodrome), and commuter—and there are 11 bicycles in our household.

Leo Baldwin
via e-mail

I have several old bikes, including a track bike, as well as the new Specialized Rockhopper A1FS, which feels pretty good. I have only ridden it 80 miles, but I'd be ready to go to Nepal tomorrow if it would let our bikes in. But (talk about bureaucrats who write rules on topics that they know nothing about), the people who run the Annapurna park district have locked almost all bikes out of the district except in January and February (peak of snowy winter), and June, July, and August (monsoon rains). So, we have postponed our trip to Annapurna until next June 1 to try to get through ahead of the rains. Thanks for writing to explain how things became the way they are today.—RAP

Dear Bob:

I've ridden street motorcycles for the last 23 years. The first thing that I do whenever I buy a bicycle for me or someone in my family is change the brake cables so the right hand actuates the front brake. I don't want any of my kids to grow up thinking that the front brake is on the left, because someday, they too may ride motorcycles. As you pointed out (ELECTRONIC DESIGN, *Sept. 17, p. 100*), the importance of the front brake for a motorcycle or bicycle can't be overstated. Also, it's important to practice using braking systems *hard* in a controlled environment to learn how to stop as quickly as possible. I have found that modulating the front brake at the point of lockup (fastest way to stop) is much easier with the dominant hand. *(Exactly my point. /rap)*

I allocate most of my cognitive resources to the right hand in any hard stop, and leave what's left over to the left hand (bicycle) or right foot (motorcycle) for the rear wheel, which is much less effective due to the weight transfer in a hard stop.

Jonathan Williams
via e-mail

The rear brakes are mostly suitable for generating heat on long downgrades.—RAP

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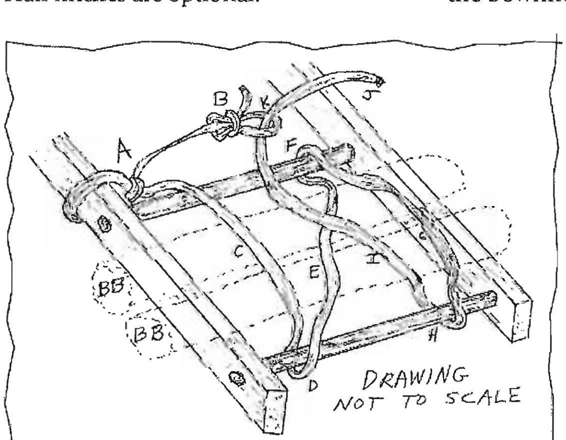
What's All This Knot Stuff, Anyhow? (Part II)

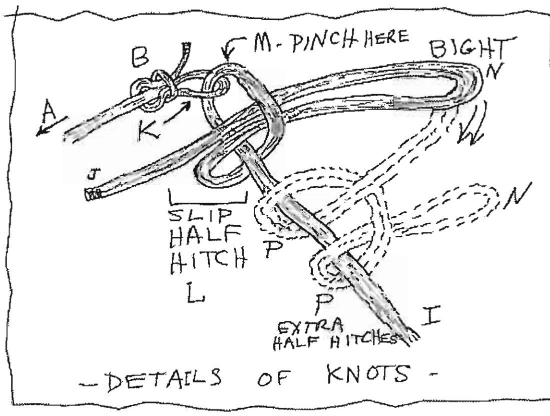
Today I'm writing about some knots that I will use this weekend to tie my tent and my sleeping bag onto the bottom of my packframe. If I need to put too much stuff inside my pack, I'll use the same knot to tie the stuff on top of my pack. By the time you're reading this, I will be using these knots to tie my duffel on top of a yak in Nepal.

I've been using these knots for about 40 years, and they're much better than any straps or "bungee cords." (Some people use these even though they're several ounces heavier.) This knot set isn't necessarily the strongest. But it's strong enough, very secure, and very easy to tie and untie. In many cases, those are *very* important features.

Let's keep this short and sweet: Assume that I have an object, or a large, bulky roll (or two or three) of stuff that I need to lash onto my packframe—or onto any frame. I start by tying a good long piece (about 12 to 15 ft.) of light nylon cord (parachute cord) to one corner of the frame at A *(see the drawing)*. I just use a few half hitches there. (The type of knot used isn't important.) I leave the short end of the cord about 15 in. long, and I tie it into a bowline at B. Half hitches are optional.



I plunk down my sleeping roll and tent as shown at BB, BB. I arrange the long end of the cord over the roll at C, then reach it around under the pack frame at D. Again I put it *over* the roll at E, *under* the frame at F, *over* the roll at G, *under* the frame at H, and back *over* the roll at I. I bring the end of the long line J through the bowline at K. Next I tie a simple slip half hitch with the long end, as shown at L *(see Details of Knots)*.



The knots are basically done, yet the cord isn't very tight. The load isn't secure, so starting at C, I lift up on the cord. I lift up at C, and push down on the roll at C. Then I pull up at E, taking up the slack at D while pushing down at C. I next pull up at G to pull the slack out of F, while pushing down at E. I repeat by pulling up at I to take up slack at H, while pushing down at G. When I get to I, I have all this slack. Now what do I do with it? I pull on the loose end J. This instantly unties the half hitch and takes up all the slack. I pull at J, then pinch the cord at M as it comes through the bowline—and I tie a new slip half hitch. Now the load is considerably tighter.

I adjust the ropes to make sure that they go around the load, or roll, in about the right places. I pull again and tighten up again, taking up slack at C, E, G, and I. I release the half hitch again, take up the slack, and tie another half hitch. Usually, one more pass gets it very tight and secure.

To finish, I take the *bight* N and pull it long enough to let me make a couple more half hitches (P, P) around the cord at I. The long end left over (J), which may be 3 or 4 ft., can be tied across the load, side to side, to provide transverse stability. Or, I just tuck it under another rope to keep the cord from flapping in the breezes. Even if you snag a cord on a tree, the knots won't come undone.

This type of knot has never come undone on me, and I almost never have to stop and take off my pack and rearrange the cord and load. Usually, it stays put. If the load shifts, I undo and loosen the cord a little, rearrange the stuff, and tighten up the cord again.

To untie this knot system, I simply undo the (very loose) double half hitches at P, P, then tug on the long line J. The slip half hitch comes apart, the knot comes completely undone, and the loosening and unloading can continue.

In Part III, in a few months, I will write about the "Dutchman," a knot to bind loads onto trucks.

All for now. / Comments invited!

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pease porridge

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Bob's Mailbox

Dear Bob:

I worked in the music recording industry for a while. The recording studios in the U.K. in the '70s wired their 1-kW amps to the speakers with 30-A, single-strand cooker wire. Sounded okay to me, but a bit loud.

Allan Hurst
via e-mail

Hello, Alan. It's easy to compute that. If you don't mind poor (high) inductance, you can use these big, fat wires. But they're awfully hard to manipulate—bulky, lumpy, stiff, awkward. Plus, low-inductance wires will give less high-frequency phase shift and less skin effect—not that anybody can hear that. If you're going to drive 1000 W into 4-Ω speakers, it would probably make sense to use heavy wires to avoid excessive heating. Hey, 15 A is a lot. I'd guess that 12- or 14-gauge ordinary lamp cord would be less awkward with less attenuation for long wires, compared to 16 or 18 gauge. But just think about this: pick any speaker wires you want, and nobody can hear any difference anyway! Thanks for writing.—RAP

Allan Hurst replies:

Bob, you're right. The wire was fat and cumbersome. But it was installed just like for a cooker—in the plaster of the walls. After all, studios weren't portable installations! I agree with you. I bet nobody could tell the difference between expensive, fancy Litz wire and cooker cable, given that both were fat enough to carry the current without undue loss.

P.S. There was a great fuss at the time about the phase shift introduced by transformers. The firm I worked for, Neve, decided to see if the problem was audible. You could certainly measure significant phase shift through a good audio transformer. So we rigged up a test jig in a posh London studio with soft-switchable amounts of shift at 3, 5, 10 kHz, etc., and ran blind tests with the local "golden ears." The results were entirely random, as we expected. I don't think that people can hear phase shift as such at high frequencies, especially because a full 360° shift at 10 kHz corresponds to moving your head about 1 inch! Most stereo imaging is down to your brain being pretty good at using the difference in time-of-arrival of transients at the two ears, to a lesser extent, amplitude, and much less again, phase (if at all), except at low frequencies when the wavelengths are big enough for coherent cancellations at both ears.

I gave up on the industry after a while, as it was impossible to correlate what the "golden ears" who bought the stuff said they wanted with any sensible engineering—though they generally had engineering managers who were a bit more sensible. I hear that the HiFi trade is now about 100 times worse.

I've been debating the evils of "objectivism" versus "subjectivism" with some guys. Some of the fantasies of the golden-ear guys are quite amusing, except that they start taking themselves seriously.—RAP

Bob:

Re: Tee networks. When I sent you the e-mail that you published in your column (ELECTRONIC DESIGN, *Aug. 20, p. 90*), I thought you would realize it was a joke and get a laugh. Maybe I could create an urban myth for electrical engineers: Bob Pease had discovered a way to tell the difference between Delta and Tee networks, other than the parasitics. I thought the excited tone of the first sentence of the second paragraph—and its exclamation point—would tip you off. But I guess I didn't have my tongue far enough in my cheek. Perhaps you should mention that it was a joke in a subsequent column.

Rodger Rosenbaum
via e-mail

No, I did not realize that it was a joke! Every week I get a letter, or e-mail, from some very serious guy arguing that I'm obviously wrong about something I said in a column, which is a bit annoying when I know that I'm right. I get responses from guys who think that I'm wrong about Taguchi Methods. I'm contacted by readers who think I'm wrong about Fuzzy Logic. I receive letters from guys who think they have discovered perpetual motion with output power bigger than the input. I even get mail from guys who think that I'm wrong about Tee networks! So I'm sorry to be so slow, but I did miss the joke!—RAP

Dear Robert:

I believe that in one of the past 12 issues of *Electronic Design*, there was a reference to a "socket/adapter" for the SOT23 family of ICs. I have searched the site with zero success. Can you help? Thanks!

Ron Raspet
via e-mail

Hello, Ron. According to NSC's Emmy Smaragda Denton, "You can find them at Fry's and in the Digi-Key catalogue. We used to send out samples of the LM45/50, etc., on a little conversion board, but we no longer do that. You can also order an LM62 demo board. The LM62 comes in a three-lead SOT23 package. URL: www.national.com/store/view_item/index.html?nsid=LM62EVAL. It costs $4.00 from us. But if you buy the parts from Digi-Key and solder them up yourself, it would probably be cheaper."

Emmy is right. I grabbed a May-August catalog for Digi-Key, and you can buy these as a "Surfboard" at about $1.50 each, for the five-pin SOT23-5, in quantities of 10. The six-pin version is a few pennies more, but it's more versatile. These are sold by Capital Advanced Technologies. I bet you can even search and find this on the Digi-Key Web site, www.digikey.com, now that we have proven that they exist. Look for Digi-Key part number 33205CA-ND. Best regards.—RAP

All for now. / Comments invited!
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