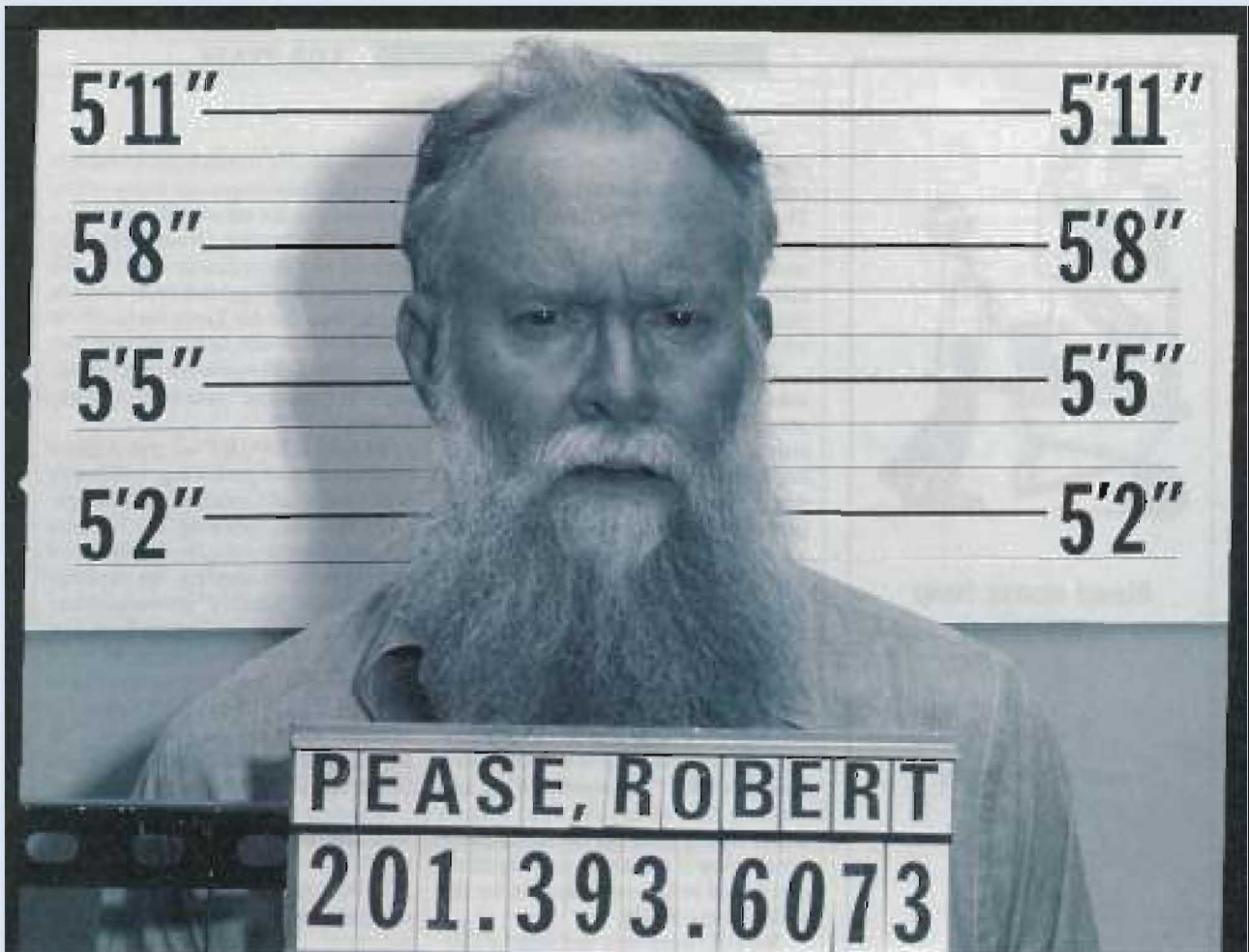


# *A Tribute to Bob Pease*

Pease Porridge – 5 (2002-2004)



## **PEASE BOOKED!**

**NOTORIOUS "ANALOG OUTLAW" SIGNS ON FOR U.S. LECTURE TOUR.**

For throwing computers out of windows and other crimes against digitalism, National Semiconductor's infamous Bob Pease—aka "The Analog Outlaw"—has been asked by the authorities to explain himself and his work in an upcoming seminar "What's All This Analog Stuff, Anyway?" Don't miss this once-in-a-lifetime event.

**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 Analog Computing Stuff, Anyhow? (Part 1)

I first joined George A. Philbrick Researches back in 1961, when Philbrick was doing some of the advanced analog computing stuff in the industry. (Note: for you young kids who weren't around then, I will explain everything later.)

At that time, Philbrick made analog computing modules—adders, subtractors, scalars, integrators, and analog multipliers/dividers—and several kinds of operational amplifiers, made with vacuum tubes, that ran on  $\pm 300$  V dc. We had fun and were profitable. (We also were expanding into solid-state amplifiers, but I will explain that another day.)

What were analog computers good for? They were good at a lot of computing tasks that modern digital computers can now do. They also could simulate functions that Spice has learned to do. Of course, like any modern computer, and as with Spice, they had definite limitations if the models were lousy. In the old days, models were oversimplified—and lousy. In the modern era, modeling is still often lousy. No surprises there.

They could simulate a lot of mechanical systems and other kinds of physical systems, such as thermal and hydraulic systems. That was the whole reason for having them in the first place. (I'll expand on this shortly.)

In their day, these systems could simulate a lot of megabytes per second—in terms of resolution of several variables. Even better, they could display their results on a big cathode-ray tube (CRT), so users could compare the output variables.

What were the weaknesses? There were dynamic ranges that were hard to compute well with full accuracy. (The upcoming digital systems were substantially unlimited, in theory, for dynamic range.) They were expensive.

They were not very easy to maintain or calibrate. This is true for most analog computers in the industry. Moreover, they were difficult to program. You had to know a lot about the system, about voltages, and about scale factors—to make it make sense when you ran the computer.

On a good day, these analog computing systems were “pancelleric.” That is, they could run at high speeds, or at slow speeds. Unfortunately, the high- and low-speed results didn't necessarily match. That's not a disaster, but it causes a confidence problem. On a good day, you could turn one knob, or dial, and watch the outputs change until you got an answer that you liked—or until you got an answer from which you could learn something. I like that part.

I plan to talk about many aspects of analog computation during the next year, especially operational amplifiers, which we now call “op amps.” But to run the operational amplifiers of 1960, which required  $\pm 300$  V dc, you need a good, stable power supply. I recently got a good old  $\pm 300$ -V supply, an R-300 from 1968. I will talk about it first, and some of the very good features of its design in the next column. To make a good voltage regulator, you need some good special-purpose op amps.

Philbrick is no longer in business. Teledyne acquired Philbrick about 30 years ago, and it then merged with Nexus Research Labs (one of Philbrick's spinoffs). Teledyne Philbrick Nexus ran for several years, then merged with Teledyne Components, formerly Amelco. In about 1985, Teledyne spun this off into Telcom. Most Philbrick products are now dead, but you can still buy a few from Telcom.

Long live Philbrick!—and the analog computers—and analog concepts—and the op amps that it helped introduce to the world!

**More About Knots:** Many people commented on “What's All This Knot Stuff, Anyhow? (Part 1)” (ELECTRONIC DESIGN, March 5, 2001, p. 142). Several readers noted that I hadn't drawn a proper bowline knot, but rather a “Dutch bowline,” which supposedly has some disadvantages. Well, I stand corrected. Several claimed to have never experienced bowlines coming untied. It's true that with some kinds of ropes, knots stay tied. But with other types or sizes of rope, knots—even good ones—tend to untie, especially if they can get slack.

The good old 1960 book, *Mountaineering—Freedom of the Hills* (p. 117), specifically recommends that half-hitches be used to “back up a bowline...for bowlines are especially prone to working loose.” This book has no ISBN number, but its Library of Congress number is 60-8907. It was published by The Mountaineers, Seattle, Wash.—RAP

**Embarrassing Typo Error:** In the recent “Equations Stuff (Part 3),” (ELECTRONIC DESIGN, Nov. 5, 2001, p. 94), I typed out that the response of the filter is:

$$V_{OUT}/V_{IN} = \text{Gain} = \frac{1}{1 + pC1(R1+R2) + p^2R1C1R2C2}$$

Actually, the C1 in the middle term was typed wrong; it should be C2:

$$V_{OUT}/V_{IN} = \text{Gain} = \frac{1}{1 + pC2(R1+R2) + p^2R1C1R2C2}$$

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**pease  
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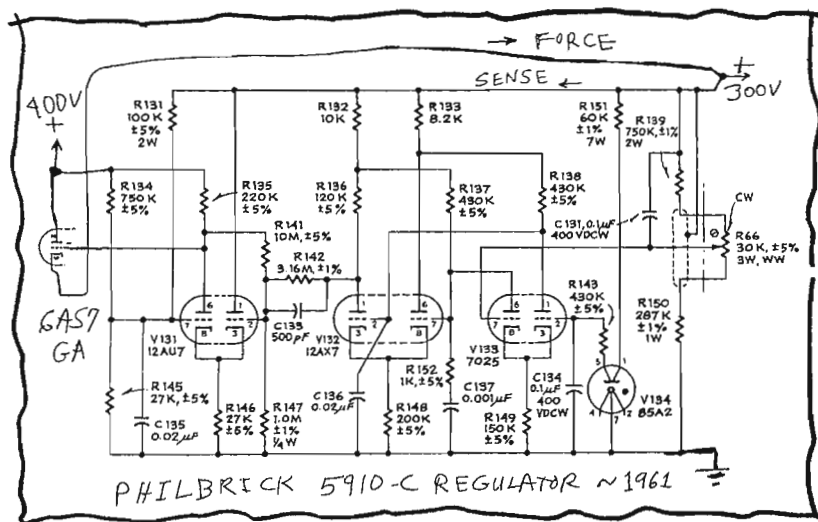
## What's All This Ripple Rejection Stuff, Anyhow? (Part 1)

Recently, I helped a guy who needed low output ripple on a power supply. His 1000-V output required low, submillivolt ripple. I designed a couple of circuits for him. Details soon. To make sure that I wasn't missing any tricks, I looked up a voltage regulator, the Philbrick 5910, designed by my old colleague Bruce Seddon about 42 years ago. It was optimized to provide  $\pm 300$  V dc at 100 mA (see the figure), or 300 mA in a larger R-300 power supply when additional output tubes are paralleled.

Anybody can design an operational amplifier (op amp) with a gain of 100,000 or 1,000,000 at dc. But this one needed to swing its output 80 V dc plus 15 V p-p at 120 Hz, with a summing-point error of less than 150  $\mu$ V ac rms. That's 100 dB of gain at around 120 Hz! Forty years ago, most regulator amplifiers had two-stage amplifiers. But this one used three dual triodes for each supply, + and - 300 V. Two honest stages of 12AX7 provide a lot of gain ( $\mu = 100$ ), and the 12AU7 ( $\mu = 20$ ) gives a good healthy drive to the grid of the output tube (6AS7GA).

Additionally, the positive feedback of R132, R133, and R141 provides much more gain—even at 120 Hz, and at dc. Although the output pass tube (6AS7GA) has a  $\mu$  of only 2, this amp can easily drive the grid to any necessary voltage, whether no-load or full-load, low-line or high-line. Also, it has submillivolt gain error, for line, load, or ripple.

There are good bypass capacitors, such as at C131 and C134, to filter and bypass the noises for frequencies above 4 Hz. That helps keep the output's noise below 250  $\mu$ V rms. This amplifier was also optimized for fast bandwidth. The output bypass capacitors (not shown) were 150  $\mu$ F at 525 VDCW, specified with good low  $R_S$ .



The 5910 dual regulator amplifier was built in a little boxy subassembly. The tubes stuck up above the box, with the passive components mounted on turret terminals along the insides of the box.

I bought a 30-year-old R-300 that was still in very good shape. I used a Variac to turn up the line voltage very slowly to "form up" the electrolytics. It would be harmful to apply full line power right away. I fired it up and it regulated nicely.

After I did a general check-out, it was time to do noise testing. I used a series stack of three 25-W light bulbs to draw  $\sim 190$  mA of load. The ripple voltage on the main ("upstream") filter capacitors rose to 9 V p-p. The output ripple-plus-noise increased from 100  $\mu$ V rms to perhaps 120  $\mu$ V—truly negligible, barely 3 ppm (p-p) of the dc output, even at full load. The ripple was barely 40  $\mu$ V p-p. Not bad! The load regulation was submillivolt, and the line regulation was very good too.

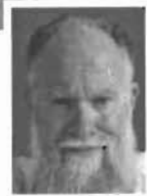
So it's encouraging that 40 years ago, a high-gain three-stage op amp could

provide excellent ripple rejection, and that old machine still runs well today. Soon, I'll show how to get low ripple voltage by adding an add-on circuit to an existing high-voltage supply. Perhaps using a fast FET op amp running on  $\pm 6$  V.

I'm looking forward to using that old R-300 to run a whole bunch of tests on various old vacuum-tube operational amplifiers. I've been waiting to do that for years! We rarely use vacuum tubes these days, but here's a good example of how tubes could do some very good work. I'll have more comments on the old art of designing with tubes, and the early days of operational amplifiers, 40 or more years ago.

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## Bob's Mailbox

Dear Bob:

I had a good laugh at your recent dialog with Allan Hurst (ELECTRONIC DESIGN, Dec. 17, 2001, p. 25) on the subject of speaker wires. Allan was right when he said that the Hi-Fi trade is now 100 times worse than it was in those days!

Consider that the "best" stereo/home-theater systems have power amps mounted just feet away from the speakers. Despite this, they will spend a fortune on massive wires, and even install "equalizers" in that short wiring! Apart from features like Litz wires, they make the cables for all parts of the system—not just the speaker wires—from "Oxygen Free" copper, whatever that is.

Not satisfied with that, these cables are marked with the direction that they're to be connected to—from the source to the destination of the signals! I had a very heated argument with one guy who insisted that if the wires were reversed, he could tell the difference in the sound! I'm in the video biz (Faroudja/Sage), and it's just as crazy.

Gwyn Edwards  
via e-mail

Get a camcorder to record the details of every test. Bet him \$1000 plus his fancy cables that he can't hear the difference, really, in a truly blind test!—RAP

Dear Bob:

I have done miscellaneous audio design for years. Originally, it was just for my own fun, analog synthesizer stuff. But in recent years, it has shifted more and more into the "audiophile" world. So, I will give you more data from an engineer's perspective.

Some of my clients are recording studios with numerous projects that they would like to do. The temptation is quite high because it's always fun to try to assume the role of creating the best device that ever existed—regardless of material and build cost. In my opinion, that's not even engineering, but more of

an art. The problem that I notice most prevalently is that the audio people are generally completely flaky. (Exactly! /rap) The terms they use are devoid of any descriptive qualities. This has stimulated me to try to develop a sense of their vocabulary, so that I can go around and sound snooty by using words like "the sound," etc. To date, I still don't know what I mean when I say it. (Neither do they. /rap)

There are noticeable audible differences when changing things such as crummy cable to decent handmade cable. But I can't really aurally quantify the difference. The ear is such a wonderful device, and extremely resolute, but it doesn't seem at all quantitative.

I think that doing custom work in this industry is quite interesting. It presents various unusual problems, bridging descriptive assessment with personal subjective assessment and providing the opportunity to work for the "golden-ears" folks that bar no bucks for the best. It offers the chance to really shine with electronic design and often forces really good engineering. This ultimately results in the simplest and most stable designs, though often ludicrous overkill.

About cables: I'm always up for the opportunity to find some audiophile who wants a custom cable made of high-purity silver wire in Teflon tubes—configured as "spread-spectrum Litz" with welded terminations to insanely expensive connectors. But what I find to be the best at home is a quick trip across the street to the hardware store. It has this nice twin-conductor, stranded-copper extension-cord stuff that's 14 gauge—for about 30 cents a foot. I think it works great. Yes, it has some of the lousy features of stranded copper, but it's fairly heavy duty and real cheap.

Maybe I would use something else if I had some big Martic Logan speakers. But because it drives some ancient Advents that I re-coned, it's great stuff!

(I agree. It's pretty good for me. But have you ever heard the results of using those flat arrays of 32-conductor wire? You parallel up all of the even wires for the ground and all of the odd wires for the speaker drive. This wire system has really low inductance. If there's any audible difference between speaker cables, these low-L ones ought to sound different, maybe even good! /rap)

Anyway, I think that participating in the modern audio field is rather amusing. There are good engineering projects for commercial items. There also are really neat custom-design opportunities, which are trying to attain the perfection that never will exist in audio, constantly pushing the audio envelope farther to the asymptotic point. (You just used an interesting phrase: "trying to attain the perfection that never will exist in audio." /rap) It's all pretty much fun, except for the part of trying to communicate with audio people. Perhaps I just have inept communication skills.

Mr. X  
via e-mail

No, I think it's the "golden-ear guys" who are inept at showing that they can hear a difference—when they can't. Best wishes in dealing with strange people like that!—RAP

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P.S. We had to postpone our bicycle trek around the Annapurnas from last October to June 1 for bureaucratic reasons. We have several people signed up, but a couple had to back out for personal reasons. We have room for one more, so inquire if you're a good, strong mountain biker looking for an excellent adventure. /rap





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**pease  
porridge**

## What's All This Drilling Stuff, Anyhow?

I had planned on drilling holes in some small strips of wood—pilot holes for brads. But I couldn't find my best small drills. I was annoyed with myself. Then I realized that I didn't have to go out and buy a drill bit of *exactly* the right size. I would just take a piece of steel wire and clip it off to make a drill bit of the correct size for the hole I needed.

I started with a short piece of an ordinary 1-1/4-in. paper clip, then drilled a hole in the wood. But the hole was too small—perhaps 0.034 in. So I took a hammer and *hammered* the end of the wire to make it a bit flatter and wider. The hole size then seemed okay—about 0.044 in. I drilled several dozen holes. The brads fit in okay, and I drove them in later. So I really have some flexibility in making drills of various sizes.

One of my favorite "specialized" drill bits is a piece of coat-hanger wire. I can start to drill through a floor with any ordinary, small drill bit. When it hits the bottom, I swap in a 6-in. piece of coat-hanger wire. If that doesn't go through, I extend it to 10 in., or more, as needed.

I have never been stumped. This hole is adequate for a couple of 22-gauge wires and useful for many household tasks, including phone wires, or a short run of speaker cable. After I have made a pilot hole, if I need a bigger hole, I hammer andpeen the tip of that "drill bit" wider, to make a hole as large as 0.2 in., or more, as required.

Many different drilling techniques are applicable. After drilling a pilot hole through from the top of the floor, I can go back from the bottom and drill up, as needed. Or, I can drill through a wall that's 10 in. thick with a 3-in. long drill and an unlimited supply of coat-hanger wire, as I did recently. Go ahead and call me a cheater, but

don't expect to stump me. Good engineers know how to solve problems with available tools.

Of course, these techniques work best on materials like wood or soft metal—not on steel. (Yes, I have good drills 4 or 6 in. long. But those are large in diameter, and I usually want just a small hole through the floor or wall.)

Sometimes people write in and ask me, "What does THIS column have to do with Analog Stuff?" Well, in this case I'm making an analog drill size, not just a digital drill size that you select from a discrete number of available sizes.

I'm still annoyed that I can't buy a light, high-rpm "1/4-in." electric drill. In the last four years, I have travelled in 24 countries, looking for 1/4-in. drills. No hardware stores, mail-order stores, or e-stores sell them. Don't try to tell me that 3/8-in. drills are "better," because they're heavier, bulkier, slower, and their chucks won't hold 0.034-in. drill bits. Maybe I'll just send off that letter to the Attorney General, complaining about the conspiracy....

A long time ago (at least 35 years), I read in some "Mechanical Design" magazine an article that praised the design of a little hand drill, which had new high-tech plastic gears. I looked closely at the picture and frowned. I went to my toolbox and dragged up the miserable, cheap, junky hand drill that I had recently bought. Yes, it was the same drill. The cheap, flimsy plastic gears didn't stay engaged. Even when the gears turned, the chuck might stop because the gear wasn't secure on its shaft. Plus, the friction was lousy. What a piece of junk, yet the magazine article bragged about its neat design.

One guy recently wrote about a problem he had shutting off his electric drill in case of a bind. If the drill grabbed and the workpiece started to

spin around or rise up, he wondered why his right hand would work so poorly at letting go of the power switch. But when drilling with his *left* hand, he could easily turn off power. He thought my idea of using my stronger *right* hand to control my bike's *front* brakes was a bad idea and that he could let go of the brakes better with his left hand. He suspected that it's a left-brain/right-brain kind of problem.

I replied that my right index finger is well trained to let go when I want it to. So I don't have any problem letting go. Besides, when drilling difficult holes, I put the object in a drill vise, with a chunk of wood under the metal, so it won't tend to grab when it starts to drill through. (If it's important to be neat, I turn the object over and drill from the reverse side, to minimize rough edges.)

I also pointed out that when my bike's rear wheel lifts off the ground, I don't want to let go of my front brake lever. I want to servo to keep the rear wheel just barely on the ground.

Note: a bicycle is inherently neutral as to which hand you use for front-wheel braking, even if your hands are not. But an electric drill always turns the same direction when you're drilling. The extra torque (in case of a stall) may try to pull the drill *out* of your right hand. But it can push the drill handle *toward* your left hand. So maybe your left hand *is* better for certain kinds of drilling. Life ain't always symmetrical!

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## Bob's Mailbox

Dear Bob:

In "What's All This Algebraic Equation Stuff, Anyhow? (Part 3)" (ELECTRONIC DESIGN, Nov. 5, 2001, p. 94), you mention: "C1 should be a pretty good capacitor, mylar or metalized mylar." I haven't been able to find mylar capacitors in my usual catalog sources, such as Mouser Electronics or Digi-Key. Have mylar capacitors become scarce like the polystyrene cap? What's a possible equivalent? Polyester? I suppose the polypropylene caps could be used, but they're quite a bit more expensive.

Chuck Olson  
via e-mail

Okay, Chuck, I guess I confused you. Sorry, it's my fault. Nobody buys a capacitor called "polyethylene teraphthalate." But that's what we're talking about. If you buy it from DuPont, they can call it "mylar." Nobody else can because DuPont holds the registered trademark on that name. Everybody else has to call it Polyester. But we're talking about the same stuff, okay? Note: I still say "Mylar" even when I shouldn't because (A) Electronic Design doesn't insist that we say "Polyester," and (B) it's too many syllables otherwise!—RAP

Bob:

Sorry to bother you with this trivial question, but it needs some real-world experience. I have a power-supply hysteresis circuit using a 3-M $\Omega$  feedback resistor. There are no special precautions in layout. Order of magnitude: what parasitic (leakage) resistance am I likely to get in parallel with this from a dirty 10-year-old board? This is a purely digital system (to the uninitiated), and it has this analog problem. Keep up the good work with your column. It's fun to read.

Fred U. Rosenberger  
via e-mail

Hi, Fred. In many cases, 300 M $\Omega$  or 3000 M $\Omega$ , if it were just ordinary dust. Maybe even as high as 30 kM $\Omega$  with glass-epoxy, best case. But a board that's soldered

badly and has bad handling of the flux could be as low as 30 k $\Omega$  or 3 k $\Omega$ . I've even seen it as low as 300  $\Omega$ !—RAP

Hello Mr. Pease:

I have a very fundamental question, and you're the first and foremost person that I had in mind to ask. How did Solid State Electronics get its name? I mean, what exactly is "Solid State" in the electronics?

Vijay Shanker  
via e-mail

Germanium, silicon, gallium arsenide, and so on are "solid" materials. Semiconductors are mostly working because of what goes on inside of solid materials. That never happened in the past. Vacuum tubes, which were the only previously known active devices, worked only in a vacuum. Because a vacuum is inherently quite different from a "solid" state, the difference in naming is clear-cut to me —RAP

Dear Bob:

I'm a graduate student at Caltech, working on a mass spectrometer. Recently, we've been having a charge problem, and the suspected cause is a teflon block. I just read some of your online comments about Teflon (ELECTRONIC DESIGN, Feb. 14, 1991, p. 115) and thought you might have some advice. The Teflon piece is upstream of the mass spectrometer. It's in direct contact with a metal lens used to steer ions in the system. The lens is held at +4 V. Could the Teflon be building up a charge simply by being in contact with the applied voltage? (I don't suspect the 4 V is nearly big enough to be a problem. /rap) Or, is the only possibility that the Teflon is gaining a charge when ions collide with it?

Rebecca Washenfelder  
via e-mail

Yeah, that sure sounds like a likely suspect, just as with my friend Arnie's test fixture. I suspect that could charge the block's voltage sky-high. Put some kind of metal over the Teflon and see if you don't get

some improvement. Then, find out why the Teflon was chosen in the first place, and get somebody's approval to re-engineer it. Some suitable resistive or conductive coating might be a good first-help.—RAP

Robert:

If I wanted to know the tightness of resistor ratios on a particular IC, or how closely matched the  $V_{BE}$  for an npn and pnp on the same device would be, could you recommend a reference source?

Denton Conrad  
via e-mail

Hello, Denton. In general, there's no way to be sure. For example, many OP-07s have a  $V_{OS}$  of 75  $\mu$ V, which would either mean 75  $\mu$ V of  $V_{OS}$  or 0.3% matching of R's. But these get trimmed, so you can't tell from that. In any given op amp, it may be hard to tell what amount of  $V_{OS}$  is caused by the transistors, and which the R's cause. Not only can't I tell you which is which, but I usually don't even know myself, most of the time. This doesn't mean that I can't make well-matched resistors, but I don't usually know how well.—RAP

Hey Bob:

When are you going to do some electronic stuff? It seems you've been off on tangents for some time now. How about giving us some of your good old circuit insight—say on ADCs, DACs, or op amps?

Fred Bandy  
via e-mail

Mix and match, Fred. More electronic stuff is in the mill. But realize that not all circuits worth analyzing (and learning from) are electronic.—RAP

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## What's All This Ginger Stuff, Anyhow?

**M**ost of you have seen the big splash about the "Segway," previously known as "Ginger," previously known as "It." It's a high-tech motorized scooter with two wheels that are—no kidding—side by side. Obviously, Ginger is a great technical accomplishment. Read the write-up of it in *Time* magazine (Dec. 10, 2001, p. 77), which was quite good, or see [www.segway.com](http://www.segway.com), especially the FAQs. Amazing. No argument. (I don't know if this is done with or without Fuzzy Logic. The FL guys all say that nonlinear problems like this one are best done with FL. Either way is okay with me.)

Let's say its unit price drops rapidly from \$8k to \$3k to \$2k. There's just one problem for Dean Kamen and his investors: no matter how many patents they have, or how well they're written, it will be too easy for competitors to do "work-arounds."

Kamen's ingenuity solves the problem of how to balance and drive a Ginger where the wheels are side by side, using two motors, five processors, a few gyros, and many fancy electronic things. (Wonderful!)

But I have seen motor-driven scooters that had zero microprocessors. (That's about twice as many microprocessors as in my car, a very strong 1970 VW Beetle.) Mr. Kamen solved a problem that hardly anybody asked to be solved.

Yes, his compact design is small—smaller than most scooters. But any engineer knows how to make a motor-powered scooter fold up to an even smaller size than Ginger. It will be great if Mr. Kamen leads us all to consider compact, efficient transportation. Some may be electric powered. Some may be gasoline powered and have more speed and more range than electric Ginger.

But here's the key point. A conventional scooter layout will always be

much cheaper, easy to drive, and safe. Who knows what kind of accident the Ginger will get into, from which it won't be able to figure a way out?

Conventional motorized scooters, whether gas or electric, are going to get a lot of attention. Their drawbacks are finite and have been well understood for over 50 years. The key is that such a scooter will always cost a small fraction of what Ginger costs—maybe 1/3 or 1/4. So while a rich yuppie might scoot down to get his mail with a Ginger, a guy on an ordinary motorized scooter can pass him. The Ginger, while cute and compact, still weighs 80 lbs. You can't very well carry it up your stairs, unless you're a real tough guy.\*

So, there's another small fraction: the weight of an ordinary motorized scooter versus Ginger's weight. Existing motorized scooters are under 25 lbs—much less than 1/2 of Ginger—not to mention, close to \$600. When you fold it up, it's smaller too. Is gasoline too messy? Use a little bottle of propane.

What a heck of a way for these brilliant guys to waste \$100 million dollars—to develop such a cute, but disadvantageous, machine. It's not imperfect, nor necessarily flawed, just not nearly as good as a much-lighter, simpler, cheaper conventional machine.

Then I spotted a serious technical problem. As the makers say, you make Ginger stop "just by thinking that you want to stop," sort of by intending to lean back. Still, while its normal braking rate may be very adequate, there's a problem: When you need to slow down hard, or stop fast, I don't think that you can make Ginger stop soon, or quickly. The reaction time is going to be lousy.

If you're rolling along at 12 mph (maximum rated speed) and want to slow down fast, the motor must speed up and push the wheels ahead of the center of gravity (CG) of the rider. Then

it can start decelerating. Well, I think that's a lousy way to respond to the needs for slowing down. Even with lousy brakes, a conventional scooter can surely stop quicker, without that delay. That's scary. This seems to be a serious flaw. Tell me I'm wrong.

Similarly, if you're going along at 12 mph and come to a downgrade, the Ginger will have to speed up and get its wheels ahead of the CG, just to maintain a constant speed, not to mention any ability to slow down.

How does an ice skater stop? He leans back and gets his feet in front of him, then turns his skates sideways and decelerates vigorously as the skate blades dig in, while still leaning back. At the last second, he stands up straight. A Ginger won't get its wheels "sideways" to stop, but it will have to lean back considerably if it wants to slow down at a decent rate. If it doesn't lean back to a scary-looking degree, it won't have good braking capability.

Any conventional scooter can stop faster. As I noted previously, that sounds scary. I'll believe Ginger when I see her. Maybe. Can Ginger tell the difference between going down a hill at constant speed, and decelerating on a level area? Oh, sure, but that doesn't make the problem easy!

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\*P.S. One guy said he wanted some brackets to hook his Ginger onto his car, and some connectors to recharge its batteries. These connectors would be called—Ginger Snaps. /rap

## Bob's Mailbox



April 15, 2002 12:00 AM  
Electronic Design  
Bob Pease

### Dear Bob:

Re: "What's All This Knot Stuff, Anyhow? (Part II)" (Electronic Design, Dec. 3, 2001, p. 88). Bob, referring to your figure, segments E and I are hypotenuses of triangles, and, therefore, longer than corresponding sides C and G. As you hike and things wiggle around, what's to keep the entire lashing from migrating to the left, so that the hypotenuses become parallel to the sides, and the lashing becomes slack? One possible fix would be to loop segment G around the right-side rail.

Steve Troy  
via e-mail

*Hi, Steve. Technically, you are right. If I had to lug a set of oiled, polished, shiny, smooth aluminum cylinders, the rope would tend to slide, and I'd have to hook loop G around the side rail. I might even have to add some horizontal lacing and bracing. But that's not a problem because I rarely carry such slippery objects—just a tent and a sleeping bag.—RAP*

### Dear Bob:

I have enjoyed your many columns over the years. Most recently, "What's All This Analog Stuff, Anyhow? (Part 1)" (Electronic Design, Jan. 7, p. 160) brought back remembrances and nostalgia. Few people know that the lunar roving vehicles were General Motors' electric cars. The mobility (motors and drives), suspension, control, and steering systems were developed at Delco in Goleta, Calif., where I spent 36 years as a practicing electrical engineer and member of the technical staff before I retired two years ago.

There were 2-hp dc electric motors in each of the four wheel hubs. Harmonic drives coupled the motor output to the wheels (hermetic). PWM control was used. Westinghouse D60-T transistors were the switches. These 200-A transistors only handled a few amperes. The large transistors provided 50-mV saturation voltages at the low motor currents (efficiency). The overall drive efficiency was about 96%. *(Yeah, that's pretty good. /rap)* Nickel-silver secondary batteries provided the power.

Cooling happened through the melting of wax (latent-heat-of-fusion). The lunar rovers could run for two hours before all of the wax melted. Eight hours of resting were needed to radiate the stored heat and solidify the wax. *(I bet if you parked it in the SHADE, the motors' wax would cool off a lot faster. But that might not be so good for the BATTERIES. They might lose potency when cold. Were the batteries recharged between outings? /rap)* [Yes.]

The mobility dynamics and suspension performance were modeled on an EAI 231-R vacuum tube  $\pm 100$ -V analog computer by yours truly. Each morning, the technician (Harold Landrum) would partly fill up a waste basket with tubes that were removed from the computer and replaced with new ones.

Bruce Murdock  
via e-mail

*I'm not too familiar with the EAI computers or operational amplifiers. I think that the Philbrick computers, using K2-Ws, K2-Ps, and K2-XAs, in K5-Us, K5-Ms, etc., ran pretty well and didn't need to be retubed more often than two or three times per year. But I really don't know how much maintenance, checking, recalibration, and troubleshooting they needed between one evening's run and the next. I never saw baskets full of tired triodes, though. Thanks for telling about the "good old days," and about electric vehicles that worked well.*

*P.S. I designed the Lunar Seismic pre-amp op amps, the Amelco 2401BG (one day on a coffee break). They ran for years and years up there—much longer than expected.—RAP*

### Dear Bob:

I enjoy your work in *Electronic Design*. I found out today from your Jan. 7 column that you worked for Philbrick in the '60s. I too was much younger then! *(Ha! That's barely 40 years! /rap)*

I have a favorite book from that period, published by Philbrick in about 1968, titled *Application Manual for Operational Amplifiers, A Library of Practical Feedback Circuits*. I can't tell you how many times over the years I have picked up that book to recenter an idea that I might be working on. *(We agree. It's a very good book—quite useful. /rap)*

The reading was such a pleasure in its composition and practical approaches. I know that it was a treasure to many others besides myself. The style re-minds me of your work today; did you contribute to it as well?

Craig Journey  
via e-mail

*The style was 60% from George Philbrick; 10% from Bruce Seddon and Pete Hansen; 18% from Dan Sheingold; and I contributed 1% or 2% of the technical stuff, but not much of the style. As you can see, though, I learned a lot from it. But George taught by making wise statements. On a good day, I teach by asking questions.—RAP*

### Bob:

I'm one of those old analog guys (with the beard also), trying to find a schematic of a Rohm pre-amp, part BA301. I can't find the darned thing anywhere (probably due to my reduced brain proficiency in using this Internet search stuff). Do you have any info?

Barry L Smith  
via e-mail

*Barry, I never heard of any Rohm linear parts. I would try [www.dogpile.com](http://www.dogpile.com), [www.altavista.com](http://www.altavista.com), or [www.google.com](http://www.google.com). (Actually, we found this at [www.yahoo.com](http://www.yahoo.com).)—RAP*

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



## What's All This Shunt Stuff, Anyhow?



April 29, 2002 12:00 AM  
Electronic Design  
Bob Pease

We often think of Ohm's Law as  $V = I \times R$ . That's not Ohm's law, but we'll use that relationship today to measure  $V = I \times R$  for some large currents. Specifically, I need to design a good 1-m $\Omega$  shunt to sense 15 A. Yes, you can go out and buy shunts in the 1- to 1000-m $\Omega$  range.\* But the small ones are too small, the big ones are pretty expensive, and none are really easy to buy.

I'll show you how I designed a couple of shunts that can easily dissipate 22 W without harm (but with minor loss of accuracy). Because this is rated to run at 225 mW, 1% of full power, it shouldn't cause too much error. Next month, I'll show you what we can do with them!

The resistance of 22-gauge copper bus is just 16 m $\Omega$ /ft, if you believe "The Book." But that's just the rated or worst-case value. When you measure it, you'll find that it's really about 13 m $\Omega$ /ft. So paralleling 12 9-in. lengths of that wire will make about 1.0 m $\Omega$ . Just connecting the wires as a bundle, though, would be too small to dissipate 20 W. The heat would be too congested.

So my best structure arranges the wires like a bird cage to spread out that heat. I'll make a couple of 6-in. buses A-A' of bus wire to support the 12 9-in. wires between the buses. But I can't just connect my 15 A to the buses. That would be too crude, and the current wouldn't be shared properly among all of the wires. I will make some sharing conductors to ensure that each of the 12 wires gets the same current. I'll put in 12 bus wires of ~14 gauge, each 1.5 in. long. These 12 wires (each with about 1.1 m $\Omega$ ) can connect a point A" to the bus A-A'.

How can this work? Easy. Bend that bus in a circle, then connect A to A'. Similarly, point B" is connected with 12 wires to Bus B-B'. Points A" and B" are provided with Force and Sense connections. Then we have a 1.0-m $\Omega$  shunt. Points A" and B" are well ballasted and the heat is well spread out, distributed over of the wires. This shunt will get pretty hot when you run it at 22 W, but not hot enough for the solder to melt. Will I have to test it at 144 A? No, I can just build and run 12 A through it. The rated fusing current for 22-gauge wire is 40 A, so 12 A isn't bad.

Now, we have a basic shunt design that can be made up in under half an hour for less than \$1, and you can pick the wire gauge, and the lengths and numbers of conductors, to dissipate almost ANY amount of heat for any number of milliohms. Will the bus A-A' carry any

current? Not any significant current, as the symmetry forces the current to mostly flow past the wire. So if that circular bus were made of #24 wire and broken in several places, you wouldn't see any significant difference from 14 gauge. It's just to hold things steady and to help spread out the heat.

Now, copper has a tempco of about +3300 ppm/°C. So if you dissipate even 3 W, this shunt will warm up and drift in its r value, perhaps +0.5%. What's a mother to do? More on this later. Don't throw out this design.

Now, nichrome wire at 22 gauge has about 1 Ω/ft with a low tempco. I could lash up 42 1/2-in. long nichrome resistors, in parallel, to make a good 1-mΩ shunt. How can I lay out 42 1/2-in. wires? I placed a serpentine between two 1/2-in. by 3-in. strips of double-sided copper-clad, spaced 1/2 in. apart. I soldered up seven wires (using strong HCl flux). Then I arranged six pairs of strips in a hexagon, with heavy bus conductors to share the currents, as above.

The actual resistors would be quite small, but the copper-clad would spread the heat out. This compact hexagon would have 3-in. sides and be 6 in. across, but only a couple of inches long—compact, but not too small to spread out the heat. It might not be perfect in precision, but its low tempco (20 ppm/°C) would be better for many cases. Any shunt should be mounted in a box with some vent holes to let out the dissipation.

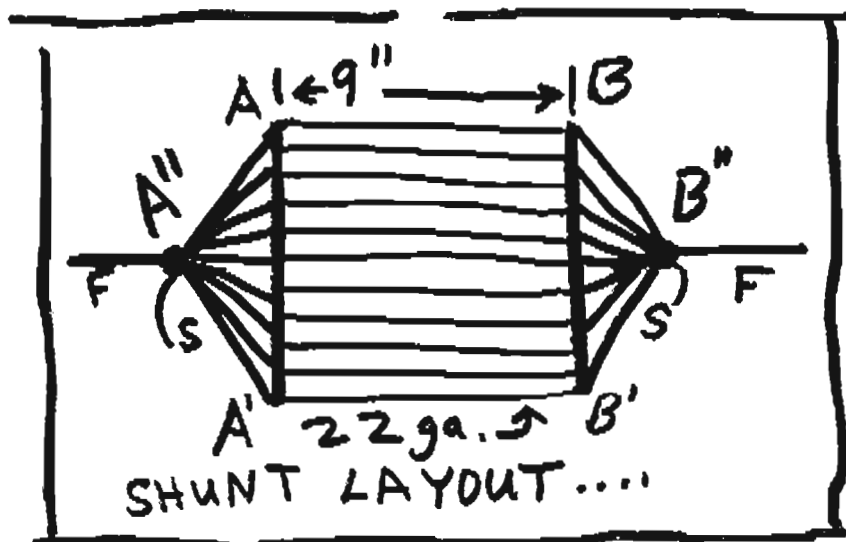
To calibrate these shunts, shove 1 A into the Force leads through a calibrated 1-Ω resistor at 1 V, and look for 1000 μV at the Sense leads. Add a few extra conductors to get the resistance down to the right calibration, or snip out a few to get it up there. Next month, we'll use one of these milliohm shunts in a wide-range watt-meter.

All for now. / Comments invited!

RAP / Robert A. Pease / Engineer  
—or:

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\*Shunts of various sizes can be obtained from many good vendors, such as ; (727) 541-5771.





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**pease  
porridge**

## RAP's Multirange Wattmeter

**A**lthough the basic wattmeter covers 1.501 kW, some people might be interested in other ranges. So, we will show here a multirange version, with full calibration (see the detailed schematic). The basic explanation is also applicable to this version with multiple ranges.

We'll start with the 1.0-m $\Omega$  copper shunt shown in the April 29 column for the 1.501-kW range ([www.elecdesign.com/Articles/Index.cfm?ArticleID=17028&Extension=pdf](http://www.elecdesign.com/Articles/Index.cfm?ArticleID=17028&Extension=pdf)). Then, I made a smaller shunt, two strands paralleled of about 12 in. of 22-gauge wire, to make up the 9.0-m $\Omega$  shunt. This gives 150.1-W full scale, with 0.1 W of resolution.

If you want a 15.01-W range with 0.01 W of resolution, you can add a 90-m $\Omega$  shunt made of 5 ft of #24 wire. For a 1.501-W range, I used a hank of 50 ft of #24 wire. Extra switch positions may be needed. These shunts are all added to the basic Wattmeter circuit. Each resistor should be trimmed within about 3% of nominal to make final calibration easier. Measure twice, then cut carefully!

The calibration for different ranges is easily made by adding suitable switches for each range. If you have a four-position, two-deck rotary switch, you could use that to connect up the shunts and the multiple gain-adjust pots, as shown. Myself, I prefer to use four DPST switches, one to turn on each range. I just have to remember to turn off each unwanted range.

Note that most rotary selector switches aren't rated for 15 A. But it's easy to find 15-A-rated DPST switches. If you are going to use a rotary selector switch, don't change ranges when heavy load current is (or will be) flowing! Remember, a load of just six 100-W bulbs would draw 25 A of turn-on transient! That would soon ruin most rotary selector switches.

If you calibrate this at about 2 A so  $V_{\text{METER}} = 1.01 \times 2 \times I \times (V_{\text{IN}} - 1.2 \text{ V})$ , the calibration will be right on at 6 A, about 1% high at 1 or 2 or 3 A, about 1% low for 12 A dc, about 2% low for 12-A sine waves, and about 5% low for 15-A sinusoidal ac loads, or as much as 10% or 20% where the rectifiers are pulling significant peak currents at the sine peaks. In all cases, this meter computes the true RMS multiplication of the  $V \times I$ , but the scale factor just tails off a couple percent, for currents above half-scale.

I computed that if you use this meter with a load that draws relatively large pulses of current, such as 0.75 A, on a 10% duty cycle, just at the peaks of the sine waves it will actually draw 120 W average power. If you read this with the meter in the 1500-W scale, it will read about 119 watts. But in the 150-W scale, it will read about 74.4 W.

All multipliers have limitations on duty cycle and pulse widths. So I just showed you where this one has its limitations. If you have some equipment that draws a lot of watts during the line voltage's peaks (because the rectifiers are charging up capacitors right at the peaks), and it seems to be up above 50% of range, try a higher range. You will get less resolution, but better accuracy.

The temperature compensation is not perfect. But at all rated loads, the errors should be well inside 2% between 0°C and 50°C.

If it is well calibrated at 110 V ac, it will tend to be off at 80 V ac by about -0.2%, or at 140 V by about +0.2%. Not too bad. This wattmeter is not suitable for reading the watts in loudspeakers, because it loses a lot of accuracy if  $V_{\text{IN}}$  is less than 60 or 80 V. (If you wanted to add the Howland Current Pump using A1 to compensate down to 2 V, you could try that. It might work pretty well up to 1 kHz, but I haven't built this.)

You can calibrate the respective ranges with 2.0 A, then 0.20, 0.020, 0.0020, and so on. Of course, you will have to readjust the zero offset or allow for some offset error in the lowest range, as there may be a small but noticeable offset in the lowest range. Can't be helped.

If you want intermediate ranges, such as 5 kW, 500 W, or 50 W, be my guest. Make all the fancy switches and shunts you need. You could even compute 15 kW or more, using a 0.1-m $\Omega$  shunt. But just remember, the shunt will dissipate over 2 W at full scale!

P.S. The basic wattmeter design is based loosely on an old design by Carl Nelson in NSC Application Note AN222. I added the ranges, the dc calibration, and several other features.

P.P.S. I haven't had time to measure the inductance, but the shunt as laid out in my April 29 column is not going to be very suitable for audio work, not even at 5 or 1 KHz. If you want to try to use this for an audio wattmeter, send me an e-mail, and tell me your snail-mail address. I'll reply by July 1. Maybe twisted pairs will make a good shunt out to 15 KHz!

All for now. / Comments invited!  
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# What's All This Wattmeter Stuff, Anyhow? (AKA Multiplication Stuff, Part III)

Last month, I designed a good 1-m $\Omega$  shunt ("What's All This Shunt Stuff, Anyhow?" April 29, p. 94). Now we'll use it in a 1.5-kW wattmeter. This one is optimized for the 80- to 130-V ac range, and for currents up to 15 A (see the figure).

How does it work? When  $V_{IN}$  is positive, the current in R1 just flows to ground via D1. But when  $V_{IN}$  goes negative, the current flows through R2 to the matched transistors. If the load current  $I_L$  is zero, the balanced transistors will cause zero output.

If there's a load current, the transistors will multiply the  $I_L$  by  $V_L$ , acting as a balanced modulator. The "product" signal will appear at the output terminals, to be read by a floating meter. A 3-1/2-digit DMM with 200.0-mV full scale works well. An analog meter with 100- or 150-mV full scale gives poorer resolution, but it gets you started.

What shunt shall we use? Previously, I said that the copper shunt had a BIG tempco, +3300 ppm/ $^{\circ}$ C. But here, the copper shunt will well compensate for the -3300 ppm/ $^{\circ}$ C of the  $g_m$  of the transistors. (Nichrome with its low tempco would be wrong.) We won't achieve perfect gain tempco—but pretty good.

This meter resolves 1 W out of 1.501 kW, using a 3-1/2-digit DMM. If you want high resolution over a wider range, check out the multirange-version schematic in the electronic copy of this column at [www.elecdesign.com](http://www.elecdesign.com). It uses four shunts to cover 150-, 15-, and 1.5-W ranges. If you can't attain info from the Web site, circle Reader Service No. 552 to acquire it by mail.

What's wrong with this wattmeter? At large currents, the multiplier cell isn't very linear. The  $g_m$  of the transistor pair falls off, according to  $\tanh(V_{SENSE}/52 \text{ mV})$ . As the peak voltage across the

shunt exceeds 10 mV, the diffamp's gain falls off by 1% or 2%, even if the average current is under 3 or 5 A. That's why I chose a 1-m $\Omega$  shunt for 15-mV "full scale" at 15 A. Calibrated at 100 V ac, its gain will be low at 80 V by about -0.1%, or high by +0.1% at 140 V. Not too bad.

This meter won't directly read the true power if the load draws current on only one half of the cycle. But a workaround is easy: plug in the load both

your pocket, etc., when you see that neon lamp glowing!

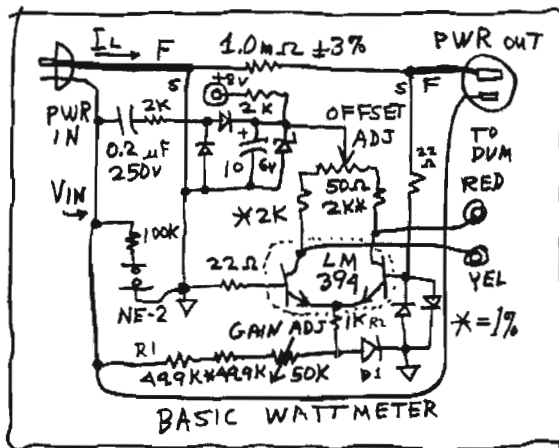
What's right about it? Well, it reads true  $V \times I$  watts in a true rms way. It rejects reactive currents, such as capacitive or inductive currents. For example, a capacitive load, like 2  $\mu$ F (rated at 200 V ac), will generate 90 VARS (reactive). But this meter reads zero because the integral over one cycle of line voltage is zero. It has low "burden"—the voltage across the shunt is normally less than 0.03% of the line voltage.

**Calibration:** A big advantage of this meter is that you can calibrate it with dc, without making or measuring lots of watts of precision ac power. First, disconnect the meter from line voltage. Apply +8 V dc (used only for calibration) to the +8-V jack and apply -100.6 V dc to the  $V_{IN}$  at the input line plug. Then, adjust the offset so the meter reads 0.0 mV.

Now, force 2 A dc through a calibrated 1- $\Omega$  resistor into the input connector prong and out of the output socket. Trim the gain adjust so that the meter reads  $2 \times 1.01 \times (V_{IN} - 0.6 \text{ V}) \times I$ . (The "2" makes up for the multiplier working just half the time.) So if you had 2.00 A  $\times$  (100.6 - 0.6) volts, the meter should read 40.4 mV. Then the meter reads 20.2 mV for a true 200-W ac load—about 1% high, but right on at 6 A, 1% low for 9 A dc, 2% low for 12 A of sinusoidal load, and about 4% low for 15 A. Next, I'll check it out at PG&E's labs!

All for now. / Comments invited!  
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forward and reversed, and take the average. Or instead, employ a big DPDT switch to reverse the output wires.

I recommend the LM394CH for the super-matched transistor pair. If that's inconvenient, make up a matched couple of 2N3904s (<http://www.national.com/rap/Story/vbe.html>). Pair them with in 0.3 mV at equal currents and temperatures, and glue them together.

The circuits in here are mostly at low voltage, but a few parts are at high voltage. You can put tape over the high-voltage components. If the low side of line power is connected to the wide prong, most circuitry should be at low voltage. But you must follow proper safety procedures while working on high-voltage circuits. Keep one hand in





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## Bob's Mailbox

**Dear Bob:**

I enjoyed your "What's All This Drilling Stuff, Anyhow?" column (ELECTRONIC DESIGN, March 4, p. 81). Here's a good 1/4-in. 4000-rpm drill: [www.coastaltool.com/cgi-bin/SoftCart.exe/a/milw/mi0101-20.htm?E+coastest](http://www.coastaltool.com/cgi-bin/SoftCart.exe/a/milw/mi0101-20.htm?E+coastest). No, at \$135, it's not cheap. Milwaukee builds first rate stuff, and I'm sure this is the last 1/4-in. drill you or your grandchild will ever need.

I have an old Black & Decker that still works, though, and I don't expect to upgrade, as it sees little use. I work with metal a lot, and the high speed is good for burning up bits. I recently discovered the advantages offered by air-powered drills. No, it doesn't do you any good unless you have an air compressor. You can get a pretty cheap, good, very high-speed air-powered drill motor from Harbor Freight—no plastic gears. A 2-hp (I know, don't get me started) compressor to run it will cost around \$100 on sale. But it's handy for other things too. Plus, the air-driven drill is light and compact.

In addition to high speed, air-powered drills have an outstanding safety feature: near zero torque when stalled. I have a 1/2-in. electric drill that's nearly lethal when the bit grabs, say when drilling into an automobile frame. I recently bought a 1/2-in. pneumatic drill motor (geared, slow) because it fit into my tight work place. I found out that it had about as much running torque as the electric one. But it was safe to hold with one hand, off balance, because when the bit grabbed, the torque dropped to a very manageable level. My electric drill motor now lives on a shelf gathering dust. (*Hmmm. Point nicely taken. /rap*)

Here's an interesting note: Carpenters use drills to turn their drill bits. Machinists use drill motors to turn their drills. I think it's a matter of what one considers to be a tool.

*Kevin Ferguson  
via e-mail*

*If I had a lot of holes to drill, an air-driven drill might be a very good way to go. But most years, the amount of drilling that I have to do would not justify that!—RAP*

**Dear Bob:**

Re: 1/4-in. electric drills. You obviously aren't looking hard enough. [www.toolcrib.amazon.com](http://www.toolcrib.amazon.com) lists several 1/4-in. electric drills. For example, see [www.amazon.com/exec/obidos/tg/stores/detail/-/hi/B00005Q7AB/qid=1017344435/br=1-18/ref=br\\_lf\\_hi\\_18/104-7271233-2720706](http://www.amazon.com/exec/obidos/tg/stores/detail/-/hi/B00005Q7AB/qid=1017344435/br=1-18/ref=br_lf_hi_18/104-7271233-2720706).

*(Yes, but who the heck do they think they are—Enron? They think that they can make a conspiracy to cut off the supply, then force me to pay \$139? A good 1/4-in. drill might cost only 3/4 or 2/3 of the price for a 3/8-in. drill—not 3x or 5x. I'll keep going to garage sales to try to find another one. Fortunately, I still have two that are in good shape! /rap)*

Bob, I agree that the price is pretty high. But your allegation was that *no one* made them, not that what was on the market was overpriced!

*Brian Lenharth  
via e-mail*

*I looked in hardware stores in 25 countries and found none. I didn't check out jewelry stores.—RAP*

**Bob:**

Your columns are priceless! Although I have sacrificed many coat hangers for tool purposes, my all-time favorite adaptation is the bicycle spoke. Decades ago I scrapped some junker bikes and saved the spokes. They're invaluable for retrieving dropped pieces in cramped engine compartments. The hook on the end is perfect, and their stiffness is ideal. Now I'll have to make some drills.

*Pete Steve  
via e-mail*

*I must admit, I haven't used bicycle spokes much, other than as bicycle spokes. I usually use coat-hanger wire, or bailing wire. But, there's no hurry. These pieces of*

*metal are just lying around, waiting until we need a drill in their size! Note that not all coat hangers are of the same gauge wire!—RAP*

**Dear Mr. Pease:**

Please forgive my formality, but I have been reading your work for so long that I have raised you to near-deity status. (*Obviously, you don't know me very well. /rap*) Anyway, my guess is that you have had multiple responses regarding the use of various forms of flattened wire, etc., for drill bits. I thought I would let you know that the common term for bits like those you made is "spoon bits" (see [www.fine-tools.com/bohr3.htm](http://www.fine-tools.com/bohr3.htm) for a picture). Such tools have been employed for quite a while (two or three centuries). Now they're primarily implemented in traditional chair making.

They work well, as you have shown, and are relatively easy to make. Also, have you considered using a small hand-powered drill rather than an electric 1/4-in. drill? I find myself leaving my electric drills in their boxes when I have only a few holes to drill.

I'm not one of the traditionalist wackos who only use hand tools, as my collection of 220-V equipment in my garage proves. But I have found that many hand-powered tools work at least as quickly for small jobs. Enjoy your columns/books/musings/etc.

*Mark Enright  
via e-mail*

*I had over 100 holes to drill. An electric drill was quite appropriate. My homemade bits aren't terribly sharp, and high rpm is suitable for such drilling.—RAP*

All for now. / Comments invited!  
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## What's All This Floobydust Stuff, Anyhow? (Part 11)

I said that you'd like Charlie Sporck's new book about Fairchild and the early days of Silicon Valley. Titled *Spinoff*, it costs about \$28. Full info is available at [www.national.com/sporck](http://www.national.com/sporck). If you can't justify buying it for yourself, get your librarian to buy it!

- My book on *Troubleshooting Analog Circuits*, now translated into Russian, can be found at [www.dmk.ru](http://www.dmk.ru). But I don't think that your search will work well if you can't read Russian. I have been told that the translation and interpretation are very good though.

- IEEE's March 2002 *Spectrum* had a good story (p. 50-55) about art, images, and little drawings on masks and chips (which *ELECTRONIC DESIGN* has also covered, April 5, 1999, p. 64H). Pretty good stuff—a "Silicon Zoo." The Web pages: <http://micro.magnet.fsu.edu/creatures/index.html> are a bit slow to come up, but worth the wait. Can you name any more examples of drawings and art on chips? The older, the better! Pass along any silicon chip art to that Web site.

- There are several excellent comments on the analog art versus digital stuff at <http://madvlsi.ece.cornell.edu/quips.html>. Well worth printing out. Suitable for framing!

- Several people told me where I can buy a Mikita 1/4-in. electric drill for only \$139. I refuse to pay that price. I'll keep checking out garage sales. I looked in 25 countries and found no 1/4-in. drills in any hardware stores. But I didn't look in jewelry stores.

- Are you interested in my opinion on a conventional driver education book? See [www.textbookleague.org/103drv.html](http://www.textbookleague.org/103drv.html) and compare it to my Web site, [www.transtronix.com](http://www.transtronix.com).

- Want to read an interview with RAP by Jon Carroll of the *San Francisco Chronicle*? Go to [www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/1999/08/23/DD32191.DTL](http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/1999/08/23/DD32191.DTL).

- Several people asked me, referring to "Sudden Cessation Of Stupidity Stuff" (*ELECTRONIC DESIGN*, Aug. 7, 2000, p. 134), if the little wood strips *really* worked and detoured the water from running into my house. Yes, they worked. It took a while to get them installed, but the 1/2-in. quarter-round strips worked well. I nailed up some and epoxied others. But it's still a good idea to keep your rain gutters mostly cleaned out!

- Another embarrassing typo error in "Equations Part II" (*ELECTRONIC DESIGN*, Oct 15, 2001, p. 90): In the second equation I said " $I_2 = \dots [ \times 1/(pC2) ]$ "—but it should be  $[ \times pC2 ]$ . Like I told you, it's hard to get equations perfect! The Web version has been fixed.

- Several people asked me, "Whatever happened to Silicon General?" Back in November of 1993, it turned into "Symmetricon." Then Linfinity became a linear-IC subsidiary of Symmetricon. So it may be stated that Linfinity is a successor of Silicon General.

- Similarly, whatever happened to Teledyne Philbrick? After Teledyne Components turned into Telcom, Microchip bought the company.

- Some people ask me about how they could get a copy of a recent column. Most of my newer columns—about 60 of them—and 26 of my old columns are posted on the *Electronic Design* Web site: <http://www.elecdesign.com/Index.cfm?Action=Pease>. This list of columns is accessible via my Web site as well. Go to [www.national.com/rap](http://www.national.com/rap) and click on "ED Columns." You can also click on "Electronic Design."

- Some people ask me about other old columns that aren't on the Web. I'm trying to add these to my Web site, but there have been delays. It's worth a try, at "Other Columns." I have added a few new items, lists, trek reports, and Horrible Pictures. If there's a column that you can't find, tell me which one you need,

and tell me your snail-mail address. Otherwise, I'll have to pry it out of you!

- Robert Klabis and I agree, if you invest your money in tax-deferred accounts, the taxes will change—the rates are bad, and may get worse. Well, we were partly right—they seem to have changed. Maybe they got better. Not much. Meanwhile, the Alternative Minimum Tax (AMT) seems to be getting worse. "What's All This AMT Stuff, Anyhow?" (Later.)

- A friend reminded me that the slide fastener for clothing was a loser until someone came up with the name "Zipper." Similarly, you can save a little time tying and untying your shoes using the Shoe Zappy: [www.ThighPower.com](http://www.ThighPower.com).

- John Trudel (formerly a columnist with *Electronic Design*) says his new Web comments on innovation are quite popular. See [www.trudelgroup.com/dyknow.htm](http://www.trudelgroup.com/dyknow.htm). I suggest taking his survey/questionnaire about innovation.

- Many people have inquired about where to buy Teledeltos paper. The original source in England will still sell you a big roll for \$95, including shipping; [www.searchkingslynn.com/senco3.html](http://www.searchkingslynn.com/senco3.html) will get you to the right address for Sensitised Coatings, or call +44 1553764836. Plus, a new source for resistive paper is online: [www2.pasco.com/products/scripts/products.taf?PN=PK9023](http://www2.pasco.com/products/scripts/products.taf?PN=PK9023). The KIT PK9023 costs \$114, but PK9025 paper with centimeter grid runs \$34 for 100 23- by 30-cm sheets. Buy your own pen with conductive silver ink. This is about 32 k $\Omega$ /square.

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

Dear Bob:

I finally got around to reading the Feb. 18 issue of *Electronic Design*. As always, I read your column entirely. The tirade of several readers (and you) on the extremes of audiophiles brings two comments to mind.

First, is it possible that youngsters (never trust anyone under 30!) have better ears than we more mature folks? (Of course, most younger audiophiles have better ears. No problem. I have no doubt that they can hear many things better than I. But I can still prove they can't hear any difference! /rap) You bet it is, unless they've destroyed them by loud music. I recall teaching electronics to a group of teachers when I was in grad school. The other teacher suggested that for the lab experiment on amplifiers, they merely twist the dial of the audio generator to 20 kHz, and measure there. I walked into a room that was quite literally painful. Unfortunately, my ability to feel that type of pain now is long gone.

Second, perhaps this is analogous to the cyclists' extreme of spending \$100 to shave 10 more grams off the weight of the bike. (Oh, rabid technophiles love to do that, even if the difference is hard to measure. But I'm still at the area of \$100 per pound. I could easily cut a pound off the weight noted below for no more than \$100. But I refuse to consider it, because on a long trek, it's impossible to prove that the lighter component will not fail. /rap) While I ride several Ti bikes, it's not the weight, but rather the ride and corrosion resistance which dictates that. A good steel frame is essentially just as light.

(In the old days, the experts said Ti "did not feel right." I guess they learned how to make them feel "right." My frame on my Specialized Rockhopper A1FS is aluminum, but I agree that it's not appreciably lighter than a good steel frame of comparable strength, durability, and price. Let's not talk about carbon fiber! Hey, I know how good a 22-lb bike feels compared to 27 lbs, 18 lbs, and 12 lbs, compared to the others. Mine weighs 27.6 lbs and that's just right for me

because I want the most durable, reliable bike I can get under \$500—and I got a good one. /rap) Besides, I've noted that a few less beers shaves considerably more weight off the bike for much less money!

David W. Knoble  
via e-mail

Yes, but you get more fun per dollar with beer! Or, in our case, rum and lemonade after our day's ride.—RAP

Dear Mr. Pease:

I really like your articles. Most of the time, I agree with the way you see things. But the "What's All This Drilling Stuff, Anyhow?" (ELECTRONIC DESIGN, March 4, p. 81) article I just read has an error in it. I don't know about American drills, but European drills always turn to the "right" (CW). (Yeah, as seen by the guy drilling, and that's another way of saying that the workpiece sees the drill turning CCW as it approaches! /rap) This means the machine is turning left (CCW) compared to the drill itself.

If the drill stalls, the machine handle is pushed toward your right hand, and eventually pulled out of your left hand. This is the opposite of what you stated in the last paragraph. (You're right. I admit that my argument seems backwards. I must have been thinking of some crazy viewpoint. But we at least agree that things aren't symmetrical. Despite the way I said it backwards, the guy agreed that he had better luck shutting off with his left hand. /rap) I think this is a good reason to use it with your right hand. Maybe it's a good idea to start building drills for left-handed people!

André Van den Wyngaert  
via e-mail

Some electric drills are reversible, and there are left-handed drill shafts. But I don't need any.—RAP

Dear Bob:

I have three comments, about your column on drills and drilling:

1. When you need to drill a hole for a nail, use one of the nails. They're always

the right size. Since there are no flutes, the holes wind up a little undersize—just what you want. (I'm not sure if the holes are as small as I want. Maybe I should chuck a nail in there and sandpaper it down a bit. /rap)

2. The reason drill motors "lock on" and wind up your arm is because of that stupid and dangerous locking button on the side. It sits right under your hand. When the drill binds, your hand naturally pushes it into the lock position, so the drill keeps going even after you let go. I don't have lockup problems because I figured that out and cut the blasted things off.

3. Concerning flimsy drills: I have a 1/4-in. Black & Decker that I paid \$5.50 for in 1964. I bought the cheapest thing that I could find to do a quick contract job for a local radio station. I figured that when it wore out, I'd get a good one. Despite running it so hard that smoke has come out, and it has literally gotten too hot to hold on to several times, it's still fine. Bearings are good, original grease, original brushes, original switch, and no plastic gears.

Isaac Wingfield  
via e-mail

A good Black & Decker is not a flimsy, cheap drill. It may be inexpensive, but it has excellent quality and durability. Thank heavens I still have one! I wish that everybody could buy one!—RAP

All for now. / Comments invited!  
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Note: Bob is off trekking this month. This time he's riding his mountain bike over the high pass Thorong La at 17,771 ft north of Annapurna. To find out how the trek went, just send him a request titled "minireport."



# What's All This Multiplication Stuff, Anyhow? (Part IV)

When I'm out on the road, preaching at Linear Seminars, I run into guys with good questions, every day. Some I can answer, some I can't, and others just take a long while for me to figure out a good answer. One question that I carried for at least 70,000 miles was, "I would like to have a voltage-controlled 'pot,' similar to the 'digitally controlled pot,' so the output will be a function of a normalized control voltage  $V_k$  (where  $V_k/V_{REF} = k$ ), and:

$$V_{OUT} = V_A \times k + V_B \times (1 - k).$$

The "wiper" moves proportionally from  $V_A$  to  $V_B$ .

I thought about this a long time and kept the question in my wallet. I pulled it out and mulled over it many random times. Finally, I had a Eureka! moment and wrote to the guy: "Hey, Jim, you asked me why couldn't I invent an 'analog pot.' After I thought about this for a long time, I figured out that the reason is because somebody already invented it. It's called the analog multiplier.

"The good news: You can go to Analog Devices' Web site ([www.analog.com](http://www.analog.com)) and look up the AD534 analog multiplier. You want to connect the  $V_A$  and  $V_B$  to the differential input pins at  $V_X(+)$  and  $V_X(-)$ . Then you also connect  $V_A$  to the  $V_Z$  output offset pin. As you move  $V_Y$  up and down from 0 to 10.0 V, you get the ANALOG pot that you said you wanted.

"The bad news: These things cost \$16 and up (even the cheapest grade, even in 100s) and I don't think you're prepared to pay that price for an audio pot. I'd love to design you an analog multiplier using the LM13600, but that's now obsolete, and we ain't got any more to sell."

Jim agreed that it was a neat solution, but much more pricey than he would pay. He plans to try out the true analog multiplier, but at low priority.

I thought about it some more. I was mentioning this trick solution the other day to a colleague. He said, "Great solution, but the LM13600 isn't completely obsolete because you can still buy the LM13700, which is the same function." I was astonished. "They told me that the LM13600 and LM13700s were all discontinued," I said. He then replied, "You go look it up." He was right.

So here I'll give you the good cookbook circuit for this "analog-controlled pot" using the LM13700 as a multiplier/modulator (see the figure). This circuit has one additional advantage: If you move the  $V_k$  a little too far, the analog multiplier causes the unwanted channel to feed through a little. In my approach, no feedthrough occurs.

If you want this "pot" to provide a precision output with no offset, you can use any suitable op amp to buffer the output. Then you'd keep the 1-k $\Omega$  pots and trim for low output offset. If you're just going to need it for audio, use the Darlington output. Use two 499- $\Omega$  resistors to replace a 1-k $\Omega$  pot. No op amps or pots necessary—costing 1/10 the price of a store-bought multiplier.

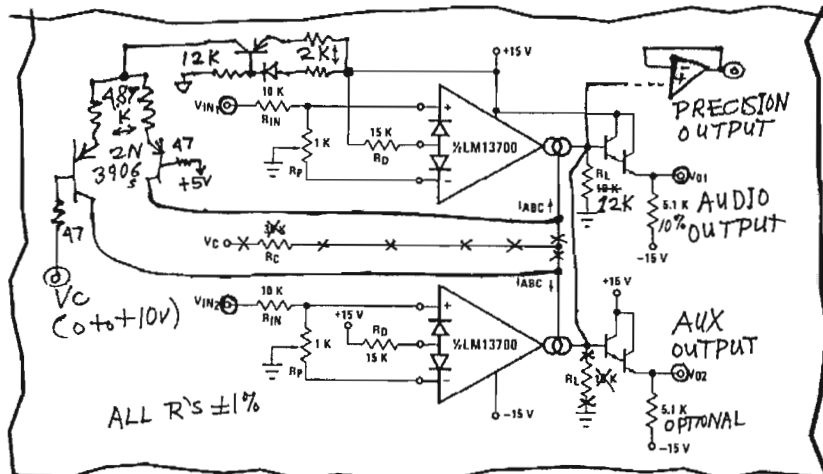
What's good about this circuit? You can implement it with rich current biases and get better bandwidth and noise. If you don't mind a little extra noise, you can run the whole circuit on less than a milliampere. Store-bought multipliers won't do that. The bandwidth will still be over 12 kHz, and you can design it to run on just about any supplies, such as  $\pm 5$ , 6, 8, or 15 V.

What's not good? This circuit isn't perfect in linearity, but it's better than 1/2% THD. The noise for a 10-kHz bandwidth is only about 70-dB down. (But the analog multiplier may even be better at some settings.) The crosstalk from an unwanted channel is just -85 dB.

After I built it, what did I see? It worked as designed. Have fun!

All for now. / Comments invited!  
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## Bob's Mailbox



July 22, 2002 12:00 AM  
Electronic Design  
Bob Pease

### **Hello Mr. Pease:**

Thanks for writing all of these interesting tidbits of information over the years. I am tempted to purchase an old VW and wire up the sound system with some of that newfangled oxygen-free copper at \$6/ft so that it will sound better. *(With an old VW, you can't even hear the sound system, unless you turn off the ignition! /rap)*

In your article, "What's All This Shunt Stuff, Anyhow?" (Electronic Design, April 29, p. 94), you mentioned that you soldered nichrome wire using a strong HCl flux. What exactly is that? *(That's not HCl, but HCl or hydrogen chloride. Hydrochloric acid is a very strong acid. Go to any good plumbing store and buy a little bottle. But be careful to wear goggles when soldering, and don't touch the stuff, and wash off all flux. /rap)* The only way that I have been able to solder nichrome wire is with silver solder. If there's an easier way to do that I would like to know!

Steve Danielewicz  
via e-mail

*I didn't know that silver solder is one way to do it. But that takes very high temperatures. So, just try the HCl method mentioned in my column.—RAP*

### **Robert:**

I always enjoy your "Stuff." When do you find time to read and write all the e-mail? I could use some. I used to make up all kinds of drills that I didn't have as a kid. So when I need a special drill, I do as you would.

I once owned a house in New England, built in 1925. It had an iron water-feed pipe from the street (~50 ft) that had almost rusted closed (~2 gpm). I was determined to "fix" it before spring when the ground would thaw and I could dig it up. I soldered a hole saw to a 1/2-in. copper pipe and made interlocking sections of pipe to make the length. I then unscrewed the water meter and elbow to get a straight shot down the pipe and proceeded to drill. I put a PVC angle with a close fitting through-hole to channel the water away from the drill, and I wore rubber boots and rubber gloves as water was everywhere with the 120 V ac.

When the water started to flow heavy, I stopped drilling and pulled out. With everything back together, life was good—until I noticed the next day that the wall was getting wet from behind. I guess the drill broke through the side of the weak pipe, and water was leaking against the house. Afraid that it would push the basement wall in, I drilled a drain hole through the concrete down low. With a hose connected to that drain we were okay until spring when I dug it up and put in copper. That was my next most exciting drill job.

Steven Smith  
via e-mail

*Hello, Steven. Thanks for sending in some of the wildest comments on drilling that I have received so far.—RAP*

### **Hi Bob:**

I love your columns and books. Maybe you can help resolve something that's been nagging at me. While fixing up a few dead power supplies, I found they had blown (among other things) the current-sensing transistor. In the designs, there was a low-ohm resistor in the hot lead, with the base-emitter junction of the current-sensing transistor directly across it. The collector, of course, goes back to some point to inject the shutoff current.

Now, if you do a little thought experiment: If you short the output, then there's full output voltage across the current-sensing resistor for an instant, and base to emitter. *(Quite right! /rap)* In a few microseconds, the series-pass transistor will turn off. *(Well, in theory. /rap)* But for a few microseconds, at a first approximation, there's an awful lot of overdrive to the current-sensing transistor!

Is it just me, or would it be a good idea to have, say, a 1-k $\Omega$  resistor to limit the worst-case base overdrive? *(Pretty much right. I would have said 100  $\Omega$ . But somewhere between 1 k $\Omega$  and 100  $\Omega$  would probably work with the best safety margin. To define any safety factor, you might apply a vicious short to the output with various R values between 47  $\Omega$  and 2 k $\Omega$ . I think if you put in 2 or 1 k $\Omega$  you will tend to destroy the main pass transistors, whereas anything below 47  $\Omega$  will likely rip out the sense transistor. That's a guess. I learned that in 1968. /rap)*

One design was in a shakily designed telemetry scope. But the other two were in multikilobuck Fluke and Hewlett-Packard equipment, usually noted for good, conservative designs.

George R. Gonzalez  
via e-mail

*Yeah, well, they're usually good, conservative designs. You should complain to Fluke and HP, and tell them I'm with you. Do you think Spice says that 0  $\Omega$  is okay? I bet that's a major part of the problem. If Spice says it's okay, then you don't have to test it, do you?—RAP*

All for now. / Comments invited!  
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**A Note On Ginger Stuff:** Is Ginger fun to drive? I did a brief test-drive of a Segway, under the watch of inventor Dean Kamen. Yes, it's easy and fun. The words that come to mind are intuitive and user friendly. I watched a couple dozen people also learn quickly as they took a brief test-ride. Obviously, we all loved it! To make this interface work so naturally certainly shows world-class engineering. I still don't think it will stop really fast, but it stops *okay*. (So does my bicycle, and considerably faster.) More later. /rap

## What's All This Knot Stuff, Anyhow? (Part III—The Dutchman)



August 05, 2002 12:00 AM  
Electronic Design  
Bob Pease

A long time ago, my father showed me how he tied a "Dutchman," a specialized knot used by truckers in the 1940s and '50s to tie a load onto a truck. But he never really taught it to me, so I didn't really learn it. More recently, I decided that I ought to document that knot. I have seen many "trucker's knots," and most of them are pretty bad.

I looked in Clifford Ashley's big book<sup>1</sup>, but Ashley died shortly after his book was published in 1944, so it's not up to date. Even though it's a wonderful collection of thousands of knots, it fails to include many modern and useful knots, such as the Prusik.<sup>2</sup>

Several people pointed out that a good knot isn't just the strongest or most secure knot, but quite often, a knot that can be tied quickly and untied easily. My slip-half-hitch system that I showed in "Knots Part II" is a good example of that, and I still say that the square knot with a couple of half-hitches meets the requirements of a good knot. Plus, it's easy to see if you have tied it right—another important feature!

For example, one guy recommended the Double Fisherman's knot (#1415) as very strong and trustworthy. Yet when I went to the Web site, it looked quite confusing. The text there cautions that it's very easy to tie one the wrong way. That's not a good knot choice to ask a Boy Scout to tie! I'll risk my neck on a proven knot, where it's easy to see if it's tied right.

The "Dutchman." Okay, what's it good for? It's a good way to use a long rope to lash down a bulky or heavy load, like onto a truck bed. I asked my Uncle Roger, who was a truck driver in that era, as my father is no longer around. Roger sent me some examples and explanations.

How do you tie it? First, the end of the rope is anchored to a hook at the front corner of a truck's bed, using a bowline or similar type of knot. Then, after a loop of the rope is thrown over the top of the load, you walk around the truck and put in a couple of loops (A and B) and a half-hitch as shown in the figure. Add some twists to loop B. Next, make loop C in the running line and pull it down through loop B. You hook loop C around the hook or cleat at the side of the truck bed.

After you dress up the knot and take up the slack, you pull down to tighten the load down. By pulling down with a lot of your weight on various parts of the loop and the running rope, and taking up the slack, and taking proper mechanical advantage, you can get of pounds of down-force from the rope down onto the load. Then, you take the running rope and loop it around the next hook on the truck bed, employing a couple of half-hitches. The rope is already returned over the load. Walk back around the truck, and keep going back and forth.

Roger admits that this may not seem to be the most secure knot, but it has been proven secure enough. It's fast to tie and quick and easy to untie, even if the rope is cold or frozen. Most other "trucker's hitches" don't untie nearly so well. I used to like the single Butterfly knot (Ashley's #331) to form loop B. But when it gets tight, it's not easy to untie. If I loop its bight through the hole two or three times, instead of just once, it's much easier to untie. Would I use that instead of the Dutchman? Maybe, if it weren't snowing. If it were snowing, I might tie a modified Dutchman with half-hitches around loop B.

Which of these knots can I tie in the dark? Which can I tie with one hand? Behind my back? Some, but not all! There are no easy answers!

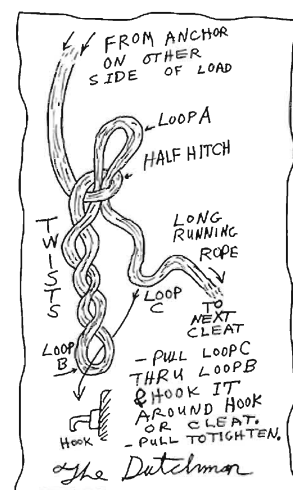
Back in the '50s, I was paid for tying one knot around the stem of a tobacco plant, and another knot around an overhead wire. Piecework. Did I tie a million knots? No, barely half of that. I'm sure some of you can beat me.

### References:

1. , Ashley, Clifford W., 1944, Doubleday. About \$63.
2. There are dozens of comprehensive Web pages on knots, like , which points to many other pages. Some are entirely too big to manage! Some are cute, and some are very clear, while others are confusing!

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.

## Bob's Mailbox

**Hi Bob:**

Many years ago, I read about a subject called "Floobydust" in a National Semiconductor book. I've been searching around and asking people, but I haven't found any good answers. What does it mean and where does it come from?

*Per-Anders Sjöström  
via e-mail*

*Floobydust just means "miscellaneous." This phrase apparently came from a customer visit between Dennis Bohn, Tim Isbell, and a customer of NSC, about 30 years ago. It may even have come from the customer's daughter. Lost in the murk of history. Best regards.—RAP*

**Dear Bob:**

I wanted to thank you for all the good, practical, and usable advice that you have given over the years. I don't understand why no one else talks of these things. I know good info can be had in some tech tips, but it's hard to find. I'm one of those self-taught audio designers that you have come down so hard on in times past, and I see the merit in your arguments. I would like to discuss some of this if you like. *(I plan to study some audio circuits soon. /rap)*

The main subject I wanted to comment on was your mentioning of typical signal diodes' sensitivity to light. I had an amplifier in which I couldn't tame the 60-Hz noise. It had vent holes in the top lid, and an incandescent light was shining down on it in its usual place of use. *(Incandescent lamps tend to be bright at dc, with only a small 120-Hz component of noise. That's because the large thermal mass of the filament doesn't let the light intensity fluctuate much. It's the fluorescent lamps that make a lot of 120-Hz hum! And at 360 Hz. Not much at 60 Hz. /rap)*

When I moved it to the test bench, removed the cover, and focused my shop high-intensity light on it, it measured very high noise. *(I haven't studied halogen lamps' emissions, nor noises, very much. /rap)* I was lucky as the light generated enough heat to cause other prob-

lems. When I moved the light away from the unit, the noise stopped. This was when I remembered reading of this phenomenon in your article. Taking an ultra-black magic marker to the input limiting diodes solved the problem. Thanks again and please publish more practical engineering stuff. I love it!

*Roger Sheker  
via e-mail*

*Isn't it funny how removing a noisy source correlates well with the noise going down a lot?—RAP*

**Hey Bob:**

I got and used my new \$150 GPS receiver for the first time in Panama two weeks ago—a Garmin Etrex. It's nifty to be able to push a button and record (with 20 ft of inaccuracy) the latitude, longitude, and elevation of land for sale, then take it home and tell (almost) exactly where I was, within a millimetre of the readout.

*Dennis Feucht  
via e-mail*

*I was just flying from Incheon, Korea, to home. I got one reading at 179° 59.5 minutes east—and a couple of seconds later, one at 179° 59.5 minutes west. So I sure straddled the International Date Line! I was sort of hoping we would fly far north, and see Mt. McKinley, but we never went appreciably north of 43° north. So I guess that's where the jet stream was that day.*

*I didn't bring my GPS around the Annapurna Circuit this time—no need to. But I took odometer readings all the way around, and it was very close to 146 miles from BesiSahar to Beni. Then we rode an additional 150 miles before and after the trek.—RAP*

**Dear Bob:**

Re: Shunts. Take a sheet of high-chrome stainless steel. Cut out a dog-bone shape with big ends for unipotential areas. Put holes in the ends for the force and sense connections. Screws and star washers worked for me. Using a pin punch and grinding, the

dimple beats chewed up a good drill. Stainless work hardens when being drilled. Trim with file. The result: a near-zero-tempco shunt that can run to a red heat under overload. Of course, you have to characterize the resistivity of the particular alloy and thickness you're using.

*Bill Schmitt  
via e-mail*

*Really? Maybe less tempco than 3000 ppm/°C, but less than 1000, or 100?? You have to watch out for the thermocouples, too! Working at such temperatures, don't expect the thermocouples at the ends to cancel really well! I tried to look up the tempco of stainless steel and found no info.—RAP*

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**More Knot Stuff:** Many people wrote in to recommend various knots that they thought were better than my square knot with half-hitches. But Mr. Ashley's tests (p. 16 to 19 and 273) showed that most of these knots weren't trustworthy enough to take 100 jiggles. Definitely not the square knot or sheet-bend (without half-hitches). Not even the single or double Carrick bends. Not even the fisherman's knot (Ashley's #1414) or the water knot (#1412). Maybe the barrel knot (#1413) or "Ashley's Knot" (#1452) are safe. I'm confident that a square knot with half-hitches would pass the test.

Mr. Tom Moyer has done some meticulous tests on knots that are usually trusted. See [www.xmission.com/~tmoyer/testing](http://www.xmission.com/~tmoyer/testing) and click on "water knot testing." Some knots fail—they slip or "spill"—at low fractions of the ultimate breaking strength. /rap



## What's All This Dilution Stuff, Anyhow?

One of my friends sent me a wee bottle of scotch whisky to take on my trek in Nepal. He planned to bring the rest of the whisky to a 45th school reunion on June 9. He would drink a toast with our fellow alumni in Mount Hermon, Mass., at 11 p.m. on June 9, and we would drink a toast at the same time at 9:15 a.m. in Nepal on June 10, when we went over the great pass Thorong La, at 17,771 ft. Cheers!

After we drained the bottle carefully and rinsed it with tea and water, what to do with the bottle? We were in Mukti-nath, where there's a very holy temple. The big shrine there has 108 little spouts in the form of bull's heads, with a little stream of water spouting from each of the bulls' mouths. I decided to collect a few drops from each stream in the little bottle. So that's what I did. Now I could give a sample of this water to any Nepali friends who would like to have it.

But how much water would each person get? First of all, you know Avogadro's number. When I went to school, it was  $6.023 \times 10^{23}$ . That's what my *Handbook of Chemistry & Physics* said. But I had to mark it up to change it to the new accepted value of 6.022. Why was it changed? I guess the chemists who supported the new value (~1986) had better arguments than the physicists who had derived the old value.

That number is the number of molecules in 1 mole of an element or compound. So 18 grams of water would have  $6.022 \times 10^{23}$  molecules of water. That is a large number of molecules. I estimated that if I put about six drops of water from each spout into my little bottle, that would fill it to about 2 ounces—which is about 56 grams. Thus, I'd capture about 0.5 grams from each spout, but at least 0.2 grams. So the original sample would have about  $6 \times 10^{21}$  molecules from each spout.

Then if I diluted the sample by 10×

and then by 10× again, each sample would have at least  $6 \times 10^{19}$  molecules—at least 60 million million million molecules from each bull's head spout. I figured that would be enough to make any devout Nepali happy. This shrine is holy to both Buddhists and Hindus, I'm told. (This isn't exactly the same as saying that the air I now breathe probably contains one molecule from the last breath that Julius Caesar breathed. But the math is comparable. Details later.)

A couple of days later, I washed my socks. I washed them with a little soap to get out the mud (and donkey-doo). I rinsed them several times. Each time I'm sure I got a dilution factor of  $e = \sim 2.71828$ . Hey, I was just squeezing them by hand in a flow of water. After about four rinses, the water was hardly colored at all. So I did four more rinses, and put my socks in a mesh bag to dry. We rode all day, and by about 4 p.m. they were nearly dry.

Suddenly I heard a thrumming sound. The mesh bag had flopped off the top of my panniers—and had rubbed against my spokes. It had "cleaned" all the mud off the spokes. And the socks were completely dirty and gritty again! Oh, well....

I rewashed the socks and inspected the color of the rinse water. It was exactly the color of the great Khali Gandaki River that flowed along our route: muddy and grey-brown-white. So my socks had very quickly regained all the color of the mud. After about four rinses, they were almost clean. After four more rinses, were they clean enough to put out to dry? How much dilution is enough? I'll be darned if there is any specific answer. But eight rinses is enough for me.

Later that night I had to sew up my shoes. I'd taken some old shoes on this trek because I couldn't find any new ones of the right size and shape and traction. I bought these shoes for about

\$20, about five years ago, and I bought two pairs. They were quite comfortable and had excellent traction, which is why I brought them, even if they were somewhat worn. Halfway through the trek, some of the glue began to lose hold. The heel began to flop around on the left shoe, and the sole on the right. I pulled out my trusty thread and needle. Where to begin?

First, I washed the shoes six times. I wanted all of the surplus dirt washed away. But down in the crevices of the shoes, surely there was a lot of dirt, germs, and filth not accessible to any washing. Could I possibly get them clean enough? Would 12 rinses really be any better than six? I decided not. After six rinses, I decided to get down to work. I stitched and knotted using some very heavy thread and a semicircular needle.

I must say it's *very satisfying* to see the glint of the needle come out from the shoe, *over* my thumb nail, which is much better than *under* my thumb nail. I was quite careful to never poke my needle under my thumb nail. After all, what is the "dilution factor" that's safe when you stick a needle into your finger, after it has come through a shoe that was washed just six times? How few molecules of filth will probably not give you any infection? That's an unanswerable question.

But I used all the lessons that my mother ever taught me about sewing, and more. My finger never got punctured, and the stitches held. And I walked and rode out the rest of the trek.

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.



## Bob's Mailbox

**Dear Bob:**

In your recent "Mailbox" (*ELECTRONIC DESIGN*, April 15, p. 69) you wrote, "On a good day, I teach by asking questions." This Socratic Method stuff has been around for a while now. It works well. But somehow it hasn't caught on much outside of the people who learned it first hand. Maybe a new tech name will revive it. How about "Socraticological Methodology?"

Paul Butler  
via e-mail

I dunno, Paul. Maybe I'm just syllable-logically challenged.—RAP

**Hi Bob:**

I was just reading your "What's All This Multiplication Stuff, Anyhow? (Part IV)" column (*ELECTRONIC DESIGN*, July 8, p. 72). As a fellow analogophile, may I remind you that the good-old, industry-standard 1496 multiplier (modulator/demodulator) chip has been brought back into production?

As you may recall, it's a basic eight-transistor differential multiplier cell in a 14-pin package. Both ON Semiconductor (née Motorola) and NJR are making them (MC1496 and NJM1496, respectively), which retail for under 50 cents. (I think I got my last ones for 35 cents each.) If I recall, National also used to make these as LM1496s. They're a lot cheaper than the AD534, and multisource too. (Yeah, but they lose linearity REALLY FAST. So if you get good s/n ratio, it's at the cost of poor dynamic range. The LM13700 is better when you consider what system specs you need to meet. /rap)

For basic multiplier functions, not much is cheaper and simpler to use. The input biasing needs a little care, and it works well into the many MHz. (True! /rap) I've used this part for assorted signal-detector circuits with great success, along with a few additional transistors or op amps. It's great for synchronous detector circuits for instrumentation applications where

you want to detect a tiny modulated signal in a noisy environment. (I'm toying with a modulated laser/light-beam guidance system for a work colleague's "Battlebot" using such circuitry. No more fiddly joysticks to operate.)

The 1496 is only reasonably linear for small signal levels. (Its siblings, the 1494 and 1495, provided many volts of range.) But these shortcomings are usually possible to design with. (The LM13700 still has advantages, I think. /rap) You've caused me to put my thinking cap on for an elegant, cheap solution to the voltage-controller pot using one of these and a few discrete transistors.

John Lord  
via e-mail

But it will be hard to hold good linearity! Best wishes!—RAP

**Dear Mr. Pease:**

I take back every uncomplimentary word I've ever spoken or written to/about you. (I don't let that bother me. So long as fewer people are cussing at me than at Bill Gates, I don't feel bad. /rap) I'm a '71 transistor, IC,  $\mu$ P, ASIC, FPGA circuits kind of guy who has lately gravitated to electron/photon interactions. They used to think the photons were digital, eh, but there are enough subdivisions to make any analog guy happy. (If you're interested in photons, have you looked into Philip Hobbs' book on electro-optical stuff? It's \$125 and worth it. /rap)

Lately, I've been having fun building every one- and two-transistor circuit that I can find. Colpitts, Hartley, blocking, Theremin mixers, starved-current pre-amps, linear LED talkers, etc. It's so cool to "hear" thunderstorms 60 miles away with a 5087-88 pair amping an FET electret mike. My wife and I once hid under the bed because we forgot the mike was "on" and feeding our stereo. (My wife and I hide under the bed for a different reason—to get away from the kids. /rap) The tornado was 35 miles east wrecking Brett Favre's place in Hat-

tiesburg, but my mixer/t-storm listener made it sound like it was right on us.

Your "Wattmeter" (*ELECTRONIC DESIGN*, May 13, p. 86) is one of the most fun, single-page, two-transistor with tempcomp multiplier, circuit-cum-explanation events that I can remember. (Thank you! It IS a fun circuit. I'm glad you like it. /rap)

With all due respect to Mr. Widlar (may he rest in cerveza-soaked partying peace), and you, I would change my first name to "Bob" if I didn't already have a great cuz by that name. You are "the man" as the (probably obsolete) kids would say, and I thank you.

Dan Garcia  
via e-mail

Well, I try to be a good teacher about analog STUFF. Thank you for the comments.—RAP

**Dear Bob:**

I need an article on "What's All This Bandwidth Stuff, Anyhow?" There are a bunch of TV commercials about increasing your bandwidth.

Leroy Lakey  
via e-mail

Leroy, I heard that Global Crossing and Enron had some things in common—besides just being a couple of HUGE bankruptcies surrounded by fraud, etc. These guys were doing trades with each other—trades of bandwidth. They traded the (potential) bandwidth back and forth, back and forth, raising the prices and the volume. Nobody ever USED the bandwidth: They just traded it. Just like the sardines—the "buying-and-selling sardines" that were only suitable for trading and buying and selling, but not for eating.—RAP

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## What's All This Doctoring Stuff, Anyhow? (Part 1)

**Y**ou may be the best doctor for you. Or, you may be the worst doctor for you. I can't tell you, but maybe I can help you figure it out. After all, even the best M.D. has to get a lot of facts filtered through you. So you're definitely part of the doctoring process, like it or not. Here are some examples:

**Potassium Stuff:** In 1989, on the fourth day of our trek, I started out hiking briskly. Soon, I began to feel weak; my heart was beating fast, and I felt tired. What was wrong? In a few minutes the leader caught up, and I asked what was wrong. He took my pulse, and my heart rate was indeed high by 2x—"tachycardia." He looked in a *big* (35 oz) book of mountain medicine and decided to give me potassium pills. After a while, walking slowly, I got better. I finished off the day just fine.

Seven days later, camped up at 14,600 ft, I crawled into my sleeping bag and got the worst case of leg and foot cramps I'd ever had. Misery. At the time, I didn't realize that the cramps were another symptom of potassium shortage. A few days before the trek, I'd had a small bout of diarrhea, and I learned that diarrhea depletes your body of potassium. Babies with diarrhea especially need potassium, salt, and sugar, or the diarrhea can kill them. In Nepal, you can buy this mixture in a little envelope called "Jeevan Jal." Just add water.

While hiking in future years, I sometimes got tachycardia and became very weak. I figured out that taking potassium\* pills (3 pills x 550 mg of potassium gluconate, sold at most drugstores or groceries in the U.S.) could prevent and banish both the tachycardia and the leg cramps. My wife wondered if I was taking too much potassium. So I wrote up what I was doing, showed it to my doctor, and asked him to sign off on it. And he did, indicating that it was okay.

It seems most people are surprised to learn of the link between leg cramps and potassium. Sadly, most medical books give no advice on this topic. But it's quite useful to know how to prevent cramps in the first place, and cure them if they begin—in just MINUTES! Now when I'm hiking hard, I take one or two potassium pills per hour to prevent leg cramps.

On our recent bicycle trek, we were on a long easy upgrade on the last day. But I ran out of potassium pills, so by 3 p.m., I could just barely walk up shallow hills without getting cramps. Every time I tried to ride, the cramps attacked my legs. Then it began to rain. I kept walking. After an hour, I decided to try a little more riding—and the cramps did not attack me! Then I slowly, carefully rode out the day.

I realized that because my legs got well cooled off, that may have chased away the leg cramps too! So, getting wet and cool was a cheap price to pay for such a good, but not obvious, educational experience! If you have a health problem, take a few pills and correlate the results. You also might come to a good solution, and your doctor may be able to explain why it works.

**Mountain Medicine Books:** The good, small book that we bring on treks is *A Comprehensive Guide to Wilderness and Travel Medicine*, by Eric A. Weiss, M.D., published by Adventure Medical Kits, Oakland, Calif., ISBN 0-9659768-0-7. About \$7, 4.5 oz.

The large book, suitable for an expedition, is *Medicine of Mountaineers and Other Wilderness Activities*, 4th edition, edited by James A. Wilkerson, M.D., published by the Mountaineers, Seattle, Wash., ISBN 0-89886-331-7. About \$19, 19 oz. This book came with us as far as Kathmandu. An excellent book, but too heavy for a trek where we really didn't expect much medical trouble.

These days, most first aid courses just tell you to give the patient an aspirin, "call 911, and hold the patient's hand until the ambulance arrives." When trekking in mountains, or backpacking in the wilderness, that advice is no help. We use those mountain medicine books to plan a good first aid kit, and to plan how to treat ourselves when the nearest doctor is DAYS away.

We probably won't publish many comments on this, but comment away. Meanwhile, we laymen—you and I—should think about what supports our health. Thinking may be more helpful than just asking your M.D. It's not reasonable to expect doctors to know *everything*. More observations in Part 2, in two weeks.

All for now. / Comments invited!  
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\* Bananas are a good source of potassium. But you'd have to eat 14 ounces of bananas to equal my minimum daily requirements of three pills weighing 0.1 ounce. /rap

*This discussion is just related to my reasons for and my choices of when it's a good time to be taking certain over-the-counter supplements. Using your own judgement to make your own personal choice is always your right. But be aware that over-the-counter medications can adversely interact with some prescription drugs you may be taking. Don't do anything suggested here without checking with your doctor first—and don't do it unless it also makes good sense to you. /rap*



## What's All This Doctoring Stuff, Anyhow? (Part 2)

**A**s I said a couple of weeks ago, "You may be the best doctor for you. Or, you may be the worst doctor for you. I can't tell you, but maybe I can help you figure it out." You should at least think about this, because you may need some doctoring when no doctor is around.

**Ibuprofen:** A long time ago, I got back spasms after some repetitive motions. These painful spasms stayed on for over a month, and no medicine seemed to help. One day I took a 600-mg pill of the new Ibuprofen. Wham, the spasms went away. I was impressed!

Recently, a friend gave me advice on Ibuprofen: "Don't take one pill at a time. Take three at once." I was reminded of this recently when I had a bum elbow. First, I stopped the motion that caused the pain. I'd tried one Ibuprofen pill every two hours—that did nothing. But when I took three pills (600 mg), the elbow pain magically subsided by about 40 dB, and then it went away.

How come? I asked our company nurse. She asked a wise pharmacist who stated that at low levels, 200 mg (one pill) per two hours, Ibuprofen is just an analgesic. But if 600 mg is taken at a time (every six hours), it becomes an anti-inflammatory too. This large dose also seems to be good at relaxing tense muscles that strain at cross-purposes, and various joint pains. This is NOT well documented in the Ibuprofen handout literature available to laymen. Your M.D. might not even know this, if you ask. H'mm. So—people are nonlinear, and/or Ibuprofen is nonlinear.

Now, taking a lot of Ibuprofen may not be good for the lining of your stomach. It can be about as bad for your stomach as large doses of aspirin and similar drugs. Refer to [www.rxlist.com/cgi/generic/ibup\\_wcp.htm](http://www.rxlist.com/cgi/generic/ibup_wcp.htm). If this doesn't scare you from ever taking Ibuprofen, I don't know what will! For me, I know

that Ibuprofen can do a lot of good, and almost no harm. I don't have to worry about every caution raised by lawyers!

Therefore, taking a large dose might not be good for you, especially if you do it repeatedly. But if it actually gives you a big improvement, you might be able to take one big dose and then stop—which isn't such a bad idea!

**Magnesium:** When I was camped up at 17,100 ft at Gorak Shep, just below Everest Base Camp, I noticed that my heart would occasionally skip a beat. You're lying there at midnight, wishing you could get back to sleep—and you hear a skip when you expected a heart-beat to come. The Mountain Medicine book says there's nothing surprising or wrong with this if it only happens once or twice per minute. It's just a fact that this happens at high altitudes.

I looked in a few conventional medical books. One termed this a "premature contraction." That's *baloney*, as it's obviously a *skipped* contraction. If a doctor tells you something *stupid*, you don't have to believe it. Remember what Mark Twain said: "Be careful reading medical books. You might die of a mis-print."

I discovered that sleeping even at 10,000 ft could cause skipped heartbeats, especially if you drink red wine or beer; or coffee, tea, or something else with caffeine; or any combination of these. They all tend to have an additive effect. Furthermore, it's *not* the alcohol that does it, because the skipping can start many hours *after* the alcohol is gone.

Then a friend said that he was taking magnesium to prevent skipped heartbeats. A special type of chelated magnesium was the only kind that worked for him. It had taken a long time for his doctors to figure out this solution. I bought some ordinary drugstore magnesium pills. They were effective in chasing

away the skipping problem, within about two hours. So if you're going to sleep above 10,000 ft, of course it's a good idea to cut down on caffeine and alcohol in general. But if you happen to have a skipped-beat problem, try a couple of 250-mg tablets of magnesium oxide. Some people agree that it works.

Books that encourage the use of supplements say potassium and magnesium are "important for good heart function." But they're vague about what pills might treat which problems. As with other "treatments," if you try some magnesium and it works, ask your M.D. why it works. If it doesn't work, ask your M.D. why it failed. If it causes side effects, stop at once and inquire.

I'm not going to be any publisher or clearinghouse for medical advice. But there are some good ideas about medicine out there. Letting the laymen comment on things that seem to work well could be more helpful than just asking your M.D. It's not fair to expect doctors to know everything.

All for now. / Comments invited!  
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## Robert A. Pease: Passionate, Talented Guru And Maverick



October 21, 2002 12:00 AM  
Electronic Design  
Ron Schneiderman  
Pease (2002)

Whether it's writing a column or designing a chip, Bob Pease likes to add a certain personal touch to his work. Since the early 1990s, he has been writing his column, "Pease Porridge," a mixture of technical advice, personal observations, and helpful hints ("those little wood strips really worked and detoured the water from running into my house") regularly for *Electronic Design*.

But then there was the first adjustable negative regulator that he built at National Semiconductor Corp., where he's been since 1976, and all of the e-mail that he answers at National. "I'm sort of the Ann Landers and Dear Abby of the electronics racket in the analog world," he says. His e-mail can be interesting. "I get stuff like, 'Hey, Bob, can you tell me what's wrong with my camcorder?' No, I can't." Additionally, Pease works on some designs for low-power devices.

Pease started in the industry in 1961. He spent 14 years designing op amps, voltage-to-frequency converters, and analog computing modules for Philbrick Researches before joining National. Since then, aside from designing analog ICs, he has written over 65 magazine articles, 190 magazine columns, and two books, including *Troubleshooting Analog Circuits*, which is now translated into Russian. Pease also holds 21 U.S. patents and is a frequent lecturer and presenter.

His biggest accomplishment, Pease believes, is the fact that many of the devices he designed are still in production, like the negative regulator. "A bunch of things. And I designed a voltage-to-frequency converter when I was back at Philbrick about 26 years ago that's still in production," he says.

No matter what anyone tells you, Pease says that you still can't tell in advance what's going to sell. "We used to say, 'Hey, that's a good idea.' Now, people use spreadsheets and crunch all the numbers," he says. "And if they don't like all the numbers, they change them until they can say, 'Hey, this is a pretty good idea.'"

Pease thinks that engineering is much more complicated today. "Mixed-signal stuff like analog-to-digital converters. You have to trust Spice for some of that design because you can't breadboard a lot of these things with CMOS parts," he notes. "CMOS devices are generally not available for breadboarding, and if they were, capacitance would screw it up." But young engineers are another story. "They usually come out of school greener than grass. They still have a lot of learning to do. But you see some good ones."

Like most people, Pease thinks that Silicon Valley has changed over the years. "This was a wild and crazy place 30 years ago, and it still is—well, maybe not quite as crazy as it used to be," he says. But that's another column.



## Bob's Mailbox

**Mr. Pease:**

I was shopping at a thrift store in Willoughby, Ohio, yesterday and found a Black & Decker 1/4-in. drill, No. 7004, type 1, with an orange \$6.50 price sticker on it. Recalling your recent article on the scarcity of new power drills with quarter-inch chucks, and not having a good one in my collection, I immediately took it to the wall outlet in the appliance department and gave it a quick power test.

It was in great condition, except for some surface rust on the chuck. I popped it into my cart and headed for the checkout counter. It was half-price day for items with orange price stickers. So, with tax it was less than \$3.50. Don't give up. They're out there.

**Martin Eich**  
via e-mail

Hello, Martin. You were wise to grab a valuable and rare item. Take good care of it and appreciate it for years! Best regards.—RAP

**Dear Bob:**

Roger Sheker's letter about the photosensitivity of input-protection diodes, which appeared in your recent Mailbox column (ELECTRONIC DESIGN, Aug. 19, p. 66), reminded me of a trick that I started using many years ago when working on low-level circuits. In the days before SMT components, I always found it very frustrating that signal diodes, including low-leakage diodes, were inevitably in clear glass packages. (Not all are. Fairchild made many low-leakage diodes in black-painted packages. But when the paint gets scratched, it's almost as bad. /rap)

As such, the photocurrents often far exceeded the actual leakage of the diode, particularly when the board was out on the bench for calibration, etc. Putting black heatshrink tubing over the diode packages improved the problem, but was a pain in production. Then I realized that I could use an inexpensive small-signal transistor (2N3904,

etc.), in a completely opaque TO-92 package, as a diode. The C-B junction is fairly low in leakage, has a high breakdown voltage, and the transistor may actually cost less than special low-leakage diodes of lesser performance.

But if you can tolerate the modest reverse-breakdown voltage (such as in back-to-back diode applications), the B-E junction makes an exceptionally low-leakage diode. Although transistor data sheets caution against breaking down the B-E junction, I have found that in protection or clamp applications this isn't particularly harmful if the current is limited to reasonable values. Hence, the B-E junction can make a useful low-leakage bidirectional input clamp, providing a forward drop in one direction, and a clamp of about 6 to 9 V in the other—without any problems due to photosensitivity.

By the way, amazingly, some small metal-can transistors DO show photosensitivity because the ceramic/glass header and epoxy seal at the bottom are translucent. Of course, today with SMT technology, you can finally buy signal diodes in opaque packages! (Yeah, but many of those junctions are still LOUSY in terms of conduction and leakage. /rap)

**Eric Kinast**  
via e-mail

Eric, I wrote this all up in my book, about 12 years ago (on p. 66 and 67). I largely agree. The B-E junction is low in leakage. But in terms of fast-turn-ON and fast-turn-OFF, which are often quite important, the diode made of (C plus B) versus E is much faster—as long as you can stand a lousy 4-V working rating.—RAP

**Dear Bob:**

I've enjoyed your series on knots (March 5, 2001, p. 142, Dec. 3, 2001, p. 88, and Aug. 5, p. 76). It's good to remember that even in this age of ROM, RAM, bits, and bytes, sometimes nothing can replace a good knot. Some years ago, I was in charge of flying a gigantic aerodynamic kite/balloon

called a dart, which was used at the White Sands Missile Range to calibrate radars. We were taught a number of knots designed especially for use with cored nylon line. We used your Dutchman when we transported the dart on a 40-ft flatbed truck. You brought back fond memories.

**Al Lacey**  
via e-mail

I'm impressed that somebody else really knew it and was teaching it! Thanks for the positive comments. I'll tell my Uncle Roger.—RAP

**Dear Bob:**

I think it's important whenever we discuss classical knots to remember that while many of the old knots worked well with hemp rope, they are not very secure with modern synthetic ropes. For example, I wouldn't trust my life on anything from the *Boy Scout Handbook*. I don't think I've seen any reference that spells out that warning, although I haven't yet looked at the Web sites you mentioned.

**Malcolm Chamberlain**  
via e-mail

You are quite correct to point out that nylon ain't polypropylene ain't hemp. Knots that were pretty good and safe, with some materials and rope sizes, are NOT so good with "modern materials." As I said in my first column, the square knots and bowlines from the old books are NOT trustworthy, as shown. But they are safe and reliable when you secure them with a couple of half-hitches. That was true for hemp. Now with nylon or synthetics, I'd still trust these basic old knots if secured with two or three half-hitches.—RAP

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



November 11, 2002 12:00 AM  
Electronic Design  
Bob Pease

As I said a few months ago *Electronic Design*, the study of ripple rejection will continue. Some guys asked me, "How can I convert a high-ripple voltage supply to a low-ripple one, or to a low-ripple one?" I am reminded of the little girl who pondered over the Sunday School teacher's question: "What must we do to receive forgiveness of sin?" After some thought, she replied, "First, you have to sin...."

So first we have to make some ripple. Figure C, located on my Web site at [http://www.pease.com](#), is a floating, battery-powered sawtooth oscillator, which I will call a NoiseMaker. Its task is to add ripple on top of the output of a quiet high-voltage supply and make it noisy enough that we can see if our ripple-rejection circuits are working—and exactly how well.

The circuit of Figure D (found on the above Web page) is not much more than an ac-coupling network found in any ac oscilloscope. But it includes safety factors and safety networks to protect the scope. After all, most scopes won't stand 300 V dc on their ac inputs. The coupling capacitors aren't rated for that. It also helps to define the bandwidth.

The circuit of Figure E (same Web page) is an ordinary ac pre-amp, because the supply we studied in February had just 100  $\mu\text{V}$  ac rms of noise. But when we get through, the noise will be so low that we'll need a pre-amp to evaluate it.

Now, how does the circuit of the figure on this page (Ripple Rejection Type A) work? Every op amp, if fed a noisy feedback path, can be made to try to amplify a counter-error signal to cancel out that noise. Even if the NoiseMaker produces 0.25 V rms of noise, the error voltage at the input of the op amp need not be more than a millivolt. That's enough to make the output move to cancel out that noise, as seen at its input.

This circuit's limitation is the op amp's gain-bandwidth product. So the amplifier must have a lot of GBW product, but its CMRR or PSRR are not very important. I think I'll try an LF411, with good bandwidth, or an LMV751, with 7 nV/ $\sqrt{\text{Hz}}$  and low  $I_B$ . If we can keep the op amp's gain above 100 at 10 kHz, we can get a 100:1 improvement at that frequency, and even more at lower frequencies. Could we use a bipolar op amp with lower  $V_N$  and worse  $I_N$ ? Not impossible, but unlikely. Hey, I'll try anything—once....

NOTE: In every application, the best choice of amplifier, and the best way to optimize the noise, depends on the impedances and on the specified bandwidth for which low noise is required. When things start changing, the optimization changes a lot. The rules for this example are: For a 3-dB bandwidth of 20 Hz to 10 kHz, get the lowest noise possible with the NoiseMaker specified—95 mV p-p at 26 kHz, plus the 100- $\mu\text{V}$  rms broadband noise of the basic Philbrick R-300.

What are the results? What's the best noise, with the best amplifiers? I didn't get this optimized before the deadline for this column. Further, I want to try out a special version of the Sallen-Key filter. We'll call that Ripple Rejection Circuit Type B.

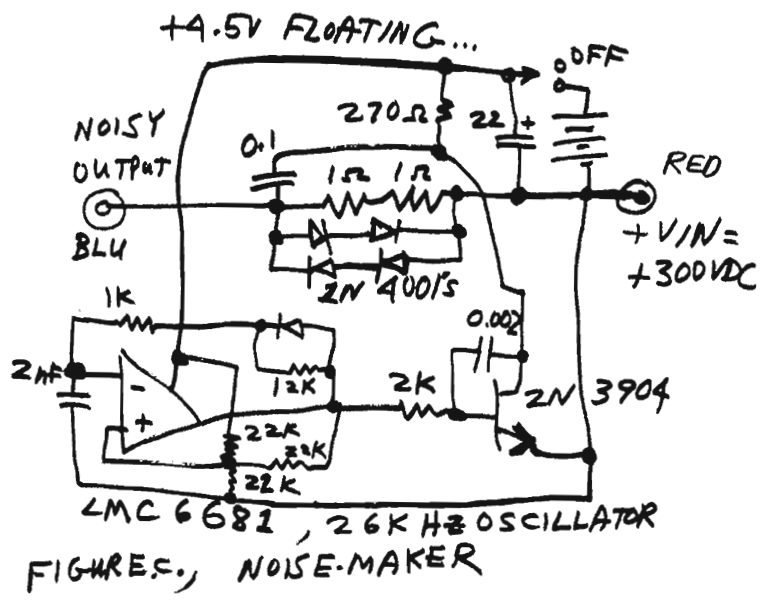
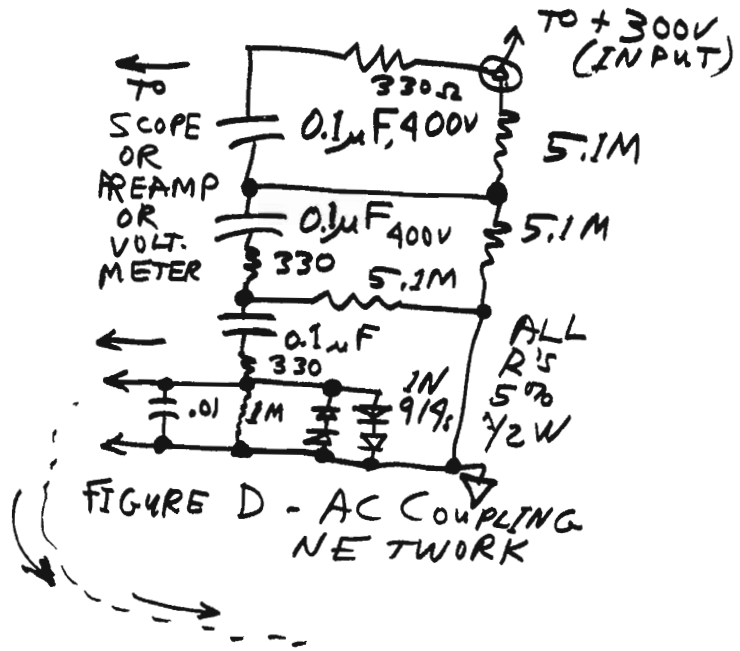
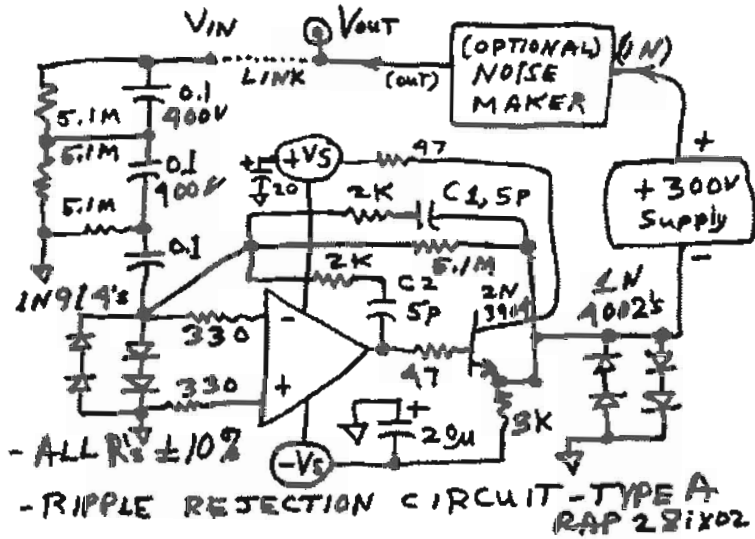
I'll have the results by next month. Then we'll see which circuit is good, which is better, and which performance is best, with what amplifier, to reject the noise of the NoiseMaker. We'll find out which circuit gives the lowest noise with the NoiseMaker turned off. Have you ever seen a 300-V power supply that had less than 1  $\mu\text{V}$  rms of noise? See you in a month!

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

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National Semiconductor  
P.O. Box 58090  
Santa Clara, CA 95052-8090

P.S. When I built this circuit, I carefully put a 330- $\Omega$  resistor in the input path, in series with each of the 400-V, 0.1- $\mu\text{F}$  mylar caps. But I neglected to draw them into the published schematic. Please add those in. Otherwise, the high charge during turn-on would fry the 1N914s! /rap

As I said a few months ago *Electronic Design*, the study of ripple rejection will continue. Some guys asked me, "How can I convert a high-ripple voltage supply to a low-ripple one, or to a low-ripple one?" I am reminded of the little girl who



## Bob's Mailbox



November 25, 2002 12:00 AM  
Electronic Design  
Bob Pease

### Dear Bob:

We routinely use stainless steel welding rod for crude shunts. It comes in a variety of diameters and we pick a size and length based on the "try-it-and-see" approach. We're not looking for exact calibrations, but rather a 50-mV signal at the desired current. We then monitor the signal, looking for a current change in the 25% range as a "lamp failure" indication. With the right flux, you can even solder copper wires onto the stainless rod for the sense points

—Tom Barker  
via e-mail

*Sounds reasonable to me! Thanks for the observations.—RAP*

### Dear Bob:

My investigation into potassium pills revealed that 99 mg of potassium equals 3% of the daily value needed and is the most common potency available. *(That is the normal statement, but I find it incredible that 33 \* 99 mg is normal and the "MDR." I never take that much in one day! /rap)* It is important to read labels carefully to ascertain that the pills contain 99 mg of elemental potassium—whether it be gluconate, orotate, aspartate, or amino acid chelate. *(The gluconate seems to take 550 mg per tablet to make 99 mg of potassium. I apologize for being imprecise in my column. See the Sept. 30 issue, p. 110. /rap)*

I found an inexpensive source of potassium gluconate pills on the Internet at [www.bioenergynutrients.com](http://www.bioenergynutrients.com). I just ordered a supply of 2000 for \$24.95 less 10%!

—Joe Dautremont  
via e-mail

*Not a bad price. Mine costs nearly twice that. But in terms of pennies per day, not a big deal! Thanks for hollering!—RAP*

### Dear Bob:

My engineer husband shoved your editorial at me. It's great. Doctors always say, "Listen closely to the history. It will give you the diagnosis 80% of the time." The history is what the patient tells the doctor. If the history is accurate, the diagnosis has a much better chance of being accurate. *(I just heard of a study: When patients want to give a two-minute explanation of their problem and symptoms, the doctor typically interrupts several times in the first minute, and the second half of the symptoms is never recited. Ha! /rap)*

Re: potassium and magnesium. In the hospital as a medical resident, I was taught to remember to give magnesium if someone was having trouble retaining the potassium that we had supplemented. This was especially a problem in people who (prior to hospitalization) had been getting most of their calories from alcohol. But it also was true for others without pristine fresh-vegetables-and-fruits diets. *(I get a good bit of fresh veggies, as my wife has many excellent veggie recipes. On some treks, when I get to 10,000 ft, there are some veggies, but not a lot. Bringing magnesium pills up to high altitudes is a cheap fix. /rap)*

In the "out-patient" realm that I now inhabit, doctors seldom mention magnesium. We don't have inexpensive and accurate blood tests for mild magnesium deficiencies, so we can look for a clinical diagnosis, such as reports of migraines, brief heart palpitations, and muscle cramps—including facial tics, abdominal or pelvic cramping, and charley horses. By examination, one may see tongue spasms, or see twitching when the cheek muscles are tapped. Note that some of these symptoms can also occur with deficiencies of potassium or calcium, or have other explanations. *(Do most doctors know what to look for, in terms of clues pointing to mineral deficiencies? /rap)*

It is good that you added the disclaimer about checking with one's doctor. People can ingest too much potassium. It is easy to check a blood level, though, to monitor this. Of course, anyone with kidney insufficiency needs to very closely coordinate their supplementation with their doctor, or they can get in trouble with potassium, magnesium, etc.

Re books: I agree with the Wilkerson recommendation. It's readable and usable. I have also enjoyed *Advanced First Aid Afloat* by Peter Eastman, MD. I don't know if it is still in print.

—Char Glenn  
via e-mail

*Most people don't get high-altitude sickness on boats, but the principle is the same: Travel in a "wilderness"—such as a large ocean—requires careful planning for first and second aid.—RAP*

All for now. / Comments invited!  
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Note: I am a big fan of the word-processing software, "PC-Write Lite," originally sold by Quicksoft. It runs very nicely on MS DOS 3.1. And it keeps on ticking, even though Quicksoft and its successor "Starlite Software" are not doing business now. But a writer from Denmark asked me, "Where can I find a book, *PC-Write Wizards Book*, on advanced software options for PC-Write?" I searched all around, on and off the 'net. This book is not easy to find! Does anybody have a copy? If so, holler. Thanks. /rap

Note: Does anybody want to buy a Philbrick R-300 power supply, ±300 V dc at 300 mA, in very good running condition? There's a guy in Oshkosh who wants to sell one. It's just like the one I wrote about last January. It's ideal for powering up your very own (vacuum-tube) analog computer. Bidding starts at \$25 plus \$32 shipping. I'll bid that, and anybody who wants to outbid me can buy it. I don't really need two. /rap

## What's All This Ripple Rejection Stuff, Anyhow? (Part 3)



December 09, 2002 12:00 AM  
Electronic Design  
Bob Pease

Okay, I wish I could tell you guys that I have improved the old R-300's noise down to  $1\ \mu\text{V}$  rms, on top of its 300-V dc output. I tried. I applied both the Type A servo amplifier from last month electronic design and the new Sallen-Key filter, Type B, shown in the figure. It's battery powered, and the LMV751 runs well on three AA cells. (If you want long and cheap battery life, use C or D cells instead.) I also used the level-shifter, and the pre-amp and NoiseMaker shown at .

Actually, I was able to work the noise down from 75 to about  $9\ \mu\text{V}$  rms, using each of the Type A and B circuits. I tried to get it lower, but the spatial orientation of the magnetic flux in the neighborhood would have made it very hard to get anything below  $9\ \mu\text{V}$ . I'll never say never, but it's not easy. Magnetic fields are nasty and hard to shield or screen out. Layout is critical and not easy. Maybe I'll just put longer wires on the pre-amps and move them far from the R-300, the transformers of all the power supplies, and the voltmeter. Might work!

Look at the careful filter structure of the schematic diagram of the figure, Type B. There should not be much  $1/f$  noise. But I had plenty of jitter, wobble, and  $1/f$  noise—much more than I expected. There was maybe 10 to 20  $\mu\text{V}$  of jitter. I considered the layout and the characteristics of the mylar capacitors (400-V capacitors running on less than 150 V dc), yet I couldn't find much of a clue as to what was causing the noise.

Then I thought about the resistors. Can an AB 1/2-W, 5.1-M $\Omega$  resistor running at 150 V generate enough  $1/f$  noise—current noise—to make a poor reading? Maybe so. I will study this later, just not this week. There are some trick tests that I'll want to run.... Hey, I never looked this closely before!

I did get some good data on the ac ripple-rejection, using my NoiseMaker (schematic is on my Web site) to try to cut the ripple of an 85-mV p-p (26-mV rms) noise at a 26-kHz nominal switching frequency, with lots of harmonics at 52 and 78 kHz. Although the Type A circuit improved the 26 mV to 0.88 mV, Type B did a bit better at 0.83 mV. But that was NOT unexpected. So it's not too hard to get a 30-dB noise improvement by employing a cheap, low-noise op amp, such as LMV751.

Both schemes worked pretty well. But Type A didn't like to tolerate a lot of capacitive load from the op-amp's output to ground—that is, the capacitance from the power-supply terminal to ground. It was able to drive the R-300's capacitance. But adding a coax cable over to the voltmeter made it grouchy at 4 MHz. So I just had to bring the voltmeter (HP3400A) over by the amplifier.

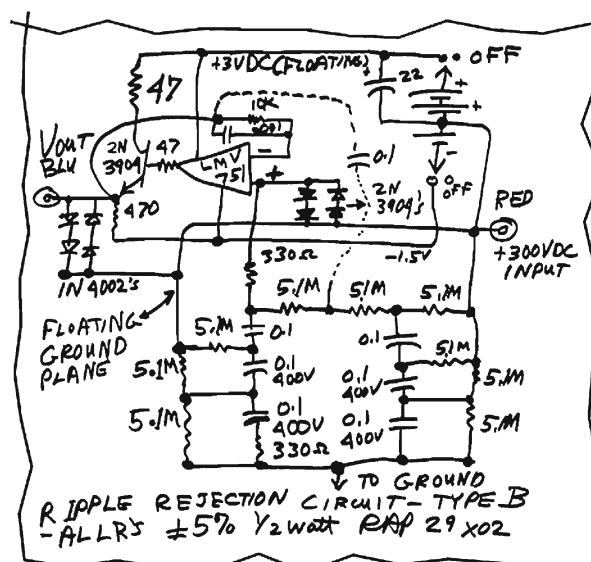
Yet Type B would surely be grouchy if there was a lot of capacitance from  $+V_{\text{OUT}}$  to ground. So any fast, nimble, low-noise amplifier may get grouchy about capacitive loads. In some cases, a series R-C damper can help. There are no easy answers. If I got a "hotter" op amp with a lot more than 4 MHz of GBW product, that would certainly help; and some 26 - to 52-kHz noise can be filtered with extra L and C. So this analysis is encouraging.

In all of these studies, I never got a shock, never caused a BANG, and never blew up any components or op amps (except when my thumb absent-mindedly nudged a  $\pm 2\text{-V}$  supply up to  $\pm 12\text{ V}$ ). So I don't feel bad, figuratively and literally.

All for now. / Comments invited!

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## Bob's Mailbox



December 23, 2002 12:00 AM  
Electronic Design  
Bob Pease

### Dear Bob:

Relating to your information on magnesium and skipped heartbeats at altitude: For those who might have respiratory problems resulting in diminished capacity to transfer oxygen to the blood, it's like being at altitude even though your actual elevation is moderate. Magnesium may be a help for those folks too.

—Clarence Netwal  
via e-mail

*Good point! As I indicated, anybody with skipped beats might consider a couple of magnesium tablets, just to see if it does more good than harm. I'd be surprised if it didn't do more good than harm.—RAP*

### Dear Bob:

Many excellent medicines trace their way back to the personal observations of some experimenter. Aspirin traces back to Native Americans chewing on a certain tree bark. Ortho-arthritis is another area where user observation seems to be making more rapid progress than the medical field.

Potassium is a critical element and the correct individual balance, too high or too low, can equally be a problem. Some people are on salt-restricted (sodium-chloride) diets (usually to prevent retention of fluids). Frequently, they use a salt substitute, which is typically potassium chloride. Too many bananas and too much salt substitute can depress the heart rate to life-threatening levels. In August 2002 my mother was hospitalized with a heart rate of 25 to 30 beats per minute. She was given IV treatments to reduce the potassium level in her blood and bring her heart rate back up. *(But I bet she had no leg cramps! /rap)*

It pays to read the labels to look at the total quantity of any chemical or drug that you are ingesting. Recently, there has been much on the news about the dangers of Tylenol overdose. Much of the problem traces back to the use of an OTC medicine that includes Tylenol (such as common sinus medicines) and then the addition of "extra strength" Tylenol to help cure the headache. Again, a problem with total intake. Doctors used to recommend taking salt tablets on long, hot hikes. What happened to that advice?

—Bruce Land  
via e-mail

*I think it is still there. I usually bring salty foods on hot, sweaty marches. In Nepal, we drank a pint of very salty noodle soup for lunch—and it was JUST RIGHT! I think we knew that we were working up a salt deficiency. We often had some salty food at supper, too, and it tasted great! Fried rice with tuna and soy sauce!—RAP*

### Dear Bob:

Here's a question for you. I have been unable to obtain a definition for "floobydust." I was wondering if you could give me a specific definition of that word. I found information that may be true: "Floobydust" is a contemporary term derived from the archaic Latin miscellaneous, whose disputed history probably springs from Greek origins (influenced, of course, by Egyptian linguists)—meaning here 'a mixed bag'—National Semiconductor Audio Handbook, 1976." And congratulations on your induction into the E.E. Hall of Fame! *(Thank you! /rap)*

—Will Compton  
via e-mail

*I think the definition goes ALL THE WAY BACK to—1975. Not much Greek or Egyptian influence. The guys who coined it were Dennis Bohn and maybe Tim Isbell, and a customer and his daughter; names mercifully forgotten.... The "dictionary" on the Web that tells you this origin of the term was a minibook written by Dennis Bohn. So, we can't stop him from spreading his own definition and origin story! But it was the name of Chapter 6 in NSC's 1976 Audio-Radio Handbook, and we all agree it means "miscellaneous."—RAP*

### Dear Bob:

Wow! I completely agree with your evolving self-diagnosis philosophy. I've had the same experience. For the most part, I now treat my body as just another engineering subsystem that needs to be debugged. My body worked fine yesterday, so if there's a problem today, the question, "What did you change last?" usually gives all the clues needed. *(We sure agree! As in "Hey, what WAS I drinking (or eating) last night?" /rap)*

If that fails to isolate the problem, I go into the mode of changing one variable at a time and recording the effects until the offending action/food/situation is isolated. I've had pretty good luck self-diagnosing. I think I'm better than my doctor at the simple stuff. I can monitor the DUT all day long! *(Exactly! But if you had leg cramps, you might not have any way to know that potassium can fix 'em. Not easy to find out! You might not know that taking three Advils, every six hours, is different than taking one Advil, two hours apart, three times. People ain't LINEAR systems. /rap)* No way my doctor would spend that amount of time. Plus, I have greater incentive to fix the problem. Of course, if simple debugging fails, I go right to my doctor. Engineers are people too. I hope your editor continues to let you ramble on nonengineering subjects. Your wisdom in all areas needs to be passed on.

—Chris Nielsen  
via e-mail

*Thank you!—RAP*

All for now. / Comments invited!  
RAP / Robert A. Pease / Engineer  
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More Doctoring Stuff: You may not know that back pain can be aggravated by (or even *caused by*) sleeping flat on your back. Put a fat pillow or rolled-up cloth or sleeping bag under your knees to relieve the pain. /rap



## Letters

December 23, 2002 12:00 AM  
Electronic Design  
Various  
Today's Engineering Curricula  
by Robert A. Pease

Our Editor's Notebook on educational software produced this interesting exchange between a reader and Bob Pease, renowned champion of analog technology.

**RAP:** "Educational Software"—isn't that a ? Most software just enhances stupidity. It confirms mediocrity and conformity and does not support those of us who have to invent new things that !

**Reader:** I'm a 2000 graduate with a BS-ETE from MSOE in Milwaukee, Wis. I found some of the comments in your article hit pretty close to home. I am currently in a position that requires me to manage a product right from the sketches on toilet paper to the delivery of the end product on customers' doorsteps! It's great and I feel extremely lucky to have as much re-sponsibility as I do. But, I have found that school did not prepare me for this role.

**RAP:** Yeah, but was it starting to be helpful? school can teach you all that you need to get along in life. At best, a good school can teach you how to !

**Reader:** In terms of being able to learn quickly and adapt, yes, I was prepared. But my analog design skills were terrible out of school.

**RAP:** 0, 10, 20, 30, 40, 50, 60, and probably 70 and 90 years ago, that was true—about learning analog methods, test methods, even, or analysis. are almost never taught in any school. Period.

**Reader:** As your column stated, our focus as students was the "cool digital stuff." VHDL was fun and new, digital logic was great, and everyone treated analog as if it were a retired five-star general; yeah it's neat, but it's old and not useful anymore.... Boy, were we ignorant!

**RAP:** Most students coming out of college are. I was. But I knew I was stupid, and I had a chance to .

**Reader:** Turns out analog is everything I do! I wish more emphasis had been placed on transistors and op amps, and most certainly on EMI-RFI shielding and theory.

**RAP:** Did your college have no courses on this? Go back and bitch like hell!

**Reader:** These are practical issues I deal with every day, yet I feel as though I have minimal basic knowledge to draw from. I've come to accept that I won't be taking over "Pease Porridge" anytime within the next 25 years, and that it takes time to be exposed to the analog world and all the applications of it.

**RAP:** Your ability to admit your ignorance—and admit you're in the middle of a severe learning curve—qualifies you to give it a try!

**Reader:** I've only begun to dabble in PWM and op-amp circuits, and I try to glean a little bit from each issue of and other publications to stay on top of technology. I figure we're all in charge of our own continuing education, right?

**RAP:** Absolutely!

**Reader:** In defense of my alma mater, I don't think any college can prepare body for thing, and I believe, generally speaking, that most jobs are in the digital/communications field.

**RAP:** Yeah, but engineers in those fields get cranked out like cookies from a cookie-cutter, and are worth as much.

**Reader:** Most of our courseload dealt with the analog circuit domain. However, I think without the practical application of the concepts learned (i.e., real design project requirements), the theoretical details seem nothing more than test material.

Hope you can use this feedback.

**RAP:** is an world. And it ain't a simple place! are struggling, just as all of who work in the demanding realm of linear circuits do, most of the time. And are gonna prevail, and are gonna prevail. Thanks for the comments! The world is a simple place, and the world is singularly difficult to learn. Best wishes! / rap

Oust Edison From Hall Of Fame

Somehow, I can't see Edison in your Engineering Hall Of Fame, despite his reputation. My reasons are many.

He adored dc, even up to the point of inventing the electric chair to scare the bejebbers out of anybody dumb enough to use Tesla's ac. He had absolutely no grasp that power sources and power users often were long distances apart. (What about farms?)

It did not permit you to remove the recording from the machine and save it. (Probably only a limitation, as he saw it.)

(Named after him, but like many other things, discovered by others.) It was essentially an early vacuum tube, but he saw no earthly use for it and considered it a curiosity only.

He tried hundreds of compounds before finally giving up and realizing that you had to get the air out of the bulb to keep the filament from burning up.

In short, the only thing Edison really invented was the think tank. He was very good at getting others to do the thinking, but he took the credit.

He really knew how to apply for patents and use them ruthlessly. Were he running a company today, it would make Enron look like small potatoes.

Okay, now that I got that out of my system, I feel much better. Thanks for listening.

## What's All This K2-W Stuff, Anyhow?



January 06, 2003 12:00 AM  
Electronic Design  
Bob Pease

The K2-W was not the first modern general-purpose operational amplifier. Loeb Julie's 1942 amplifier came earlier and had some real advantages. But the Julie amplifier didn't offer much gain, even after adding positive feedback. It didn't have much output power either, although a healthy cathode-follower output could easily be added. (See

The K2-W wasn't as powerful as either the M-IX Gun Director op amp or the Nike Ajax amplifier. But those drew four times as much power and featured a full-output frequency only out to ~100 Hz. They also required five regulated power supplies. (See these at the Web site.) But from 1951 to 1971, the K2-W at \$22 was one of the best, lowest-cost op amps you could buy.

Specs: Voltage gain was 20,000 typical, and 10,000 minimum, for a ±50-V swing into a 50-kΩ load. Not wonderful, yet not terrible.

Frequency response: 300 kHz for unity gain, which is adequate for a low-power op amp. Also, its full output to 50 kHz was 100 times better than the Ajax or M-IX.

Input bias current: Philbrick bought good 12AX7s to run at 150 V V<sub>pk</sub> (V-plate-to-kathode) at 300 μA, without gassing up. So, the grid current was a minuscule 10<sup>-8</sup> amperes. Wow, 10 nanoamperes! In monolithic terms, that means any op amp better than an LM324 was probably about as good as a K2-W. In 1971, the LM308 finally beat that, but just barely.

How about V<sub>os</sub>? It was guaranteed to be -1.5 V (design center) ±0.25 V dc typical, ±0.5 V max. No, I'm not kidding. The K2-W's offset arose from the obvious imbalance at the output of the first stage driving to the second stage. To keep life simple, the offset was allowed to be one-sided, so a single 2.6-V mercury battery could be applied via a 0.5-MΩ pot to cancel out V<sub>os</sub>. Back then, that was acceptable. For inverting amplifiers, a fixed voltage divider fed the pot. Obviously, if the K2-W's V<sub>os</sub> stayed inside 50 mV after you trimmed it, that's comparable to a ±10-V op amp keeping its V<sub>os</sub> inside 10 mV. It took a while for solid-state amplifiers to beat that consistently.

Output power: ±1 mA into a 50-kΩ load. Obviously, high impedances were the rule in analog computing in those days! The K2-W could drive 20 1-MΩ loads—at its output, pin 6.

CMRR? Oh, there was never a spec on . The K2-W had a guaranteed spec of ±50 V of common-mode range, but no spec on CMRR. When I measure it, I bet I'll see 33 dB. The Julie amplifier would beat it by 35 dB, due to its balanced design.

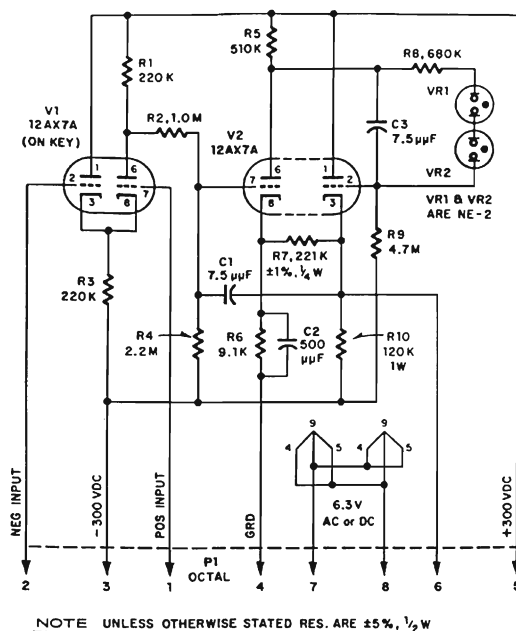
Why was the K2-W so popular? It was compact and modular. You could easily plug it in, unplug it, and swap. Plus, it was cheap at \$22. (Remember, when the μA709 came out in 1968, the price was set at \$25 for the cheap grade, and its V<sub>os</sub> spec was 7.5 mV max.)

Also, the K2-W came with instructions. The 28-page showed about 100 ways to use it. I've always said, if Philbrick hadn't shown everybody all the good things you could do with a cute, little op amp, Bob Widlar couldn't have given away his 709s. The Philbrick applications engineering guys made the whole industry happen. They gave it a good start. After solid-state amplifiers came along and became inexpensive, the industry boomed.

In future columns, I'll show some of the good things you could do with a K2-W. After all, it was ideal for George Philbrick's analog computing—that is, computing in seconds, milliseconds, or any speed in between.

See associated figure.

Comments invited!



Schematic Diagram, Philbrick K2-W

## Bob's Mailbox



January 20, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I found Eric Kinast's observations (*Electronic Design, Oct. 28, 2002, p. 84*) about photosensitivity most interesting. I wasn't aware that small metal-can packages can have light leaks. Years ago, I resolved to always use metal-can packages, rather than plastic, when low leakage was required. I had had a bad experience with TO-92 packaged 2N5555s, which I found to be very photosensitive. I may have encountered a bad production run, because he has found TO-92s to be "completely opaque." (*I am not aware of any TO-92-packaged devices that are sensitive to light! If you saw some that seemed to be sensitive, "a bad run" does not explain that. The input diodes on our LMC662 low- $I_B$  FET op amps are consistently better than 6 fA, and about  $10^{-15}\Omega$ . Not bad for a plastic-package device. /rap*)

As for his discussion of breaking down BE junctions, I have had much the same experience. That is, there seems to be no harm if the current is limited to reasonable values. I have used reverse-biased BE junctions as makeshift 8-V zener diodes in breadboards. I have also seen equipment in volume production unwittingly designed with transistors in nearly continuous BE reverse breakdown. To my knowledge, none of those transistors ever failed.

- **John Connell** (*via e-mail*)

- **Pease:** I have used 2N2369s that were quite touchy. We had to replace some used as zeners at 4.5 V that had croaked. Some npns can be damaged and degraded if you zener the  $V_{BE}$ , and the beta falls for a while. And it may creep back up partway in a year. Don't assume there is no damage, unless you know where to look. In particular, don't take 10 npns from your drawer—and zener their  $V_{BE}$  junction to find their  $V_Z$ —and if they are not what you need—don't just put them back! They may be degraded and drift for months!

**Dear Bob:** The lowest-leakage diode I ever found was the gate junction of a JFET. Back in 1970, it worked fine for storing charge on a small capacitor for 15 or so minutes. A coworker told me about it.

- **Raymond Payne** (*via e-mail*)

- **Pease:** Yes, but was it in a metal can, or in plastic? Usually, the plastic ones are better!

**Hi Bob:** I was a PC-Write aficionado (full version). It came installed on the first 486 computer that I bought in I think around 1987. I used it for years. In fact, I purchased the last upgrade the day that Quicksort closed their doors. They cashed my check but didn't send the upgrade. :-)

I continued to use it regularly until about 1997 when I switched to using Word. But I maintained a copy of PC-Write for reading old documents. I was constantly cutting and pasting into Word or completely retyping documents so I could convert them to PDFs. Last April, I ran across a program called "WordPort" ([www.acii.com/](http://www.acii.com/)) that can read PC-Write files and convert them to Word and other formats.

Then, in a spring-cleaning frenzy, I tossed PC-Write. I had everything—the Wizard book, the Macro book, the Font selector, the whole ball of wax. But it was occupying about 2 ft of bookcase space. With only 55 ft of available shelf space, and piles on the floor, ancient stuff had to go. (I even tossed all DOS stuff before version 6.22.) Sorry about that.

For nondocument editing, I have all of my technical programs default to using UltraEdit—a very nice alternative to NotePad, with no size limits, and with regular-expression capability.

- **Jim Thompson** (*via e-mail*)

- **Pease:** Hello, Jim. "Junk" is something you throw out two weeks before you need it. Fortunately, I DID find a copy of the Wizard book.

Comments invited!  
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## What's All This K2-W Stuff, Anyhow? (Part 2)



February 03, 2003 12:00 AM29  
Electronic Design  
Bob Pease

Here are some additional comments on the K2-W that did not fit in last month's column Electronic Design. The K2-W had gain and dc stability, and it was fast enough for many analog computing schemes—100 times faster than the M-IX amplifier mentioned in Part 1.

Uses: George A. Philbrick Researches, at 127-129 Clarendon St., implemented of K2-W's each month in the popular analog computing modules, such as the K5-U, K5-M, and so forth. That got the production volume up.

What if you did not like the offset drift to be  $\pm 50$  mV per day? Philbrick would be happy to sell you an add-on K2-P Chopper-Stabilizing Amplifier, to cut the drift to below  $1/2$  mV per day—and that's not too bad stability referred to full scale! It was priced at \$54.

What if you wanted more output swing than the paltry  $\pm 50$  V? For \$33, you could swap in, to the same socket, a K2-X or K2-XA that would swing  $\pm 100$  V at up to 3.3 mA. Not too poor. In fact, many modern operational amplifiers are not rated to drive 330 mW!

A \$400 R-300 power supply would provide enough power for 70 K2-W's, so the 'W really was light on its feet in terms of power needs.) One reason why the R-300 was so good in its accuracy and stability was so that it could compensate for the K2-W's lousy PSRR. This ALSO was never specified, but it was about 18 dB.

Note: Walter Jung has written a very good chapter on the history of op amps, in a new book, , published by Analog Devices. The cost is \$22. That's no more than the price of a K2-W! The chapter includes Walt's comments on the K2-W, plus a photo and schematic of the unit.

### A SUSPICION NOT UPHELD:

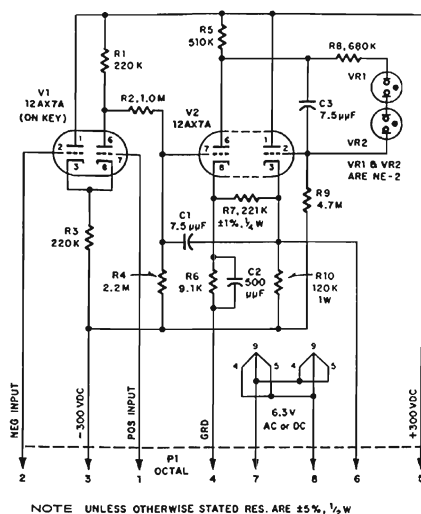
I finally got some data on the K2-W. I was really expecting  $Z_{out}$  to be lousy, worse than the data-sheet value of  $1 \Omega$ , because the K2-W's gain of 10,000 minimum rely a lot on the Positive Feedback from the 221 k resistor. I was thinking that the output did not have much  $g_m$ . But actually, the cathode-follower output did a pretty good job.  $Z_{out}$  (closed-loop, as a unity-gain follower) was about  $0.24 \Omega$ . So I'm pleased to see where my erroneous thinking was corrected!

Note: In the schematic, the balanced input stage went to a single-sided level shifter down to the grid of the second stage, down near  $+2$  V. This stage gets positive feedback from the output follower, via 221 k $\Omega$ , which was required to get the gain up from 4000 to 20,000. Note also the 15-pF Miller capacitor around the second stage, and the two NE-2 neon lamps used as level-changers to the grid of the output follower. (The op amps in the Heathkit analog computer were the same, except they used three 52-V zeners—Ha!

### WHAT ABOUT THE PACKAGING?

The components of the K2-W were ingeniously hay-wired over a jig. Of course, everything was carefully hand-soldered. Then it was closed up inside two plastic shell halves. The K2-W's octal base plugged into the user's socket, and the nine-pin tubes plugged in at the top. The whole thing stood just 4.1 in above the chassis. Not bad for \$22.

Comments invited!



Schematic Diagram, Philbrick K2-W



## Bob's Mailbox



February 17, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** They say doctors make the worst patients, but all my doctors say engineers are the worst. I guess we ask too many questions. I always feel better if I know what's going on. I even like listening to the air-traffic controller, if I can, when flying. Then I know where we are, where we're going, and who's up there with us, even when you can only see clouds.

Anyway, I take several diabetic medications. Some of them have nasty effects if you change or miss dosages. An increase in dosage can make you very hungry, so you overeat, causing higher blood sugar, etc. After a while, it settles down, but the response is a right-half-plane zero—in control jargon.

I test my blood sugar level (BSL) every morning. The tester has a large memory. About every month or so, I plot the data in Excel. The last time I changed medication, my blood sugar got down to 40. This was dangerously low, so I stopped taking it for a while, and it got too high. Finally, the doctor, who I see every three months, prescribed a smaller dose.

I noticed my response to the new dosage had a very nice, two- or three-week time constant. So I decided to try a little biofeedback. I chose a control point of 100 for my morning blood test. If it is above 100, I take that particular medication. If it is below, I don't. It is now very nicely controlled.

If I had to do this through the doctor, the three-month sample rate would turn it into an unstable system. Sampling every day makes it act like a linear control system (like God intended). The doctor expressed no interest at all in my system. All he said was, "Most people figure out how to control their blood sugar."

Like you said, sometimes you are your best doctor. Now all I need to do is listen to the other guy about diet and exercise, and I won't need the pills.

• **David A. Fox** (via e-mail)

• **Pease:** *If you can exercise a lot, you might skip a lot of cycles! I take metformin HCl, and it seems to be very mild and not nasty. Before I started taking it, I could not get my BSL down below  $160 \pm 10$ . As soon as I took the metformin, the average ramped smoothly down to  $110 \pm 10$ . Now when I am hiking, I just omit the metformin in the morning and let the exercise keep my BSL down. I do take one pill at night. The other night, I forgot to take my evening dose. I realized this when I woke up at 2 a.m., so I went to the kitchen to take half a pill and test myself, to see if I was up at 150 or what. To my surprise, my BSL was at 121—not bad. Apparently, if you can lower your BSL, it makes your pancreas more effective at producing enough insulin, and it makes your body more effective at using the insulin. The best part about taking half the dosage is that you don't have to refill your prescription nearly so often! I do that with my digoxin, aspirin, lasix, etc. But I do not chintz on my potassium. I take three full 550-mg (really 99-mg) pills each morning. This also provides a safety factor, because if I get in trouble from too small a dose, I can go back to a full dose!*

**Hi Bob:** You bring back the good old days when ingenuity was king. Now it's more like a monolithic society regarding electronics (stifling creativity).

• **George Gatzonis** (via e-mail)

• **Pease:** *Hi, George. If you look at all the digital junk, of course it is discouraging. Of course it is stifling creativity. Almost all audio and video equipment is made in batches by the millions, with horrifying menus, by "monolithic" Japanese corporations. Electronic music? All done by the menus. But the analog world is not quite so bad. You can still design things that work and are useful and fun. I'm sure some people will argue that if you know how to write code (which I am not likely to learn), you can write some code and wrap it around a small microcontroller, or micropower processor, and invent things that are fun and useful. As for myself, my favorite programming language is solder.*

**Philbrick Vacuum-Tube Power Supplies:** Right now we have five guys interested in buying an old Philbrick "R-300" power supply, 300 mA at  $\pm 300$  V—but only one supply. If anybody sees an old Philbrick power supply, such as an R-300, R-100B, R-500, or R-600, let me know, and I can help find it a good home. /rap

## What's All This Recipe Engineering Stuff, Anyhow? (Part 2)



March 03, 2003 12:00 AM  
Electronic Design  
Bob Pease

Several people have asked me, "What the heck is 'Pease Porridge?' Is it a kind of oatmeal?" Not at all. Oats have nothing to do with it. Every general cookbook has a recipe or two for pea soup with ham. Here is a delightful recipe for a Pease Porridge, but without ham or pork. This old recipe for Scotch

Broth/Pease Porridge was contributed by Dottie Atwood and Lurana Cook, 2001:

Simmer 3/4 lb or more of lamb necks in 5 cups of water. Add salt and pepper to taste. Cook about 1 hour. Pick over meat, remove bones, cool broth, and skim off fat. Soak 3/4 cup dried green split peas and 1/4 cup barley in 2 cups of water while meat is cooking. Then add to broth and meat. Simmer 30 to 60 minutes, or until peas and barley are done.

Add 1/2 bay leaf, 1/8 teaspoon rosemary and thyme, 2 chopped carrots, 3 chopped onions, and 3 chopped celery stalks. (Parsley is good, too.) Simmer 30 minutes or until vegetables are done. Adjust salt and pepper. It's a great variation on Pease Porridge!

### UNBAKED BOURBON BALLS

By Dorothy D. Blair, , Barbourville, Kentucky, ~1954

- 1 cup confectioner's sugar
- 1 cup finely chopped nuts—walnuts?
- 2 1/2 cups crushed vanilla wafers (~9 oz.)
- (1 cup shredded coconut—optional)
- Mix ingredients in bowl.
- Add 3 tablespoons Karo Syrup
- 1/4 cup bourbon
- Mix well with hands and/or spoon.
- Shape into ~3/4-in. diameter balls, using your palms.
- Roll in XXX sugar (with cocoa added as an option).
- Best when aged.

Transcribed by R.A. Pease, April 2002.

I have never made the option with coconut, but I often make a double batch, with 1/8 cup cocoa added for one batch, for a chocolate version. I am sure this be made with rum, but it tastes wonderful with bourbon. I never drink bourbon, but it is just right in this recipe. Bourbon lovers may prefer to omit the Karo Syrup, chopped nuts, vanilla wafers, and confectioner's sugar.

Comments invited!

### BOB'S MAILBOX

Hi Bob: That was a nice surprise to see your Pease Porridge moved to the front of the magazine. Now I don't have to flip to the back pages first.

—Jonathan Williams

## Bob's Mailbox



March 17, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** When scanning the index (electronic design, *Jan. 6, p. 20*), I saw "K2-W" and put on the brakes. Hey, I bet that's Philbrick's stuff. Yes, it is! I looked in my junk box because a couple of K2s were once in there. No, tossed out—damn. I still have a catalog pamphlet somewhere and the Palimpsest.

I was working at General Dynamics (then Electric Boat), and Jim Reswick at MIT and I put together a hydrodynamic simulator for the Nautilus SSN-571, the first nuclear boat. It was back in 1954, I think. Anyhow, we had five racks of K2-Ws with probably eight or 10 K2-Ws in each, a bunch of Philbrick multipliers, several function generators, and a *monster*  $\pm 300\text{-V}$  power supply. Even George came down to Groton, Conn., to see his stuff work! (*Almost 50 years ago! /rap*)

One thing that history has overlooked: I finished setting up the 3D hydrodynamics, and while I was "flying" the boat for the naval architects, the depth controllability at high speeds of the simulated boat was much better than usual. The hydro guys were mystified because their predictions were way off. I checked all of my coefficients and sure enough discovered a mistake! I had "placed" the bow planes on the sail (conning tower, to land lubbers) instead of the traditional bow position! High up there, we found the turbulence of the bow was avoided and the boat maintained depth smoothly at all speeds.

The hydro guys went back to their drawing boards (literally boards back then!), and on the next boat they convinced the BUSHIPS to *really* put the bow planes there. All the boats after that had bow planes on the sail, because they were more effective, much smaller, and quieter. The Russkies never caught on to this for many years. Then they did it, too. So, the K2-Ws have a place in submarine history due to my mistake! (*Wonderful! What a fantastic story! /rap*)

George Philbrick, Jim Reswick, and I were pleased. (*Me too! But mounting those control planes on the sail would seem to be very conspicuous! Like a sore thumb? How could anybody miss seeing the planes there? Maybe they hid them, or folded them up, when on the surface? /rap*) Thanks for the memories!

• **ROY MURPHY** (via e-mail)

• **Pease:** *I bet the Russians took a long time to match our learning because (A) what we were doing looked so stupid that they couldn't believe we were doing it, and (B) they didn't have any K2-Ws!*

See associated figure.

**Dear Bob:** I loved your article on the Philbrick K2-W! Several tube op amps I designed in the early 1980s are similar to the K2-W. I used zener diodes rather than VR tubes for plate-to-gate coupling. (*The neons were usually adequate. And in 1952, they were much cheaper and more available! /rap*)

I ran a spice simulation and a paper-and-pencil analysis of the K2-W. The gain spec for the K2-W must be 2000, not 20,000. If I remember correctly, the gain equation for a triode amp is  $(\mu R_L)/(R_P + R_L)$ . The plate resistance ( $R_P$ ) of a 12AX7 is 170k and the  $\mu$  is 100. This works out to a gain of 56 for the first stage. (*That's about the right ballpark. /rap*) The gain of the second stage is reduced to about 20 by the local feedback between the two cathodes of V2. Therefore, the total open-loop gain is approximately 1100. I ran a Spice simulation of the amp and got a small-signal gain of 1100. The Micro-Cap 7.0 Spice I used does not have any VR tubes, so I used some zener diodes and tweaked a couple of resistor values.

• **DAVE CUTHBERT** (via e-mail)

• **Pease:** *Au contraire! That's positive feedback (PFB)! The gain without the 221-k $\Omega$  resistor is about 2k, and the PFB increases it a lot. Spice should not lie so much!*

**Dear Bob:** The schoolgirl that you quote in your column (Electronic Design, *Nov. 11, 2002, p. 92*) must have been peeking into M. Luther's letter to Melancton: "Este peccator & peccate fortiter..." (be a sinner & sin hard, but believe even harder...)

• **GIDEON YUVAL** (via e-mail)

• **Pease:** *Your point is nicely taken! But the philosophy is slightly different. After all, what if the little girl decided to "believe even harder" about sin? Remember the immortal words of Mae West: "Whenever I have to choose between two evils, I always choose the one I haven't tried before."*

## What's All This Analog Computing Stuff, Anyway? (Part 2)



March 31, 2003 12:00 AM  
 Electronic Design  
 Bob Pease

Some time back, I threatened to show you how we used op amps to make analog computers. Okay, in the figure I show a simple six-op-amp circuit to make an analog computer that represents the familiar problem of . It simulates the motion of a car over its wheel, when stimulated by a "bump." Equations are available on request.

This computer uses one differentiator to simulate the shock absorber's kick when the wheel hits a bump. In concept, one could use a bunch of differentiators, but they cause more trouble than integrators. So we'll use two integrators—the traditional method. The first integrator represents the way the car's vertical velocity is inversely proportional to its mass and is proportional to the of the spring forces plus shock-absorber forces. The second integrator simply states that the position is the integral of the vertical velocity.

If it had no damping coefficient, this circuit would bounce and ring severely, just as your car would bounce a lot if it had no shock absorber. So we add A6 to represent the damping effect of the shock absorber. Apply a little ramp, or step, and the response of the output will do about the right thing. I built one of these in 1960. Did I ever run it? No. Maybe it was too intimidating. But I built this version and it runs quite well.

Note that the two gain paths through A6 can have different coefficients for positive and negative signal velocities. This represents "double-acting" shock absorbers. These could also be made nonlinear.

Now you can make a similar circuit, but with different mass and different spring constants, to represent the rear wheel. Connect them with suitable links to represent the tilt of the car, front to rear, and to couple in the car's longitudinal moment of inertia. Start writing equations—lots of equations.

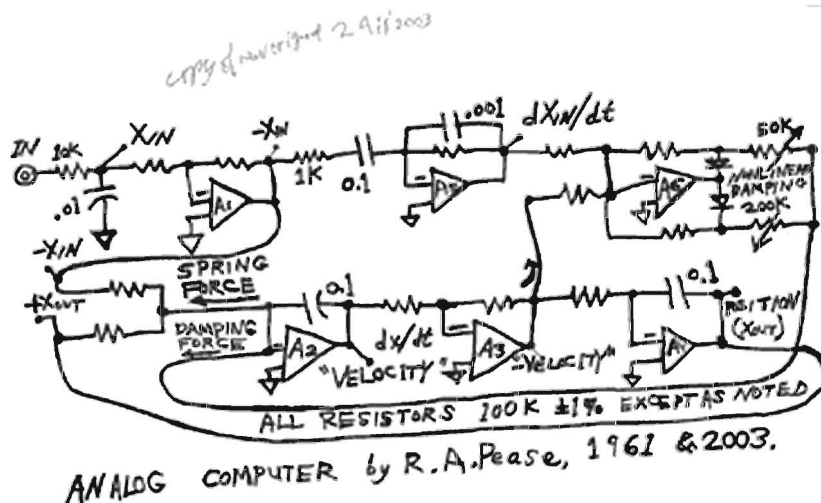
When this "car" hits a "bump," in the above simulation, does this represent the actual motion of a car? No, not really, as the tire's springiness and lossiness are serious factors in the suspension. So you must engineer another set of 12 op amps to represent the tires. These must link forward and backward between the main and the systems to get the right damping factors. I mean, the force from the tire does not just act on the springs. The springs act on the tires too. So, you have to pay careful attention to a large number of equations.

This now begins to get close to a good simulation of the car's suspension—if you get the right "tire inflation." The tire's characteristics are kind of nonlinear, too, when excursions are large—especially when the tire comes off the ground! You really ought to design that into the simulator. (Then if you make a duplicate computer to simulate the right side to match the left side, and add the representation of an "anti-sway bar," you can simulate the "car" hitting "bumps" timed differently on the left side compared to the right. Or, hit a bump during a curve.)

Now, you might be able to do some engineering on a car, to make various experiments. Then if the modified car matches the modified circuit, you have learned a lot. More on this topic next month.

\*January 7, 2002; p. 160.

Comments invited!



27p

## What's All This Analog Computing Stuff, Anyway? (Part 3)



April 14, 2003 12:00 AM  
Electronic Design  
Bob Pease

In my last column, I showed you how to build an analog computer that simulates the motion of a car over its wheel when stimulated by a "bump" electronic design. Could these systems be simulated with Spice? Sure, these days they can. Yet analog computers have been around since the 1950s, and Spice has only been around for 25 years, meaning the heyday of analog computing lasted well over 20 years. It's true that special-purpose simulation programs for analog systems were written for digital computers in the late 1960s and early '70s. So, we can't say, "analog computers would still be here if only...." But simulation using digital computers became a lot easier when you could use Spice. You didn't have to write your own Basic program.

Do analog computers always "tell the truth"? Not a whole lot better than Spice. There are 1000 ways that Spice can tell lies, and there are hundreds of ways that an analog computer can lie—but they are lies.

Did I simulate the system shown in my last column with 48 K2-Ws? No, but I did use one K2-W plus approximately six sections of LMC6082. It worked.

### Using Your Analog Computer

In fact, there are many real-world systems that can be simulated pretty well with analog computers. My truck speed controller electronic design was an analog computer. It worked surprisingly well and gave me no trouble. My PID controllers for temperature control have worked well. The ball-on-beam balancers electronic design that I built were analog computers. And my final, best version was a hybrid (analog digital) computer. Many analog circuits that I design are rather like analog computers. I never assume these circuits are going to work right the first time; I always lay them out to make it easy to tweak, adjust, and adapt.

Maybe I can show some results on my Web site. Go to and look for analog computing near the top.

Now that we have an analog computer, how do we use it? The strong point of an electronic analog computer is that it's fairly easy to manipulate a variable to see what the system will do. (That's a major advantage of all analog systems.) These days, you can change a coefficient of a Spice parameter in just a few seconds and see the results in (perhaps) just a few seconds more—best case. Thus, digitally facilitated computation can be reasonably interactive. But it wasn't always that way. We old-timers can remember when a "Spice-deck" was really a huge stack of punched cards, and if you turned in your simulation job, it could take hours to get a result. Asking for three variables might take days, if you had enough priority to get good computer time. Analog computers have always had real-time interaction between the twist of your wrist to change the coefficient, and the response on a CRT. So, you can get a good feel for what is happening in your system.

Stay tuned for Part 4, which will come in one of my May columns. I'll be talking about various methods for adjusting the analog computer's coefficients. You'll also get to see George Philbrick's gain-setting schemes.

Comments invited!



## Bob's Mailbox



April 28, 2003 12:00 AM  
Electronic Design  
Bob Pease

Hi Bob: I enjoyed your columns on the K2-W amplifier (Electronic Design, Jan. 6, p. 20 and Feb. 3, p. 22). I knew I had a couple of Philbrick items in my collection, so while in the crawl space this morning I dug them out—a K2-P and an SK2-B. Both have the original boxes and the packaging material.

The K2-P still has the original data sheet with it. Unfortunately, someone spilled something on the large tube shield for the SK2-B. I'm not sure that's the original shield, anyway. *(The 7119s did have a heatsinking shield to help them get the heat out. It's not critical. I still think an SK2-B or K2-B1 mounted horizontal would get the heat out better than when vertical. /rap)*

I used K2-Ps to build a controlled-potential electrolysis system while at RPI for my MS in chemistry. Along with an HP dc amplifier, it made a nice setup that produced some interesting chemistry results. I grabbed these two because someone was throwing them out! Glad I saved them. *(Good man! /rap)*

• **Jon Titus**(via e-mail)

• **Pease:** Hello, Jon. Take good care of that old junk! K2-Ps are slightly uncommon. I got a couple. SK2-Bs, which I helped design, with the 7119 output tubes are quite rare. Heck, nobody ever bought those. But we had to be prepared to sell them. If you ever want to see them put to work, I could show you how. An SK2-V (or K2-XA) in the middle would do it!

**Dear Bob:** Well, your schematics look a lot better these days! *(Some do—some don't! /rap)* Now we'll have to work on your black iron-stove drawing ability. *(I think that it's perfect! I hereby quit improving. /rap)* Trouble is, my drawing ability is nil so I'll just say your stove looks a lot better than I could ever do. *(It's adequate. Hey, you did recognize it as a stove. If not, then I have lousy skills. /rap)*

On another topic, it looks like the Mil and Hi-Rel boys are discovering the ugly side of Moore's Law lately. The EDA industry has continuously shrunk down through the micron barrier into nanometer-size features. The 90-nm barrier is the latest, and 65 nm is next according to the VLSI boys.

Unfortunately, someone forgot to tell Mil COTS and long-life Hi-Rel boys about *electromigration*. This is the new wear-out mode that gets worse as we descend the nanometer ladder. *(What's this "we" stuff? I vote against "continued improvements" that actually bring more grief and less improvement. Was it Yogi Berra who said, "Progress was okay, but it went on too long."—?? /rap)* The famous long life of integrated circuits is now a false myth. Today's microprocessors and embedded ICs will wear out in three to seven years. That's not the expected 25-year operating life of the telephone industry, or the 40-year operating life of, say, the U.S. Navy AEGIS program.

After three to seven years, your new car's embedded microprocessors may not be a problem—if you use it intermittently. *(Do you know how many processors are embedded in my new car? I'm talking about my new 1970 Beetle? Yeah, you guessed it—none! Our linear ICs will not poop out for many kilo years, typically. /rap)* Maybe someone in the semiconductor industry should tell the future victims about their misfortune. Isn't Moore's Law great? My middle name is Moore. *(Sorry about that. /rap)*

• **Dave Weigand** (via e-mail)

• **Pease:** Gordon Moore says there are  $10^{18}$  ants in the world, and every year now we make more transistors than that. Maybe if he gets to 65 nm, more transistors will die every year than ants!

**Hi Bob:** Have you ever been to Pease Pottage in Sussex ([http://freepages.genealogy.rootsweb.com/~villages/sussex/pease\\_pottage.htm](http://freepages.genealogy.rootsweb.com/~villages/sussex/pease_pottage.htm))?

• **Fred Stevens** (via e-mail)

• **Pease:** I was pretty darn close to it last summer, coming up the A24. We were just four miles west of Pease Pottage. But we had no reason to go through it, as it was slightly out of the way, and we were trying to beat the traffic into London. Maybe next time I'll have a chance to stop and see this village. Thanks for the reminder!

## What's All This Analog Computing Stuff, Anyway? (Part 4)



May 12, 2003 12:00 AM  
Electronic Design  
Bob Pease

In the little analog computer example shown last month, if we wanted to change the of the "car," we could change the feedback capacitance for A4. But it's inconvenient to adjust the value of capacitors or change around a large number of them. So instead, let's apply a to the input resistor.

Instead of the 100-k $\Omega$  resistor going from the summing point of A4 to the output of A3, we could have a 50-k $\Omega$  resistor going to the tap of a 50-k $\Omega$  pot, driven by A3. Or, we could have a 10-k $\Omega$  resistor going to the tap of the pot. This pot could be a 0.1% linear potentiometer—a 50-k $\Omega$ , 10-turn pot—with a turns-counting dial. These pots can still be bought for about \$20, plus \$20 for the dial, from Vishay-Spectrol. Now you could turn the gain up an octave, or down one or two octaves, making the "car" lighter or heavier. Similar gain adjustments could be applied to the paths for + and - damping factors at A6. (But I just used dumb rheostats.)

You've probably noticed that the pot setting, when the pot's wiper is loaded with a fixed resistor, will cause a nonlinear effect. To get 100% of the input conductance, you might set the pot to 100%. But to get 50% of the maximum gain, you'd typically set 63% on the pot. To get 25% or 29% of full-scale gain, the makers of analog computers—almost all of them—had special procedures for "pot setting" to some odd rotation value so the user could get the desired gain. Or, they could measure the actual gain as a function of an observed setting. You'd turn the pot and measure the voltage at "V<sub>POT</sub>."

George Philbrick didn't like that. He had coefficients that could be dialed in with sets of sort-of "BCD" conductances, using 12-position rotary switches. So if you didn't want 100 k $\Omega$  (10 micromhos), you could set the dials for 8 micromhos, or 9 or 11 or 22. Or 9.9 or 9.8 or 9.7, or 7.7 or 6.6 or 5.5. Or any gain coefficient between +1% and +1000%, or -1% to -1000%, or to zero. This was a very neat and NOT nonlinear gain function, even if it was kind of "digital."

George didn't let his computers just use binary-coded input conductances. That would take four precision resistors for each decade of gain-setting. He used ternary gain schemes. For example, if you wanted to change from an input conductance of 1 micromho, to double that gain from -1 to -2, he would connect in [3 micromhos -1 micromho]. To accomplish this, he would put in a 333.3-k $\Omega$  resistor to one summing point and a 1.000-M $\Omega$  resistor to a precision current inverter to give a net conductance of 2.0 micromhos. Each decade needed just three resistors, such as 1 M $\Omega$ , 333.33 k $\Omega$ , 166.67 k $\Omega$ ; then, 10 M $\Omega$ , 3.333 M $\Omega$ , 1.666 M $\Omega$ ; and so forth.

This meant that every computing function, whether summer or integrator, needed two good precision op amps per channel—one for the function, and one for the current inverter. But that's okay, because many functions needed to accept + and - inputs or provide + and - gains. The Philbrick "K5-U" computers had this feature from 1958 to 1968. The company implemented a good number of accurate summing resistors, but no tweaking of "precision pots" was ever necessary.

Comments invited!

## Bob's Mailbox



May 26, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I understand your views about Spice. I'm sure you're aware that companies periodically appear to promise better analog EDA, but most seem to fail. (There's a promising firm called Barcelona, but it's not far along yet.) Here's my question for the master (meaning you, of course): Do you think that the process of analog circuit design will ever be "automated" to the degree that digital circuit design is now "automated"?

*(Absolutely not. Anybody who claims that he or she can automate the design of any analog function is thinking of subtrivial analog functions—that is, analog functions that nobody would want to buy. See below at "CHD." Even the layout of analog functions on a pc board, or on a chip, is usually nontrivial, and it typically can't be done by automation or by computer. In any high-performance system (40 milli-in.<sup>2</sup> or 10 in.<sup>2</sup>), there are usually serious constraints on where different blocks get put or how they are connected. As you well know, "ground" is NOT "ground." In many circuits, there is no ground that can be treated as "ground." Hot components heat other components. Wild signals get transmitted to nearby components. Also, if you're not careful, they will be transmitted to the outside world as RFI.*

*Moreover, anybody who says that his computerized system, or EDA, can do most of the layout does not understand the situation. He might lay out somebody's circuit, but not one that's high performance. You are familiar with the phrase in which CAD stands for "computer-aided design." If you get involved with this, then you might appreciate how the phrase "CHD" means "computer-hindered design." We see it all the time. /rap)*

If so, do you have a time frame when this (analog EDA) might take place?

**Geoffrey James** (via e-mail)

**Pease:** *Do you have any schedule for when Hell is expected to freeze over? About as soon, I'll say.*

**Dear Bob:** You did it again! I read your articles about the K2-W (Electronic Design, Jan. 6, p. 20 and Feb. 3, p. 22), and sentimental feelings overcame me. This tells you about my age, and it was/is interesting to see the tremendous advances in the electronics field.

I had the fortune and opportunity to take a tiny part in the process. I am talking about the 1950s, when I was working at the Allen B. Dumont company in Passaic, N.J. I was a design engineer fabricating radar tubes and circuitry for the Navy. One of the early experiments was a huge contraption to compute elementary math.

The storage media was a vidicon-size vacuum tube called Radechon with a fine nickel mesh plus an MgF<sub>2</sub> layer evaporated on it as the storage surface. It was essentially a scan converter—one could read out the data at any arbitrary scan system and speed. This tiny tube was serviced by four 9-ft tall racks with several hundred flip-flop and other tubes. We had to arrange an extra three-phase power feed with about 15-kW capacity to fuel the few kilobyte storage process! It came in "handy" at winter times. We would turn on the racks and warm our frosty hands with the hot air emanating out of the tubes.

At any rate, I just wanted to say that I enjoy your wisdom while I'm repairing and restoring ancient vacuum-tube radios! Best regards.

**Paul Lukas** (via e-mail)

**Pease:** What a wild old machine! Obviously it was an experiment that worked, but it took too much maintenance and was surpassed by less (not so desperately) complicated schemes! I just built an old 1943-design op amp using two 6SL7GTs, and it worked darn well! A pair of them would make good mitten-warmers!

**Dear Bob:** In the March 3 issue of *Electronic Design*, the recipe for Unbaked Bourbon Balls appeared. It calls for "Karo Syrup." Do you use the dark or light variety of Karo Syrup when you make the cookies?

**Kevin Kocher** (via e-mail)

**Pease:** I think I usually use the light stuff, but I use whatever is around. There's not enough of it in there to make much difference!

## What's All This April Floobydust Stuff, Anyhow? (Part 12)



June 09, 2003 12:00 AM  
Electronic Design  
Bob Pease

Since it's now June, you can consider this my April Fools' joke. And now on to the latest Floobydust items: There's a new educational facility on the Web, called Analog University, from National Semiconductor. It supplies good teaching materials on several linear and analog topics, as well as op amps, voltage regulators, and so forth. It has material on advanced, intermediate, and basic levels. It provides video lectures, Q&A, quizzes, and tests. Plus, it has a pretty good natural-language search engine and a knowledge base. If you have a question about something analog, and it doesn't make sense to you, try this out.

This is not just for analog-circuit design engineers. It helps any engineers who must learn how to do some linear circuits. Its purpose is to provide improved time-to-learning for people who have to design linear circuits with fast time-to-market. It's not just for NSC engineers, nor for NSC customers. It's for everybody, which means not just engineers. It's very good for technicians too. And who is the Dean of Analog University? RAP is the Dean. No fooling. You can check it out at .

### THE WOM

Some of us old-timers recall the "WOM," a "write-only memory." This was useful when a large number of bits were generated during high-speed testing and they had to be destroyed to prevent cache overflow, etc. This was announced by a famous four-color advertisement in many of the electronics magazines of the day. It must have cost a lot of money to run this advertisement. Was it really paid for by Signetics? Check out these Web pages: [and](#) .

### PRO AUDIO REFERENCE

This is a big book with lots of information on Professional Audio. Some of it is a pitch for good audio systems designed by Rane Corp., and some of it is an excellent encyclopedia on audio, edited by Dennis Bohn, the Dean of Floobydust. It's worth \$34.95. You can buy it from Rane's Web site at [, or from Barnes & Noble.](#)

If you look in this book under "Sound Pressure," you can learn that the reference point known as "0 dB" is really at 20 micropascals, which is about 2.90 nano psi (pounds per square inch). (It's actually 2.908, if you care, about 0.002 dB of accuracy.) Thus, the number of dB that corresponds to + and -1 atmosphere of peak pressure, or  $\pm 14.7$  psi peaks, is about 191.1 dB. So when a sine wave of sound gets to that level, the peak pressure would be double atmospheric pressure, and trough pressure would be about zero, which is hard to generate or imagine.

### PITCH

How many of you guys have noticed this? You are listening to music, or even the pitch of your computer's fan, or a dial tone. Then as you bite down hard on some tough nuts or a popcorn cake, the pitch seems to dip momentarily by about half a note. I hear this plainly. Try it.

Doppler shift has a similar effect and is well understood, but it's quite different. Audio experts can give me no theories on why the number of cycles arriving at your ear (per second) seems to be changing when it isn't! Do you hear it?

Comments invited!

## Bob's Mailbox



June 23, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Hi Bob:** I have been a reader of your application notes and articles for years and have always enjoyed your writing. Lately, your articles (for example, on the K2-W) have reminded me of two Monty Python actors reminiscing about the past: "You lived in a cardboard box? We dreamed of a cardboard box.

We slept on gravel in the middle of the road and had to move every time a car came along...." The biggest difference is the subject. Now it is more like:

1. You had a 300-baud modem with acoustic coupling? We dreamed of a 300-baud modem. All we had was a battery and two wires and we had to tap out ASCII code.
2. You had a battery and two wires? We dreamed of having a battery. We had to whistle into the handset and listen to the return tones to write our computer programs.
3. You had a phone you could whistle into? We dreamed of a phone. All we had was....

(Check. We dreamed of vacuum tubes. We only had relays and had to file their contacts every night. /rap) You get the idea. I enjoy these "electronics war stories." I am guilty of doing that kind of thing myself. Ever tried to convince your student that 8-in. floppy drives existed? Keep up the great articles.

- **Lawrence King** (via e-mail)
- **Pease:** I know a friend who has a hard-drive disk that's 42 in. across. Thanks for the comments.

**Dear Bob:** Your column on the Philbrick K2-W (Electronic Design, Feb. 3, p. 22) brought back memories of experimenting with  $\pm 300$ -V dc op amps. As a recent graduate, I was part of a team at Melpar Inc. that was developing an analog formant vocoder well populated with K2-Ws (three tabletop racks). I was also responsible for designing the vocal pitch-measuring circuit. I had a breadboard circuit (yes, on a length of 1- by 12-in. plank) spread out on the bench, fed by a microphone. My Glorious Leader was looking over my shoulder and decided to reverse the phase of a coupling transformer (with the circuit powered up). The ambient noise in the room gave him a small shock, resulting in an "ouch," followed rapidly by "OUCH," and "OUCH!!!" as he became part of an unstable feedback loop.

- **Ralph Gaze** (via e-mail)
- **Pease:** Uh, yeah, a K2-W is NOT guaranteed to NOT swing more than  $\pm 99$  V!! And, there are circuits where the amplitude could grow gradually! YIPES! Thanks for the story.

**Dear Bob :** I was wondering if you know where I can find an I versus E curve for Copper-Oxide rectifiers. I don't think that this type was listed in your *Troubleshooting Analog Circuits* appendix E chart. Any ideas?

- **Dale Roche** (via e-mail)
- **Pease:** Hello, Dale, I don't think I have ever seen that curve! But I'll ask around. Nope, ain't found one yet.

**Hello Bob:** I am searching for some beam power tubes and thought I would give you a try. I am specifically looking for a 6417 and/or 7551. Both are nine-pin types typically found in mobile VHF power-amp applications in the 1960s and early 70s. Have you any collecting dust in the junk box? (No. /rap).

- **Dennis Monticelli** (via e-mail)
- **Pease:** I tried [www.dogpile.com](http://www.dogpile.com) and shortly found [www.thetubecenter.com/tubelist11.html](http://www.thetubecenter.com/tubelist11.html). It has 6417s at about \$6 and 7551s at \$9. I just searched for "6417 tube." I quit at this one Web site that had both. Have fun looking further. Dogpile often beats Google. Also, [www.hamtubes.com/tubes/list5.htm](http://www.hamtubes.com/tubes/list5.htm) also seems to have both types for the same price.

**Hi Bob:** In the preface to Morse and Feschbach's *Methods of Theoretical Physics*, thanks are given to, among many others, Robert and Jane Pease. Were you a really advanced child prodigy, or are these relatives?

- **Steve Heider** (via e-mail)
- **Pease:** No, that was not me, nor is it anybody I know. There are LOTS of Peases around.



## What's All This Goodbye Stuff, Anyway?



July 07, 2003 12:00 AM  
Electronic Design  
Bob Pease

Okay, friends, recently I was hit by unpleasant surprises: Three of my good old friends died. One got badly injured in a car crash and never recovered. Lung cancer struck another—quite unfair because he never smoked. The third was fighting kidney cancer and thought he would lick it. But he didn't.

I really thought it was unfair that these guys never had a good chance to say goodbye. I never had a fair chance to say goodbye to them and tell them how much I loved them and appreciated all the things they did for me—and the world—and all the times they were nice, even more than necessary.

I have had a very good life. I'm not saying goodbye to guys just yet. All guys, my readers, have greatly enriched my life. You have made me laugh, smile, and jump up and down. I have enjoyed life a lot, and you guys have helped. I have been wonderfully affected by all my readers, and I hope I have done some good things to make your life happier too.

When I go on a trek, I prepare individual notes to several persons. Hey, I'm an amateur at this, but if I survive to go on six more treks, I'll get this right. This was all typed first in May 2002 when I was preparing to go trekking by mountain bike around the Annapurnas. How did I know I'd make it around this insane trek?

Before my first trek in 1989, a friend cautioned me that I should have my will made out and expect to have some small chance of encountering life-threatening problems. She was right. But the chances of a life-threatening problem on most of my treks have been less than driving to work, and I haven't had any accidents there.

On that 1989 trek, there were several steep slopes, east of Syabru, where, if we got sloppy or tripped, we could slide on a sand-slope and get seriously hurt and even fall into a raging river. Nobody slipped or fell.

A few days later, I had gone past all of the hard, dangerous parts of the trek. Nancy and I were ambling down over a closely cropped lawn when I tripped on a tiny nubbin and fell, scratched my knee, and made a small tear in my pants. Then I sat there on the short, green grass and laughed and laughed! On the dangerous places, I had no slips. Yet on the easiest lawn, I fell, ripped my pants, and scraped my knee! It was hilarious!

If you go hiking in difficult places and have no problems, but then you trip on a speck of dust on a sidewalk, fall, and get hurt a little, laugh along with me! (I know a guy who hiked 1000 miles in Nepal, one summer, with no accidents. When he got back to Kathmandu, he tripped over a potted palm in the lobby of his hotel and broke three ribs.)

You too can put together a general goodbye note to all your friends. Then, scribble out individual notes to your close friends. Put some of each into stamped, addressed envelopes. Now, hide these addressed letters in a suitable big envelope and store it in a safe place. So where is that? Also, how will they be found?

The only secure way that I can think is to give your best lawyer a sealed envelope to be opened only in case of your death (or some phrase that would apply if you are lost at sea and your body cannot be found). Inside, have instructions to mail the letter to your spouse, or colleague, and inside that place the "key" to find the cache of goodbye letters, ready to be mailed.

I mean, you can't really give such a letter to your secretary or friend who might be curious about why it says to open "only in case of death." Also, you can't just leave them for your spouse, because he or she might be killed in the same crash as you. There may be other trapdoors that are immune to curiosity. Tell me, and we'll give out the best ideas. Anyhow, you should set up these letters to send out your final goodbyes, rather than wish that you could write and send one when it's too late.

Comments invited!

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## Bob's Mailbox



July 21, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** My first car was a 1955 secondhand Cadillac DeVille convertible; tube radio, automatic station seeker, service every 1000 miles, total life 100,000 miles (Swiss miles, up the mountains), end of life due to multiple mechanical failures. *(My first car was a 1962 VW Beetle; oil change every 5000 miles, total life of 169,000 miles, end of life as it was throwing a rod, but not until after I parked it at the junkyard's door. What a hardworking car. /rap)* My latest car was a 1993 Olds Silhouette, all digital; service every 10,000 miles, total life 250,000 miles, end of life due to multiple electronic failures. *(My latest car is a 1970 VW Beetle; change the oil every 5000 miles. Total life, since I bought it four years ago, is 110,000 miles—so far. It's a hardworking car and running very well with its 33-year-old technology. /rap)*

Where is the big step ahead in technology? *(That's a good question. /rap)* I started in electronics, with analog computers (PACE) in fact, and I drifted into mechanical engineering. I'm a happy guy. I also want to say that I like your Mailbox. Keep on with it!

- **Urs Meyer** (via e-mail)
- **Pease:** You seem to have been sucked into the GMC theory. What are you driving now? I seem to have been sucked into the 1970 VW theory. I'm going home in 10 minutes, at 68 mph. That's fast enough for me. I'm a happier guy. Thanks for the comments!

**Dear Bob:** I have just finished reading *Edwin Hubble, Mariner of the Nebula*, by Gale Christianson (1995). Woven in the life story of the great astronomer are references to a colleague of his, Francis G. Pease. In the book, Francis Pease was not only a very good astronomer, he was also shown to be an outstanding engineer, designing various astronomy instruments, figuring out how to make the 200-in. mirror for Palomar, etc. A most fascinating fellow! Are you related to Francis Pease? There seems to be a certain level of engineering talent going along with the Pease name. Just thought I would ask.

- **Tom Clarke** (via e-mail)
- **Pease:** There are probably 4888 OTHER Peases unrelated to this project. I am in the same state. Best regards.

**Hi Bob:** It's always a pleasure to read your columns, wherever I can find them. I am an analog guy who lived in Europe until 1997, and that's where National did something that was very appreciated among engineers: biodegradable boxes and packaging. And they were even made from post-consumer recycling pulp. *(I am not sure if I have ever seen those. When we get cardboard boxes, I just reuse and/or recycle them. /rap)*

The National rep told us that engineers took those home, and with the addition of some H<sub>2</sub>O and seeds, they grew alfalfa and kitchen herbs on them. So I did that as well, and it worked! *(Neat as hell! /rap)* After the "harvest," you just took the whole mess and brought it to the composting bin. What happened to those ideas?

- **Joerg Schulze-Clewing** (via e-mail)
- **Pease:** Good question. I'll ask around. Perhaps some of our readers want to comment on this.

**Dear Bob:** When I was a sophomore EE student at Pitt in 1969, I took an analog computer lab. We had three small EAI analog computers with several patchboards each. I remember we set up the pots by connecting each pot to a bridge after it was connected and balancing it against a precision multiturn master pot. This was done in a "pot setting" mode that, in retrospect, grounded the inputs of all the amplifiers. *(I've never done THAT! /rap)*

I also remember that scaling calculations had to be done for both variable scaling and time scaling. In addition, I was in the minority of students that would prepare for the lab ahead of time and had a schematic and scaling chart prepared. So my lab group usually finished our projects quickly and got out of the lab early.

- **Joe Birsa** (via e-mail)
- **Pease:** It's quite important, even today, to plan ahead! Thanks for the comments!

## What's All This Refrigerator Stuff, Anyway? (Part 2)



August 04, 2003 12:00 AM  
Electronic Design  
Bob Pease

A friend of mine was cleaning expired medicines out of his first aid kit. Fine. But when he threw out the salt pills, I got mad. How can salt pills lose potency? I grabbed up all the medicines that had expired just a couple weeks ago and threw them in my refrigerator. I mean, any medicine that was potent two weeks ago isn't very bad now. (True, if it was stored at high temperatures for its rated life, it might be getting weak.) Now if I keep it in my refrigerator or freezer, it will stay good for years. I often come back from a trek and store a hundred bucks of pills in the freezer. I also store extra 35-mm film in my freezer.

Somehow, after 40 years, we got smart. Rather than just storing food in our refrigerator, Nancy decided to load "food groups" into plastic boxes—ordinary boxes, Tupperware, Rubbermaid, or the equivalent, perhaps 2 by 8 by 11 in., or as convenient. If a box is too big or too small for one group, we use it for something else.

First, we put a box for jams and jellies on the left-hand side. Then came the cheeses. We keep jack, cheddar, blue, Parmesan, and others in a mid-size box on the right side of the middle shelf. This makes it easier to (A) find cheese when you want it and (B) not lose cheeses, which is different from (A). Then we have a box for mustards and tangy sauces down at the bottom. Even more recently, we put a box for tortillas and bread in the middle of the refrigerator.

If you try this, you will be amazed at the results. There's a time to be disorganized, and a time to be organized. This is not a bad way to get organized. By pulling out one or two boxes, you can see and find other things that might otherwise get lost. For example, "I there is some (mayonnaise) in there, somewhere." Pulling out a few boxes helps you find the (mayonnaise)—or whatever.

Today, I had 16 chicken thighs to bake. I just took out the whole box of tangy stuff. I sprinkled and poured and spread various sauces on pairs of chicken pieces—curry paste, black bean sauce, salsa, barbeque sauce, Hoisin sauce, honey-mustard sauce, ginger-garlic sauce, and so on. I also used some old recycled aluminum foil to keep the flavors segregated, when possible. Then I put the box of sauces back.

I baked the chicken for 20 minutes at 350°F, basted them with the fat and juices, turned the chicken parts over, and basted them again. I think I figured out that 20 more minutes was about right. And, I added slices of onions at the start. Ain't no such thing as too much onions.

This idea of using these boxes is such a good idea, and I have not seen it done nor discussed anywhere, that I think it makes a good column. To heck with Heloise! She's too late to figure this out! So buy a couple of medium-sized plastic boxes and try it out on the foods you have in large quantities. Who did the engineering of this? My wife Nancy did it, and in terms of organizing, I agree, it makes perfect sense. I'm too slow. This also works for spices and yogurt—maybe even op amps?

By the way, I haven't heard of anybody trying to use Fuzzy Logic, recently, to improve a refrigerator. I have hardly heard of anybody using Fuzzy Logic for .

**Comments invited!**

## Bob's Mailbox



August 18, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** Just got around to seeing your June 9 column. The apparent shift in perceived pitch you asked about is due to the lack of compensation in the inner ear for changes in environment. While not an expert on ears, here's the way I understand it: The inner ear has resonant fibers in the cochlea that stimulate attached nerve endings at a level corresponding to the fiber response amplitude. An array of nerves scans the outputs from these fibers and develops what amounts to a Fourier transform of the received sound. If a single frequency is received, only one fiber has a max response. The array locates it and reports that to the brain. If biting changes the pressure in the inner ear, the resonance of the fibers shifts, a new fiber becomes the max responder, and the analysis array, not being compensated for pressure changes, sees only that a different fiber is now responding and reports a change in received pitch.

Another effect that is fun to observe is the AGC function of the ears. If you are hearing a medium-level broadband noise and then drive a nail with a hammer, the AGC will respond to the peak sound of the hammer blow and suppress the broadband noise for a fraction of a second. Recovery follows the usual exponential curve and restores the original sensitivity in a few tenths of a second. You have to do this outside so the echo of the hammer does not mask observation of the recovery process, which is faster than the echo time constant of most rooms.

- **Richard D. Lee** (via e-mail)

- **Pease:** That's one of the most thoughtful replies on the subject I've seen. About a third of my readers say they hear this effect. We don't know if younger or older people hear it most.

**Dear Bob:** Without further evidence, I can't accept Dave Weigand's assertion (Electronic Design, *April 28, p. 20*) that today's embedded microprocessors are going to last only three to seven years, limited by electromigration. I would guess that electromigration goes as voltage squared. But smaller silicon geometries are running on lower voltages. My rough guess is that operating voltage is roughly proportional to feature size. Therefore, since a roughly square function beats a function roughly to the power of one, it seems likely that electromigration should be "less" of a problem as chips are shrunk to ever smaller sizes—not more of one. (*Not at all! Electromigration (E/M) is proportional to (current density in aluminum paths)<sup>N</sup> and to (temperature above 100°C)<sup>M</sup>. It may be proportional to the product of those two terms, where N and M are at least 2, or 3, or 4—or maybe more. NSC's parts are designed very conservatively for E/M. Our QA guy told me we get less than one complaint per year about E/M. /rap*)

Newer, faster CPUs seem more sensitive to ESD events than older ones. So, perhaps ESD is the culprit for any finding of shortened lifetimes. (*Nope. Next time you wander into a computer store, ask the clerk how fast the 2300-MHz processor is expected to wear out due to electromigration. If you plan on living in, and computing in, an igloo, you might be quite pleased with the answer. If not, probably not. /rap*) By the way, I am a member of the mountain-bike-to-work crowd.

- **Alastair Roxburgh** (via e-mail)

- **Pease:** Very good, but at 40 miles out, I bicycle to work very rarely. Sometimes I ride my bike down to the train and ride that to work. That is easy—five miles down, and 330 feet down the hill to Caltrain—about 21 minutes. But riding back up that hill is rather slower, like 45 minutes. Naw, as long as my 1970 Beetle is running, it is cost-effective.

**Dear Bob:** Regarding your reply to Lawrence King in "Bob's Mailbox" (Electronic Design, *June 23, p. 20*): You had relays? We only dreamed of relays. All we had were these stones marked with 0 on one side and 1 on the other. We flipped them over manually to perform calculations in binary arithmetic. Yep, we were real familiar with the original Latin meaning of calculus.

- **Bill Frank** (via e-mail)

- **Pease:** Thanks, Bill. I love it!

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) —or:  
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## What's All This Spicy Stuff, Anyhow? (Part III)



September 01, 2003 12:00 AM  
Electronic Design  
Bob Pease

Recently, an engineer sent me his analysis of my current limiter, in "What's All This Current Limiter Stuff, Anyhow?" Electronic Design, using a power MOSFET. He studied it and decided he did not like my optimization. So, he re-optimized it—using Spice. I studied his letter and replied.

I explained that he had not understood the functions of some of the diodes in the circuit. When he changed or removed a diode, the stress on the power MOSFET would be greatly increased, and I guessed that a factor of about 3 would cause great destruction and fireworks. (I thought about revising my working circuit to see if it would actually blow up when thus brutally stressed, but I decided that it wasn't worth the effort or aggravation.)

He replied, "But the Spice analysis shows the peak power on the FET was not too big." I just pointed out that the Spice analysis was probably not very accurate as to how many kilowatts would occur in that FET—for a few microseconds. Models (Spice models) for devices are not very accurate in high-power, high-current, or transient regions. I pointed out that when you actually buy a transistor, it is a pretty good model of the actual device and how much abuse it can stand. But a Spice model of the transistor is not.

Well, the engineer apologized for his (possibly) imperfect analysis of the circuit. But he observed that Spice was still a good tool for inexperienced engineers and students. "Spice may not be necessary, and is certainly not sufficient, but it does allow one to try 'what ifs' easily, and it does help considerably in understanding how circuits function," he said.

This got me mad: "I respectfully disagree: Spice takes away your ability to get good insights on what is happening. Spice actually HURTS your understanding of how circuits function."

Then he wrote, "What you must allow is that it takes much time (and you have the 'appearance' at least of having been around for ages!) for one to gain the experience of lots of designs. And if Spice can help, then I am all for it." And that is just my point! Building a circuit and blowing it up can help your design and engineering and learning process.

Building it in Spice does not help. And, I claim, using Spice will hinder your ability to design. An engineer should design as many things as possible, scribbling on the backs of envelopes, or modifying breadboards. Pretending that Spice is a substitute for that is an error! Pretending that Spice is even helpful is an error.

I mean, how are you going to learn to run a good marathon by hobbling around on crutches? Spice is a crutch. Sometimes Spice is a motorized crutch. And sometimes Spice is a rubber crutch. I've been around long enough to see Spice lie to me and my friends thousands of times—often seriously enough to force a major redesign of a circuit. And sometimes Spice tells you the wrong direction to go. Spice often tells you that a circuit won't oscillate. That's a lot of help, when you sit there and see it oscillating. After all, if doing Spice analysis is "necessary but not sufficient," and if you can't trust Spice anyhow because it is really not sufficient, why the heck bother with it?

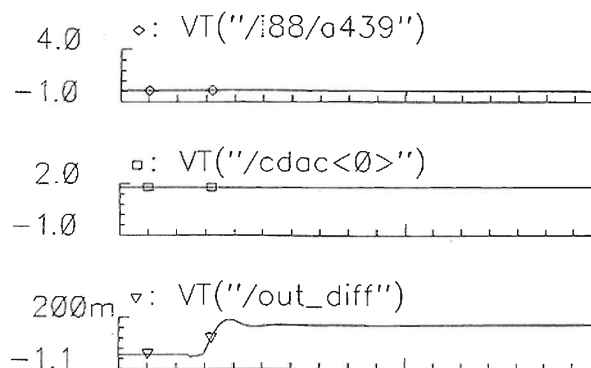
See associated figure.

### \* EDITOR'S NOTE:

\* "What's All This Spicy Stuff (Part I)," , November 22, 1990, p. 127

\* "What's All This Spicy Stuff (Part II)," , December 13, 1990, p. 87

Comments invited!





## Bob's Mailbox



September 15, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Mr. Pease:** I have been reading your column for nearly 15 years. I'm a mechanical stress analyst with no knowledge of electrical engineering. But I still get *Electronic Design* to read your column. You make me think. That is one of the nicest things I say to anyone. (*I am glad you noticed: My favorite goal is to get people to think! /rap*)

I'm sorry to hear about your loss. I know how you feel. Five years ago, one of my lifelong pals died in a freak accident. (*And I bet he didn't leave a note. Most people don't. They don't think of that. /rap*) We'd been best friends for nearly 30 years, having met in third grade. I was a pall bearer at his funeral, which was on his 35th birthday. Our friends are one of the greatest gifts we get from God. Since Jeff died, I have told most of my friends how important they are to me. (*That is very good, maybe the best thing. /rap*) I like your idea of leaving them a note, just in case. I think I will follow your suggestion.

• **Doug Hall** (via e-mail)

• **Pease:** That is the second-best thing—but much better than nothing. You may be able to add on other notes later.

**Dear Bob:** I was looking at some old photographs the other day, taken years ago on a variety of trips and holidays with friends, family, colleagues, and people I'd loved and/or liked well enough to have a day out with. These photos were nearly all of views like dramatic waterfalls or mountains and landscapes that had impressed us at the time for one reason or another. My companions only got photographed in order to add scale to the scene, or because they happened to be in front of the camera. Why take a photo of someone you see often, after all?

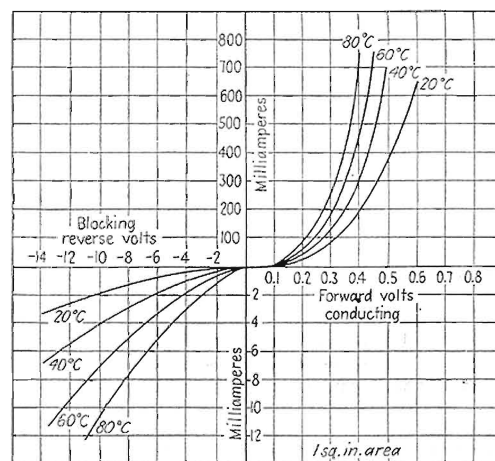
It so happens that a number of the people in the pictures have since died, and I now realize how foolish it is to take a picture of a mountain, say, which I can go back and see anytime, but neglect to take a picture of the fragile, short-lived human beings who I'll never see again. It was the photographs of the people that gave me the most pleasure and brought back the best memories. Bit of a sad letter this is—sorry. But from now on, I will take pictures of people. The impressive scenery will have to take second place.

• **Martin Williams** (via e-mail)

• **Pease:** You made a very good point. I agree. Thank you. I like to take one photo with the person most prominent, one equally shared, and one of the waterfall or mountain as the feature. But these days, I like to take mostly videotape. This way, I can focus on the person, get comments, then shift and split the scene with the "waterfall," and then focus on and zoom in on the "waterfall." Meanwhile, I encourage the person or persons to keep talking. Do you have a camcorder? If not, why not? Audio adds a lot! And good camcorders are cheaper than ever, at just \$300 or so.

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) —or:

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As requested by Dale Roach (ED, June 23, p. 20). /rap

Courtesy of General Electric Co.

**Linear Seminars:** A couple of years ago, I went on tour with National's Linear Seminars to 30 cities in the U.S. When I got to Alabama, I met a very enthusiastic fan who was happy to see me in person. He said his buddy was thinking about coming to the seminar. But, "Naw, Bob Pease is not going to actually go to every one of the 30 cities. That would wear him out..."

Well, I actually went to every one of those 30 cities. I refused to let it wear me out. Those of you who saw me noticed that I lecture about good Analog Stuff with enthusiasm! Well, we're going on the road again this September and October (and Europe after that). Look it up, and register, at [www.national.com](http://www.national.com). And, I really plan to attend and lecture at every one of the 31 cities.

**Channel P?** Bob Pease has his own TV channel. This web-cast is now accessible from our archives on the National Semiconductor Web site. Various analog topics will be discussed by a panel of analog experts and enthusiasts, every month. Sign up at [www.national.com](http://www.national.com). /rap

## What's All This Spicy Stuff, Anyway? (Part IV)



September 29, 2003 12:00 AM  
Electronic Design  
Bob Pease

This recent talk about Spice reminded me of a debate I had with a student engineer. At my lecture at the excellent technical university in Buenos Aires, he asked me, "Mr. Pease, you tell us we should not use Spice, but for our courses, we cannot breadboard everything. There's not enough time. What should we do?"

There's a stumper! I told him I didn't have an answer, but I bet I could think of one. I vamped for time. I asked him a few questions. I stalled for more time. Then I got a good idea. I told him, "Here's what you ought to do. When you have to design a circuit for a class, it is okay if you design it and evaluate it in Spice. It may not work well right away, but you can optimize it until it is pretty good. Evaluate all the important characteristics. Document it well. Save the Spice-run results.

"Now is a good time to make a breadboard. Make it up and analyze its characteristics. Compare them to the Spice results. Is there good agreement on some characteristics? Is the disagreement poor, or disastrous? Write down good notes on all the disagreements.

"Now go into Spice and try to find why there is disagreement. Go into the breadboard, too, to see if that can explain what's funny. Hey, breadboards don't always tell the truth either. When you understand the discrepancy between reality and theory, things. If you want, you can do that in Spice. Get it so it is likely to work well.

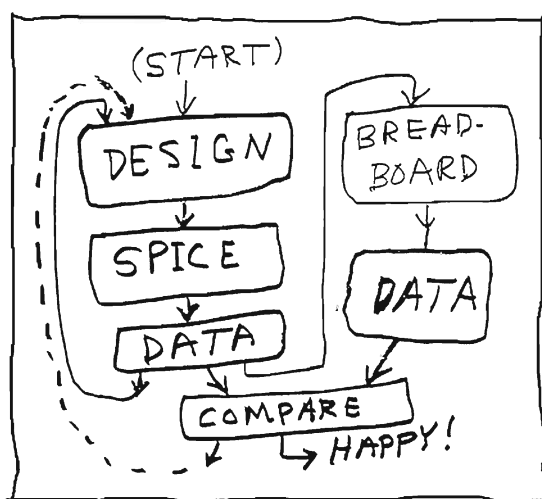
"Now go back and update your breadboard so that it will agree with the circuit that you optimized in Spice. Take data. Is the agreement acceptable? When you finally have agreement, write down the full set of notes on the disagreements and put them in a book. This will be a big book, documenting all the differences and discrepancies between Spice and the real world. Is that a pretty good idea?" The young engineer said it sounded like a good idea.

Then I thought of another angle: "Do you have an Intranet site here at your school?" He said yes. I said, "Good. Put all the information into your Web site so that every student will have good access to this 'disagreement' information. Is that a pretty good idea?" He said he liked that, too.

Now, a breadboard of a high-frequency circuit may not give any good agreement with the Spice results. A monolithic IC has very few strays, but a breadboard may have a lot of package strays. The breadboard may be stable, but the Spice version might oscillate. What to do? Well, you can't very well make a breadboard with package strays removed, but you can build two Spice circuits, one with package strays, and one without.

When you transform the Spice circuit, by going from "WITH package strays" to "WITHOUT," it may go faster. But it may be unstable. Still, the Spice circuit with strays might match the breadboard to a reasonable degree. Don't forget to include inductances. The inductances of a breadboard are often much larger than those of a smaller circuit.

Note: It is not always literally correct to criticize Spice for poor simulation of the real world. Sometimes the discrepancy results from poor models. Heck, most Spice models are oversimplified and don't account for self-heating. And Spice usually can't incorporate a self-heated model into a simulation. I say that it's not unfair to lump all the problems as problems of Spice, even though many are caused by models. Sometimes these can't be easily separated.



### \* EDITOR'S NOTE:

- "What's All This Spicy Stuff (Part I)," , November 22, 1990, p. 127
- "What's All This Spicy Stuff (Part II)," , December 13, 1990, p. 87
- "What's All This Spicy Stuff (Part III)," , September 1, 2003, p. 24

Comments invited!

## What's All This Credit Card Stuff, Anyhow?



October 13, 2003 12:00 AM  
Electronic Design  
Bob Pease

While I was cruising up the A30 from Penzance to London, I stopped to buy 28 liters of petrol (about £20). I pumped the gas and tried to pay. "Your credit card is not valid." Oh, jolly. How about my backup credit card? "That's not working either." I gave the man a £20 note and vowed that as soon as I got to my hotel in London, I would get to the bottom of this. My credit card had worked fine just the day before, paying for lodging. Why had it suddenly stopped working?

When I got to London, I called my wife. She told me the Fraud Squad of my credit company had called her. It wanted me to explain what was going on. "Why didn't you just tell them I am in England and trying to use my credit card to pay my bills?" I asked. Nancy said that the company refused to listen to her and wanted to hear it from me. "Here, call this 800 number," she said. But you can't normally call an 800 number from overseas. After a few rounds of arguing, I finally got a phone number to call from London. I called and told the company that it had better stop cutting off my credit.

The clerk said the credit card company's computer had detected a "nonstandard usage pattern" and shut off my credit. I explained that I had been going to England in July and using that credit card every year for at least five years, and if I did use it in England, would be a nonstandard usage pattern. The gal agreed to reinstate my credit, but she said there was nothing anybody could do to stop the computer from cutting off my credit.

My Visa card just happens to be a "United Mileage Plus Card," issued by First USA Bank. (You would think a company linked to United Airlines might expect me to use it on a trip, far from home!) But some other credit companies are also very touchy. I know one guy with a different card, and that company shut off his credit when he used it 140 miles from home. The company didn't even tell him until a week later. So if you're going on a "long trip" of, say, 100 or 200 miles from home, don't be surprised if your credit card is shut down by an overzealous computer. And if you go overseas, make sure you have a "real" telephone number, not just an 800 number, so you can call your bank and complain.

Even when my credit card was shut down, my debit card kept working. So it's always good to be prepared with several kinds of "credit," especially while overseas. I also keep a couple of spare, backup, unused credit cards at home in case I return from a trip with cards shut down or missing.

I finally got a reply from the credit card company: "If you are going on a trip, notify us in advance, and we may be able to keep the computer from shutting off your credit." As you may have noticed, I'm on a lecture tour to 31 cities, and many more cities in between, where I might buy gas or a meal. So I sent the company the list of 31 cities, by certified, registered mail. It cost me \$9.85. I replied, "I would not REALLY want to have to take your stupid credit card, and shove it up your nose because you cut off my credit in one of these 31 cities, or adjacent cities." I also told the company that it had never given me any warning that it might cut off my credit if I used my card far from home.

I got a nice letter saying, "Even though you have informed us you will use your credit card on that trip, our computers may still shut down your credit if it sees something it doesn't like.... In that case, just call 1-800-123-4567 to ask us to re-start your credit." Not bloody likely. I expect to be burned by these idiots, and I'm prepared to chop up their credit card. Details to follow. You should just be prepared to recover when you are burned by your credit card company. Keep good phone numbers with you to complain.

Comments invited!

## Bob's Mailbox



October 27, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** Re: "What's All This Spicy Stuff, Anyhow? (Part III):"\* Spice is a modeling tool. Modeling is necessary because "worst-case" parts are seldom available for use in a test circuit, and because some situations can only be modeled. (*Worst-case parts are not usually well represented in Spice models. /rap*) Any model is limited by the approximations used, by parasitic components not included, and by pitfalls of the modeling technique. (*THERE is a set of understatements! We tend to agree. /rap*)

Spice analysis can be exceedingly accurate and can provide insight into circuit operation. (*Sometimes... sometimes it can be TOO accurate—in misleading ways. And when it gives what seems to be an accurate answer, that builds up unfounded trust, which sets the stage for disaster when it starts LYING. /rap*) It can also be misleading and give impossible results. (*There is another understatement! /rap*)

The analyst is responsible for the accuracy and appropriateness of the model. (*Yeah, but most kid engineers have no way to comprehend this./rap*) A Spice model can rapidly provide detailed and accurate answers, easily explaining the unexpected. It's a thinking tool, rather than a substitute for thinking.

- **Peter Koninsky** (via e-mail)

- **Pease:** Most engineers I see use Spice as a substitute for thinking. As I said, a CRUTCH. I prefer real thinking. Best regards and thanks for writing.

**Dear Bob:** Spice should only be used by someone who already knows the answer to the problem being simulated.

- **Jerry Steele** (via e-mail)

- **Pease:** Nicely put!! I tend to agree!!

**Hello Bob:** I have been an avid reader of your columns for many years. I especially enjoyed "What's All This Spicy Stuff, Anyhow? (Part III)." Your comments about Spice telling you the wrong direction to go reminded me of the time I used the Mapquest software program to find a small town in Wisconsin. By carefully following the directions given by Mapquest, I ended up 50 miles west of my destination! Call me old fashioned, but give me a map and compass anytime.

- **John Kessinger** (via e-mail)

- **Pease:** One time I had some very good and precise Mapquest directions on where to find National Instruments in Austin, Texas. The instructions put me 1.4 miles southwest of where I wanted to be. Puzzled the hell out of me! Spice can easily do the same. And sometimes, it DOES. Mapquest maps only list the names of a few of the roads in the area. REAL maps list the names of ALL the roads. Viva La Difference!

**Dear Bob:** I have just one thing to say regarding your column on Spice. BRAVO!!!

- **Bob Grober** (via e-mail)

- **Pease:** Thank you!

**Dear Bob:** I just can't waste any more time trying to find this answer on the Internet! It seems like such a simple thing, and perhaps that's the problem. What is the meaning behind the symbols now used on electronic power switches to indicate "On" and "Off"—you know, the "I" and "O" symbols? The closest I got to the answer was an indication that they are IEC international standard markings, but no discussion of meaning or origin. Another place said that they represent binary "1" and "0," but that seems too obscure for what is meant to be universally understood symbols. Can you shed some light on this?

- **John Reynolds** (via e-mail)

- **Pease:** Hello, John. I can only guess about the same as your guess. I and O are slightly more international than ON and OFF. I'll ask around.

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\*Electronic Design, see Sept. 1, p. 24.

## What's All This Three-Level Grader Stuff, Anyhow?



November 10, 2003 12:00 AM  
Electronic Design  
Bob Pease

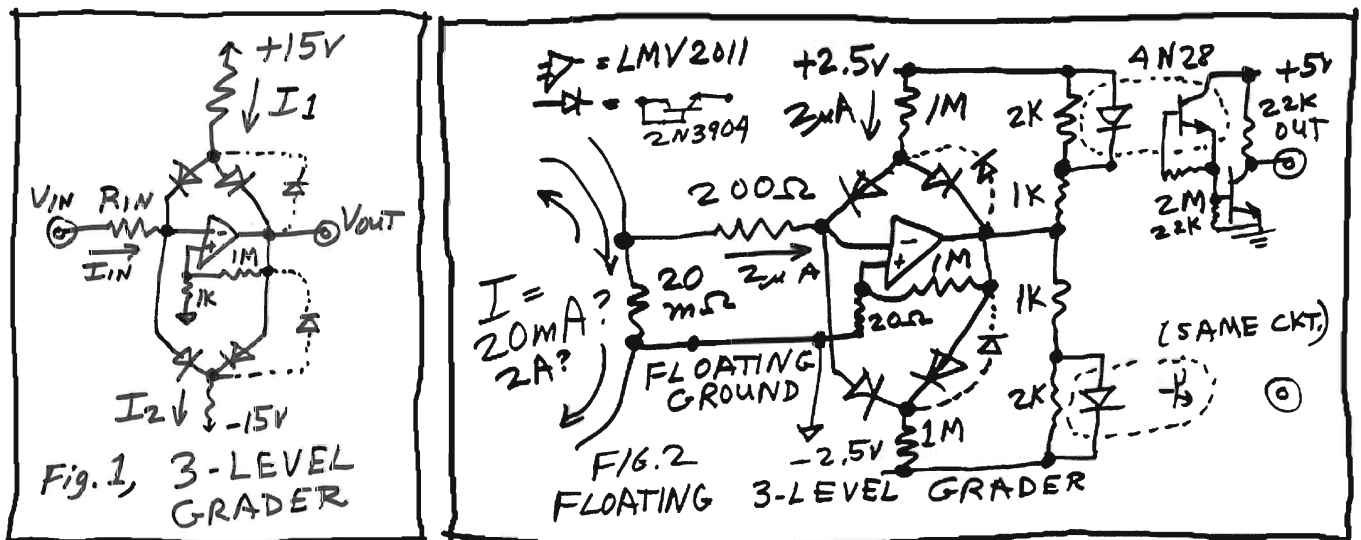
About 40 years ago, when I was at Philbrick, I worked a lot on operational-amplifier (we NEVER said op-amp) applications. Every once in a while, a customer would ask about a "zero-crossing detector," or more simply, just a "crossing detector." We never thought of calling this a "comparator." We usually made the customer happy with an op amp, a couple resistors, and maybe a few diodes in the feedback, so he could get a response in a few dozen milliseconds, perhaps. (When Widlar brought out the  $\mu A710$ , we were all astonished by the sub-microsecond response!)

But I did figure out how one op amp can perform two comparisons. Back when an op amp cost \$20 and UP, that was NOT insignificant savings. When  $I_{IN}$  is around zero, the output is around zero. If  $I_{IN}$  exceeds  $I_2$ , the output will switch to a large negative level. If  $I_{IN}$  reverses and exceeds  $I_1$ , the output will switch to a large positive level. So here is a sort of with three output levels, which provides nice advantages. This went into the Philbrick 1966. I never heard of anybody else who invented a three-level grader using just one amplifier.

Recently (38 years later), a guy asked me if we could help him with a circuit to detect a fairly small current (20 mA) even if the current may at other times exceed a couple amperes. He also had to detect when the current exceeded +20 mA, or -20 mA. And the common-mode range could exceed 10, 20, or 40 V. Therefore, most linear, direct-coupled circuits were not going to do the job for him. What's a mother to do?

Figure 2 is a basic three-level grader, with two optically coupled outputs that are brought down to ground by 4N28's. The LMV2011's low  $V_{OFFSET}$  of  $3 \mu V$  ( $20 \mu V$  max) is quite small compared to the  $400\text{-}\mu V$  signal. Neither output is ON for input currents  $-16 \text{ mA} < I_{IN} < +16 \text{ mA}$ , but each output responds when the input signal exceeds plus or minus 22 mA. Response is a few milliseconds for small input overdrive, falling below  $20 \mu s$  for large currents. I had to build this, to prove it would work—and it does. So in some cases, getting one amplifier to do the work of two is NOT a silly deal. Getting signal information down to ground from a high voltage level is not that hard, if you know the tricks.

Comments invited!





## Bob's Mailbox



November 24, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Hi Bob:** Re: "What's All This Spicey Stuff, Anyhow? (Part 3)."\* What can I say? Hallelujah! Balm to my soul! (*Amen! /rap*) To explain: I work for a large power semiconductor manufacturer. Here we are pretty much split into two camps—the modellers and the empiricists—with myself firmly in the latter camp.

*(Okay, then I tend to be on your side. Mostly. /rap)*

I increasingly find myself in the frankly bizarre position of having to defend my bench results against Spice simulations that disagree with my results. This is "Alice in Wonderland" to my mind. (*Zackly!! /rap*)

Sure, you can criticize my methods. But if you're happy with my methods, then the results I produce must be "The Truth," right? If those results differ from the results of simulations, then it's the simulations that are wrong, not reality! (*In most cases, I agree with you. But, these examples are in the early design stages. Surely, when you get closer to final designs, the breadboards will indicate who is right—right? /rap*)

If I look at the people who are in the two camps, I would say that the empiricists, without exception, come from practical "hands-on" backgrounds. Typically, they are people who have been building circuits since they were kids and whose first approach to a new idea is to go build it. The modellers, on the other hand, tend to come from purely academic backgrounds. And how come I rarely (if ever) see any of those guys in the lab? Hmmmm... Anyway, please continue to fight the good fight. (*Absolutely! /rap*)

- **Name Withheld** (via e-mail)

- **Pease:** The proof of the pudding must soon be in the eating. And the proponents of simulation may soon be eating crow—at least in most cases. I will concede that in rare cases simulation does tell the truth better than breadboarding. Also, we will certainly agree that breadboards do lie in some cases. So we must be wary of situations where the breadboards could be wrong!

**Dear Bob:** You can never preach enough about the dangers of Spice—or any simulator tool. As one who went from two-way radio tech to EE in the wireless sector, I laugh at the number of engineers who bet their paycheck on software! Nothing beats engineering with all senses: touch (feels hot), sight (resistor red hot), sound (snap of the IC blowing up), and—of course—smell (of the burning pc board). And when I go back and see where I went wrong, I learn more and retain more. Let's hear more and maybe even management may come to understand that.

- **David Donaldson** (via e-mail)

- **Pease:** Hello, David. We sure agree a lot!

**Dear Bob:** "Why be difficult when, with a little bit of effort, you can be darn near impossible!" Is this the latest industry mantra? Refer to the pinout of the SOT23-5 version of the LMV2001 and the LMC7101: pin 1: output, pin 3: noninverting input, pin 4: inverting input. Okay so far. But, pin 2: *negative* supply for the LMV2001 and *positive* supply for the LMC7101! (*THAT is the paddle. /rap*) It's the same with pin 5: *positive* supply for the LMV2001 and *negative* supply for the LMC7101. Is there a coherent reason for this? I could almost believe it for a very high-frequency item. But these are both definitely not gigahertz-bandwidth devices. Nor are they from different manufacturers where you may expect the "we must be different" attitude. It's hard enough trying to keep up with the wide variety of new offerings without having this sort of nonsense to cope with. Comments please!

- **Peter Pohl** (via e-mail)

- **Pease:** In the SOT23-5, the die has to sit on the paddle, and the substrate of the die has to go to the middle pin of the three. Thus, all CMOS devices need the middle pin of three to go to +Vs. And on bipolar amplifier chips, the -Vs has to go to the middle pin of three. I am sorry as heck. But if you want to go argue with silicon, and with copper, count me out of the argument because I cannot help on this.

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) —or:

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\*Electronic Design, Sept. 1, p. 24.

## Bob's Mailbox



December 18, 2003 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** Bob Widlar was a good friend. He was one of the few people I've known with a photographic memory. I was employed at National throughout the '70s, where we were designing a chip that would use an on-chip-substrate reverse-bias generator. Prior designs had the substrate connected to ground. Our team got into an argument about the relative thermal-conductivity characteristics of a chip whose substrate was connected to ground versus one with a reverse bias applied. (*I am sure I would have supported the argument that grounding was irrelevant. I could not prove it by theory, but I could by simple experiments! I bet Widlar knew that too! /rap*)

No one knew the answer. Then someone observed that it was, after all, Friday afternoon, and Bob was in town and would surely be at Marchetti's, a bar around the corner from National. It was past 3 p.m., so we all went over. Bob was there. We were all digital guys. Bob never liked digital guys, but I had a secret. I offered to buy Bob a Budweiser if he would help us settle an argument. He agreed.

After I asked Bob the question, he did the most amazing thing. He sat back, rolled his eyes up to the top of his head, and began to quote chapter and verse from a 1966 Journal of Physics and thereby explained to us that the primary component of thermal conduction in silicon is the crystal lattice—and not the free electron carriers. It was worth the Budweiser to get the answer. We had some more after that.

- **Gordon Force** (via e-mail)
- **Pease:** I have never seen that side of Widlar, but I do not doubt it. He did know many things VERY well—sober or not.

**Dear Bob:** Regarding your article "What's All This Credit Card Stuff, Anyhow?" (Electronic Design, Oct. 13, p. 20), I can relate big time. I too have suffered the credit-computer death while on foreign travel. Over the last three years I've made some 15-plus trips to Sydney, Australia, and paid all my expenses with one credit card. For the first few years I had no problems. But now if I don't give them advance warning, I get slammed at either the hotel I'm staying at or some restaurant.

My worst experience was while I was on travel in Japan. I was staying at a hotel in a small town where practically nobody spoke English and they denied my card while I was checking out. After some effort to get a hold of my wife to get it cleared up, I got the same ridiculous response that I would have to contact them directly. Idiots! Who do they think write those checks to pay the bills anyway? (*Uh—yeah. /rap*)

The only thing I can figure is that some moron in the credit-fraud department convinced his management that if we install this new software, we will save the company millions. Meaning, let's inconvenience the hell out of our customers because, hey, what are they going to be able to do about it anyway? They are most likely on travel—we've got them over a barrel.

I'd like to take this twit and drop him/her in the Aussie Outback with only a pocket full of plastic and me on the other side of that computer terminal!

- **Mark Miscione** (via e-mail)
- **Pease:** 'Zackly. And, carry a backup card.

**Dear Mr. Pease:** I have had similar problems with cards. The most amusing follows: I was traveling on a "long trip" roughly 200 miles from home and had a gas station deny my card—sort of. The clerk ran my card and the machine gave him a message to contact the credit card company. He called them and they asked him to put me on the phone. After explaining that I was really me (without any verification), and why I was traveling outside my normal pattern, they allowed the charge to go through. I guess that if I were a thief, I would have declared so in my conversation with the credit card clerk and awaited capture by the local authorities.

- **Eric Bienert** (via e-mail)
- **Pease:** Uh—yeah!! I love it! Meanwhile, my credit has not crashed after two months on the road.

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## What's All This Forecasting Stuff, Anyhow?



January 12, 2004 12:00 AM  
Electronic Design  
Bob Pease

Well, I am going to make a few comments about "forecasting." I will primarily observe that most efforts at forecasting are a waste of time. I remember when one of the CEOs of NSC in the old days (NOT Charlie Sporck) forecast that the semiconductor industry would never have any more downturns because all the business is well controlled. For the last couple of years, the semiconductor business hasn't generated any downturn. But when our customers' customers stopped buying things, and then our customers stopped buying our products, our business did turn down. We still made some profits, but our customers were sick, and we also caught a cold. Now we seem to be recovering. But I can't say we predicted—or caused—the upturn. (Our CEO Brian Halla claims he predicted the upturn for June 21, 2003. Maybe so.)

Roosters seem to crow to forecast the dawn. But if the sun doesn't come up, they can't force it to. Predicting, wishing, and causing something to happen are three different animals.

I can cause some things to happen (not very many), and I could wish for others. That doesn't necessarily make them happen. About 10 years ago, I predicted that somebody would generate hydrogen from sunlight by putting a magic potion into a bucket of water and pouring it over a cookie-sheet full of sand. When sunlight is applied, hydrogen would be generated! I'm not going to say this will never happen, but I refuse to bet on it happening any particular time soon.

Can we forecast that Moore's Law will fail? This has been debated many times. But recently, Intel decided to make microprocessors that are more effective in terms of hours of work per milliamper-hour, rather than just a huge number of megahertz of clock rate. I mean, how many of you can type at 200 MHz? 800 MHz? 2100 MHz? 2 MHz? 0.2 MHz? 0.02 MHz? It's great for Intel to focus on a better amount of computing (and typing) per watt-hour of battery life.

The late Frank Goodenough, a well known editor, and I once were at a power conference where people were predicting wise ways to slow down the processor's clock and cut power dissipation when there is no need for high speed. Ain't it about time it really happens? Great. But the guys who said that this was a good idea couldn't make the sun come up any quicker. Still, because I read about this in the today, I guess this isn't a real forecast. I'm just happy we're heading in the right direction.

It's often thought that Yogi Berra said, "Predicting is very hard, especially about the future." But nuclear physicist Niels Bohr said that. I don't know if Yogi Berra ever said that, or Casey Stengel, but neither one probably said it first.

A well-reputed pundit and seller of "forecasts" at a major stock market recently admitted (anonymously) in a major financial newspaper that most of his "forecasts" were useless as soon as they were published. Why would I doubt this? Why would I have to wait for them to be published for them to be worthless?

Can I foresee that analog circuits aren't going to dry up and blow away, as many digital guys were predicting for dozens of years? Yeah, but that's a cheap guess.

### Comments invited!

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## Bob's Mailbox



January 19, 2004 12:00  
Electronic Design  
Bob Pease

**Hello Bob:** I don't know if you remember me but I worked at National Semi a while back, both in quality assurance and for the automotive group as an apps engineer. I have a Spice story for you. Recently, while preparing for a job interview, I had my first serious encounter with Spice. I had a first-round phone interview with the hiring manager, and the one minor concern he had was that I had no experience with Spice.

I am a systems guy, and most of my board designs in the past really never required Spice. I usually used a white board, some quick transmission-line calculations, and some good common sense. However, with newer RAM technologies and much higher frequencies being utilized, using Spice to do some prelayout simulation is becoming more commonplace. Therefore, I decided (never having used this beast) to download a student version of PSpice from Cadence just to play with. The one nice thing about Spice is that you can make changes to things on-the-fly to see how certain parameters affect a circuit. With transmission lines, this is kind of hard to do in the lab. Varying line lengths and the parasitics on termination resistors is really hard to do in a lab. *(You can always snip a transmission line to be shorter, but it's not so easy to relengthen it! /rap)*

I have always wondered what the exact effects are of the distance of your source terminator from a driver and the effects of the termination resistor's parasitics. I had initial ideas, but I kind of wanted to confirm it.

Well, I thought to myself, here is a good thing to try that Spice is perfect for. I suspected that moving my source terminator too far from the driver should set a smaller, but nonetheless distinct, reflected waveform on my signal. The parasitics of the resistor should tend to filter out high-frequency sharp edges and whatnot. This all made sense because that's what the parasitics used to do on the gates of the power MOSFETs that I used to work on at National. My plan was set.

I entered the schematic into OrCAD and fired up the PSpice window, and I got the nice reflected waveform on top of my signal. It kind of even looked like stuff I had seen in the lab with poorly terminated lines. This thing really works! So I immediately switched back to OrCAD, shrunk the length of the line to the terminator down to some very short value, and reran the simulation. To my absolute shock and dismay, the reflected waveform was still there. This made no sense.

So I closed the PSpice program, went back to change all the parasitics to very small numbers, and then reran the simulation. And the reflected waveform was gone. How could this be? It made no sense. I repeated the experiment several times. But each time, the result was the same. *(Here, you're talking about a case where you know what the answer ought to be—MUST BE—so you're very skeptical when it gives an absurd answer! It's important to know what will make sense! /rap)*

I concluded, therefore, that maybe Spice was right. Maybe there was some kind of resonant circuit being set up by the RLC parasitics that was doing this. So I shut the machine off and pondered the subject over lunch. Finally, when I just could not accept it, I powered the machine back on and reran the simulation. This time, I got the results I expected with the shorter line. After fooling around, I figured out what had been the problem. Apparently OrCAD and PSpice are not really integrated but are two separate programs. For whatever reason, unless you kill the PSpice program, even though the computer resimulates, you always get your previous results. The two programs only seem to talk to each other when PSpice is started. So what happened was that when I only changed line length, I changed just one parameter. So I just switched programs and closed the waveform window. When I changed all the parasitics, which takes a lot longer, I sort of got frustrated and killed the whole PSpice program. You might want to add this one to your list of Spice gotchas. Always close Spice after simulating.

- **Michael Rally** (via e-mail)
- **Pease:** Wow, what a mess! I always close Spice—BEFORE simulating!

Comments invited!  
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## What's All This Noise Gain Stuff, Anyway?



February 02, 2004 12:00 AM  
Electronic Design  
Bob Pease

On my recent seminar tour, I asked about 4000 engineers, "How many of you use noise gain?" About 2% of the people held up their hands. Sigh. Noise gain is not very important or critical. That is one of the reasons why op amps are so popular. They tolerate almost any kind of feedback and any noise gain. You can often see that by inspection. But when it is important, things get interesting pretty fast.

Let's start with a definition of noise gain: Noise gain is the reciprocal of the attenuation from the output of an op amp (or any feedback loop) to the input. In Figure 1, the attenuation is  $R_{IN}/(R_{IN} + R_F)$ . So the noise gain is  $(R_F + R_{IN})/R_{IN}$ . Or,  $(Z_F + Z_{IN})/Z_{IN}$ .

As I say in my lecture, it is not a good idea to try to memorize that, because that just ensures that you will forget it. But you ought to recognize the cases where life gets interesting.

If  $Z_F$  is 100 k $\Omega$  and  $Z_{IN}$  is 1 k $\Omega$ , the noise gain will be about 100—or, technically, 101. This normally ensures that the loop is very stable because the noise gain crosses the amplifier's gain-bandwidth product at a place where there is almost never any problem. However, the name "noise gain" also reminds us that this really is the gain for the noise! So figure 1 is often used as a noise-test circuit. And, as noise does properly extend down to dc, if the op amp has a  $V_{OS}$  of 1 mV, then the output offset will be 101 mV!

If  $R_F/R_{IN}$  is a small number, and the noise gain is not very high, the curve of Figure 2b can apply. Most op amps are happy with any noise gain from 1 to 2000. But be cautious about any amplifier that is specified for "Gain of 10 minimum." Such an amplifier has excessive phase shift at high frequencies, and it will surely oscillate if the noise gain is not at least 10 (or as stated). But, refer to NSC's App Note LB-42.

Reactances: If we add a feedback capacitor across  $R_F$ , the noise gain can be high at low frequencies, but it will fall to 1 at high frequencies. Guess what? This cuts the output noise—a very popular move!

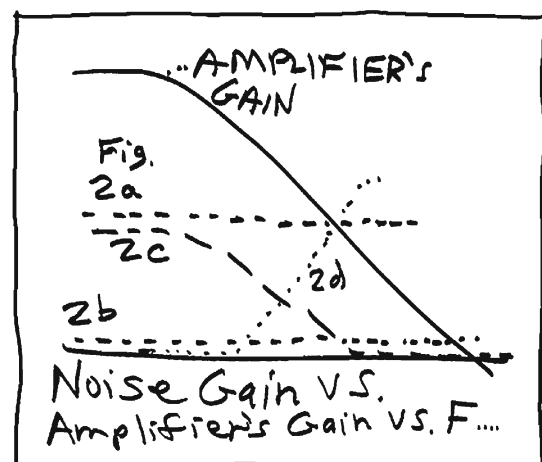
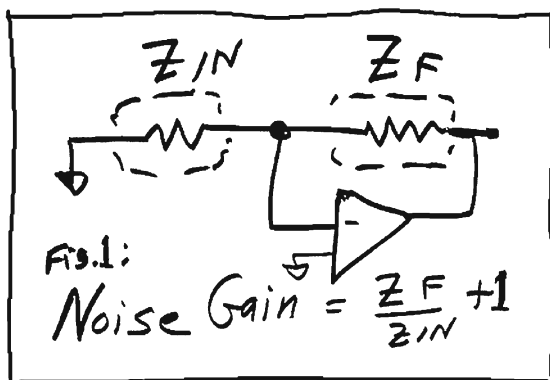
However, if your application circuit happens to have a lot of capacitance on the summing point—which might happen if you had a large photo diode or a lot of cable capacitance—then the noise gain will rise at higher frequencies. This can cause serious problems because when the noise gain rises, it tends to cross the op amp's gain-bandwidth product too steeply. And, the 12-dB per octave slope will cause severe ringing. This ringing or oscillation can usually be cured with a small feedback capacitor. The nominal value for this capacitor will be  $\sqrt{2C_{IN}/(GBWP \times 2\pi R_F)}$ . For a typical circuit with a summing-point capacitance of 100 pF, the  $C_F$  may need to be 5 to 10 pF—not too huge.

Note, however, that while most of this analysis is computed in the frequency domain looking at Bode plots, the evaluation of loop stability is normally done in the time domain. Hit the input with a little step of current and see how well the output settles without excessive ringing.

Often, an engineer proposes to use a "tee network" for his feedback resistance to avoid having to buy a large-value resistor. I almost always say that that's a bad idea. Why? Because of the noise gain! Either due to the noise, or the bandwidth, or the drift, any tee network with a factor of more than 2 is usually a terrible idea. A noise gain of 10 or 100 or 1000 is often a terrible idea!

Next time you work with an op amp, think about the noise gain. If it is a simple case, it won't require more than a moment. But if it is complicated, it might require more than an hour! Or if you neglected to study the problem properly, you're in for days of grief!

Comments invited!





## Bob's Mailbox



February 16, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Hi Bob:** A coworker in Denmark informs me that Bang & Olufsen forbids transistors to drive capacitive loads without some form of series impedance. (*"A foolish consistency is the Hobgoblin of small minds."* /rap) This came about due to my use of an LM7805 with the usual filter capacitors and no series resistance in between either the load or on the input to the LM7805.

- **Ken Harstine** (via e-mail)

- **Pease:** Just about every IC linear circuit can be made to oscillate under some worst-case circumstances. So even an IC can be misapplied, and you have to make sure your circuit—whether IC or transistor—is stable and has good safety margins for being stable under all working conditions. But a heavier capacitive load usually does more good and no harm at all for the output of a voltage regulator, such as an LM7805 or LM317. This is because these ICs have the series resistance built in. That's what integration provides, as an advantage. And you can tell that to your colleague in Denmark!

**Dear Bob:** This is a more technical question than the administrative foolishness that you recently suffered. I use a debit card for shopping, and recently the swipe readers have increasingly failed to read the magnetic stripe. In most cases, this forces the sales assistant to type in the numbers manually, but it is a slow process and prone to errors. A week or two ago, I was surprised when the girl on the checkout, on failing to get the swipe reader to read it, just popped the card into a plastic bag and reswiped. Amazingly, it worked!

Since then, several others have done the same thing. It is evidently a widely known trick. One variation is to stick some Scotch tape over the stripe. Again it magically makes the card work! So what's going on here? At first, I thought it might be simply wear on the read head, causing it to "see" more than one symbol. Moving the card away would attenuate the contributions from the adjacent symbols more than those from the symbol opposite the reader and improve the S/N ratio. On further reflection, however, I realized that the fault was with my card, not the reader. The stripe is looking a little worn, but not excessively so. Any ideas?

- **Martin Williams** (via e-mail)

- **Pease:** I would have guessed the same theory you did. Maybe that's a bad theory, in which case I can't guess.

**Dear Bob:** Re: "What's All This Fuzzy Logic Stuff, Anyhow? (Part VI)" (*Electronic Design, Dec. 4, 2003, p. 20*), I wanted to make some comments about your racecar driver example. It is doubtful that any driver can consistently hit the start-braking mark better than 0.1 s, which would imply that the cars would be all over the place going through a turn. Because most of the top performers can hit the apex of the curve within an inch or two, something else has to be working here.

That ability to hit the mark happens because the drivers don't work right at the limit of adhesion, but somewhere below that. This gives them "room" to modulate the braking to allow them to hit that mark. The better drivers use smaller margins most of the time, but other factors determine the minimum time around a course (given the same car).

The best drivers ever, Jim Clark and Jackie Stewart, would seem slow through the corners because they were so smooth. Actually, they were slower than other drivers in certain parts, braking a little earlier and less abruptly. This seemed to keep the vehicle in better balance and allowed them to get more acceleration coming out of the turn than the others could manage. This was surprisingly effective, and I can remember one GP of Canada in the 1970s when Stewart pulled out a 10-s lead on the first lap, with the next two in line having a clean shot too.

- **Don Rumrill** (via e-mail)

- **Pease:** It's true that braking at the last possible millisecond might cause the car to run too slow in the corner, bounce around as the brakes are cut off, and—as you point out—to be less balanced and slow coming out.

Comments invited!

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## What's All This Mnemonic Stuff, Anyway?



March 01, 2004 12:00 AM  
Electronic Design  
Bob Pease

"On Old Olympus' Topmost Top, A Fat-Eared German Viewed A Hop." Isn't it amazing? I read that back in '56 in Sinclair Lewis'. That is a little rhyme to help medical students remember all the nerves in the head. I never learned all the nerves, but I think one of them was the Occipital nerve.

However, the little rhyme sure does work, because I have remembered it over 46 years. I bet a number of old doctors and medical students still remember that.

Tricks like that are often useful to remember other things. How come I remember ROY G BIV when it doesn't tell me the color code of resistors? Ah—that is the sequence of colors in a prism or rainbow! I remembered the mnemonic even though I forgot what it's good for! For the resistors, many remember the old line, "Big Boys Race Our Young Girls, But Violet Generally Wins." Heck, I dunno. I never used that. I just learned all the colors. Red, red, brown is 220, and I learned all the rest of the color-coded resistors, and I don't need any royg biv to know. If I ever saw a yellow, yellow, yellow resistor, I would immediately wonder why I never saw a 440-kΩ resistor before.

And several jokes have the punchline of "Port is Left, Starboard is Right." But all I need is to recall that there are more R's in right than in left, and also more in starboard than in port.

What size is the density of air? How many ounces per cubic inch or foot? That's easy. (A) I wrote that down on page 64 of my pretty good book, and (B) a stack of cubic feet of air (if you could do that at uniform sea-level density) that would stack up to 28,600 feet would weigh  $144 \times 14.7$  pounds. So the weight of the air is  $14.7 \times 144$  per 28,600 cubic feet. And of course, 29,027 feet is the height of Mount Everest, which is about 1.5% higher than that stack of 28,600 feet. Thus, the density of air is about 384 liters to weigh 1 pound, 1.19 grams per liter, or 0.074 pounds per cubic foot.

Everybody has his own ways to remember things that aren't obvious. Avogadro's Number ( $6.022 \times 10^{23}$ ), Boltzman's constant ( $1.38 \times 10^{-23}$  in MKS units), and the charge on one electron ( $1.62 \times 10^{-19}$  coulombs) are old friends that I can't ever forget. Not to mention pi, which I can always remember to 14 decimal places, just in case I need it.

One time I was having trouble getting to sleep, so I decided to see, what was the error in saying that  $\log_{10}$  of 2 = 0.30103? So I started doing the math in my head. Hour after hour. I decided that if  $\log$  of 2 = 0.30103 + k, then the log of 1024 must be 3.0103 + 10k, and log 1.024 must be 0.0103 + 10k. So how many times do I have to multiply 1.024 times itself to be equal to about 2? I never did get to sleep worth a darn. But I did convince myself, after about three sleepless nights, that k must be about -0.000000004. So the log of 2 is 0.301029996. In other words,  $(0.010300 + 10k) \times$  about 29.227 is about 0.30103. I just computed 1.024 to about the 29.227 power, computing all the decimal places in my head. I did a of long multiplication in my head. But that's not mnemonic. That's just deriving it, from first principles. Still, I can now recall that the log of 2 does not end at "0.30103" but ends with "0.301029996 (to nine decimal places)."

My seventh grade teacher once decided he had to "punish" me for some imagined offense. So he me to remember the square roots of all the digits from 1 to 10. Okay, a couple of them are trivial. And I never find much use for the square root of 7. But the 1.414, 2.236, and 2.828 are loyal and useful friends. What useful mnemonics do you guys use?

Comments invited!

## Bob's Mailbox



March 15, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** As I'm sure you know, field service work often requires extreme engineering. But sometimes, the quick fix doesn't do the trick. Some years ago, we were in a situation where we needed about 18 V ac from a 220-V source. A junior engineer dug through our bag of parts and came up with two

110-V transformers, a 6.3-V unit, and a 12.6-V unit. "Eureka!" he said. "We can just put the primaries in series and the secondaries in series and everything will work just fine!"

An older head said, "Whoa, what about the current rule? Here we have two different N's, which means two different current ratios, but we're trying to put the same current in both transformers. If you tried to put the 220 V across the two primaries, the 6-V primary might go to 140 V, which is excessive. The 12-V primary would go toward 70 V—not enough. *(The old guy is surely right! The 6.3-V output can easily put out 1/3 more, but the 12.6-V transformer will likely put out 1/3 less, and the output voltage will be down a couple of volts. It might seem to function, but the 6-V transformer might overheat due to magnetic distortion—not a great idea. /rap)* You may enjoy spending a few minutes figuring out just what does happen in a simple circuit like that."

• **Robert Dehoney** (via e-mail)

• **Pease:** For sure, this is a fun problem. If you put a couple of watts of suitable resistor across the primary of the 6.3-V transformer, and if the load is fairly constant, this might work quite well. My first guess is to put a 10-W, 10-k $\Omega$  resistor across the primary. The voltage might even out at 110 V in the primaries, and then you'd get about 18 V on the secondary at I would guess 1 or 2 A, or 18 W. Is this a bad guess? I now guess that a 10-k $\Omega$  resistor, dissipating about 1.5 W, would not be enough. You might need 3 k $\Omega$ , putting 5 W into a 10-W resistor, to help get the primaries to be equal in voltage for an 18-W (1-A) load.

*I just picked up a piece of nylon fish line, about 300 yards of 32-lb test, that was all tangled. I found it in a tree. I eventually got it all untangled, into two pieces, on neat little bobbins. THAT was a good and fun, challenging problem.*

**Dear Bob:** Given your views regarding Spice, what can you say about the selected few computer models that are driving the global-warming discussion?

• **Jim Paquet** (via e-mail)

• **Pease:** I think that most computer models are poor. The data I have seen indicate the world is NOT warming up nearly as much as the computers say—satellite data. So what's wrong? I'm not an expert. I'm just a suspicious old curmudgeon. Just two weeks ago, I read that diesel smoke provides about as much global warming as 1/4 of the carbon-dioxide theory. That means if we cut the carbon-dioxide emissions in half, there would still be an overheating problem due to the diesel smoke. There are no simple answers. Yet nobody knew this until two weeks ago. What do I believe? We should be skeptical. Who has a model of what kind of hell will break loose if the Gulf Stream stops flowing? I'm nervous about that.

**Hey RAP:** I have been asked to help with a small in-line amplifier project and I was thinking of using the LM384. But we would like to model it in Spice. Is there a way to get the characteristics of the internal devices so that we could make a subcircuit model for our simulation?

• **Tim Crouse** (via e-mail)

• **Pease:** The LM384 is quite old, and nobody knows anybody who can get very interested in making a good model, or any model at all. I mean, the LM384 was in our 1980 Audio-Radio Handbook. How many engineers who designed things in 1980 are still ALIVE? Why don't you just make a tiny model: gain (dc) = 50, bandwidth = 450 kHz,  $Z_{OUT} = 1/2 \Omega$ ? Just run this and let it ride. How can you go wrong? And after you run the Spice work, you have to run a breadboard.

Comments invited!

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## What's All This Analog PowerPoint Stuff, Anyhow?



March 29, 2004 12:00 AM  
Electronic Design  
Bob Pease

Those of you who have attended my lectures know that I usually say, "Some companies—such as Oracle and Teradyne—have outlawed PowerPoint. When PowerPoint is outlawed, only outlaws will have PowerPoint." Then I point out that I am the Analog Outlaw, because I use "Analog PowerPoint."

Last night on the plane to Copenhagen, I ran into another engineer, Dave Allingham of Satelcom in Ascot, England, who uses Analog PowerPoint, just as I do.

Exactly what is Analog PowerPoint? It's the use of hand-drawn plastic foils on an overhead projector. Obviously, this is an "obsolete" technology. But when everybody else uses PowerPoint these days, this is a good way to get people's attention. It's not the same old, boring PowerPoint foils. Now, my friends all know that I take pride in making my foils just sloppy enough, but not (usually) too sloppy. I suppose you could letter your foils up any way you want, neat or sloppy. You could even use a "ransom-note font." But you want to make your foils distinctive. And this is one of the best ways.

One of the best things about Analog PowerPoint is that you are always prepared to make up a new foil to illustrate another point—or to make up a foil to answer somebody's question. Most PowerPoint users don't have a good solution for that.

Not every foil has to be a complete statement. Sentence fragments often work quite well. And little quick pictures, too. Not every foil has to be displayed for more than 10 seconds. But I do not subscribe to the idea that a 20-minute lecture should take just 15 slides. People who make slides too busy are largely responsible for the unpopularity of PowerPoint. Further, many people resent that the effort to make a fancy PowerPoint presentation is greater than the thinking that went into it.

Of course, one weakness of Analog PowerPoint is that its size and weight are linearly proportional to the number of foils. This week, I am using about 104 foils to present for 45 minutes, plus a couple dozen alternate foils for special occasions, and a couple dozen blanks. I think the sum of this weight is almost three pounds. That makes my knapsack kind of heavy. If I bring 400 foils to present for three hours, that gets downright heavy! But it's still lighter than a laptop computer, and more compact. (Be sure to number your foils, so if they get out of sequence, they can be straightened up.)

Analog PowerPoint can use art from any imaginable place, like newspapers, magazines, paragraphs, or notes; plus photographs, hand drawings, and typed text. Or, you can take other PowerPoint drawings and mark them up with red arrows and blue labels, as you like. You can superimpose one drawing atop another, such as a hand-sketched label atop a figure—added on at the last minute. Of course, getting these materials into a proper scale requires a photocopier with expand/shrink capabilities. You need a copier that won't go berserk when you feed the plastic blanks through it. But that's not so hard to find these days. For certain effects, you'll want access to a color copier. But these are more commonly available now.

Also, you need a friend who is a good speller and a good editor to proofread your foils. That's because there is no good spellchecker for Analog PowerPoint. The same is true for "Digital" PowerPoint. To be fair, I should point out that the cost, expense, and effort of making a real PowerPoint presentation may be justifiable in case there is a huge viewing audience.

So this is the story of how Analog PowerPoint got to be the way it is today. Try it. You'll like it! And always remember, "If you can't be the best, be different!" And even if you are the best—be different.

Comments invited!

P.S. Hey, it may be April 1 when you read this, but I'm not fooling. You guys who have seen my lectures know that this is how I present good stuff./ rap

April 12, 2004

## What's All This Doctoring Stuff, Anyhow? (Part 3)



April 12, 2004 12:00 AM  
Electronic Design  
Bob Pease

Recently, I got an e-mail from Jim Stewart in Davis, Calif.: Bob, I wear glasses for nearsightedness and astigmatism and I'm 51 years old. For the last 15 years or so I've had problems with driving at night. My father and my brother-in-law also have had the same problem, so I don't think it's just me. Trips to the optometrist only got me the reply that I was getting old. Being both an engineer and serious amateur photographer, I know something about optics and I was convinced that there was a solution. [Electronic Design

I noticed that the lenses in my glasses were selected as a compromise between near and far vision, with the compromise assuming lots of light. "Lots of light" implies that the iris is "stopped down," giving a lot of depth of field. The problem with this is that at night, my iris is wide open with very little depth of field, and I couldn't focus well on anything of any distance away.

I went to a new optometrist and told him that I'd like him to make me a set of glasses for night driving and that I'd tell him exactly how to make them. He agreed. After he examined my eyes and gave me a prescription for new normal glasses, I had him prescribe a pair that were set for good distance vision plus another 1/2 diopter of sphere correction towards infinity.

The glasses worked better than I ever expected. Just the joy of going outside at night and seeing the stars as pinpoints of light instead of blobs would make it worth the cost. Night driving is no longer a dreaded chore for me. I still have a little problem with headlight glare, but it's minor now that I can focus clearly.

As soon as I read this, I recognized instantly that this is a perfect continuation of my theme from Doctoring Stuff, Parts 1 and 2, as referenced above: Do NOT just let your doctor tell you what is good for you. Listen to what he (or she) says, and ask questions. THINK. In this case, Jim's first optometrist was not interested in communicating. He was assuming that a compromise lens prescription would make the patient happy. He didn't want to hear any dissent. So, Jim had to go out and find another doctor who could help him avoid the unacceptable performance of a compromise. Wise. Great engineering! Now Jim can drive cheerfully and much more safely at night.

I'm lucky that at 63 my eyesight at night is still almost perfect. But I know several people who have complaints such as this, and they may have the exact same problem, subject to the exact same solution. And we will check it out. Is 0.5 diopters the best correct amount of compensation? Quite likely it is really close, but we are still checking into this. Most optometrists just have a mirror so a 20-ft viewing distance can be folded into a 12-ft office. Are they prepared to test your eyes for proper focus at 200 ft? In the dark? White letters on a dark field? Ahem....

So if you have trouble focussing on what is going on at night, and your lenses for nearsightedness are suspect, consider this outside-the-box solution: Get a pair of "night-driving glasses" that are optimized for best focus at 200 ft rather than at 20 ft, and you may be much happier and safer. (Contact lenses likewise? I'll guess so!) And, keep on thinking!

**Comments invited!**



## Bob's Mailbox



April 26, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I designed magnetic stripe readers in the eighties and would like to comment on your recent "Bob's Mailbox."<sup>\*</sup> Three tracks are defined on the standard card. Most credit, ATM, and debit cards use track two in the middle of the stripe. It has data at 75 bits per inch and a checksum. In the old days, the crummy tape oxide would lose magnetic energy. Nowadays, they have very high magnetic durability.

Unfortunately, the read heads must all be spring-loaded to follow the stripe surface. And as the stripes wear, they sometimes get little bumps and troughs that cause the heads to skip over bits and, of course, get checksum errors at the end of the stripe. The plastic bag trick and Scotch tape tricks simply allow the head to ride smoothly over the now even-more-distant magnetic stripe and read it okay. I wish this was a question on *Who Wants To Be A Millionaire* so I would have a shot.

- **Ken Mathews** (via e-mail)
- **Pease:** Hi, Ken. Thanks for the explanation. Yeah, it all makes sense. Good luck the next time you're a contestant!

**Hi Bob:** Thanks for your recent article on noise gain (*ELECTRONIC DESIGN, Feb. 2, p. 22*). Every once in a while, your column has something very useful (like some of your earlier stuff on control theory). I always try to find your column in the hopes that it might have such good stuff—in lieu of the typical rant about something non-technical, or topics such as the recent rant about Spice versus prototyping. I usually know I can blow off your column unless I see one of your little scribbly schematics in the middle of it.

- **Tony Alfrey** (via e-mail)
- **Pease:** Hello Tony. I don't argue about which column is IMPORTANT. But even if I don't include a cute little schematic, you can bet the column is about THINKING. Read it briefly. You may or may not like it, and you may or may not find it educational. But many people get something from my columns.

**Dear Bob:** I've enjoyed your columns for many years. I'm now at the stage in life where I'm into hearing aids (too much time in small airplanes over 50+ years). I put on a "behind-the-ear" hearing aid for the first time a few days ago. It's somewhat helpful but not as good as a three-band equalizer from Radio Shack (separately adjustable bands labeled 900 Hz, 3 kHz, and 6 kHz) at one-tenth the cost.

It's good to get rid of the lead from the amplifier to the earpiece, but the official "hearing aid" leaves me hungering for more of the 6-kHz stuff to really understand the consonants. I looked at the response curves for a number of digital and analog devices. They all seem to roll off at about 4 kHz, with the gain being essentially 0 dB at 6 kHz.

The PhD audiologist says this is an industry problem. (*That's probably right. Part of the problem is that if you turn up the gain at 4 to 6 to 8 kHz, you get a big boost for the noise, resulting in a mediocre noise-to-signal ratio./rap*) Based on my limited knowledge of amplifiers, this doesn't make sense to me. In the "good old days" of fine audio amplifiers, "flat from 20 to 20,000 Hz" was the marketing hoo-haa everywhere. (*Oh, but this is for best-case listening conditions. It's nice to avoid bad rolloffs and bad phase shifts of about 3 kHz, if you can help it. Most people can't hear the stuff at 20 kHz, but they like good bandwidth past 4 and 8 kHz. But even telephones have only 3 kHz, and you don't need—or want—much more than that for good audibility. /rap*)

The speakers must certainly be limiting, but I'd expect that to be a low-end problem. Is there some limiting physics about pushing airborne audio energy down small passages? A Web search on "hearing aid bandwidth" doesn't turn up much.

- **Dick Reilly** (via e-mail)
- **Pease:** Look up Etymotics Research (Oak Grove Village, Ill.) and Mead Killion. If you're trying to get good audibility, his company may have good advice. If he can't help you directly, ask him where to turn. He's a smart cookie and very helpful.

Comments invited!  
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\* *ELECTRONIC DESIGN, Feb. 16, p.22.*

## What's All This Cruise Control Stuff, Anyhow?



May 10, 2004 12:00 AM  
 Electronic Design  
 Bob Pease

Okay, Pease. You brag that you can slap together a good breadboard in an hour or two, all hay-wired over a copper-clad ground plane. How come it took you to build circuit? Well, most breadboards are quick to build, and easiest to work on, if they are openly spaced and laid out broadly.

This circuit has to go in my car, be reasonably compact and neat, and have trim pots that are usable when driving—not by a screwdriver. So it took a while for me to find the time to lay it out right and make it easy to control.

Yes, one can buy a car with cruise control. I rented such a car recently. It was boring past tears. But I must admit that it kept my speed down so I didn't get a ticket. Have you ever seen a "High Traffic Enforcement Zone" highway sign? Several of these signs are on Route 6 between Orleans and Wellfleet, Mass.—and they mean it. So I set my speed at 43 mph in the 40-mph zone.

I would not want to fit a "conventional" cruise control on my 1970 Beetle. The car slows down a little on long upgrades anyway, and I like that. But I don't want a "speed limiter" as I featured in Parts 4 and 5 of "What's All This Fuzzy Logic Stuff, Anyhow?" Electronic Design. I just wanted a little reminder, so I cooked up the circuit shown in the figure.

A1 rattles back and forth at a low (~4%) duty cycle, at about 12 seconds per cycle. The high and low parts of the duty cycle are set by P1 and P2, to suit your taste. A1 turns A2 ON and OFF—mostly OFF.

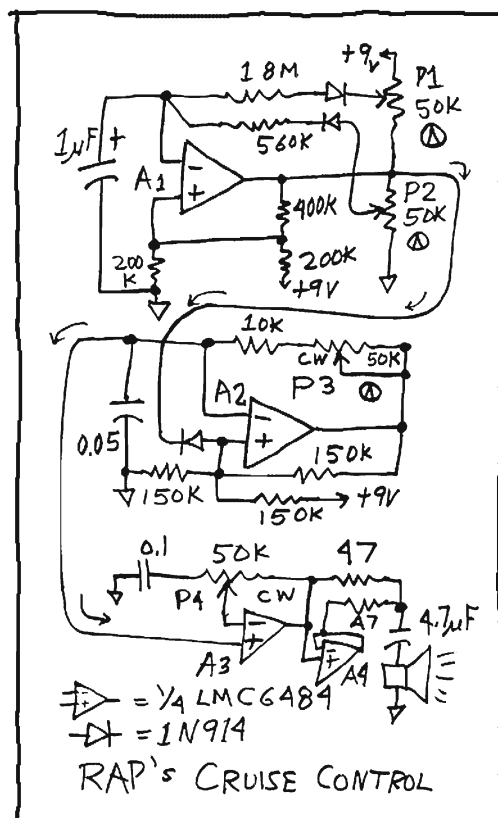
A2 is an adjustable-frequency oscillator. I set the pitch, using P3, to match the speed of my engine at the speed I want. The exact pitch is not important. I just set it to the speed I like, perhaps 68 mph in a 65-mph zone. About 3700 rpm?

A3 and A4 are amplifier/drivers. Their output amplitude is adjusted by P4 on the way to the speaker. The whole thing runs on a 9-V battery, or a 9-V regulated supply powered by the car's 12 V.

The theory is that if the brief "beep" of the speaker matches the pitch of the engine, I'm happy. If the engine's pitch is higher, that's supposed to remind me that I'm going faster than my set speed, and I should perhaps slow down. If the engine's pitch is too low, I am either slowed down on a hill, or I am dawdling. Of course, I have to be able to hear the engine's exhaust pitch over the whining of the cooling fan, the gears, and the passengers. (Of course, this will work only in a stick-shift car, not on any automatic transmission. But it will work in every gear.)

Will this work? Can I train myself to respond to the match or mismatch of the pitches? Will it work naturally, almost as second nature? Tune in next issue! Actually, it does seem to work pretty well. I wouldn't, in my right mind, recommend that you, in your right mind, should one. But if you did, it would work.

Comments invited!



## Bob's Mailbox



May 24, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I really enjoyed your piece (and your articles in general) on Analog PowerPoint.\* It gave me a chuckle and reminded me of my own experience. I was invited to speak at the TAPR conference about CIRCAD (a CAD program). Before I could speak, I was forced to sit through several "endless" PowerPoint presentations. I found myself falling asleep and had to excuse myself to go sack out for an hour to build myself up for my own talk. The funny thing is that I found myself wishing to not do the same thing to others that had been done to me.

So when I stepped up to talk to the room full of people, the hosts asked me where my laptop was. I said I was going to try it without using PowerPoint. One of the fellows blocked my way and put his hand out. "No, really, where is your computer?" he asked. I repeated my statement and he stared at me as I walked up to the podium with a drink coaster. I asked how many of the designers there remembered when schematics were mostly started on napkins and drink coasters. Lots of hands went up (*GREAT!!! /rap*), and I gave a short talk on what I felt was the history of CAD design and so forth. I explained the steps needed to do a proper design, etc.

But the real kicker is that I was called later and told that my talk was the most popular one at the conference! I think that "reading" what is on a PowerPoint slide is the reason people veg out. I can read a lot faster than anyone can talk, and turning down the lights is the perfect mix for putting me to sleep. If the slides show things that can't be said, I think it's positive. (*CHECK! /rap*)

By the way, at a raffle after the program, my drink-coaster schematic was offered as a prize. The winner, very excited, ran back to his table and yelled out, "Hey this thing has TUBES in it! 6V6s, I think."

- **Jay Craswell** (via e-mail)
- **Pease:** *Keep up the good work! You should have that drink coaster FRAMED!*

**Dear Bob:** Your chronicle about "Mnemonic Stuff" (electronic design, *March 1, p. 14*) reminded me about how I *learned* the color code while attending technical school. In the workshop, all the resistors were in a huge drawer. They were well organized by value in rows and columns, starting at 10  $\Omega$  and ending at 22 M $\Omega$ . The first time I pulled that drawer open, I did not realize there was no stop, so all the resistors fell out. There were maybe close to a hundred of each value, mixed on the floor like a kid's toy. By the time I had put them all back in the correct order (the color code should read from left to right), I knew the color code! I never had to *learn* it again!

- **Philippe Trolliet** (via e-mail)
- **Pease:** *Uh, yeah, Philippe. I guess that was a good learning experience! Fortunately, the resistors would have fallen into little clumps, not perfectly randomized!*

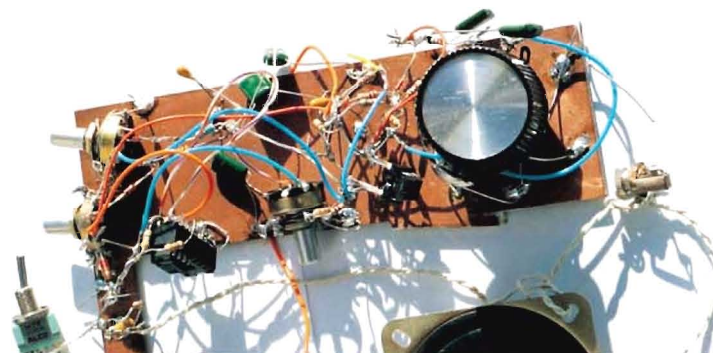
Comments invited!  
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**Cruise Control Revisited:** I got the "Cruise Control" beeper circuit working and used it for a couple of weeks on the open road. It sorta worked. It really did. I could tell if I was above the set speed, and I could hold the speed I wanted a little better than I could do without it. Then I parked it. Put it away. It wasn't doing me any good in terms of safe driving. I would cruise along at 68 mph and discover that I would get into a minor 63-mph traffic jam. When I tried to go around it, I realized I had waited too long, so I had to wait at 62 mph for all the faster guys to pass me.

When I just drove at a normal rate, I would see the jam up ahead, and I'd speed up to maneuver around it. MUCH safer. Even the ordinary "Cruise Control" of a store-bought car has the *same* problem. So holding a constant cruise speed is not a great idea, unless you are just trying to avoid speeding tickets. My good, old Beetle can go over 85, but I can't go fast enough to get a ticket out here. I'll just keep on rolling at 68  $\pm$  2 mph—*without* my beeping "Cruise Control." /rap

\**ELECTRONIC DESIGN*, March 29, p. 18



RAP's cruise control circuit

## What's All This Mnemonic Stuff, Anyhow?



June 01, 2004 12:00 AM  
Electronic Design Europe  
Bob Pease

On Old Olympus' Topmost Top, A Fat-Eared German Viewed A Hop.' Isn't it amazing? I read that back in '56 in Sinclair Lewis' Arrowsmith. That is a little rhyme to help medical students remember all the nerves in the head. I never learned all the nerves, but I think one of them was the Occipital nerve.

However, the little rhyme sure does work, because I have remembered it over 46 years. I bet a number of old doctors and medical students still remember that.

Tricks like that are often useful to remember other things. How come I remember ROY G BIV when it doesn't tell me the colour code of resistors? Ah – that is the sequence of colours in a prism or rainbow! I remembered the mnemonic even though I forgot what it's good for! For the resistors, many remember the old line, 'Big Boys Race Our Young Girls, But Violet Generally Wins'. Heck, I dunno. I never used that. I just learned all the colours. Red, red, brown is 220, and I learned all the rest of the colour-coded resistors, and I don't need any royg biv to know that. If I ever saw a yellow, yellow, yellow resistor, I would immediately wonder why I never saw a 440-kΩ resistor before.

And several jokes have the punchline of 'Port is Left, Starboard is Right'. But all I need is to recall that there are more Rs in right than in left, and also more in starboard than in port.

What size is the density of air? How many ounces per cubic inch or foot? That's easy. (A) I wrote that down on page 64 of my pretty good book, , and (B) a stack of cubic feet of air (if you could do that at uniform sea-level density) that would stack up to 28,600 feet would weigh 144 X14.7 pounds. So the weight of the air is 14.7 X 144 per 28,600 cubic feet. And, of course, 29,027 feet is the height of Mount Everest, which is about 1.5% higher than that stack of 28,600 feet. Thus, the density of air is about 384 litres to weigh 1 pound, 1.19 grams/litre, or 0.074 pounds /cubic foot.

Everybody has their own ways to remember things that aren't obvious. Avogadro's Number ( $6.022 \times 10^{23}$ ), Boltzman's constant ( $1.38 \times 10^{-23}$  in MKS units), and the charge on one electron ( $1.62 \times 10^{-19}$  coulombs) are old friends that I can't ever forget. Not to mention pi, which I can always remember to 14 decimal places, just in case I need it.

### Trouble sleeping

One time I was having trouble getting to sleep, so I decided to see what was the error in saying that  $\log_{10} 2 = 0.30103$ ? So I started doing the math in my head. Hour after hour. I decided that if  $\log 2 = 0.30103 + k$ , then the log of 1024 must be  $3.0103 + 10k$ , and  $\log 1.024$  must be  $0.0103 + 10k$ . So how many times do I have to multiply 1.024 times itself to be equal to about 2? I never did get to sleep worth a darn. But I did convince myself, after about three sleepless nights, that k must be about -0.00000004. So the log of 2 is 0.301029996. In other words,  $(0.010300 + 10k) \times$  about 29.227 is about 0.30103. I just computed 1.024 to about the 29.227 power, computing all the decimal places in my head. I did a lot of long multiplication in my head. But that's not mnemonic. That's just deriving it, from first principles. Still, I can now recall that the log of 2 does not end at '0.30103' but ends with '0.301029996 (to nine decimal places).'

My seventh grade teacher once decided he had to 'punish' me for some imagined offence. So he forced me to remember the square roots of all the digits from 1 to 10. Okay, a couple of them are trivial. And I never find much use for the square root of 7. But the 1.414, 2.236, and 2.828 are loyal and useful friends. What useful mnemonics do you guys use?

Comments invited!

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## What's All This Theme Park Stuff, Anyhow?



June 07, 2004 12:00 AM  
Electronic Design  
Bob Pease

My colleague Jon Carroll wrote a story a while back when he was in India. An Indian friend of his said, "Isn't it wonderful? Read here in this newspaper! There's going to be a new theme park that this businessman is going to develop, right here in India. And the theme of the theme park is going to be India!"

Jon read the newspaper article. He thought about it. As politely as he could, he told his Indian friend, "That is the stupidest thing I have ever heard. India already has a theme park with that topic. India a theme park, and a very good one."

Jon went on in his story to mention all the rich people, beautiful people, nice people, poor people, ugly people, cows wandering the streets, and beautiful architecture (and all the other architecture) that make India a wonderful theme park. Scenes, sounds, smells, great food, things you can buy, music, and people talking and making their sales pitches all make India a great place to visit! Something dreamed up by Disney-minded people would never compare. It would just be plastic junk. I think he mentioned later that this proposed Indian theme park was never built.

But India is, even today, a great theme park. By the time you read this, I'll be in India. Japan, where I am right now writing this, is another great theme park. France is another, and England, Scotland, and China. Mexico, Brazil, Germany, Switzerland.... Nepal is pretty darned good, if you like hiking. Climbing a long way up toward Mt. Everest makes a great theme park. There's nothing like it in the world! Just thinking about going up through the Khumbu, to Gorak Shep, Kala Pattar, Everest Base Camp, and the Great Khumbu Icefall makes me shiver. Disney could never get the yaks to make it authentic. Yaks don't live below 11,000 ft.

Here in the U.S., we have New England, New York, the great Southwest, Southern California, the Midwest, etc. Each place makes an excellent theme park. There are quite a few others. But the overall view is that each distinctive part of the world is a great area, well worth visiting. Each place has unique sights and sounds. A plastic replica would not be worth visiting.

I have had the privilege of seeing a good number of these theme parks. Many of them are wonderfully inspiring. I want to encourage you to go to some of them, when you can. Introduce yourself to them, and allow yourself to discover all the nice people and all the other wonderful things.

Heck, the subway system in Tokyo alone makes a great theme park. It is a great maze, with more than 1000 stores and 1000 restaurants and many nice people. It has many signs to decode. And a cast of thousands? No, a cast of millions. And some parts of it have cute little trains that connect a thousand people per hour to other nearby theme parks, such as Osaka, at speeds of 180 mph! Stick that up your nose, Mr. Disney! I rest my case.

Comments invited!

Dear Bob: I read your column on a regular basis and enjoy it very much. However, in your Analog PowerPoint column (electronic design, March 29, p. 18), you mention that your foils are "hand-drawn." Doesn't this mean that it's really "digital" PowerPoint?

- **Peter King (via e-mail)**
- **Pease:** Nope, Peter. The appendages sticking out from the ends of my hands are really ANALOGUES, not digits. I made a special deal with Doctor Science to have this approved.



## Bob's Mailbox



June 21, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I enjoyed (well, as much as experiences of the sort would let me) a few months ago when you were discussing the convenience of modern credit-card billing shenanigans\*—relating to my own protection and my typical spending patterns. My mother expounded to me a tale of this as it relates to a company that does this "service" in-house. I thought that was a bit odd. I wanted to forward it because it is more of the same. But my mother seems to have handled it well. I know she did better than I probably would have, but it may be a true "mother thing." (*Note, mothers usually have learned how to handle idiots. But I think your mother handled it better than usual! /rap*) Here is verbiage she sent me, knowing I was going to forward it along to you. The name of the business is blotted out.

"I purchased several books three times in 10 days at XXXX. When attempting to purchase additional books within two weeks, XXXX informed me that I had a 'bad check' alert on their register and they could not accept my check. Bad move on their part! I had the manager come to the register and he said that it must be the case ('bad check'), and I said absolutely not and that we would call my bank to verify the balance. The bank substantiated my statement of more than adequate funds.

"I suggested the manager contact the XXXX head office to verify their practice—which SEEMS to consist of stopping business if a person places orders for more than three items in less than 10 days. (*THAT certainly would seem a special DIS-incentive to discourage repeat customers. Like, sorta the opposite of "Frequent Flyer Miles."* /rap) He called back to tell me that no such practice existed. I got the name and number of the head office and contact person and called. Finally, I reached someone that confirmed that XXXX does use this practice 'to protect' their franchises.

"I talked with the local manager again and gave him the name and phone number of my head-office contact. He called and learned this is a practice. The manager apologized profusely and I requested that he send a letter of error to my bank and credit agencies, which he did. He also gave me a \$50 gift certificate for the trouble and embarrassment. I very seldom shop at any XXXX after that experience."

I just thought this was great and that it spoke more along the lines of the topic that you brought up. Although it's regarding checks, it is an important note since it is so typical to verify based on routing and checking account numbers scanned from the checks these days.

• **Colin Shaw** (via e-mail)

• **Pease:** It sure does seem these guys are screwed up, and their right hand does not know what their left hand is doing. I think I know what kind of business they should be in: They should hold a big GOING OUT OF BUSINESS SALE! And, I'm glad your mother knows how to handle mistreatment of her credit.

**Hi Bob:** Your "Analog PowerPoint Stuff" article was great (*Electronic Design, March 29, p. 18*). I wish I had a nickel for every idiotic, substance-less PowerPoint presentation I have ever been forced to soak up. It also reminded me of the view graph competition that took place a few years ago between Dave Middlebrook and Slobodan Cûk of Caltech. They and their respective students were always trying to outdo each other with Analog PowerPoint overlapped sheets. Movement of the sheets resulted in some very clever animation effects and were always great to break up the formality. I wish I could remember some of the specifics, but the details are lost in the mists of Machhapuchhre!

• **Nicholas John Tsacoumangos** (via e-mail)

• **Pease:** Those are great mists! I saw those mists on the evening of June 15, 2002, at 7:00 p.m., from NauDanda! Then we bicycled down to Pokhara, in about one hour flat, ALL downhill. Thanks for writing.

Comments invited!

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\**Electronic Design, Oct. 13, 2003, p. 20*

## What's All This Floobydust Stuff, Anyhow? (Part 13)



July 05, 2004 12:00 AM  
Electronic Design  
Bob Pease

When I go on a plane trip, I carry a mid-size, self-addressed, padded envelope in my briefcase—about 7 by 9 in.—along with five 37-cent stamps and some suitable stickers or tape for sealing it up. Why? Because I might forget to put my jack-knife or diagonal nippers in my checked baggage. The other day, I went through security and the bright-eyed X-ray technician found a pair of nippers I had not seen in a long time. Fortunately, I had time to throw the nippers in the envelope, mail it back to my house, and still make the plane with plenty of time to spare. Because I was prepared, it only took a couple of minutes. If you ever carry a jack-knife or sharp tools that might be confiscated—in your pockets or briefcase—bring a big envelope with stamps.

Or if another person forgets, you can sell him this envelope for a couple of bucks to save him from having his favorite knife confiscated. Of course, you have to figure out some way for him to contact you, after the trip, to get the knife from your house to his!

I have a good reminder to prevent me from forgetting to put my knife or nippers in my checked baggage: I keep my old baggage tags on my suitcase until I have stowed my knife. When the airline person at the desk tries to remove those tags, I realize that I may have forgotten to stow my knife.

### JOY OF SOX

The other day, my wife recommended that I try some new hiking sox. The last time she told me to do that, in 1989, she recommended her favorite heavy wool hiking sox. They gave me bad blisters. I should have known better. Fortunately, after I went back to my normal sox, the blisters healed before the end of the trek. I should have never started out against the rule of "Dance with the girl that brung ya."

My normal hiking sox system is a pair of light nylon-cotton sox on my feet and some heavy wool sox over that. So this time, I got smart. I put on my light nylon sox on both feet. Then I put one of my normal old heavy wool hiking sox on my left foot, and one of her new sox (Bridgedale Trekker, about \$10/pair, Factory Seconds at Sierra Trading Post) on my right foot. To no great surprise, her new sock was a little more comfortable. If I were skeptical, I would try it again with the new sock on my left foot. But my feet are symmetrical, and a 1-dB improvement is believable.

The other part of my hiking system is my Vasque Gore-Tex Expedition boots (~\$175, and worth it). And when I'm on a trek, I sprinkle about 1/3 teaspoon of baking soda into each boot, every day, to help keep them smelling good. Important!

### WHAT'S ALL THIS RENDEZVOUS STUFF, ANYHOW? (PART 2)

A couple of times I have had to meet a guy at a Japanese railroad station on a tight and important schedule. Sometimes I go there to check it out, a day ahead—and THERE IS NO SUCH PLACE, as described! If I did not invent a better rendezvous, I would miss a train and an important business trip. Awful! I mean, "Meet you at the McDonald's near the Marunouchi entrance to Tokyo Station" may not describe a unique place.

So I invented a new rendezvous that works well in Japan because it defines a unique place. If we're going to take the train on any line, we will just say something like: "I will meet you at the north end of the platform for the NORTH-bound trains on the CHUO-line (heading toward Shinjuku) at Tokyo station."

Now at any time, there may easily be 80,000 people in the Tokyo station. But very few dozens of people are at the platform for northbound trains, on the Chuo line, and only a few are at the north end of the platform!

## Bob's Mailbox



July 19, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I have enjoyed your writings and presentations for years. Please keep up the good work. I've learned a lot from you even though my technicians have named me the SandMan for all the ICs I've returned to their native state of sand. I'm trying to find the name of the circuit designer of the Signetics SE555/NE555 timer. Can you point me to someone who might know?

### Mike Turner (via e-mail)

#### Pease:

We were just talking about that the other day. The inventor was Hans Camenzind, who has (had?) a lab on Virginia Street in San Francisco, on Bernal Heights. I heard that the 555 was originally just a feasibility test chip for various features (current mirrors, comparators, etc.) that might be used in future ICs. When customers found it useful, it took some work to redesign it hurriedly into a real IC. I'm not sure if that's true.

**Hi Bob:** Re your "Cruise Control Stuff" (electronic design, May 10, p. 18). It started when I ended up with a Lincoln Town Car from a friend's estate. The car was so quiet that you couldn't sense engine or transmission malfunctions until they became gross and expensive.

What I came up with was entirely passive—a small loudspeaker driven through a series capacitor and low-pass filter from an arm of the wye stator winding of the alternator. The alternator has a unipolar 15-V square wave that Ford brings to an external terminal. (*How odd! /rap*) The frequency is high compared to the exhaust note, but I adjusted it so that its level just exceeds cabin noise, and it's completely unobtrusive. If I get the time, I'll divide it down by eight or so. (*If it works now, changing it might do harm, not good! /rap*)

What you get is a precise sense of how well or poorly the transmission is shifting. And you can even hear an intermittent single-cylinder miss, something you'll never notice otherwise in a big V-8 under light load. (*REALLY! /rap*) It probably helps if you don't have a tin ear, but the tone helps you maintain a constant speed without the other noise clues you get from a lighter car—as long as the torque converter is locked up. (*Interesting. I never would have thought of it, but I guess you had to try it. I had to try MY scheme. /rap*)

This signal is also available at the cigarette lighter, but it's only millivolts and you'll have to amplify it. This is worth doing when test driving a used car. A small PC speaker that is happy with 12 V does the trick. On a recent BMW, you will also hear the chorus of the dozens of microprocessors that you hope are your friends.

### Bill Schmitt (via e-mail)

#### Pease:

Thanks for the interesting comments on your "Cruise Control" circuit. All of the microprocessors in my car are my friends—all ZERO of them.

**Dear Bob:** An old geezer like you driving at 68 mph? You should have your license revoked. You're endangering people's lives, you know.

### C.M.W. (via e-mail)

#### Pease:

I am NOT old, and my reflexes and eyesight are perfect. 68 mph is NOT speeding. The only thing unsafe about driving at 68 is that the median speed out on I-280 is about 78 mph. At 68 mph, 95% of the cars are passing me, and I'm passing 5%. I will not drive at 78 mph, in my car, just to be closer to the median speed. I am not endangering anybody else, nor myself, at 68 mph. I just got back from South Africa where I was driving between 75 and 85 mph, and I was still down at the 20th percentile. When in Germany, I drive 85, 95, 105, or 125. That is miles/hour, not kph. And I am DAMN careful at ALL speeds, fast and slow. I'm STILL not usually above the 50th percentile. Best regards, and thanks for the silly comment.

Comments invited!

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## Bob's Mailbox



August 23, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Hello Bob:** I recently saw a question in *Nuts & Volts* magazine asking why the three-pin linear regulator package pinouts differ between the positive and negative regulators. The answer was that it prevented the input voltage from going to the regulator if a wrong polarity regulator was inserted in the circuit.

*(That is not true. In a few cases, that might happen, but there is no cause or effect or intent. /rap)*

I initially thought it might have something to do with what part of the regulator chip is the substrate and ends up as the tab or case of the IC. *(Exactly! Most TO-5 or TO-39 [hermetic] cans have the case tied to the third pin [as viewed from below], which would be the collector of a transistor. It's hard to buy a TO-5 can where the case isn't tied to the third pin. /rap)*

Then I got out the catalog and looked at all the various fixed and adjustable regulator packages. The negative regulators (top views) are arranged GND-IN-OUT or ADJ-IN-OUT, except for the TO-39 "H" package, which is IN-OUT-GND or IN-OUT-ADJ. So much for my substrate theory. *(On a TO-220 or TO-202 plastic package, the negative input voltage is the middle pin, which ties to the paddle. The die has to sit on the paddle. This is usually true for TO-92s too. The "negative-input" supply is the "collector" pin, which is often called the collector on a transistor. The middle pin is the "collector" on most plastic transistors. /rap)*

The positive regulators are even more varied. The fixed regulators are IN-GND-OUT, while the adjustables are ADJ-OUT-IN. *(Correct: The negative voltage substrate of a positive fixed-voltage regulator is the middle pin of a TO-220. The negative voltage substrate of a positive adjustable regulator is the middle pin of a TO-220. /rap)* Once again, the "H" packages are an exception with GND-OUT-IN or OUT-ADJ-IN. *(Correct: The negative voltage substrate of a positive fixed regulator is at  $V_{OUT}$ , and that is the middle pin of a TO-220. /rap)*

I once updated a dual-rail linear regulator using TO-220 transistors to one using adjustable LM317T and LM337T regulators. The LM337T dropped right into the B-C-E pins of the pnp negative transistor, while I had to cut and jump tracks to use the LM317T in the npn positive-regulator spot. What is the real reason for the varying pinouts of linear-regulator ICs?

### Charles Hansen (via e-mail)

**Pease:** Hello, Charles. In general, you are right. The substrate is the most negative bus, which is the pins as I listed them. The thing that looks strange is that on an adjustable regulator, such as an LM317, the ADJUST pin is slightly more negative than the substrate. But that is okay.

See associated figure

**Dear Bob:** I just read your column on "Theme Park Stuff" (electronic design, *June 7, p. 18*), and I commend you. It has always been a source of sorrow to me that working families spend all their time and money visiting a sanitized Disney "global village" just to buy their kids cheap imported figurines. And it's at 10 times the original price, when they could have actually gone to those places and experienced something--for the same money. *(Airlines are reasonable these days, but not that cheap!! Sigh. /rap)* But I guess if you insist on safe, protected environments not linked to reality, then that is Disney. But I'd pick the Indian theme park any day.

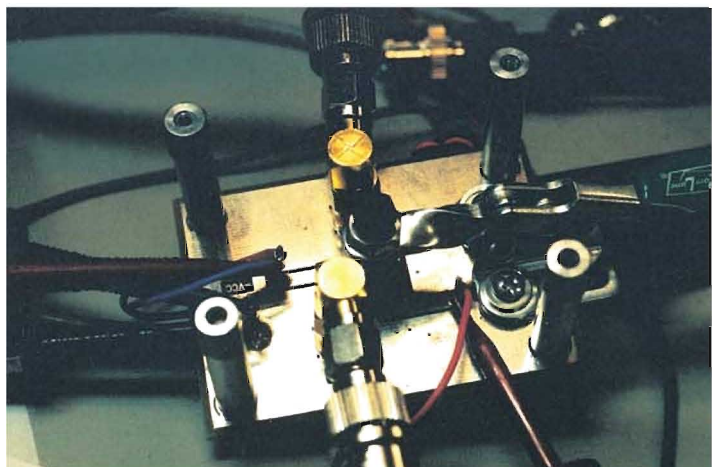
### Jeannine Neagle (via e-mail)

**Pease:** I'm with you, Jeannine. NSC's security guys cautioned me that I should avoid any personal travel when I went to India and South Africa. I specifically ignored that and travelled around a lot--but carefully. When I climbed up Table Mountain, which overlooks Capetown, I hiked like a fool--but left my suitcases at my hotel, rather than in my parked car. I experienced no break-ins and no muggings. In fact, all day, I saw no other hikers!! Similar to my hiking around Lady Grey and Barkly East. I met lots of nice people in South Africa (as well as in India), where I also spent several hours hiking around Mysore. But I was nearly mugged (of my camcorder) by an elephant. They forgot to tell her the script!!

Comments invited!

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## What's All This Clinometer Stuff, Anyhow?



September 01, 2004 12:00 AM  
Electronic Design Europe  
Bob Pease

When I decided to go on a bicycle trek in Nepal a few years ago, I planned to instrument the tough hills with a clinometer to measure the slopes I'd be ascending and descending. Well, designing a 'clinometer' shouldn't be Rocket Science. A weight dangling from a pivot can tell you the slope of a hill.

So I set out to engineer one per these needs: A clinometer must be enclosed to read correctly despite winds. It must have good damping to reject vibration. If I'm gonna carry it to 18,000ft, it must be light. It also has to be waterproof and durable to keep working, despite knocks and bumps.

So how to plan this? I mounted the pointer inside a slice of a clear plastic cottage-cheese bowl and bolted it to a light frame made of copper-clad with spacers. I cut holes in the copper-clad frame to cut weight, and I covered those holes with thin mylar to keep the wind off the pointer. The copper-clad frame had arms that I taped to the frame of my bike (Specialized Rock-Hopper). Very stable. The pivot was a piece of brass tubing from an old ball-point pen soldered to the copper, with paper-clip wire inside the tubing, weights hanging below, and a pointer above. Calibration was easy—mark the dial versus a measured slope.

But when I started riding, I realised that I had not solved a basic problem – the damping. Even with heavy oil inside the 'pivot' – inside the brass tubing – there was not enough damping. I tried adding a few thin mylar vanes to damp the pendulum's motion, versus the air inside the dish. This had minimal effect: The Q of the damping fell from 5 to ~4. H'mmm. I rinsed out the oil and put in grease. Now the damping was much too heavy. The pointer would never settle to the true value. Okay, now what?

I thought: where's the compromise between too little damping and too much? I thought about it and found the solution. While the tubing was still full of grease (SAE 90), I pushed out a little of the grease and added a little oil (SAE 10-30). The oil was along the paper clip, inside the grease. There was some mingling. The resulting gradient of grease and oil worked well! The grease and oil did not contaminate each other, and the damping stayed good. It did not freeze up when cold or get too soft when hot. What did I learn from this meter?

I could ride uphill okay, but as I pedalled, the meter did not indicate well because the bike was surging. That's okay. When I came to a steep hill, I'd ride as hard as I could, then stall. Then I could stop and read the slope.

But when riding downhill at a smooth and constant speed, with brakes on smoothly, I could peek down, and the meter would indicate the true slope.

In Nepal, the uphills were sometimes steep or moderate. But the trails were mostly rocky, and not much riding uphill could be done after the first day, except for the fifth, sixth, and eighth days. So the meter wasn't useful to indicate any 'average' uphill slope.

On high slopes, many trails were more than 28% – too steep to ride. But I biked many slopes less than 14%.

On the downhill at Phedi (below the 17,771-ft pass, Thorung La, north of Annapurna), there was an 'improved' trail, rough and stony, as steep as -50%. I'd let my bike down a few feet, then clamp on all brakes, then walk down a couple steps, and repeat this. Tough trail!

So I didn't learn much from this meter. But what a great trek – see at [www.national.com/rap/trekking/bek](http://www.national.com/rap/trekking/bek). I didn't need a meter to tell me that. And I learned that a suitable gradient of oil and grease could provide good damping.

See associated figure

Comments invited!

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WHY DID BOB PEASE DECLARE HIMSELF THE CZAR OF BANDGAPS?

FIND THE ANSWER ON: [HTTP://WWW.NATIONAL.COM/RAP/HORRIBLE/CZAR.HTML](http://www.national.com/rap/horrible/czar.html)



CLINOMETER COUNTRY. THE THORUNG LA PASS IN THE DISTANCE



## What's All This Input Impedance Stuff, Anyway?



September 06, 2004 12:00 AM  
Electronic Design  
Bob Pease

A young teacher went to Temple. Several priests and pharisees asked him questions. They asked trick questions to try to fool him. The teacher very sweetly and correctly answered their many tricky questions. All those present were amazed at the teacher's wisdom in answering these difficult questions.

Then a pharisee asked him another trick question. He drew a circuit in the dirt. "Look at this op-amp circuit. It is often used as an example of a well-balanced circuit. Have you heard of this?"

The teacher agreed that he had seen this circuit and that it is a well known, well balanced circuit. Then the crafty pharisee asked, "But what is the input impedance at the negative input that A1 has to drive? That is R1, right? Such as 1 k $\Omega$ ." The teacher nodded. "But the impedance at the positive input, which A2 must drive, is R1 + R2. That is 101 k $\Omega$ , right?" The teacher nodded.

"Therefore, because these input impedances are grossly unequal, this is a sorely imbalanced circuit and not capable of doing good linear work." The pharisee rested his case.

The teacher stroked his beard. He questioned the pharisee, "So you are concerned that A2 can easily drive a light load, but A1 cannot easily drive a heavy load?" The pharisee jabbed that this was exactly the terrible problem.

More beard stroking. Then the teacher pointed, "But what if both inputs are driven together to +10 V dc? Both A1 and A2 have to drive the same 101-k $\Omega$  common-mode load. That does not sound like a poorly balanced circuit."

The pharisee was stunned. He had not thought of this. He said nothing. Much silence. He was beginning to suspect that he was in trouble. The teacher thought, and went on, "If the output impedance of A1 or A2 was perhaps 1 $\Omega$ , you are still concerned that the gain would be different for the positive channel, and the gain for the negative channel would be lower. That is your concern?" The pharisee gulped and nodded.

The teacher said, "If you put a millivolt into the negative input, and you want the gain to be 100, and you want the output to be 100 mV, the 1 $\Omega$  will cause the output to be about 0.1% low, or actually 0.0999% low, because the 1 $\Omega$  won't be able to drive the 1-k $\Omega$  input impedance with perfect gain, right? The output signal will only be 99.9001 mV, right?" The pharisee gulped and nodded.

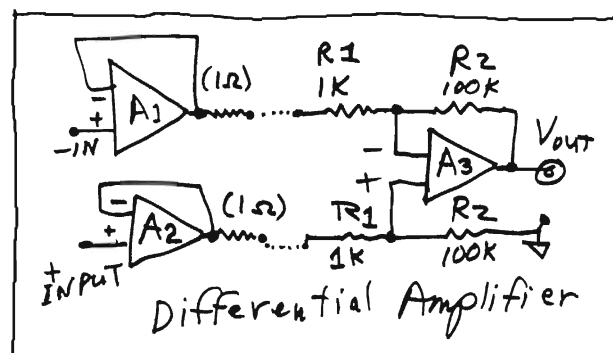
"And if A2 has to drive the positive input, the 1 $\Omega$  will cause negligible error when driving 101 k $\Omega$ , right?" The pharisee nodded. But the teacher poked at the drawing in the dirt and made his point: "If the positive input moves 1.000 mV, and the positive input of A3 moves exactly 990.0892  $\mu$ V, that's a very minor attenuation error caused by the 1 $\Omega$ , right?" The pharisee thought and thought and nodded nervously.

The teacher observed, "But the 1 $\Omega$  in series with the A1 output will cause the gain for the positive input to be hurt. The gain for the signal at the positive input of A3 won't be 101, but will be 100.9001, right?" Nod.

"And the 990.0892  $\mu$ V X 100.9001 equals 99.9001 mV. Despite the alleged difference in input impedances, the gain for signals at the positive and negative inputs are exactly the same. If that were not true, the CMRR would not be so good, relying on the symmetry," the teacher said.

"Go, my son, and sin no more." The pharisee slunk away. And all who were attending were stunned by the wisdom of the teacher's answer.

Comments invited!



## Bob's Mailbox



September 20, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** There's an error in your recent "Mailbox."\* What you "heard" about the 555 timer is a bit off the mark. Your story mixed up the 555 with my work on semicustom ICs, which happened about the same time. If you want the actual story, you can download my new book, *Designing Analog Chips, from my Web site, www.arraydesign.com. It's free.*

At Signetics (January 1968 through December 1970), I developed the first semicustom chip, used internally to get a new design onto silicon in about two weeks and then debug it. I have been using this approach since then to fabricate custom designs for quantities below a million/year.

I proposed the 555 timer when I left Signetics and developed it as an independent. It went from breadboard straight into layout--the same layout still used today, save for shrinking it once.

Hans Camenzind (via e-mail)

Pease: *Okay Hans, so the 555 was really designed as a product, not just as a test pattern. Thanks for clearing this up. I've started to read your book. It looks great! I recommend that all engineers read it.*

**Dear Bob:** Some of your comments about Spice simulation put me in mind of an engineer I knew in the early 1970s. Chris was fascinated with the possibilities of the digital world. I think he built an RCA 1602-based microcomputer, which could make lights flash, depending on how you set the switches. At the time, I really didn't get it.

Anyway, Chris was a big proponent of digital simulation. He told me that breadboarding analog circuits was primitive, and you could never prove much by building a model. You could always "get one of anything to work." He insisted that I really needed to use RF-OPT and Spice. I eventually did, and I must say they did some good, if only by forcing me to sit down and analyze my circuits in detail to make a simulation model to plug into the program. *(But I'll say, "You can always get a digitally simulated circuit to work." And after all that work, it is NOT automatic to say you can build them in production. That's my point. /rap)*

Chris loved tricks and illusions. One of his favorites was to hold a pencil mid-length between thumb and forefinger and wiggle it. It gave the illusion of bending--the "Rubber Pencil" illusion.

I decided to go him one better. I took a white eraser rod for an electric drafting eraser, sharpened one end in a pencil sharpener, and decorated it with colored markers and the ferrule and eraser tip from a pencil. When I did the "Rubber Pencil" trick, he was flabbergasted! *(Jolly good!! /rap)* That is the difference between Spice and reality.

Roger Burchett (via e-mail)

Pease: *Sometimes there is good correlation between Spice and reality. Jolly fine. But when the correlation is LOUSY, then you will waste a lot of time--and money.*

**Hi Bob:** I enjoy reading your column very much. Thank you! However, I take exception to the snub you made at Disney in "What's All This Theme Park Stuff, Anyway?" (electronic design, June 7, p. 18). As an engineer, I appreciate all the high-tech stuff they have designed. And as a kid at heart, I appreciate all the fun I have!

I would argue that Disney's intent is not to diminish all of the wonders of the world, some of which you mentioned, but to have people enjoy them. By creating the incredible reproductions, they are in fact promoting some of these wonders to people that may never have the financial or time resources to see the real things.

Jon Kanter (via e-mail)

Pease: *It still only costs a few tanks of gas to go see the nearest theme parks, such as New England, the Grand Canyon, New Orleans, or the Rock Museum in Cleveland.*

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) --or:  
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## What's All This Pease-Cohen Effect Stuff, Anyway?



October 04, 2004 12:00 AM  
Electronic Design  
Bob Pease

Back in 1965, I designed one of the best op amps in the world, the PP25A. It had less than 1 mV of  $V_{OFFSET}$ , and 150 pA of  $I_{BIAS}$ , using good Amelco n-channel JFETs. Its yellow epoxy package had an impedance far above 1 million megohms. Nobody had a better amplifier. Then I designed an improved one, the PP25C, using TI JFETs. The input current was less than 15 pA in standard tests (at  $V_{CM} = 0$  V).

Then I applied these PP25Cs with our PPT&H Track-and-Hold Module. Our leak-rate tester said that the leak rate was good at 0 V of  $V_{CM}$ , and at +10 V of  $V_{CM}$ , but it degraded rapidly at a  $V_{CM}$  of 10 V. In fact, the input leakage there seemed to be worse than the standard PP25A!

We did some extended evaluation on these TI FETs. When we tested for  $I_{GSS}$ , with no drain current flowing, the  $I_G$  was quite small. But when we measured the  $I_G$  as a function of  $I_{DS}$ , the  $I_G$  increased about with the  $I_{DS}$ . Oops! Further, this excessive gate current increased exponentially when the  $V_{GD}$  passed a threshold! Bummer! And, this leakage increased even on the Amelco FETs, if we got the  $V_{DS}$  big enough.

Why was this happening? I cooked up a theory that it was related to the imperfect contact of the drain, to the drain's metal. When drain current flowed, much of the current flowed properly into the drain. But a portion of the current flowed back as minority carriers and was collected at the gate. This effect was magnified when the  $V_{GD}$  got large. Joel Cohen of Crystalonics had observed this effect and had a similar theory. We mashed our theories into one and called it "The Pease-Cohen Effect (PCE)."

Soon, we found other data that debunked this theory. Apparently, this excess leakage is caused by "hot electrons." It can even occur in MOSFETs, flowing to the back gate (substrate). It is typically a bigger effect in p-channels than n-channels and bigger in compact, high-performance, tiny-geometry FETs. But, it was NOT caused by imperfect metallic contact at the drain. So we had to throw that theory out. Yet when engineers bump into this, we still say, "Oh yeah, that's the Pease-Cohen Effect."

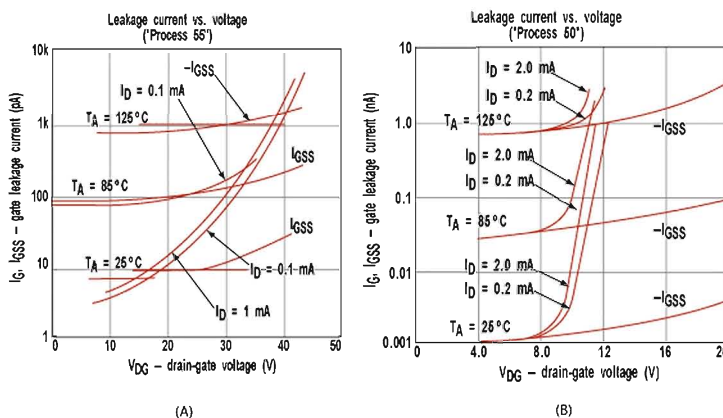
So if you discover that a JFET's gate leakage increases dramatically, with the drain current, at high voltages, don't be surprised. If some FETs work well, don't let anybody swap in an "equivalent" type, with no proper qualifying tests. The "equivalent" may have completely different (worse) amounts of PCE leakage.

Comments invited!

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P.S. One day, Amelco's salesman, Ed Barrett, came by with a "new, improved" matched JFET pair, but he wouldn't let me evaluate it. He said, "Everybody wants to evaluate this FET by putting it on the curve-tracer. Some customers think it's the best matched pair they ever saw. Others look very closely, and they say it's not all that well matched." I asked Ed why he wouldn't let me evaluate it. He said, "It wouldn't work well for you because you would plug it into the front end of an op amp—and it would not work." He admitted, "That is because it is really just one FET inside, bonded out to both sides of the six-pin package. It looks pretty good on a curve-tracer. But if tried to use it, it wouldn't amplify." A point well taken! The joke was on—everybody else!! /rap

P.P.S. Could I have starved down the PP25C's source currents from 300 to 50  $\mu$ A and run the amplifier with lighter damping? That would have decreased the excess gate current by 6 $\times$ . But I never thought of that until just now! Dumb! /rap



# What's All This "Selective Fit" Stuff, Anyhow?



October 18, 2004 12:00 AM  
Electronic Design  
Bob Pease

Back in the late 1950s, George A. Philbrick Researches would cheerfully sell you a \$22 K2-W op amp that would swing  $\pm 50$  V as its rated output (per my old column\*), and for \$33, a K2-X that would swing  $\pm 100$  V of output. But there were problems with the K2-X.... After the assemblers built up a group of 50 of these K2-Xs (with all the resistors and capacitors wired to an Octal Plug, and a couple of nine-pin sockets), a test technician would sit down with 50 12AX7A tubes and 50 6AN8s and try to get them all working.

Typically, the 12AX7As gave no problems, but the 6AN8s would not all work. After the first 30 amplifiers were matched up and tested out, the last 20 amplifiers would not meet specs, no matter which tubes were mated with which amplifiers. So, we could not ship 50 op amps until the test technician cheated and borrowed some tubes from the next batch of tubes.

Well, that gets our first 50 out, but how about the next batch? We can't borrow those tubes forever. At the end of the week, there might be a few dozen op amps that would not work with any tube and several dozen tubes that would not work with any amplifier. H'mmm.

Ahem. What exactly was wrong with the circuit? Apparently, the tolerances piled up, and the Plate of the pentode would not swing 230 V p-p (see the figure). In those days, it was—apparently—easier to buy a few hundred more 6AN8s and keep refitting the tubes and the amplifiers together.

Who designed the K2-X? Did Roger ("Tim") Noble design it? Maybe. Roger was a very bright and talented guy who could solve problems even without a college degree. He could make any K2-X work. But he could not make every K2-X work.

Roger did a redesign of the K2-X, to be called the K2-XA. It used a more consistent triode-pentode, the 6BR8A. When he had cooked up a good circuit, I remember Roger called everybody over for a demonstration. He showed us the new, improved circuit, with poor gain and poor swing. Then he added a resistor, and the gain magically popped into spec.

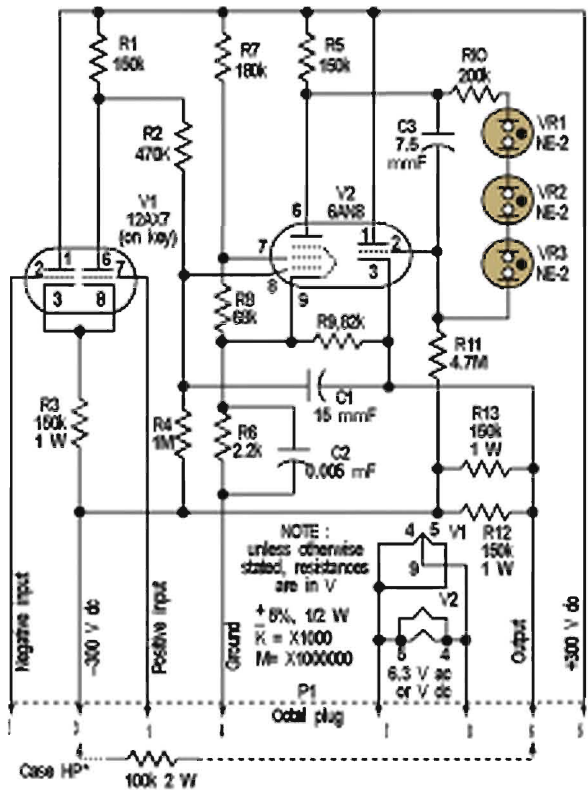
We were all impressed that the new K2-XA had a chance to work better. But I was a bit skeptical. I asked Tim which resistor he had changed. He said he had increased the resistance in the screen circuit. So the distortion cancelled out, and the gain improved. I thought about it and went away, not saying much.

Months later, we realized that the K2-XA had the same kind of "selective fit" problems. The 6BR8As did not provide any magical 100% yield, or 95 %, or even 85% or 75%.... The basic problem was that the pentode could not satisfactorily swing 220 V p-p with a 300-V power supply. If the pentode turned OFF, the plate still would not go high enough. If the pentode turned on very hard, its plate voltage would still not go low enough. The resistor tolerances would build up, the neon lamps' operating voltages would have tolerance errors, the 6BR8A's tolerances would build up, and nobody could make all the darned things work.

I am sure Tim tried various trim schemes to put a trim resistor across some of the resistors to bring the circuit into operation. But part of the problem was that a 4.7-M $\Omega$  resistor would have to be shunted by a trim resistor of 62 or 100 M $\Omega$ , and in those days, Allen Bradley did not make those high values. They did, later, in the 1965 era. Check out the next issue for the "final solution" to the problem.

Comments invited!

\*Electronic Design, Feb. 3, 2003, p. 22.



## What's All This Input Impedance Stuff, Anyhow?



October 26, 2004 12:00 AM  
Electronic Design Europe  
Bob Pease

A young teacher went to Temple. Several priests and pharisees asked him questions. They asked trick questions to try to fool him. The teacher very sweetly and correctly answered their many tricky questions. All those present were amazed at the teacher's wisdom in answering these difficult questions.

Then a pharisee asked him another trick question. He drew a circuit in the dirt. "Look at this op-amp circuit. It is often used as an example of a well-balanced circuit. Have you heard of this?"

The teacher agreed that he had seen this circuit and that it is a well known, well balanced circuit (see the figure). Then the crafty pharisee asked, "But what is the input impedance at the negative input that A1 has to drive? That is R1, right? Such as 1 k $\Omega$ ." The teacher nodded. "But the impedance at the positive input, which A2 must drive, is R1 + R2. That is 101 k $\Omega$ , right?" The teacher nodded.

"Therefore, because these input impedances are grossly unequal, this is a sorely imbalanced circuit and not capable of doing good linear work." The pharisee rested his case.

The teacher stroked his beard. He questioned the pharisee, "So you are concerned that A2 can easily drive a light load, but A1 cannot easily drive a heavy load?" The pharisee jabbed that this was exactly the terrible problem.

More beard stroking. Then the teacher pointed, "But what if both inputs are driven together to +10V dc? Both A1 and A2 have to drive the same 101-k $\Omega$  common-mode load. That does not sound like a poorly balanced circuit."

The pharisee was stunned. He had not thought of this. He said nothing. Much silence. He was beginning to suspect that he was in trouble. The teacher thought, and went on, "If the output impedance of A1 or A2 was perhaps 1 $\Omega$ , you are still concerned that the gain would be different for the positive channel, and the gain for the negative channel would be lower. That is your concern?" The pharisee gulped and nodded.

The teacher said, "If you put a millivolt into the negative input, and you want the gain to be 100, and you want the output to be -100 mV, the 1 $\Omega$  will cause the output to be about 0.1% low, or actually 0.0999% low, because the 1 $\Omega$  won't be able to drive the 1-k $\Omega$  input impedance with perfect gain, right? The output signal will only be -99.9001 mV, right?" The pharisee gulped and nodded.

"And if A2 has to drive the positive input, the 1 $\Omega$  will cause negligible error when driving 101k $\Omega$ , right?" The pharisee nodded. But the teacher poked at the drawing in the dirt and made his point: "If the positive input moves 1.000 mV, and the positive input of A3 moves exactly 990.0892  $\mu$ V, that's a very minor attenuation error caused by the 1 $\Omega$ , right?" The pharisee thought and thought and nodded nervously.

The teacher observed, "But the 1 $\Omega$  in series with the A1 output will cause the gain for the positive input to be hurt. The gain for the signal at the positive input of A3 won't be 101, but will be 100.9001, right?" Nod.

"And the 990.0892  $\mu$ V X 100.9001 equals 99.9001 mV. Despite the alleged difference in input impedances, the gain for signals at the positive and negative inputs are exactly the same. If that were not true, the CMRR would not be so good, relying on the symmetry," the teacher said.

"Go, my son, and sin no more." The pharisee slunk away. And all who were attending were stunned by the wisdom of the teacher's answer.



## Bob's Mailbox



October 28, 2004 12:00 AM  
Electronic Design  
Bob Pease

In my last column, I promised to tell you how we fixed the "selective-fit" problem with the K2-XA op amp.\* Let's take care of that before we get to this month's letters. The "final solution" for the K2-XA was to add a transistor to the circuit (*see the figure*). This allowed the circuit to hold the pentode's cathode at 120 V.

With a total 420-V supply, the 6BR8A's plate could easily swing 240 V p-p, and the problem of swing and "selective fit" went away. Admittedly, the test tech had to select and install a selected resistor in the positive feedback loop. This resistor did correlate approximately with the beta of the npn. That npn was an SM1009 or SM1011, a fairly high-voltage npn silicon Mesa that we bought from TI. After that, we never had any problem with "selective fit." But we sure did all learn a tough lesson about "selective fit." Sometimes "selective fit" does get some good things. Other times, it leads to trouble!! /rap

**Dear Bob:** Greetings from Idaho! My uncle and I read your article, "What's All This Clinometer Stuff, Anyhow?" (*Aug. 9, p. 20*) with interest and amusement. As you're a highly acclaimed electronics design engineer, we think that you could have used a strain gauge, a hot-wire anemometer, and a microcontroller for this project. (*Yeah, but I certainly would not use such a scheme without good battery life! As I mentioned, I needed to keep the whole thing down at 1 ounce. Including batteries. /rap*)

Or, may we suggest the Lev-O-Gage clinometer, available for \$12.99 from West Marine ([www.westmarine.com](http://www.westmarine.com))? To quote my sailor uncle, "Your roads are probably smoother than a rough sea."

### Kris Willoughby (via e-mail)

Pease: Some of our roads were smoother. But, some of our roads were staircases. Is that rough enough for you? Obviously, no clinometer is going to make sense of that!

**Dear Bob:** I'm glad to see you helping to tell the world that PowerPoint is a prolific source of artificial stupidity (*March 29, p. 18*). Here is how I sum up the PowerPoint mindset... Original text:

*Roses are red, violets are blue, Sugar is sweet, and so are you.*

After running through the PowerPoint mind:

- Roses
- Violets
- Sugar
- You

Seriously, have you noticed that weak PowerPoint presentations lack verbs? They're just lists of things to talk about; they don't actually do the talking! (*But people who use PowerPoint have been told not to put too many words on one foil. So they leave out "unnecessary words" and only put in the key words. You gotta admit, if you put up the whole poem, and people can just read it, it takes away all the suspense! People do altogether too much reading of their own foils!! I minimize that, usually. /rap*) And the fancier the background picture, the emptier the content!

### Michael Covington (via e-mail)

**Pease:** *That's just my point! All the effort went into making a pretty view, and no thought went into the contents. Usually.*

THEY'RE BACK!

*Electronic Design* has put up about 125 of my most recent columns and about 85 recent Mailboxes. Go to [www.national.com/rap](http://www.national.com/rap) and click on *ED columns* to get to [www.elecdesign.com/Departments/DepartmentID/6/6.html](http://www.elecdesign.com/Departments/DepartmentID/6/6.html). The index works pretty well and is chronological. There's a lot of good columns in there—even old ones that were not in there a few years ago. /rap

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) —or:  
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## What's All This Magazine Stuff, Anyhow?



November 15, 2004 12:00 AM  
Electronic Design  
Bob Pease

The dictionaries have always said that a magazine is a military storage place, in a fort or ship, to keep bullets, gunpowder, shells, and other important (or dangerous) military supplies. If an enemy shell hit your , you would be a . Moviemakers capitalize on that.

Nowadays, everybody reads magazines—collections of stories on various topics and themes. There are thousands of magazines you can read. I get several technical magazines in addition to . I get , , , and . I get a dozen general-interest magazines—, and —that I always read; and others that I try to read. And .

How did the name get started? In the 1700s and early 1800s, when printers developed new capabilities for popular publications (including drawings and other art), they started selling journals or reviews—and they called them "magazines" because they held so many good stores of miscellaneous (dangerous?) information. And here we are today.

According to my 1894 \*—a good witness of this period—"As from the 'pamphlet of news' arose the weekly paper, wholly devoted to the circulation of news—so from the general newspaper was specialized the weekly or monthly review of literature, antiquities, and science, which, when it included essay-papers, made up the , or miscellaneous repository of matter for information or intelligence." And: "Perhaps the first germ of the is to be found in the (1691-1694) of Peter Motteux, which, besides the news of the month, contained miscellaneous prose and poetry." (I'd love to add poetry—but we ain't got the space..../rap)

On the numbers: "ignoring weeklies, and those published more often than once a week (on account of distinguishing them from newspapers) there are biweeklies 47, semi-monthlies 175, monthlies 1034, bi-monthlies 12, quarterlies 59." And that was data from the in 1883. Ya got the picture? The publishers were going wild! And they still are. I just heard that 1000 new magazines were started last year. (They didn't say how many old ones went belly-up.)

So what does a good "magazine" do? It presents the reader with a broad array of ideas that are timely. News stories, new products, new IDEAS. It's like a shotgun, trying to hit a little of what many readers will be interested in. A good magazine tries to tweak the readers' interest to get them back every issue. The editorial pages try to make thoughtful comments about various timely topics—again to tweak the interest of the readers. This can lead to a good "Letters to the Editor" column.

A magazine also tries to maintain continuity with features and columns. Here at , we have a Design Brief section that is very popular with me and a lot of other readers. I almost always learn something in there. And of course, many people like my column. And my "Mailbox," sometimes called the "Dear Abby" of electronics. (Some people say they are annoyed when I talk about anything other than just electronic circuits, as I am doing here. Sorry, guys.)

Magazines also carry advertisements. These are important because they pay for the whole thing (or, with paid subscriptions, a lot). They are also very important because they inform us of new products that we will like or that can help us get our work done. Let's give a big cheer for . The world would be boring without them!

Comments invited!

\*1894 (Volume XVIII, p. 537a)

## Bob's Mailbox



November 29, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** I was just looking through *Electronic Design* and noticed something in "Bob's Mailbox"\* about the 555. Interestingly enough, I did an improved version of the then NEC555, or ICM555. The TI TLC555 all-CMOS timer was designed using a "brand new" TI CMOS process, intended to fit into the same socket as the NEC555 or ICM555, but it offered improved performance. *(Yeah, but not at an 18-V supply! What voltage did your design work down to? Let me see—the NSC LMC555 will run from 15 V down to 1.5 V. It's alleged to run on 5 V, even up to 3 MHz, while running on less than 1 mW. Not too poor, although I have never run one myself. Did we steal the design from you, or whatever? When? I have no idea. I do not know who "designed" our version. Hans Camenzind claims he cooked up a low-voltage version of the 555. I never checked to see if it worked down at 1.5 V. I have no idea which version—yours or ours or Hans'—will work best in difficult applications. If yours is still selling, it must be pretty good. /rap)*

I know this device well. The TLC555 version of the 555 device line is my design. I designed it in 1983 while I was employed by Texas Instruments. It is great to know that this product has stood the test of time. In fact, you can still pick up one at your local Radio Shack today.

**John Morgan (via e-mail)**

**Pease:** *Yeah, but can you buy them in Akihabara? I have bought my good old LM337 in a shop in that Tokyo district! And I designed that 27 years ago.*

**Dear Bob:** I have just read your Pease Porridge about theme parks (electronic design, *June 7, p. 18*). I agree with you completely. But, you forgot in your list one of the most amazing theme parks in the world: Spain. I recommend you visit us. I am sure you will agree with me.

**José Vicente Gigante Ripoll (via e-mail)**

**Pease:** *Hey, hey, José. I agree that Spain is a wonderful place. I have spent a couple of excellent weekends in Spain. One of my friends and I went up to Segovia, drank a lot of wine, and took a couple of two-hour walks up in the high hills. It was glorious and beautiful! We chose to drive on roads that were supposed to be horrible, but they were quite nice. Then, four of us drove down to Toledo, and that was very pleasant. And, we hiked all around Madrid. We took subways, walked, shopped, and went around Juan Carlos' Park with the great sculpture. I apologize for not mentioning all the possible theme parks. And Spain is an excellent one! I enjoyed the heck out of it with my friends. It was great!*

**Dear Bob:** Hope all is well with you! I ran into an old circuit that scales an analog input and does some gain amplification. Right on the front of the amplifier, it has a protection scheme using two JFETs. They are connected with drain and source shorted, and one protects to the +7.5-V rail and the other to the -7.5-V rail. I understand that the transistors look like protection diodes. But how do JFETs compare to bipolars (I have seen you do this, I seem to recall), compared to just silicon diodes? Is it an issue of voltage drop? Capacitance? Leakage? Is one better than the other? The signals are not fast. It is an old Leeds and Northrup chart recorder.

**Chris Eddy (via e-mail)**

**Pease:** *Most FETs have to be made with clean processing, so they are pretty low leakage. This was figured out 40 years ago. They are certainly lower leakage than almost any glass diodes—AND the light does not get in. These days, most bipolars are made with good, clean processing. If you get some 2N3904s, 2N4250s, or 2N3707s, their C-B junctions (leave the emitters open circuit) are just as good. The C-B junction is not blindingly fast, to turn ON or OFF, but for this job, that's not a problem.*

Comments invited!

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## What's All This Merit Badge Stuff, Anyway?



December 08, 2004 12:00 AM  
Electronic Design  
Bob Pease

Yes, I used to be a Boy Scout, and I think I earned about six Merit Badges. Did they have an Electricity or Electronics Merit Badge back in 1954? Probably, but I did not earn that one. I did pass swimming, though. So how can we get kids interested in electronics these days when there are no heathkits?

Well, I got some fun ideas. Let's look at the figure. We take an audio signal—such as one from a function generator, or a radio, or a record player, or a CD player. We patch it into the input of the amplifier network. Then we patch the output into an ordinary audio amplifier (Hi-Fi set) and listen to it. Depending on what components we insert into the amplifier stage, what does the output sound like?

If you put in weird capacitors, what does sound like? If you add a diode or two, what does sound like? If you make filters—low-pass, bandpass, or notch—does sound pretty weird?

What if you scrape a grounded file across the terminals? Raspy, eh?? Filters? Oscillators? Refer to my Web site, , and search on "RAP's Merit Badge Workbook" for various recommended circuits. Do they sound weird? I hope so!

If you can borrow an oscilloscope, and you look at the waveforms, does the observed waveform make sense in terms of the audio weirdness? I have thought of several ways that I wanted to get kids involved with audio and with electronics as a hobby, and this is the best idea I have come up with so far.

Can they use a "solderless breadboard?" Oh, sure, this is one case where the impedances and frequencies are moderate, so the limitations of the "solderless breadboard" at high frequencies aren't harmful.

Do the Boy Scouts already have an Electronics Merit Badge? I am sure they do. I'll go search it out and try to understand it. But I think my ideas will be fun for the young experimenter. You can't get hurt—or electrocuted. You probably won't become deaf. I think even a Boy Scout who does not know a lot about electronics can learn and have fun with these experiments. And a kid who is not a Boy Scout can have fun, too!

### BOB'S MAILBOX

**Dear Bob:** You ask "How many engineers who designed things in 1980 are still ALIVE?" (electronic design, Millions! I am in touch with many of my contemporaries who are alive and kicking vigorously. I have on hand an RF signal generator that I designed in 1944.

I was still designing in 1980 and for several more years. Later, I tried to keep other engineers from making the all-too-common mistakes with which I was familiar, including failure to read the footnotes of a specification sheet. My last design was a couple of battery-operated emergency lights at home to turn on automatically in case of a power failure. Later I'll tell you about my 10,000-V ac test setup and my recent tests on insulation and the only human volunteer I could get—me.

Comments invited!

## Bob's Mailbox



December 16, 2004 12:00 AM  
Electronic Design  
Bob Pease

**Dear Bob:** It was with initial interest (eyes resting on the large-font title), then mounting dismay that I engaged in the misfortune of reading your article "What's All This Input Impedance Stuff, Anyhow?"\* Being familiar with the Scriptures, it is quite clear you are parodying a portion of the ministry of Jesus Christ (while He was on Earth) to demonstrate an electronics principle. As a practicing Christian, I feel the parody, however educational in technical content, was wrong to do, simply wrong. *(I must say, this does not look like parody but a parable. Surely Jesus did not have any patent or copyright on the use of PARABLES. Surely He was a great teacher when he used parables. /rap)*

Having met you at a seminar and having been an admirer of your intelligence and your ability to dispense knowledge on heady subjects in accessible form, I'm ashamed and embarrassed for you. I don't like reading religious parodies. *(I do not do PARODY on the Christian religion, or on ANY OTHER religion. I respect all religions. /rap)* And I'm sure others don't either. Stick to the science and discourse we all love and appreciate you for and leave the Holy Bible out of that. I refuse to think you would consciously blaspheme on purpose. What one person considers light humor can nonetheless be considered blasphemy by others. Please be careful.

*John P. Rivera* (via e-mail) **Pease:** I do try to be careful. But there are many pharisees, and we must combat them and stop their erroneous ideas, as politely as we can--even by using parables. Thank you for writing and telling me your opinion. I do not agree that I was being blasphemous or irreverent. I was trying to use some excellent format--yes, taken from the Bible--not PARODY, but PARABLE. I am sorry I disturbed you, but I think we can use parables when we do so politely. /rap

**Dear Bob:** On my master's thesis, back in 1966, I used a PACE analog computer with a 100-V dc swing. Was this machine equipped with K2s? *(I am sure NOT. PACE had its own designs for amplifiers. /rap)* On the tolerance problem with the K2-XA, let me take a shot. I would deeply distrust the neons, operating in the lower-than-mA range.

**Urs Meyer** (via e-mail)

**Pease:** Well, you might be skeptical, but we never had any problems with the neons! Never! Even after 40 years, my K2-Ws and -XAs are still working fine. What unreliability mode would you expect? Actually, we mostly used an improved NE-2--not sure if it was the NE-14--that had a dot of radioactive paint on the outside to help make sure it would light up. Consequently, the Navy would not let K2-Ws onto submarines. We made the K2-WJs (mil version) with zener level-changers that were more expensive, but not radioactive.

**Dear Bob:** I think that you and Martin Williams are right with your theory about card readers (electronic design, *Feb. 16, p. 22*). I would only add as follows: Many of these old types of readers do not reliably read my Discover card, too. Another trick, in addition to the one described in the article, is to swipe the card much faster. *(In some cases this might work. But in the cases that are helped by adding a plastic layer, the signal is already too strong. And the thin plastic has the useful task of making the signal weaker. /rap)* This will increase the frequency of the magnetic modulation and the amplitude of the head output, giving a "crispier" electrical signal for the reader circuitry to work with. Of course, there always is the best trick up one's sleeve--to order a replacement card.

*Al Belotserkovskiy* (via e-mail),

**Pease:** *Recently, I was trying to check into a hotel room. I inserted the plastic "key" at a normal rate. It would not work. I tried it faster and slower. That didn't work. Finally, my wife tried it very slowly, and it finally worked.*

Comments invited! [rap@galaxy.nsc.com](mailto:rap@galaxy.nsc.com) --or: >  
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