A Tribute to Bob Pease

Pease Porridge – 1 (1990-1992)

WHAT'S ALL THIS ANALOG STUFF, ANYHOW?

This is the first of a series of columns about analog and "linear" circuits written by Bob Pease, Staff Scientist at National Semiconductor Corp, Santa Clara Calif. We think our readers will get a lot out of Bob's seemingly off-the-wall, yet insightful views of the engineering world.

Why? Why am I going to all the trouble of writing about "linear" and analog circuits? Everybody knows that linear circuits are dead. Nobody's buying or designing in linear circuits; they are all being replaced by digital signal processors. Analog computers have been dead for years. Why bother?

Well, these days, even though there are trends to perform a lot of functions with digital computations, people are finding that there are still a huge number of things that cannot be done properly without analog circuits. It's true that some of the trendy new radios claim to use a lot of digital techniques, but even there, the receivers and amplifiers are analog circuits—even if the the receiver's frequency appears to be digitally controlled.

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

When people are designing digital computers, they need analog techniques to make good layouts for fast buses. They need power supplies— either linear ICs or switch-mode circuits (which use analog circuits internally). And, as for us analog designers, the old-timers and the rookie engineers—well— this column is intended as a soapbox for me to talk about linear circuits, and then for me to listen to your opinions and comments and questions.

I have a lot of opinions, but I'm also very interested in what makes you tick. I may not be the smartest engineer in the whole analog jungle, but I have sort of volunteered to start writing this, and we'll see what happens—what interesting debates we get into. I have a bunch of opinions about ICs, data sheets, testing, computer simulation, education, troubleshooting, along with a whole slew of little topics.

In every darned issue of Electronic Design, I'll try to have some provocative or insightful topic. Some will be pretty technical, others will be more philosophical in nature. But one thing's for sure, I'll try not to bore you. For example: What's all this heuristic stuff, anyhow?

HEURISTICS?

The other day I was talking with a young college graduate from a prestigious Eastern engineering school. He explained that his specialty was analog synthesis. I perked up my ears—I hadn't heard much about that. Where could I read more about this? "Oh," he said, "in some of the IEEE journals." Hmm. He started to explain the approach. It's a heuristic approach, he said. Hmm. What's a heuristic? He said, "You don't know what a heuristic is? Really?" I explained no, that we didn't have any heuristics when I was in school.

(Note: Mr. Webster says that heuristic means "serving to guide, discover, or reveal; specif.: valuable for stimulating or conducting empirical research but unproved or incapable of proof—often used of arguments, methods, or constructs that assume or postulate what remains to be proven or that leads a person to find out for himself.—from the Greek, heuriskein, to discover, find.")—Gee, that sounds like analysis or optimization to me—not synthesis.

The young man explained that when you make a lot of optimization experiments, heuristic refers to the starting place, the initial guess. H'mm. He said, "You feed in some requirements and some specifications, and it optimizes the performance." Hmm. Now, what circuit does it use? "Oh, it uses the circuit that you give it." Hmm.

THE KEY QUESTION

If you give it a circuit that doesn't work well enough, how does it generate a circuit that works better? "Oh, it doesn't." I explained to this young fellow, that in our whole product line, about 99% of the circuits are not optimized at all—at least not "optimized" in the sense he understands. If you really OPTIMIZED them, they would all be a little different than they are now. But each one has a different circuit that is a revolutionary—not just an evolutionary—change from any previous circuit. So there may be places in our company where optimization is useful and a good idea.

But I wish he wouldn't call it "analog synthesis," that seems to be a misnomer. The circuits around our area—the ones in the NSC Linear data books (and, I bet, in the PMI and Analog Devices data books, too), were not "synthesized" except by bright engineers who knew that the old circuits wouldn't cut it, and a new circuit was needed. Good luck, young fellow!

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Noise Stuff, Anyhow? (Part I)

Recently I was invited to a meeting to see the results of a new high-performance, low-noise transistor project. I looked at the technical report. The new transistors were indeed quieter than the old ones. In fact, they were 2 to 4 *orders of magnitude* quieter than the conventional ones. I was suspicious. What was the test method? Oh, here is the test circuit *(see the figure)*.

Now, I asked, were the betas high or low? I was told they were pretty low, but they can be brought up later. I explained that when the betas get low, if they're not very well matched, the test circuit's output can peg—right up to the + or – rail. Then, of course, the apparent output noise gets rather small. (Ohhhhh!)

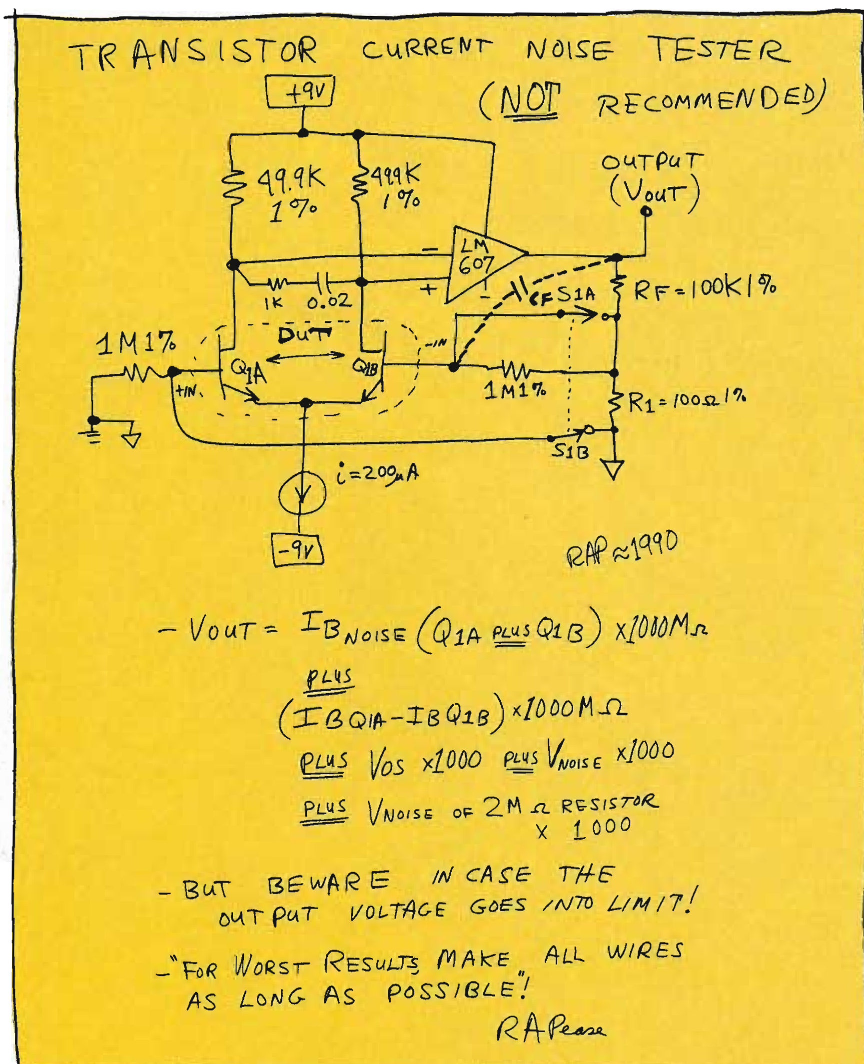
BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

When this circuit is running okay, the current noise is amplified by a big resistance: 1 MΩ × (N+1), where N is the closed loop gain, (R_F/R_1). So, the output will include: (I+ noise of Q_{1A}) + (I– noise of Q_{1B}) × 1000 MΩ. However, the offset current (I+) – (I–) will also be magnified by 1000 MΩ. So even 9 nA of offset current will cause the op amp's output to try to go to +9 V. If the power supply won't let the output get to a fair balance, the output will peg. Naturally the output becomes very quiet—the circuit has stopped amplifying the noise.

I also pointed out that ideally the circuit could measure the base-current noise of the transistor, or device under test (DUT). But the layout of the circuit is quite critical. Just 1 pF of capacitance (C_F) from the output to the base of Q_{1B} will cause a lag in the response: 1000 MΩ × 1 pF = 1 ms, so the noise will roll off above 160 Hz. You can make a layout with less than 0.1 pF, but you have to think about it and engineer it.

When we checked the test box, it was laid out very neatly: The output wire was bused alongside the summing-point (base of Q_{1B}) wire, and the bandwidth was indeed less than 100 Hz. In a future column, I will talk about what a picofarad looks like and the harm it can do to you. So, even if the output wasn't pegged and you looked for the noise at 1 or 10 kHz, this test circuit would give an answer that's considerably quieter than the *theoretical* minimum for the transistor. Now here's a good place for a sanity check.

It's not impossible to measure the noise of a transistor's base current, but you must have a suitable circuit. I wrote a paper back in 1968, and as I look at it today, the only things that changed are the names of the op amps. You can't buy any of those old discrete-transistor, potted-module op amps any more, but the testing



PEASE PORRIDGE

approaches are just as valid. Maybe I'll write an updated version. In this case, the problem was that a 1-MΩ resistor and a noise gain of 100 or 1000 (provided by R_F and R_1) wasn't a good idea. The stray capacitances and the noise of the 1-MΩ resistor are detrimental to accuracy. It's better to use a real 100-MΩ or 1000-MΩ resistor.

In fact, a 20-MΩ or 5-MΩ resistor is justified because it will still give plenty of signal-to-noise ratio, and a lot more bandwidth. More on how to do this in the next issue.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Neatness Stuff, Anyhow?

October 25, 1990 12:00 AM
Electronic Design
Bob Pease

Once upon a time, there was a rapidly converging conflict: My boss thought my office was getting messier and messier, and he wanted me to make it neater. Now, this was just a year or so after my desk had won a $500 prize for being the "Ugliest Desk in Northern California." So I guess he thought he was justified in pressuring me to clean up my act. He solved that problem by making it one of my goals to get my office to an acceptable (whatever that meant) level of neatness. Well, we never found out what that meant. Every time he would ask me how I was coming on the neatness campaign, I would tell him all of the other things I was doing to help our customers.

What if I came in on a Saturday with good intentions of neatening up some of my office, and the phone rang. Should I tell the customer, "No, I won't help you, I have more important things to do"?

So every year he would mark me down points in my review for not fulfilling my goals. He finally got so discouraged that he left the company. The poor guy. He just wasn't devious enough! He could have waited until the next earthquake and told one of the guys to knock over a couple of my piles of papers. Then he could then explain that I had to get it at least to a reasonable level of safety. But he never figured that out, and I didn't tell him until after he left.

Some people keep their desk neat because that's what feels good to them. I find that neatness is not a priority compared to a number of other things, such as answering the phone when a guy needs help, or volunteering advice when a customer has a problem. Some people find it easy to keep a neat desk because they throw out things that make it look messy. I just don't operate that way.

One time I was working on a Saturday after being at National just a few months. My desk was already stack up pretty high. Another guy was at his desk, which had just a few dozen things on it. He was picking them up, one by one, studying them, and then throwing most of them in the wastebasket. I commented, "You sure do keep your desk neat." He said, "Yeah, if I find something I don't need, I throw it out." I said, "Doesn't your wife ever get nervous?" He replied, "It's my third wife ..." No, I don't operate that way.

One day, an engineer stepped gingerly into the entry way of my office and asked, "Bob, do you have a Siliconix catalog?' I replied, "Sean ... you're standing on it." He looked down and, indeed, he was. He was impressed. But I knew right where it was, because I had recently tossed it over by the doorway so I could then put it in the bookcase by the door. Sean just happened to walk in before I put it in the bookcase.

More recently, I inherited a couple of filing cabinets and a huge 7 ft. x 3 ft. x 7 ft. cabinet from a Fairchild laboratory. Our secretary explained that I would have to junk it unless I could find a use for it. I said, "Well, I could always put it in my office." She looked at this huge ark and said, aghast, "No, you couldn't do that."

I thought about it. I got a yardstick, and I figured out that, with an inch to spare, I could do that. My technician and I spent nearly all morning reassembling that cabinet and easing it into the corner of my office. I put about 1/3 of a millior cubic inches of my paperwork into that, and into the other file cabinets, and improved the appearance of my office so much that our senior secretary admitted that I qualified for an "Enviros Award." In the past, the various departments would vie to achieve cleaner clean rooms and higher-yield fab lines by having better cleanliness. A whole department of 20 or 30 people would work real hard to cut down the number of particles in their area and win an Enviros Award. But got my Enviros Award single-handedly. I hate to guess how many particles I straightened up.

Right now, my office seems to be in the getting-messier-again phase. When I have to review a mask set, with precision down to the last tenth of a micron, I get my head in the right mood to do that. And when I'm done, in sheer rebellion I guess, I abandon the neatness for a while. I save what seems to me to be of value. Often that includes documents and papers and notes that other people would think aren't very valuable - until they come to see me years later, hoping I might have the information they need. Often I do. Go ahead, call me retentive. See if I care.

Now that the NBS has changed its name to the "NIST" or "National Institute of Standards and Technology," I have figured out the next way to enhance the neatness of my office. I'm going to buy a big dresser with 6 big drawers and a mirror and everything. I'm going to put it right at the entrance of my office, and put our ultra-precision resistors and capacitors in those dresser drawers. And I'm going to call it "The National Bureau of Standards."

Comments invited! / RAP
Robert A. Pease / Engineer

RAP Update: This was the fourth column I wrote, the fourth to be published. And suddenly I began to get some Fan Mail. A lot of people said they had desks that were pretty close behind mine in sheer messiness. My desk still is a Federal Disaster Area. I tried to put a recent picture of my desk in this web page, but it isn't even recognizable as a desk. Is it?

What's All This CMRR Stuff, Anyhow?

Recently, many people have asked me about how to test op amps for common-mode rejection ratio (CMRR), which is defined as the delta of the offset voltage (V_{OS}) versus the common-mode voltage (V_{CM}). The first thing I tell them is how *not* to measure CMRR *(Fig. 1)*. If you drive a sine wave or triangle wave into point A, it seems like the output error, as seen by a floating scope, will be (N+1) times (V_{CM} divided by the CMRR).

But that's not quite true: you will see (N+1) times (the CM error *plus* the gain error). So, at moderate frequencies where the gain is rolling off and the CMRR is still high, you will see mostly the gain error, and your curve of CMRR vs. frequency will look just as bad as the Bode plot. That's because with this circuit, that's just what you will be seeing!

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

It turns out that a few op-amp data sheets still exist in which the CMRR curve is stated to be the same as the Bode plot. The National LF400 and LF401 are two examples; next year we will correct those curves to show that the common-mode rejection ratio is actually much higher than the gain at 100 or 1000 Hz.

Ah, let's avoid that floating scope. We'll drive the sine wave generator into the mid-point of the power supply, and ground the scope and ground point A *(Fig. 2)*. Then we'll get the true CMRR, because the output won't have to swing. Right? Wrong! The circuit function hasn't changed at all; only the viewpoint of the observer changed. The output *does* have to swing, referred to any power supply, so this still gives the *same wrong answer*. You may *say* that you asked for the CMRR as a function of frequency—but the answer is, in most cases, the curve of gain vs. frequency.

What about, as an alternative, the well-known scheme where an extra servo amplifier closes the loop and doesn't require the op-amp output to do any swinging *(Fig. 3)*? That's okay at dc. So it's adequate for dc testing with automatic test equipment (ATE), for production test, and for stepped dc levels.

And it will give the same answer as my circuit (which I'll discuss a little later) at all low frequencies up to where it doesn't give the same answer. Now what frequency would that be? Nobody knows! Because if you have an op amp with low CMRR, the servo scheme will work accurately up to one frequency. And if you have an op amp with high CMRR, the servo scheme will work accurately only up to a different frequency.

Also, the servo amplifier adds so much gain into the loop that ringing, overshoot, or marginal stability at some mid frequencies is inevitable. That's much too horrible for me to worry about. I'll just avoid that by using a circuit which gives very consistent and predictable results.

When I ran an LF356 in the circuit of figure 1, I got an error of 4 mV pk-pk at 1 kHz—a big fat quadrature error, 90 degrees out of phase with the output *(Fig. 4, upper trace)*. If you think that's the CM error, you might say the CMRR is as low as 5000 at 1 kHz, and falling rapidly as the frequency increases. But the actual CMRR is about 0.2 mV pk-pk *(Fig. 4, lower trace)*. As a result, the CMRR is about 100,000 at 1 kHz or any lower frequency. In addition, the CM error on this unit isn't really linear. As you get near –9 V, the error gets more nonlinear (this is a -9-V to +12-V CM range on a 12-V supply; I chose a ±12-V supply so my function generator could overdrive the inputs).

As you can see, this business of CMRR testing isn't trivial. Just how, then, can we test for CMRR and get the *right* results? Well, there's a darned fine circuit I invented myself about 22 years ago *(Fig. 5)*. It has limitations, but it's the best circuit I've seen. Let's choose $R_1 = R_{11} = 1k$, $R_2 = R_{12} = 10k$, and $R_3 = 200k$ and R_4 = a 500-Ω single-turn carbon pot, or its equivalent.

These values will permit us to set up a more-or-less balanced bridge, with a fine trim for dc balance. In this

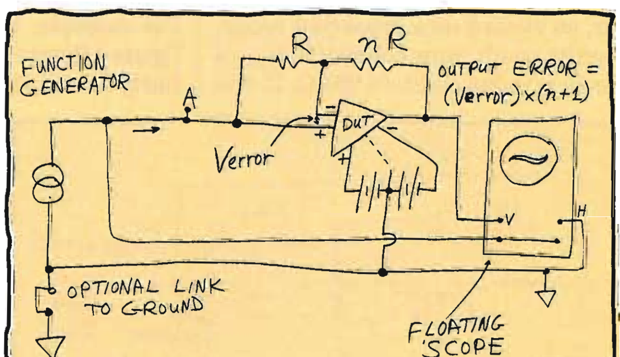


FIGURE 1: NOT A GOOD TEST CIRCUIT FOR CMRR (COMMON MODE REJECTION RATIO)

BECAUSE $V_{ERROR} = \frac{V_{CM}}{CMRR}$ PLUS $\frac{V_{OUT}}{A_V}$

RAP ≈ 1990

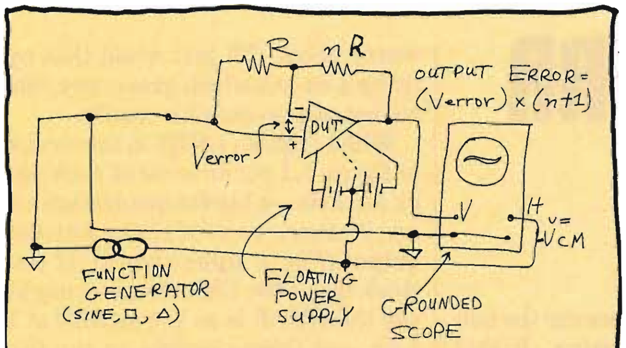


FIGURE 2: THIS IS STILL NOT A GOOD TEST CKT. FOR CMRR

BECAUSE VERROR STILL = $\left(\frac{V_{CM}}{CMRR}\right)$ PLUS $\left(\frac{V_{OUT}}{A_V}\right)$.

RAP ≈ JULY 1990

case, the noise gain is defined as (R_f/R_{in} + 1), or about 11. Let's put a ±11-volt sine wave into the signal input so that the CM voltage is about ±10 volts. The output error signal will be about 11 times the error voltage plus some function of the mismatch of all those resistors.

Okay, first connect V_{in} to the scope's horizontal input, V_{out} to the vertical input, and operate the scope in cross-plot (X-Y) mode. Trim pot R_4 until the output error is very small, or until the slope is nominally flat. We don't know if the CMRR error is balanced out by the resistor error or whatever, but it turns out we don't care. Just observe that the output error, as viewed on a cross-plot scope, is quite small. Now connect in R_{100a} a nice low value, such as 200 Ω. If you sit down and compute it, the noise gain rises from 11 to 111. Namely, the noise gain *was* (1 + R_2/R_1), increasing to (1 + R_2/R_1) plus (R_2 + R_{12})/R_{100}. In this example, that's an increase of 100. So, you're now looking at a *change* of V_{out} equal to 100 times the input error voltage, (and that is V_{CM} divided by CMRR).

Of course, it's unlikely for this error voltage to be a linear function of V_{CM}, which is why I recommend you look at it with a scope in X-Y mode. Too many people are inclined to make a pretend game that CMRR is constant at all levels and CM error is a linear function of V_{CM}. So they just look at 2 points and assume every other voltage has a linear error; and that's just *too* silly. Even if you want to use some ATE you will want to look at this error in at least 3 places—maybe even at 4 or 5 voltages.

Another good reason to use a scope in the X-Y mode is so you can use your eyeball to subtract out the noise. You certainly can't use an ac voltmeter to detect the CMRR error. For example, with the waveform of figure 4 (lower trace), the CM error is fairly stated as 0.2 mV pk-pk, not 0.5 mV pk-pk (as your meter might say if you let it include the noise).

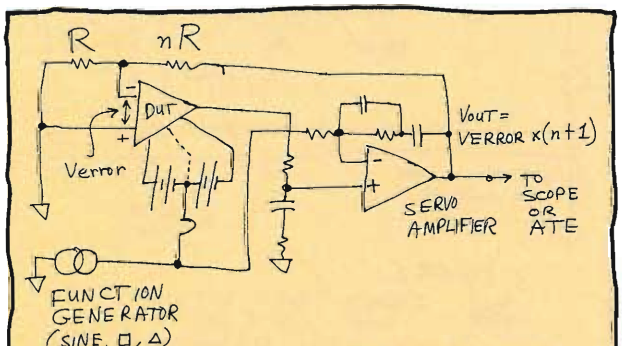


FIGURE 3: ADEQUATE DC TEST CIRCUIT FOR CMRR. AC PERFORMANCE WOULD DEPEND ON ALL THOSE Rs & Cs (VALUES NEVER DEFINED!)

RAP JULY 1990

Anyhow, if you have a good amplifier with a CMRR of about 100 dB, the CM error will be about 200 μV pk-pk. When it's magnified by 100, you can easily see an output error of 20 mV pk-pk. If you have a really good unit with CMRR of 120 or 140 dB, you'll want to clip in the R_{100b}, such as 20 Ω, and then the delta (noise gain) will be 1000. The noise will be magnified by 1000, but so will the error, and you can see what you need to see. *Now,* I won't get embroiled in the question: Are you trying to see exactly how good the CMRR really is, or just if the CMRR is better than the data-sheet value? In either case, this approach is the best way I have seen.

For use with ATE, you don't have to look with a scope; you can use a step or trapezoidal wave and look just at the dc levels at the ends, or the middle, or wherever you need. Note that you needn't trim that resistor network all of the time, nor do you have to trim it perfectly. All you have to know is that when the noise gain changes from a low value to a high value, and the output error changes, the *change* of the output error is of interest—not really the pk-pk value before or after, but the delta. You don't *have to* trim the resistor to get the slope perfect, but that's the easy way for the guy working at his bench to see and appreciate the changes.

This is a great circuit to fool around with. When you get it running, you'll want to test every op amp in your area, because it gives you such a neat high-resolution view. It gives you a good *feel* for what's happening, rather than just hard, cold, dumb numbers. For example, if you see a 22-mV pk-pk output signal that's caused by a 22 μV error signal, you know that the CMRR really is way up near a million, which is much more educational than a cold "119.2 dB" statement.

Besides, you learn rather quickly that the display's slope and curvature are important. Not all amplifiers with the same "119.2 dB" of CMRR are actually the same. Some have a positive slope, some may have a negative slope, and some curve madly, so that if you took a 2-point measurement, the slope would change wildly, depending on which two points you choose (if you increase the amplitude of the input signal, you can also see plainly where severe distortion sets in—that's the extent of the common-mode range).

Limitations: If you set the noise

PEASE PORRIDGE

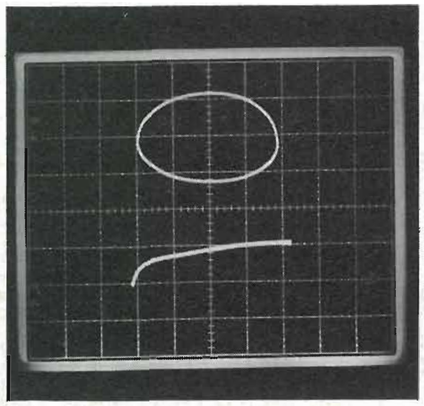


Figure 4

gain as high as 100, then this circuit, of course, will be 3 dB down at (F_{GBW}) divided by 100, so you would only use this up to about 1 kHz on an ordinary 1-MHz op amp, and only up to 100 Hz at a gain of 1000. That's not too bad, really.

To look at CMRR above 1 kHz, you might use $R_{100c} = 2k$ to give good results up to 10 kHz. In other words, you have to engineer this circuit a little to know where it gives valid data. You can't avoid the fact that thinking is required. Sorry about that.

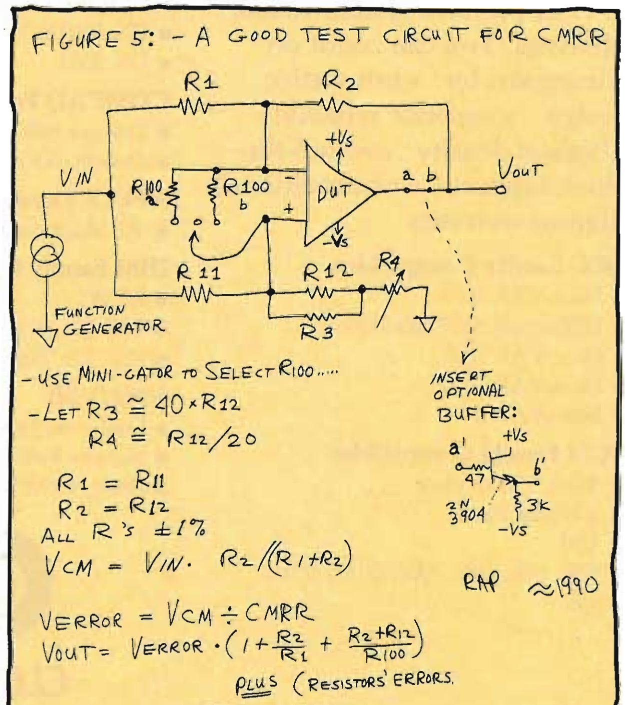
For really fast work, I go to a high-speed low-gain version where $R_1 = R_{11} = 5k$, $R_2 = R_{12} = 5k$, and $R_{100} = 2k$ or 1k or 0.5k. This works pretty well up to 50 kHz or more, depending on what gain-bandwidth product your amplifier has.

For best results at ac, it's important to avoid stray capacitance of wires or of a real switch at the points where you connect to R_{100a} or R_{100b}. Usually I get excellent results from just grabbing on to the resistor with a mini-gator clip. You can avoid the stray pF that way. If you use a good selector switch, with all of the wires dressed neatly in the *air* (which is an excellent insulator) you may be able to get decent bandwidth, but you should be aware that you are probably measuring the ac CMRR of your set-up, not of the op amp. Actually, I was discussing this circuit with a colleague, when I realized the best way to make up this 20-Ω resistor is to connect one 10-Ω resistor to each input, and then clip the other ends together with a mini-gator clip up in the air. Balanced strays, and all that.

If you have an op amp with low gain or low gm, you may want to add in a buffer follower at a-b *(Fig. 5, again)*, so the amplifier does not generate a big error due to its low gain. The LM6361 would need a buffer as it only has a gain of 3000 with a load of 10k, and its CMRR is a lot higher than 3000. Altogether, I find this circuit has better resolution and gives less trouble than any other circuit for measuring CM error. And the price is right: a few resistors and a mini-gator clip.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090



PEASE
PORRIDGE

WHAT'S ALL THIS SPICEY STUFF, ANYHOW? (PART I)

Recently, I was down in New Orleans at one of the IEEE conferences—the International Symposium on Circuits And Systems. The keynote speaker, Professor Ron Rohrer from Carnegie-Mellon University, commented thoughtfully about many aspects of education for engineers. But what he said that really stunned me was his observation that "In the era of Spice, nobody designs on the back of envelopes any more". Ouch! It is becoming more and more true that young (or lazy?) engineers can't do much designing without some computers or high-powered calculators. They really cannot design things without a lot of assistance from computers. Spice just happens to be one of my pet peeves, and I will start gnawing on its ankles today.

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

Now, I've always been a friend of analogies, analogues, analogs, similes, models, and metaphors. When I worked at George A. Philbrick Researches, the company's motto was, "The analog way is the model way." In those days, we sold some analogue computers, even though that part of the business was shrinking and the popularity of the op amp was on the rise. But we all tried to follow the party line: that analog computation was a serious business. And it still is, although as a percentage of the electronics business, it has shrunk to a tiny fraction.

Still, there are many times where a little analog computation is exactly the right thing, and someday I will expound on that.... But, Spice (Simulation Program with Integrated Circuit Emphasis) is a rather popular and powerful tool these days, and almost everybody finds it useful to some extent. I remember when my old boss, Tim Isbell, showed me how to use it—and then we spent half a day horsing around because it said we had 72-V forward voltage across a diode, but there was no current through the diode. I will emphasize just a few of the basic problems with Spice today.

The main problem is that people tend to trust its answers, as they trust most computers, long after the reason to trust it should have evaporated. I have come very close to fist fights and screaming contests when a person claims that such-and-such an answer is obviously right because Spice gave it to him. Conversely, I normally try to avoid working with Spice unless I can first run a calibration program on it, so it gives me an answer that makes sense—a sanity check.

This is much like the old days of the slide rule: You couldn't use the slide rule unless you already knew approximately what the answer was. It's not like a calculator, where the decimal place is provided on a platter. You have to provide your own decimal place. In other words, you are forced to be a pretty good engineer before you even pick up your slide rule, or your analog computer. But people who use Spice are often buffaloed or fooled by any absurd kind of answer.

So, trusting your computer seems to be one of the new trends that I would like to see quashed. It's too easy to find, weeks later, that the computer told you a lie, because the data you entered had a typo error or a monumental goof.

Now, never let it be said that Pease recommends you use analog computers or breadboards instead of Spice because analog computers don't make errors. Spice lies, but analog computers do not? Oh, please, don't say that: analog computers lie, too, and so do breadboards. But I prefer them because they often offer a greater insight and understanding as to what's really going on. So if you survive their problems, you are smart enough to keep out of other kinds of trouble. But that's just a bunch of philosophical stuff.

The thing that makes me nervous about Spice is that it was largely designed by a group of grad students (Laurence Nagel and others at Berkeley) back in 1973. Now, when you find a problem, a discrepancy, a glitch, a flaw, an error that seems to be built into Spice, can you go back to the people who designed it? Hardly. There's no continuity. There *are* some people who claim to "support" Spice, but I'm not usually impressed with their statements.

My biggest gripe with Spice is its lack of convergence. The ordinary Spice 2G6 has all sorts of problems, even if you don't use FETs (we find that FETs usually make the convergence situation *really* unhappy). For example, one time I had a moderate-sized circuit with about 33 bipolar transistors, and it didn't converge well. Then, all of a sudden, one day it started to converge beautifully and quickly.

I was so impressed, I backed up to find the"scene of the crime." I tried to duplicate all of the changes I had made since I last had problems.

It finally turned out that I had an unused resistor and an unused capacitor each tied from one node to ground. Nothing else was connected to that point. They were originally "commented out" by an asterisk. But, at one point, I deleted the asterisk and the useless R and C were dropped into the circuit—they just happened to make the convergence a lot better.

When I removed the R and C, things got worse again. This lead me to appreciate two things: that the convergence is a lot more fragile than we suspect; and that we may be able to randomly throw useless resistors into a circuit, and sometimes they may help to improve the convergence.

In other words, if you have a circuit that shows bad convergence, the computer might have a subroutine to randomly sprinkle a few resistors into the circuit and see if that helps—a kind of "autoconverge" scheme. At present, we're still working on this, and it may be a useful approach. But, this concept isn't *too* surprising if you've ever heard that the convergence of a circuit may be improved or degraded *depending on the names and numbers you call the nodes of the circuit.*

If you swap a couple nodes' numbers, and things get better (or worse), doesn't that make you nervous? Or at least *suspicious*?

Some people claim that dynamic ramping up of the power supplies can help improve the convergence. Maybe. I agree, it's worth a try, but I recall a lot of circuits where even ramping didn't work. Another serious problem I had with Spice was when I ran some simple transient tests—triangle waves—on the collector of a transistor. I ramped the V_C up and down from 5 V to 15 V, back and forth, and ran several tests. Then I added some complicating factors, and wanted to look at the circuit for the first 202 μs of a 10-kHz triangle wave.

Namely, after the first two cycles of the triangle wave, I decided to look at the collector current (i = C x dv/dt) of the transistor at t = 201 μs. I got my answer printed and plotted, and it didn't make any sense. I studied the whole circuit, and I used every troubleshooting technique I could think of, and it didn't make any sense. The current through the 1 pF of C_{BC} was not 0.2 μA, but 5μA. How could that be?

After several hours, I finally decided to look at the incoming waveform (which I knew would be a waste of time because I knew very well what I had told it to do.... I had commanded it to go back and forth from 5 V to 15 V, at the rate of 50 μs per each ramp). But when I looked at t = 201 μs, the dv/dt had suddenly increased from 0.2 V/μs to 5 V/μs. It turned out that because I had commanded the Plot mode to stop at 202 μs, the transient generator had decided to go from 15 V to 5 V—not in the time from 200 to 250 μs, but in the span from 200 to 202 μs. The dv/dt sped up by a factor of 25, without being asked to, for a completely unexpected reason.

Nothing I had ever seen about Spice, nothing my friends had ever heard, would lead you to expect this. In fact, Spice sort of encourages you to look at the waveforms any time you want—it offers a sort of "infinitely versatile, expanded-scale oscilloscope," and if it has a dv/dt that suddenly changes, well that's quite a surprise.

So, I immediately wrote an open message to all of my friends at National, warning them about this potential problem; and now I'm writing about this to warn all of my friends everywhere. These are just some of the reasons I'm not enthusiastic about Spice. It's goofed me up, me and my friends, too many times.

My boss points out, it's not necessarily true that all kinds of Spice have such bad problems with convergence or bad computations or spurious signals. And that may be so. If somebody who knows all about different Spice products wants to write in and assure our readers that *his* Spice will never do that, well, that's fine by me. But, meanwhile, just remember—I don't *hate* these digital computers. *They* hate me; I *despise* them. Stay tuned for the next column, because I'm not finished with Spice yet.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

WHAT'S ALL THIS SPICEY STUFF, ANYHOW? (PART II)

The other day I was standing out in the rain, talking with a design engineer from the East Coast. He said all of the other engineers at his company ridicule him because they rely on Spice, and he depends on the breadboards he builds. There's just one hitch: his circuits work the first time and their circuits don't.

To add insult to injury, his boss forces him to help his colleagues get their circuits working, since he has so much time left over. I said that sounds pretty good to me, so long as his boss remembers who is able to get out the circuits when it comes to doing reviews for all of the guys.

This guy gave me a tip: Don't design a circuit in Spice with 50-Ω resistors. Use 50.1 Ω, it converges better. Hmmmm. That sounds kind of intriguing.

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

Right now I'm struggling with a Spice model of a circuit. Not of a new circuit, but of an old circuit: the bandgap reference of the old LM331 that I put into production back in '77. It's a good thing I put it into production before we got Spice, because if I had first run this through Spice, I'd have been pretty discouraged. Spice says this circuit not only has a rotten tempco, but that it oscillates like a politician.

I went back and double-checked the actual silicon circuits. They soar like an angel, have very low tempco, and are dead-beat when you bang on them. They have no tendency to oscillate; they don't even ring. So why does Spice persist in lying to me? Doesn't it realize I will break its back for the impertinence of lying to the *Czar of Bandgaps*? I'm a little busy right now, but in a while I will find out why it lies to me. The Spice and CAD experts around here tell me, "Oh, you must have bad models." I've been told that before, when I was right and the experts were absolutely wrong (I mean, how can a single FET oscillate at 400 kHz?? With the help of 2 resistors...). More on this topic later.

I've already gotten several letters from readers expressing general interest and enthusiasm concerning this column about linear circuits. Already a couple writers have asked, "How about all of these new models for op amps? Won't they lead linear designers in a new direction?" My replies to them start out by covering a couple examples of old op-amp macromodels that have raised questions for over a dozen years.

A guy calls up and asks me, "What is the maximum dc voltage gain on an LM108?" I reply, "well, it's 40,000 min., but a lot of them run 300,000 or 500,000, and some of them are as high as 3 or 4 million." The customer sighs, "Oh, that's terrible...." When I ask why it's terrible, he explains that when the gain gets high, the gain-bandwidth (GBW) product will get so high that it will be impossible to make a stable loop if the GBW product gets up to dozens or hundreds of megahertz.

Sigh. I sit down and explain that there's no correlation between the dc gain and its spread when compared to the GBW product and its spread. The guy says, "Oh, I read in a book somewhere that there's good correlation, because the first pole is constant." I tell him to throw out the book, or at least X out those pages, because the first pole is *not* at a constant frequency.

These days, I read that several op-amp companies are giving away free Spice models. What do I think of these models?

Well, on a *typical* basis, I have read that some are pretty good. In several *typical* situations, they slew and settle (and ring just a little, as real op amps do) and have as good accuracy as a real *typical* op amp and its feedback resistors. Maybe in a few years, models of slow op amps will be trustworthy. But I don't think you can get very good results from modeling the fast ones. Why? Pc-board layout strays. Enough said.

And besides, how good are those models if you ask their makers? Are the models guaranteed to give such a good representation of reality that if Spice gives good results, the op amps are guaranteed to work? Well...no, not exactly. In fact, from what I've read, none of the op-amp models are guaranteed for anything. The only thing they can do "guaranteeably" is give a customer *something* when he begs for Spice models. It's guaranteed to make the customer go away happy and to keep him busy for a while. But it's not guaranteed to make him happy in the long run. This is because the performance of high-speed op amps and precision circuits depends so critically on the layout and on the resistors and capacitors, making the model itself almost irrelevant.

Now some people might say, "How does Pease dare to say that?" It's easy. I haven't got any Spice models of my op amps to give away. Not at this time. And if I did, or when I do, I won't be able to guarantee them either. At best, I may be able to say, "If you are a good engineer and use these models as a tool to pioneer some experiments that are inconvenient to test on the breadboard, you may find these models are helpful. But you had better check things out with a breadboard to confirm the circuit. For example, you can use Spice to 'measure' some voltages or currents that are so small and delicate that you really could not measure them with a scope, a buffered probe, or current probe—not in the real world. *But,* if you try to rely solely on these models, without breadboarding, they won't tell you the whole story. Your crutches will collapse, sooner or later, and you can't say I didn't warn you."

I showed this column to Bettina Briz in amplifier marketing, and she said, "Bob, you can't say *that.*" I said, "Oh, tell me where I have said anything that is untrue, and I will fix it." She admitted that what I had said probably was...quite true. Then I said, "Well, why try to soft-pedal the truth, and pretend that you can trust computers all of the time? Wouldn't that be a disservice to our customers?" And Bettina replied, "When *we* have models, we'll have to try to educate our users. We'll point out when you can trust the models, and when you shouldn't. So, after that, are we in disagreement?" Well, maybe we did agree after all.

At present, we have a small library of op-amp models released with Analogy, Beaverton, Ore. They're only level I models, (low precision), and while we have made some progress on good-precision ones (level II), they're not released yet. These are "behavioral models" rather than Spice models, and we think they have several advantages over Spice models. There are some min/typ/max specifications that pretty much correspond to data sheet limits. If you use them wisely, they may be helpful—subject to the conditions I listed in the previous paragraph.

These models aren't free, though. They're not even cheap. But we think they're worth what you pay for them. Still, none of these models are guaranteed.

Why try to soft-pedal the truth and pretend you can trust computers all the time?

Now, seriously, where can you get a model of a transistor that's guaranteed? And to run under all conditions? I don't think you can beg or steal or borrow or buy a model of a transistor that's guaranteed. Or of a capacitor. The same holds true for a resistor.

I don't think you can beg or steal or borrow a transistor model that's guaranteed.

But I can guarantee that every op amp you can buy or make has some characteristics that can't be absolutely modelled by any computer model. If you happen to depend on that feature, or the absence of that feature, it's only a matter of time before you get in trouble.

I will also guarantee that just because you made one breadboard, and it works well, you can't put that circuit into production and get 1000 units in a row to work well. *Unless,* of course, you're a smart engineer and design the circuit "properly" and do your worst-case design studies, and plan for well-behaved frequency response, and so on. And I think that's true no matter where you buy your op amps. What's new? What color is the king's new underwear? Dirty gray, same as everybody else's.

I think there are a number of Electronic Design's readers out there who will want to comment on this topic. You may be dubious or skeptical of Spice models. You may be dubious or skeptical about my views. Your comments are invited. You may have experience with Spice or other macromodels. Good? Bad? You tell me, and I'll pass along your comments to the editors (we may have to allot a little extra space for the Letters-to-the-Editors column for a while). The guys who believe in Spice macromodels, whether they're somebody that buys or sells op amps, well, they're also invited to write in. I promise to faithfully pass all of the letters along (with appropriate comments on the side). But I think you can already tell how skeptical I am.

I was at an evening session at the IEEE Bipolar Circuits and Technology Meeting in Minneapolis recently. Several companies that sell CAD tools had done some serious work to analyze the circuit for a 12-bit a-d converter (ELECTRONIC DESIGN, *Oct. 25, p. 16).* Even the ones that had only a little time to put in showed that macromodels were feasible and effective as a way to do good analysis while saving computing time. That was the primary objective of the study. But even the ones that put in the *most* time at analysis didn't recognize (or didn't comment about) that the noise of the reference and the comparator were rather large, and you could not achieve 12-bit resolution without slowing down the response a lot more than you would have to do otherwise (for a circuit where you didn't have to consider the effects of noise).

If a good designer of ADCs had these tools, and he knew where to look for noise, or where to insert lead inductance or extra substrate capacitances, he might use some of these CAD tools to help him design a better ADC. But if he just believed what the computer told him, he would probably be badly fooled.

Once, a customer called me up and asked me how to get my LM108s to stop oscillating in his circuit. He explained it was a simulated LM108 with some simulated feedback resistors, and simulated switches and filters. Hmmmm. I asked if he had made up a breadboard, and if it oscillated. He said he had made it and it didn't oscillate. Hmmmm. I asked him, "If you built up a breadboard and a computer model, and the real breadboard oscillated, but the computer did not, you wouldn't be calling up to complain, would you?" He stopped and thought about it. He cogitated for a while. He said "I'll call you back." And he hung up. He never did call back. I mean, what would *you* do?

All for now. / Comments invited!
(Now there's an understatement.) /
RAP / Robert A. Pease / Engineer

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Splicing Stuff, Anyhow?

Several months ago, a reader wrote in to one of the local newspapers, "If I want to move my speakers a few feet further from my amplifiers, can I splice in a few more feet of speaker cable, or should I buy all new cable? My brother-in-law claims that splicing would hamper the sound." The resident expert at the paper stated that the brother-in-law was wise, as the spliced wire would give inferior audio results.

I promptly wrote in to the resident expert, asking him on what basis he could say this. Was he claiming that *he* could *hear* the difference? I demanded that he show us readers how the spliced wire could possibly make any difference. I challenged him to listen to any music, under any audio conditions, and I would swap in various pieces of speaker wire (enclosed in boxes, on a double-blind basis) that had 0 or 1 or 2 or 6 or 12 splices. How, short of clairvoyance, could he tell which wire had the splices, using ordinary audio-frequency signals? Of course, if you used an impedance analyzer with a bandwidth of several gigahertz, you could "see" some of the splices. But, for good high-fidelity audio, there's no way you could discern this, especially as a splice may make the wire's impedance lower or higher or unchanged.

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

The expert, with his "golden ears" and all, never wrote back. So, I sent my criticism to one of the local skeptic's groups called "BASIS," the Bay Area Skeptics Information Sheet.

They edited it lightly, and in their newsletter, they printed my complaint, which amounted to this: If a person claims to talk to the dead, or summon spirits, or show extrasensory perception, then we must apply some skepticism so as not to encourage gullible persons to invest their money in these hoaxes.

> **How, short of clairvoyance, could he tell which wire had the splices using ordinary audio-frequency signals?**

But if a person who is endorsed as the "high-fidelity expert" says that you can hear the difference between spliced and unspliced wires, then we, as technical people, have an obligation to express our doubts and our skepticism. Why should a hi-fi salesman be able to sell a bright-eyed yuppie a $50 hank of speaker wire, (or $100 or $200 or $400 or more, which is where the really high-end speaker wire is priced these days—believe it or not) just because an "expert" says it's *better* to buy new wires rather than splice on a few extra feet? Obviously, ethics in technical electronics and science is involved here.

Many hi-fi experts, with their "golden ears," claim that they can hear differences in sophisticated speakers, expensive amplifiers, or just fancy wires, that I can't possibly discern or detect. It might take many thousands of dollars to just buy the equipment and duplicate the experiment. And, their ears might be correct—much more discerning than mine, more than I could imagine. But, when the "expert" talks about wire and splices, then I find myself compelled to comment and raise doubts. There *are* some experiments that even I can propose and that I could conduct, that would be decisive, if the "expert" did not duck the challenge.

Now, there are many persons who have *golden ears* and will claim that they can easily distinguish between *good*, *better*, and *best-quality* speaker cables. However, when these persons are invited to a double-blind test, they usually have a strong tendancy to demur. Some people like to call this the *the shyness factor*. Other people liken this to the tendency of cockroaches to scuttle into a dark corner when the lights are turned on.

I was only slightly concerned about how to conduct the test, because to do a fair test, you might have to change back and forth from, say, speaker wire #1 to speaker wire #2 or #6. If you do that with screwdrivers and pliers, it might take a long time to make the changes; a critical listener's judgment might be affected by long delays, and it would be unfair to ask for good judgment under those conditions. But if I proposed to use a number of selector switches, the man with the "golden ears" might argue that the switch's impedance would be worse than the splices, so a switch would be suspect! No, you can't use switches when you want to do an A-B comparison!

But in the last few weeks, the hi-fi review column of this "expert" was discussing how he compares different speakers: He said to change from one set of speakers to another, he uses switches! I just hope the switches don't cloud his judgment, as if they were (God forbid) *splices*.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

WHAT'S ALL THIS TESTING STUFF, ANYHOW?

The other day, Graham Baskerville, my boss' boss, and I got into a screaming contest. But we weren't in disagreement. We were in complete agreement that there was a problem, and we were thinking of examples to illustrate the problem.

One of the first examples was "The Noise Test." Many years ago, in a quarterly report, a manager glowingly explained that on the model XYZ, the yield loss due to noise had been cut to a trivially negligible level for the last quarter. Graham said that he inquired politely how this was accomplished. After a little investigation, he found that the "yield" was excellent because the test circuit was broken. To restore sanity, he made sure that the noise test now had a lower limit, so if the tester was broken, nothing would pass, and the tester would have to be repaired. Now, that was many years ago, but the general problem of ensuring that your tester makes sense never goes away completely.

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

I countered with the story of the reference circuit that had a yield problem. The marketing manager wanted to take a big contract for 1% trimmed parts, but the yield wasn't very good for parts with a 1% tolerance. I got some data from the product engineer and studied it. That's strange—the yield for 1% parts was *okay* before trimming the output.

The problem turned out to be a false algorithm. (What *is* an algorithm? Isn't it just a logarithm that got twisted around? When I was a kid, we had lots of logarithms, and I think it's kind of suspicious that you don't see them any more....) And when we went back and corrected the trim scheme, the yield was, of course, quite adequate.

I guess the moral of the story is that there are plenty of things that we shouldn't trust blindly. I tell the test engineers that I'm going to check to see that things make sense when we're all done. And *they* had darned well better check on *me*, because nobody is immune from screw-ups. Certainly not me.

Specifically, when you create a test, you have to make sure that the results make sense. If the answer is zero, and that doesn't make any sense, then you should probably set a minimum limit. What if a part normally has a power drain of 2 mA, and 3.0 mA maximum? What if you saw a batch of parts with less than 1/2-mA current drain? Wouldn't you tend to get suspicious?

What if we assumed the slew rate could be guaranteed by correlation with the power-supply current but there was no minimum limit on the test for current drain? A sanity check is in order! Some other time, we can think about other interesting cases that deal with "minimum limits."

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

What's All This Rzamble Stuff, Anyhow?

Sometimes I go on hikes with my sons and my wife. Sometimes I go on hikes without them; sometimes they go on hikes without me. Here in Northern California, just in the San Francisco Bay area, there are many dozens of parks, and many hundreds of miles of trails in these parks.

Sometimes my wife leads a hike for the local chapter of the Sierra Club. Sometimes my son Benjamin (age 25, he has a full Red Cross certificate and I don't, so I am not eligible to lead hikes) leads the same hike. I have been on some of their hikes. What they amount to is a Ramble. Or, as I mistyped the other day, a Rzamble, which is a word that sounds pretty good to me.

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

The main point is, that when you go on a hike with my wife, you will probably have a pleasant ramble. If you go on the same hike led by my son, you will have a pleasant ramble, but it will be a *different* ramble. If you join me on these hikes through the world of analog ideas, that will be a *different* Rzamble, and I hope you find it enjoyable. I read several daily columns in the San Francisco Chronicle—columns by Herb Caen, who has been writing daily columns more than 50 years. I don't know how he can do that! I also read columns by Jonathan Carroll, who is a little bit *meshugineh* (a little crazy) and quite amusing. Art Hoppe is another. I have big thick envelopes full of columns by Stanton Delaplane and Charles McCabe who wrote for the Chronicle for many years, but they died a few years ago. I must say, I have always been impressed with people who can assemble a few hundred words, *everyday* (or, every weekday). This column I'm writing is every 14th day, and I must admit, that ratio of 14:1 or 10:1 is a *huge* difference. I maintain an awesome respect for people who can put out a column every day.

When I took on this project, I knew immediately that if I had to *meet* a deadline, I would be in deep trouble. So, I would have to write a whole bunch of columns, and get *way* ahead of the game. Fortunately, I have had a little help from my friends, and I think I'm ahead of schedule—thanks to Frank Goodenough, ELECTRONIC DESIGN's editor in Boston. I have been encouraged and am making good progress at keeping ahead. I'm sure if I start to fall behind, Frank will chew on my ankles and get me straightened out.

How can I crank out all these words? Well, it helps to have a decent word-processing machine to write on. Why am I typing this on an IBM-compatible Personal Computer (made by Compaq)? Well, I own an old Coleco ADAM word-processor at home and it works perfectly adequately for writing memos and letters. But, it's not set up to transmit text encoded in ASCII, neither by modem nor by floppy, to Frank Goodenough in Boston or to the editors back in New Jersey. So I have this IBM-compatible machine, with processing by PC-Write-Lite* from Quicksoft, which works pretty well.

And while I'm a great fan of analog computers, I must say they're not terribly successful at saving and storing and transmitting text. I once set up a pair of voltage-to-frequency converters to put the X-Y coordinates of some letters and words onto a stereo cassette recorder. It did work. I was able to store the words. But the resolution was marginal, the throughput rate was awful, and the amount of tape to store 100 words would be absurd.

And when we played it back, using a brace of frequency-to-voltage converters and a pen-plotter, the words and letters were shaky due to the jitter and wobble and wow of the timebase of even the best (analog) audio tape recorder. So, I'm not going to even try to use an analog-computer word processor—even though it's not absolutely impossible. I'll use one of these new-fangled digital word-processors (which is not yet as user-friendly as my old ADAM) and plunk down my words. It works, and I don't gripe much about things that work.

What I really want is a word processor like that new Super Food Processor: You can feed in a 2 × 4, and the processor will grind it up into sawdust. Then you can put the sawdust into its hopper, and it will extrude them out into a rigid 2 × 4.

I just want to be able to do that with *words*, too!!

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*PC-Write-Lite, available for $79 from Quicksoft Inc., 219 First Ave. N #224, Seattle, WA 98109—a very reasonable price, and a plausible, darned-nearly user-friendly piece of software. I recommend.

p.s. —Herb Caen just announced in June that—after 52 years in the game,—he's going to cut back from 6 columns to 5 columns per week. That's still a huge number of words per week. But, no more "Sunday columns" from Herb Caen.

What's All This Teflon Stuff, Anyhow?

Once upon a time, a long time ago, a friend of mine, Arnie Liberman, designed a really good operational amplifier with a very low bias current—less than 0.1 pA. Now, when you want to measure and test a current as small as that, you don't just measure the I × R drop across a resistor, because even with a 100,000-MΩ resistor, it's hard to get resolution or accuracy. (0.1 picoamperes × 100 kMΩ = just 10 mV). So Arnie set up a test with an integrator. If this amplifier had an output drift rate (or ramp rate) of 5 mV/s with a feedback capacitor of 10 pF, that would prove that the amplifier's input current was 5 milli × 10 pico, or 50 femtoamperes.

But you can't just run an integrator without resetting it occasionally. And Arnie knew you could not easily find a relay that would short out the feedback capacitor without introducing lots of leakage and a bad jump when you turned off the drive to the relay's coil. So he made up a "relay" by applying a lever to a long push-rod which reached into the sealed box where the test was going on. The push-rod would close the contacts and short out the capacitor. Then when you backed off on the push-rod, the integrator would integrate the current, and all you have to do is measure the output's dV/dt to tell if the input current was within spec. And this worked fine, even at the level of small femtoamperes.

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

It worked fine in 1971...it worked okay in 1972...it worked in 1973. But after you started the test, you had to wait many seconds for the output dV/dt to stabilize to the point where you could get the right answer. Later, in 1973, you had to wait almost a minute to get the right answer.

In 1974, when you had to wait 3 or 4 minutes to get any valid reading, somebody in Production Test finally complained to Arnie that you couldn't get very many units tested in a day. So Arnie went to troubleshoot the test fixture. And he was puzzled for a while. What could cause such an erroneous reading? Soon, he realized that the push-rod was the culprit. If you pushed it back and forth, just a tiny bit, the integrator went berserk. But how could that be? The push-rod was made of Teflon. And it slid in Teflon bushings. How could there be a big error caused by the push-rod?

But as it turned out, that was indeed *exactly* the problem. When the push-rod slid in its bushing, it generated thousands and thousands of volts of static electricity. Now, on most ordinary insulators, those charges would drain off shortly. But because Teflon is such a good insulator, the charges would bleed off over a long, *long* time (through the air). Some of this charge would go into the summing point of the amplifier—for many seconds.

As the Teflon got drier with time, the time constant got longer and longer until he had to fix it. Arnie replaced the Teflon push-rod and Teflon bushing with a grounded metal push-rod, in a grounded bushing, with just a tiny sliver of Teflon insulator on the end that pushed against the switch contacts. The problem was banished. It just goes to show that if you have the *best* materials, and the *finest* concept, and you misapply things just a *little*, you can get some *terrible* results.

Recently, I was testing some of my operational amplifiers, LPC662's, with MOSFET inputs. The bias current was consistently down in the 2- or 3-fA area. It was so small that it really was hard to measure. I had a 10-pF integrator running, similar to Arnie's, but I was trying to get 20 times greater resolution. The resolution was marginal, as there were some jumps in the signal. The signal had long tails and additional errors if you tested a good amplifier after a bad one had pegged. And the switches didn't always give zero error on a damp day. So I wrote down a list of the fixes I needed, and I set my new technician Paul to work on them.

Paul made some imaginative and bold improvements. I had suggested that he should plot the ramp on a strip-chart recorder. Paul set up a digitizing scope and programmed it to spit out the answer scaled directly in femtoamperes.

I asked Paul to set up a simple circuit to drive a 6-V reed relay so there wouldn't be much charge coupled into the circuit from the voltage that drives the coil. Paul set up a clever adaptive circuit to take advantage of the small difference between the relay's pull-in and drop-out current, so that he fed the coil 2.6 V all of the time. You only had to hit the coil with a small pulse of voltage, positive or negative, to close or open the contacts, respectively.

I cautioned him that if the wires wiggle, they can couple a lot of charge and noise into the input. Paul strung the whole circuit up on rubber bands, as a shock mount, so that people walking on the floor nearby would not ruin the measurement.

Also, I cautioned him that we would soon need a good, low-leakage socket, guarded with Teflon insulation. Again, Paul gave me better than I asked for, with a big slab of Teflon for all of the components to be mounted on or above.

I explained to Paul that the slow recovery from overload was caused by the silver-mica feedback capacitor which had poor dielectric absorption. I gave him a capacitor that I had made—filled with air—about 0.5-in.-by-2 in.-by-4-in. of air, to make a 5-pF capacitor. It had copper plates and guarded copper side-frames.

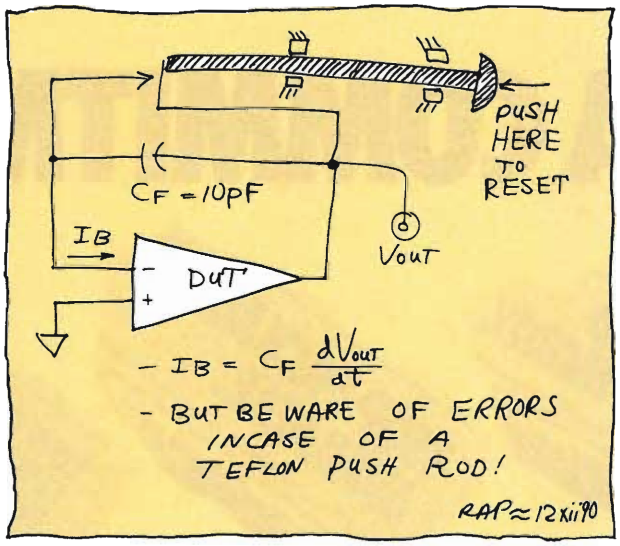
Now, first of all, why am I telling you all of these details? If I design a tester with greatly improved performance to help me test a really high-performance product, why should I tell all our competitors so that anybody in the world can test their products using the improved tester? Why should I give away all of these hard-earned secrets?

Here's a preliminary answer: It's probably true that some competitors might learn how to test better and faster if I give them my techniques. But my customers will also learn faster. There are more of them, and it's more important to teach them, because they're still trying to come up the learning curve. There's not much point in keeping secrets about testing if our customers are kept in the dark. It's just not fair to make your customers guess what is a good way to test your products.

Note that that is *not* the same as telling the customer exactly how we test it (we have testers, big expensive Teradyne setups, with monstrous interface boxes and complex software, and it would be much too complicated to tell everybody exactly how we run each test). But we do feel obligated to give any customer a good, valid test circuit that gives the same data as our production tests.

Okay. Paul set up this fixture. But there were a few little problems. For one, the output ramp would occasionally give a jump at random times. This jumping seemed worse than previously. Also, I asked Paul to test a whole group of parts, and he said, well, it would take longer than one day to test those parts.

OH?? I knew Paul could test those parts in less than a day—unless there was something wrong. I asked, *well,* why can't you test a part in a minute or two? He replied, "The output is off-scale and doesn't even come on-scale for 2 minutes." That didn't seem right. It wasn't until 3 days later that I slapped myself on the forehead at 6 A.M.—it was the Teflon factor. Paul had added lots of Teflon around the circuit, and the charge stored on its surface was the major cause of the long tails. When I got to work, I asked Paul to cover up as much of the Teflon as he could with aluminum foil—and ground it. He said the settling got a *lot* better. So he then removed all of the Teflon, and the slow settling went away. Just like Arnie's problem and Arnie's solution, 16 years earlier!



The next problem was with those darn jumps. Now, we could program the tester, not just to test the ramp for 60 seconds, but to test for six 10-second segments. If the answer was the same for 3 or 4 of the segments, then that is probably valid data and we should just ignore segments where the data had a big JUMP. Yes, we could do that. But, where did these jump errors come in?

The jumps were only 10 mV or so, always in the same direction, and at random times. Older fixtures did not have as many jumps. Why? The answer seemed to be related to that nice big feedback capacitor I had made. The circuit *did* have fast settling—not such a long tail as the older silver-mica feedback caps. But Paul spotted some literature—some Keithley data sheets—and some notes in Jiri Dostal's book* about cosmic rays and charge.

Dostal observed that when a cosmic ray or alpha particle or other energetic subatomic particle passes through matter, it often causes a discharge of electrons. If there's a sensitive detector nearby, some charge may come through the air and cause several thousand electrons to arrive at the detector.

Not just one electron, but several thousand—hey, that was the size of the jumps we were seeing—5 pf × 10 mV is about 50 femtocoulombs, equal to 300,000 electrons. So we researched a little more and realized that if we made a smaller volume of air adjacent to the delicate summing point of the amplifier under test, we should be able to cut down on the rep rate of these little jumps. So we're now preparing two feedback capacitors. We're not sure which one we will use, but they should both work quite well.

One has an air dielectric, but it's only 1 in. by 1.2 in. with 0.080-in. spacing between the plates. It will have less than 1/10th of the volume of the old air capacitor. The other feedback capacitor will use about 5 inches of twisted pair, using one piece of bare bus wire, and another wire with sleeving made of...Teflon. If you put it in the right place, Teflon is really *good* stuff. Some time I will tell more about which capacitor we used, and the other details we need to test for femtoamperes. Sockets?? Relays?? Ha!!

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*Jiri Dostal, *Operational Amplifiers*, Elsevier Scientific, 655 Avenue of the Americas, New York, NY 10010; (212) 989-5800. About $113.

What's All This Cost-Accounting Stuff, Anyhow?

Once upon a time, I was down at Lewis' Restaurant in Norwood, Mass., waiting in line to order a Lewisburger, which was a fantastic hamburger with blue-cheese dressing and potato salad and ham. A voice came booming across the noisy restaurant, "Hi Bob." I replied, "Hello Maurice, what's new?" Maurice wandered over and said, "How come you are still using the wrong formula, the *old formula*, for Factory Cost?" Old formula? I never heard of a new formula. You mean the formula of Parts Cost + 450% of Labor Cost is obsoleted? Maurice said, "Oh, that's been obsolete for months. Didn't anybody tell you? The *new* Factory Cost is 2 × Parts Cost + 3 × Labor Cost." Well, I ordered my Lewisburger, and ate lunch and bantered with my friends. But on the way back to my office, the wheels began going around in my head. How could they change the formula for Factory Cost and not inform people? How could they accept that, after "a few months," people were still using the incorrect formula, but it was no big deal? And they wouldn't bother to tell a guy unless they happened to bump into him at a restaurant? So I went to see my boss, Richard Randlett, to ask him if he knew what was going on.

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

He said, yes, he had heard about the new formula, but he didn't know it was officially in effect. And, besides, he didn't want to bother us with unimportant details. We should keep on engineering our designs using good judgment, as usual, and not worry about this "New Factory Cost Formula," and other academic things like that. Not a big deal. Well, okay, I went back to work. But within an hour, I was back at Richard's office.

"Hey, Richard, you know that low-cost converter I am working on?" Yeah. "Well, I was going to use a double-sided pc board, but with the new formula in effect, it would be cheaper to use a single-sided board and a few jumpers. The parts cost will go down quite a bit, but the labor will only increase a little."

Richard sat there. He thought about it for a few seconds. Then he saw red! "No, don't make that change!!" I replied, "But Richard, the new Factory Cost Formula says it's wise to add a few seconds of labor to save a lot on parts cost." But Richard pointed out that even though that was what the bean counters were telling us to do to save money, it would be wrong. He told me to keep on optimizing the costs, assuming that Labor Costs would be multiplied by 4.5 compared to the Parts Cost. Meanwhile, he would try to get this resolved, and get the formula changed back to a reasonable proportion. He'd get me an answer within a month.

Well, one month later, Richard was still trying to get the problem resolved. Two months later he was gone, and three months later, I resigned. So to this day, I don't know how this was ever worked out. But I did know that I could not do my job if nobody would tell me the rules, and if the rules kept changing to contradict themselves. One set of rules told me that it was wise to add jumpers instead of plated through holes. And a second set of rules told me that was foolish and costly, and I should do it the other way. And if no one could tell me which rules were valid—hey, that's a problem. I needed to solve that problem, but nobody could help me resolve it. So I voted with my feet and left that company, and I haven't worried about that kind of problem. Until recently.

Of late, I was collaborating on a small regulator chip where we wanted to trim the output to high accuracy. That would take about 10 Zener-zap trims. And those would tend to take up lots of die area—probably a 50% increase over the circuit area.

Conversely, if we put in laser trims, that would keep the die size small, but the cost for trimming each die would rise considerably. How much would it rise? We did not have the cost data. And when we got the cost data, it was kind of outdated, and we did not *entirely* believe it. But the time for trimming with 10 laser cuts would basically take an extra second, due to the need to get the laser aligned with the die. And the cost of testing on a tester with a laser is about double—about 4 cents/second—versus 2 cents/second on a tester without a laser.

That is true, even for the tests when you're not using the laser. This is because the whole machine must be paid for, even if you're not utilizing all of the tester. So, 3 seconds × 4 cents/second is noticeably different than 2 seconds × 2 cents/second. For an 8-cent difference, you can pay for a much bigger die area!! So that convinced us there was probably a cost advantage if we could avoid laser trimming.

But those considerations were overruled by a more important consideration: The need to fit the die in a small package. There were some small plastic packages that the larger (cheaper) die would not fit into. Still, we realized that in the future, we will be sharpening up our pencils more often. What is the right way to keep the costs low? What are the rules in *our* business? We're not sure, but we're trying to get some of these rules nailed down. Then when it *is* important, we will have the rules available—and believable. And that's not a trivial statement.

What are the rules in *your* business? Do you know what they are? Do you believe them? Are they ever subjected to thoughtful scrutiny, or are they so old and dusty that you know darned well that nobody has thought about them for many years? Do people change them without understanding all of the ramifications and repercussions? Maybe it's time for a sanity check.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

LETTER TO BOB

Dear Bob:

The most disturbing thing to me about Spice is that many companies have adopted a philosophy of going directly from Spice to board design. You know, and I know, that analog design has too many subtle traps—breadboards must also be built.

I've seen too many simulations where the problem wasn't lack of convergence, getting error messages, weird results, or weird waveforms; but rather something even more disturbing: Getting good simulation results on circuits that I knew, or that breadboarding later showed, did not and could not work worth a darn.

JERRY STEELE,
Applications Engineer
Apex Microtechnology Corp.
Tucson, AZ

What's All This Statistical Stuff, Anyhow?

I've always been a fan of Mark Twain and his writing. He had a rather good perception of the American people, and many topics that he wrote about are fascinating to this day. One of my favorite quotes of Twain is: "There are three kinds of lies: there are "lies," there are *damned lies*, and there are STATISTICS...."

One thing that doesn't help me a darned bit is "statistics," at least in the sense that most mathematicians and engineers use them. I find most statistical analyses worse than useless. But I *do* like to use charts and graphs. I took some data of diodes' V_F versus I_F recently. The data was a little suspicious when I wrote down the numbers, but after I plotted the data, I *knew* there was something wrong. Then I just went back and took more data until I understood what the error was, ac current noise that was being pumped out of the inputs of the digital voltmeter, crashing into the diode, and causing rectification. If data arises from a well-behaved phenomenon and conforms to a nice Gaussian distribution, then I don't care if people use their statistical analyses—it may not do a *lot* of harm. (Personally I think it does harm, because when you use the computer and rely on it like a crutch, you get used to believing it and trusting it without thinking....) However, when the data gets screwy, classical statistical analysis is worse than useless.

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

For example, one time a test engineer came to me with a big formal report. Of course, it didn't help that it arrived at 1:04 P.M. for a Production Release Meeting that was supposed to start at 1:00 P.M. But this was not just any hand-scrawled report. It was handsome, neat, and computerized; it looked professional and compelling. The test engineer quoted many statistical items to show that his test system and statistical software were great (even if the ICs weren't). Finally he turned to the last page and explained that, according to the statistics, the ICs' outputs were completely incompetent and way out of spec. Thus, the part could not be released.

In fact, he observed, the median output of the output was 9 V, which was pretty absurd for the logical output of an LM1525-type switching regulator, which could only go to the Low level of 0.2 V or the High level of 18.4 V. How could the outputs have a median level of 9 V?

How do you get an R-S flip-flop to hang up at an output level half-way between the rails? Unlikely.... Then he pointed out some other statistics—the 3 sigma values of the output were +30 V and -8 V. Now, that's pretty bizarre for a circuit that only has a +20-V supply and ground, (and it isn't running as a switching regulator, it's just sitting there at dc). The meeting broke up before I could find the facts and protest, so that product wasn't released on schedule.

It turns out, of course, that the tester was running falsely. So while the outputs were all supposed to be *set* to +18.4 V, they were actually in a random state. Half of the time the outputs might be at 18.4 V and half of the time at 0.2 V. If you feed this data into a statistical program, it might indeed tell you that a lot of the outputs would be at +9 V, and some of the outputs might be at -8 V, assuming that the data came from a Gaussian distribution. But if you *look* at the data and *think*, it's obvious that the data came from a ridiculous situation. Rather than ramming the data into a statistical format, the engineer should have checked his tester.

Unfortunately, this engineer had so much confidence in his statistical program that he spent a whole week preparing the Beautiful Report. Did he inform the design engineer that there were some problems? No. Did he check his data, check the tester? No. He just kept his computer cranking along, because he knew the computer analysis was the most important thing.

We finally fixed the tester and got the product out a little late, but obviously I wasn't a fan of that test engineer (nor his statistics) as long as he was at our company. And that's just one of a number of examples I trot out when anybody tries to use statistics that are inappropriate.

I do like to use scatter plots in two dimensions to help me look for trends, and to look for "sports" that run against the trend. I don't look at lots of data on good parts or good runs, but I study the *heck* out of bad parts and bad runs. And when I work with other test engineers who have computer programs that facilitate these plots, I support and encourage those guys to use those programs, and to *look at* their data, and to *think* about those data. I support anything that facilitates thinking.

A couple years ago, I was approached by an engineer who was trying to use one of our good voltage references with a typical characteristic of about 20 ppm per 1000 hours long-term stability at +125°C. He was using it around room temperature, and was furious because he expected it to drift about 0.1 ppm per 1000 hours at room temp, and it was a *lot* worse than that. He asked why our reference was no good. I pointed out that amplifiers' drifts and references' drifts do *not* keep improving by a factor of 2 every time you cool them off another 11 degrees more.

I'm not sure who led him to believe that, but in general, modern electronic components aren't greatly improved by cooling or the absence of heating. In fact, those of us who remember the old vacuum-tube days remember that a good scope or voltmeter usually worked better if you kept it running nice and warm all the time, because all of the resistors and components stayed dry and never got moist under humid conditions. I won't say that the electrolytic capacitors might not have liked being a little cooler. But the mindless effort to improve the reliability by keeping components as cool as possible has been overdone. I'm sure you can blame much of that foolishness on MIL-HBDK-217 and all its versions. In some businesses, you have to conform to -217, no matter how silly it is, but in the industrial and instrument business, we don't really have to follow its every silly quirk and whim.

One guy who argues strenuously about -217 is Charles Leonard of Boeing, and you may well enjoy his writing (Leonard, Charles, "Is reliability prediction methodology for the birds?," *PowerConversion and Intelligent Motion,*" November 1988, p. 4). So if something is drifting a little and you think you can make a big improvement by adding a fan and knocking its temperature down from +75 to +55°C, I caution you that you'll probably be disappointed because there usually isn't a lot of improvement to be had. It's conceivable that if you have a bad thermal pattern causing lots of gradients and convection, you can cut down that kind of thermal problem. In general, though, there's not much to be gained unless parts are getting up near their maximum rated temperature or above +100°C. Even plastic parts can be pretty reliable at +100°C. I know the ones I'm familiar with are.

(This column is an excerpt from the soon-to-be-published book I have written entitled "Troubleshooting Analog Circuits." This endeavor will be published by Butterworths in April 1991.)

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Dear Bob:

Sure enjoyed your Spice article in Electronic Design. I've followed your musings for years, gosh, decades. Please don't ever stop. There is another aspect of the simulation thing. It is a matter of philosophy, I guess, and it has concerned me for a long time: The sense of accomplishment that comes from doing something the first time. Once you've done it, you've done it (how many endure the agony of climbing Mount Everest a SECOND time?). In the real world, this concept is intuitive, I think. But in the world of simulation, we confuse what we have accomplished with what we have imagined; worse yet, what the computer has imagined! Dreams and reality mingle, and we are led astray.

Case in point: Stirling engine development (one of my loves) has gone high tech. The talent and money is flowing toward the computer, not the lathe. We simulate, learn, simulate, etc. Each time we make an improvement it is rewarding, and provides the psychological boost needed to continue. Because it isn't so rewarding to do the same thing again, we don't bother to repeat in metal what we've already "built" on the screen. Soon the simulation errors compound until there is no way to distinguish dreams from reality.

I sometimes wonder if we could have experienced the industrial revolution at all, if somehow the computer had already existed. It is very tempting to simulate a thing rather than constructing it.

Simulation ain't the same as really doing it. Perhaps a close parallel? Or, to say it another way, is it possible that the boob tube in the office takes us on the same sort of journeys as the boob tube at home?

DARRYL PHILLIPS
President
The Airsport Corp.
Sallisaw, Okla.

I couldn't agree more. -RAP

Dear Bob:

I just finished reading your column "What's All This Spicey Stuff Anyhow? (Part 1)" in the Nov. 22 issue and I thought I'd share my own experiences with circuit simulation and EE education with you.

I am 33 years old, and was trained in math and computer science. Two years ago, I decided to pursue a Masters degree in EE at a well-known northeastern university. I told the boss that I was going to specialize in the mathy end of EE, like Control Theory, Signal Processing etc., but I had a hidden agenda. I wanted to learn electronics.

It's all worked out because I have learned electronics, but only sort of. You see, at this institution's outlying campuses, where they crank out BSEEs and MSEEs by the score, there are no labs. I repeat, no labs. No breadboards, no scopes, no components, no nothing. Any design that takes place is on the computer using a circuit simulation program. I have suggested to several professors that a real live lab would be very helpful, but they just "hurrumph" about the computer being just as good as a learning experience. So you see, it's not just lazy (young or otherwise) engineers copping out on the design process, it's the educational system taking the path of least resistance.

I have improved the situation for myself somewhat. I designed and built a dc power supply (you're probably saying "big deal," but that's pretty good for a mathematician!) I bought a breadboard, a selection of components, and a digital meter. With this setup, I can do quite a bit of experimenting on my own. My father, an "old tyme" electrical engineer, is so glad that his mathematician son has seen the light that he's salvaged an old scope from who knows where for me. I'm looking forward to its arrival.

As far as my experiences with the circuit simulation program are concerned, I concur with your opinion. We didn't use Spice, but some other Spice-like program. It was graphically oriented and very user-friendly, but it had the same crazy convergence problems that you describe. One project we had was to design an analog multiplier. Changing the quiescent current through the Gilbert cell ever so slightly made the difference between fast convergence for steady-state analysis and sitting for 15 minutes watching the cursor blink. Then, to add insult to injury, the case that converged for steady-state analysis didn't converge for Fourier analysis. I finally was forced to give it up. Interestingly enough, my professor accepted "Program Did Not Converge" as a correct answer.

CHRISTOPHER LENNON
Bedford, Mass.

Ouch! This guy's heading in the right direction, but the schools aren't. -RAP

Dear Bob:

I feel that your most recent column (Spice, Part II) needs some comment. You say, "I don't think you can beg or steal or borrow or buy a model of a transistor that's guaranteed." First, to what kind of transistor are you referring: bipolar, JFET, MOSFET, small signal, large signal, power, microwave, discrete, integrated devices?

Second, your statement implies that a single "transistor" model should be guaranteed to "run" under all conditions. Suppose I suggest that you should be able to design a single OP AMP that works equally well for all applications? I suspect that you would not only laugh in my face but that you would think to yourself that I am a fool for having made the suggestion in

PEASE PORRIDGE

the first place. Well, to suggest that a single transistor model should "run" under all conditions is equally laughable. Am I hitting below the belt?

Third, you seem to want to place the total responsibility for the success of the model upon that person who developed the model. However, I get the impression that you have no sympathy (or respect?) for a user of one of your op amps who misuses your op amp. Below the belt again?

Fourth, you seem to believe that those "transistor" models which have been built into the circuit simulation program Spice represent the complete set of models from which one can choose. The sad truth is that those "transistor" models built into Spice represent just about the worst set of models from which one can choose. Why is that the case? Because industry gets those models for free from the Univ. of Calif. at Berkeley as the result of student slave labor and typically is not willing to pay the price for truly physical and accurate models.

....You suggest that you may wish to BUY a guaranteed transistor model. Well, you can. My company has developed and markets Spite (SPI Transistor Emulator), the world's best CIS/SIS (MOS if you prefer) transistor model. The Spite model does employ physically meaningful parameters and parameter values. It also simulates, with unprecedented accuracy, a transistor which is properly used. Would you like to guarantee me that your op amp will always "run" for me no matter what I do to it? There just isn't any point in building a lot of unnecessary complications into the model to protect the unknowledgeable user from himself.

So what do you want your guarantee to say? Send me a reasonable specification and a purchase order and I will write your guarantee for you.

DR. JAMES E. SMITH
President
Semiconductor Physics, Inc.
Escondido, Calif.

I use mostly bipolars, but for CMOS this looks tempting! -RAP

What's All This Perfection Stuff, Anyhow?

Once upon a time, a lady went shopping for shoes. She went into a shoe store and said to the salesman, "My good man, I would like to buy some alligator shoes." The salesman showed her some alligator shoes. But *this* one had a flaw, and *that* one had a blemish, and *that* one had a scratch. He went back and got more shoes. But when the lady inspected them, she found an imperfection that was unacceptable to her every time. Finally, he brought out every pair of shoes he had, and she was not prepared to buy shoes with such defects. In great exasperation, the salesman told her, "Look, lady, you're not perfect. I'm not perfect. How do you expect an alligator to be perfect?"

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

One of my latest ventures involves the writing of a book. On October 30, 1990, I handed in a complete, polished manuscript. I don't know how many words, or how many pages, but it was about 700,000 bytes, and the Fed Express guy had to struggle to get it on its way. This was a refinement of some stories on the troubleshooting of analog circuits I wrote a couple years ago. I took the old stories and added a lot of new info, tweaked and refined a lot of the text, and corrected some typo errors, finally rounding it into pretty good shape. With a little luck, the book will come out on schedule this month.

On November 14, I sent to the publisher a package of new corrections and changes. Only one envelope, but there were 28 items in there. When I talked with the publisher, I could tell she was smiling, seeing that I was willing to put so much effort into getting things right. On November 30, I assembled an envelope with more corrections, changes, refinements, and upgrades. I mean, some of the people had moved in the last month, so I certainly had to put in an address correction. In several cases, the distributors who sold things didn't sell them any more. In other instances, I remembered a new technique that I had forgotten previously. So, when I send in this package, I'm really making progress—because there are only 27 items.

Next week I expect to remember a couple more items. I'm not sure exactly when the smile will completely disappear from my publisher's face, but it's only a matter of time. She will say, "It's time to shoot the engineer, and put this to bed and print what we've got." And I'm sure I will have to agree with her pretty quickly. But meanwhile, I know I have to correct the spelling of one guy's name. We can't leave that wrong. And an old friend is mailing me some more info on some diodes...and there are curves that don't look quite right ...and there are some photographs that still have to be developed, not to mention the ones that haven't yet been taken....

"Time to shoot the engineer." That's a phrase that has been around for a long time. Almost as soon as I got out of school and into industry, I began to hear people explaining that the need for perfection was all very fine, but it *must* not go on much further. When is the circuit going to be *good enough*? Perfection isn't necessarily justifiable. What is *good enough*? And whose opinion is to be relied on? Sometimes the engineer is correct that there are some improvements that *have* to be made. Other times, it's not so clear.

For example, we were recently trying to release a new product, but the distribution of one parameter was not quite centered. The yields might occasionally fall off more than we liked. So we proposed an optional metal mask that would bring the distribution back close to center. But this might cause some problems at high temperatures. And it might cause some dynamic problems. And even if it didn't cause serious problems, it might get some of our customers cross if they had to re-qualify our product, because we had made a change in a mask, even though it would be a *very tiny* change.

What's the right thing to do? Accept the yield loss? Change the data sheet? Delay the release of the product and risk the loss of market share? If we wanted to compromise, where would we do it? Hey, I don't know how you run your business, but in our business, there aren't any easy questions. If you're making alligator shoes, and your QC department says you can ship only shoes that have no visible flaws under a magnification of 5X, you're not going to be selling a lot of shoes. But, most of the time, our shoes are on our feet, at least 3 or 4 feet away from our eyes or anybody else's eyes. From that vantage point, "imperfection" is quite different.

Now, I'm not proposing that we refuse to ship amplifiers because they're not "perfect." I mean, if a perfect amplifier is one that has less than 0.5 mV of offset voltage, we have a *lot* of perfect amplifiers. Just 10 years ago, customers were pretty happy to buy that kind of "perfect amplifier." But these days, even 15 μV isn't "perfect." And if you build lots of amplifiers with less than 10 μV, and they all test out good, and then you allow them to warm up, and you temperature cycle them through an oven, are they still "perfect"—better than 15 μV? If you want to buy a "perfect" amplifier, do you require big safety factors against every possible condition? You may wind up going barefoot: The price for a "perfect" pair of shoes might be more than you would be willing to pay. Sometimes we have considered that amplifiers at this level of precision might have a looser AQL than normal—perhaps 0.5% instead of the typical 0.01%. But our QC people don't want to concede that.

If we test an amplifier for noise, and we do it 30 times, the data might show low noise on 27 of the passes. But on 2 or 3, there might be a small deviation—an increase (or a decrease) in the test result—whether or not the *amplifier* actually made more noise. Heck, you can't design a noise test to be perfectly repeatable—that's inherent in the nature of noise. Now, if a unit passes a test at its "class" or final test, it must never be allowed to fail its guaranteed specs if you re-test it. That means you must have wide guardbands, as wide as the deviations of the system's noise. If an amplifier that reads 1 μV pk-pk most of the time can read 0.8 μV some times, and 1.2 μV other times, that would tell you that you must have a guardband of *at least* 0.4 μV, and maybe 2 or 3 times that. So you could sell to a guaranteed spec of 2.2 μV—even though most of the parts are 1 μV pk-pk. Is that the spec you want to buy?

Once, a long time ago, a bright young engineer was working on semiconductors in England. The transistors were passing a 27-V breakdown test very reliably. But this semiconductor company was a subsidiary of a large plumbing-supplies company. And if you're making boilers or gauges or pipes, you've got to have a 3:1 ratio between the working pressure and the bursting pressure. So, this semiconductor company wrote their data sheets for a 9-V transistor, while their competitors were selling to a 25-V spec. Needless to say, the young engineer knew there was no future in a business where perfection and safety factors make the playing-field so badly tilted. And that was why Bill Frusztajer left England and came to the United States, where he became head of Teledyne Crystalonics.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Mentoring Stuff, Anyhow?

Once upon a time, a new engineer came to work in our group. A woman. Now, in some areas, it's really not a surprise to have a new engineer or a woman engineer, but in our group, that did not happen very often. So when Jane arrived, we all tried to be polite and cheerful, for a change, and not just scream at her and give her a hard time, as newcomers are sometimes treated. Now, Jane was a bright young woman, but there were a lot of things that she had to ask questions about, so she would ask various people. Sometimes she would ask me, and sometimes she would ask Andy, another of the old-time experienced engineers. We didn't just fall over ourselves to help this bright young engineer. But we did realize that the more questions we answered, and the faster we could bring her up the learning curve, the quicker we could get a lot of help out of her and turn her into a *real engineer*.

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

So we were reasonably cheerful at answering some of her dumb questions (like where do you find things that aren't filed or indexed rationally?), and some of her very thoughtful questions (why do we keep telling customers this or that when it's not true??). And we tried not to just throw answers at her, but to explain the reasons behind the answer.

One day, I wandered over to get some info out of a book, and Jane asked me a question. Andy had the answer quicker than I did, and I was standing around reading the book, while Andy explained the answer to Jane. When he was finished, I said, "Hey, Andy, you know, Jane is your protégée, right?" Andy agreed. I continued, "And Jane is my protégée, too, right?" Andy agreed. I then said, "And, Andy, do you know what that makes us?" Andy could not think of the correct word. I said, "That makes us dirty old men." And all *three* of us broke up into laughter. Around here, no-one and nothing is taken very seriously....

Actually, there *is* a word that applies, so if a person is my protégé (male) or protégée (female), then I am a Mentor. I attended a nifty conference on Bipolar Circuits and Technology in Minneapolis in September. I must say, although it doesn't get *nearly* as much publicity as ISSCC, it's getting to be nearly as good as ISSCC, so long as you are really interested in bipolar circuits (if you're a hard-core MOS enthusiast, there's no reason for you to come to Minneapolis in September). The after-lunch speaker this past year was Jim Williams of Linear Technology Corp., Milpitas, Calif. Jim talked about several topics, but his most serious pitch was that we must do a lot of mentoring. We can't just hire a bunch of kid engineers, ignore them, throw garbage at them, and then chew them out. We probably never *could* do that. But in the 1990s, it's reasonably easy to see that the nurturing of new or young engineers is a major part of our jobs.

When I was a kid engineer at Philbrick, I had a number of excellent teachers, engineers who taught me many different aspects of the profession. I must say, though, I was a rather *green* engineer, because I never had a hobby of ham radio, as many engineers did. In fact, I only transferred from the Physics department to become an EE in the fall of my senior year.

At Philbrick, Dr. Achard helped me appreciate technical writing. Bruce Seddon taught me a lot about worst-case design. Al Pearlman answered lots of my questions about transistors. Bob Malter did not have much time for dumb questions, but I studied his designs and asked a few questions that were not *too* dumb. I mean, learning how to ask questions that are not *too* dumb is a significant part of every student's education. After studying and learning from a whole bunch of people for over a year, I was just barely able to design my way out of a paper bag_with a little help. It took me a few more years before I understood the whole picture, well enough that I could design amplifiers without too many fatal flaws, or latch-up modes, or features that did more harm than good.

So if we also want to hire good engineers to work on linear or analog circuits, we can't just find them in thin air, and we can't just hire them from our competitors. And we *certainly* can't just find them coming out of colleges. I mean, when a student graduates from a good engineering school, the best I can hope for is that the student has learned some good study habits, some good attitudes toward work, and some ability to analyze several kinds of circuits. But not everything. Can I hope that the student really knows how to design an op amp? Well, I hope that an engineer I am interviewing knows a little bit about designing *something*. If he (or she) can design and analyze some things pretty well, there's good hope I can teach them enough to come up the learning curve quickly. That's only fair. If I can make *them* look good, then they can make *me* look good.

So I should try to avoid the "mushroom treatment," not heap manure on them and leave them in the dark. I should teach them sometimes, throw problems at them other times, challenge them, and try to set a good example. I should avoid letting them get stuck, or hung up, or discouraged. I may not be able to answer every question. I may demur, or duck certain questions, and tell them to go figure it out for themselves. It's a little bit like when you have kids. You can't teach your own kids everything, but you try to steer them in a course where they can learn what they need.

I remember when our sons were just learning to read. For a while, my wife and I agreed that *each* of us read everything that Benjamin read. After about a month, we agreed, well, one *or* the other would try to read everything Benjamin read because he was just too omnivorous for each of us to fit in the time to read everything. A month after that, we sort of gave up, as we could not possibly keep up with his appetite for reading. We tried to read samples of what he was reading. But, we had gotten him turned on and he was off to the races, devouring every kind of book and magazine that was suitable for young people, and many grown-ups' topics as well. Now that both my sons are taller than I am, they throw me an occasional bone, some good things for me to read that they can recommend. Turnabout is fair play.

Now, when we assign projects to engineers at work, I can't keep up with all of the details, and I can't know all of the answers. But I have to keep in touch, to tell if there's trouble, to facilitate the search for answers, and to prevent the guy from getting discouraged. This is even necessary for an experienced engineer! Because there really aren't many easy projects that our customers want us to do, every engineer gets some very challenging projects. Challenges are great for young engineers, but mentoring would advise you against loading on an unfairly heavy load. Similarly, I have to keep an eye on the project, to make sure the engineer doesn't make a false assumption and go barrelling down a path that is dead-end. Everybody recognizes that after it has happened, but it's a little harder to see it in advance.

Wow, Pease, it sounds like you really are in charge of a big group. How many people does Mr. Super-manager Pease have working for him? Well, about 2 engineers, 2 technicians, and one guy who is half-way up from technician to engineer. But, I must say, by default, I have given some of my technicians a lot of liberty, and they have responded by coming up with some brilliant moves, interspersed with a few occasional marvelous blunders. So, I have 2 boys at home, and 5 boys at work, and, oh boy, do we have fun.

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

WHAT'S ALL THIS "SMWISICDI" STUFF, ANYHOW?

A long time ago, I went out to dinner with Dave Ludwig, an old friend of mine from Massachusetts. We went to a fancy Italian restaurant. After we had ordered our entrées, the waiter asked, "Would you like a salad?" I declined, but Dave said he would like one. "What would you like in your salad?" Dave said lettuce and tomatoes.

In a few minutes the salad arrived. Yes, it had lettuce and tomatoes. It had three kinds of lettuce, and tomatoes and chick-peas and croutons and onion slices and green onions and Italian cherry peppers and slices of hard-boiled egg, and three kinds of salad dressing on the side. I sat there with barely suppressed astonishment, and Dave just sat there with a quiet, resigned smile. After the waiter departed, Dave explained: There was no point in complaining or griping or hollering, because at the best, the manager or the headwaiter would just come over and say, "Hey, you don't have to eat anything you don't want, and you don't have to pay for anything you don't want, so, what's your complaint? Show Me Where It Says I Can't Do It." And he explained that he was an aficionado of these kinds of stories, which we will of course abbreviate to "SMWISICDI."

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

He pulled a faded clipping from his pocket. The newspaper story was about the advantages of home ownership. "If you own your own home, you can play the piano at midnight." I thought about it. I said, "Dave, I can't play the piano worth a darn. But this story says that I can play the piano at midnight if I own my own house."

Dave smiled and agreed. "You just *think* you can't play the piano. But, have you ever tried at midnight?" I had to admit that I had not. But, one of these days, I will try playing at midnight, to see if I'm any better than at any other time. What I suspect is that at 12:00:02, I'll suddenly be a rotten pianist again.

Now I, too, have gotten interested in SMWISICDI stories. In fact, last week I mailed 5 ounces of SMWISICDI stories and clippings to Dave. For example, I clipped out a story about how the Israeli Army solved the problem of what to do when Palestinians throw stones at the soldiers. The Israeli Military invented an automated stone thrower to retaliate. An eye for an eye, a tooth for a tooth—and a rock for a rock? What if the U.S. Army sent out a Request For Quote on developing, manufacturing, and deploying a rock-thrower? What if Jack Anderson got wind of this, and confronted the Joint Chiefs of Staff? They would just tell him, "Show Me Where It Says I Can't Do It."

Last week, Wanda Garrett, our senior applications engineer for amplifiers and regulators, got a phone call from an unhappy customer. He had used one of our ICs to design a switching regulator, and it didn't work well at all. The output had glitches and burps and excessive ripple and noise. The regulation was poor, the loop stability was rotten, and the efficiency wasn't even very good.

After a lot of inquiry, Wanda discovered that this person had built up the switcher on one of those solderless breadboards. OHHH!! Patiently, Wanda explained, that is exactly what you expect when you use one of those solderless beasts. The inductances are awful, the capacitances will cause crosstalk between adjacent buses, and if you try to build a switching-type regulator, *of course* it will work badly. And the customer replied, "SMWISICDI."

Now, Wanda was a little taken aback. She had to admit, of all the things that we might have told people they should not expect to work, this was one that we didn't *specifically* warn against. But, to put the shoe on the other foot, she asked, "Where does it say you *can* do this?" And the customer replied that in the solderless breadboard's promotional brochure, it says, "Ideal for high-frequency and high-speed/low-noise circuits." Wanda observed that was probably not quite true—neither for linear circuits, fast digital circuits, fast ADCs, nor switchers. Then she pointed out to the customer that the LM2575 data sheet does spell out: "As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients that cause problems. For minimum stray inductance and ground loops, the length of the leads indicated by heavy lines should be kept as short as possible. Single-point grounding or ground-plane construction should be used for best results."

So we really *did* tell every customer that you need a good layout, right in the data sheet. Of course, if the customer *believes* that solderless breadboards are really great for high-frequency circuits, then we have a problem—which Wanda was able to resolve and explain. The solderless breadboards do cause many troubles.

First of all, most fast ICs, whether linear or digital, require a good ceramic power-supply bypass capacitor, right close to the IC. But with those long buses inside a solderless breadboard, it's hard to get a bypass capacitor with less than 3 or 4 inches of loop. That won't help a switcher or any other fast circuit. Then, the capacitance between adjacent buses—typically 2 to 4 pF, depending on the size—is going to cause stray coupling that will probably make the circuit unhappy. That's my experience. Furthermore, when you have a switching transistor turning off, its collector or drain can easily slew at 600 V/µs or more. If your "catch" diode is spaced more than an inch from the inductor and transistor, the L di/dt can cause dozens of volts of overshoot, which may overstress the switching transistor (exceeding its voltage ratings), not to mention generating some horrible spikes in the air.

And those white slabs—they are *not* Teflon. They aren't polystyrene or polyethylene, either. They are made of nylon, or something similar, so the leakage can be pretty bad on a warm or humid day. Even worse, if you push a whole lot of wires into those little solderless connectors, the little scraps of solder will get scraped off until there's a whole pile of solder scraps hidden inside. Then they can start making intermittent short-circuits between adjacent buses—won't *that* be fun to troubleshoot.

So Wanda explained all of these reasons not to use a solderless breadboard for making a switcher. She sent the customer a little PC board that was neat and compact to help him get a prototype of the circuit working—one of the LM2575 "Simple Switchers." Note, we normally think that these "Simple Switchers" cannot miss—they're very easy to apply. But, if you try to build it on a solderless breadboard, even a simple circuit can be hurt—ruined—by the strays of a poor layout. Simple, yes. But foolproof and tolerant of a truly bad layout? No.

Then she warned the rest of us Applications Engineers that customers might be having trouble when using solderless breadboards, ultimately complaining "SMWISICDI." I'm just passing on this warning to you readers.

Finally, Wanda said she was going to try to put a disclaimer in our linear databooks and applications handbooks, that the "solderless breadboards" are unsuitable for any applications other than medium-speed, medium-impedance-level, and medium-precision circuits. It may sound silly, but I know that she'll find a way to put in a caution flag where it's appropriate. I mean, Wanda is the Czarina of Linear Data Books. She can put anything she wants in there. Show Me Where It Says She Can't Do It!

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Brick Stuff, Anyhow?

This is an esaeP's fable. Once upon a time, a very proper Bostonian lady decided to build a new home, so she hired an architect to design a new brick house. When he finished the design and showed it to her, she said, "That's very nice. Now, how many bricks will it take?" The architect replied, "About 76,000 bricks, ma'am." She said, "How many bricks, exactly?" He asked, "You really want to know *exactly* how many bricks?" She said, "That's right. I want to buy exactly the right number of bricks."

The architect realized that this was a reasonable request, so the next day he told the lady. "Exactly 75,885 bricks." So she had that exact number of bricks delivered, and the masons and bricklayers worked for many days. Finally the last bricklayer set the last brick into place at the peak of the last part of the house. The bricklayer turned around and saw that one brick was left. So, he picked it up and threw it over his shoulder. Now if you were planning a project, you might want to plan carefully so that you had the right resources to finish the job. You might even plan to have some safety factor or margin, so that if some unforeseen problem caused delays or trouble, you would still be able to fulfill your obligations. For example, if a few bricks were broken, you wouldn't want to have to go back to the brickyard and ask them to build some more bricks with the identical pattern, would you?

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

Some managers, though, write a schedule and if there are any unforeseen problems, they want the workers to invent bricks out of thin air, just to get the project back on schedule and back on budget. They claim they should not have to allow extra resources that might just be wasted. I mean, if they bought 75,886 bricks, the workers would just waste one or two, wouldn't they? They might just take a brick and throw it over their shoulder.

By the way, have you ever tried laying bricks? I've done a little bricklaying, and while it looks like a simple "digital" procedure, it is *not.* It requires analog precision and judgment to get the bricks level and each course flat. Also, when you're trying to fit an irregular space, you find that the broken pieces are pretty useful, as often you can find just the right length to fit in. If not, you have to break a brick into pieces until you get lucky and get the right size piece of brick. It's an analog business.

Now here's another esaeP's fable. Sometime later, that same proper little old Bostonian lady decided to travel on the MTA to visit a friend. She started out on the subway with her little poodle sitting on her lap. At the next stop, a large churlish man got on and sat down beside her. He took out his Record-American and spread it out at full width. Naturally, the newspaper flopped around in front of the little old lady's face, and right across the ears of her poodle. Not very polite. After a short time, she nudged the newspaper. The man retaliated by nudging her poodle. He put out the newspaper again, encroaching on her space. She gave a *flounce* to the newspaper. He gave a *shake* to her poodle. She could not abide this, *throwing* the newspaper on the floor. He *threw* the poodle on the floor. She then took the newspaper and *threw* it out the window! He took the poodle and *threw* it out the window!!

Of course, at this point, pandemonium ensued. She screamed, and somebody pulled the emergency cord, and the conductor came running up as the trolley screeched to a stop, and the lady tried to explain, "This terrible man, he threw my little dog right out this window." And as the conductor and the lady and the terrible man all looked out the window, the little dog came trotting up the tracks. And what did he have in his mouth? The newspaper? No, the brick.

Now, this starts out with one absurd story, and it rzambles along and crashes into a fragment of the first fable. What's the moral of this story? I'm not sure. Maybe it's that you can't count on logical things happening all of the time. If your train of thought derails, what can get it back on the tracks? There are no easy answers to that one. But in the real world, you may find things happening that are worse than you expect. You may also find things working better than theory predicts, and you should be prepared to take advantage of them.

Remember, it was Branch Rickey who said, "Good luck is the residue of design." Good luck doesn't just happen to the lucky; it sometimes "happens" to those who are prepared to grasp it. Another aspect: Only a few years ago, we were reading about "The office of the future: The paperless office"—what a joke! Our offices generate more paper than ever (most of the computerized reports are never read). We now have a quasi-infinite thicket of computer files, floppy disks, floppy directories, and only the vaguest idea where to find that memo you sent out to an important client just a couple years ago. Are there new "file manager" programs that claim they can find anything in all of your files? Sure, and can I sell you a bridge? If you ask one of these file managers for a newspaper, will it give you a brick?

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

ADDRESS:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Critical Thinking Stuff, Anyhow?

Last year, I attended a little conference of Community College Electronics Teachers up at Truckee Meadows Community College in the foothills north of Reno, Nevada. I must admit, I was not very familiar with the exact nature of Community Colleges (two-year colleges). But I wanted to learn more, because we've had some very good luck hiring bright young people from some community colleges, and I wanted to understand why. I wanted to case the joint.

One of the first speakers asked the entire audience of 100-plus teachers, "How many of you built model airplanes when you were young?" To my amazement, about 92% of the people held up their hands. So, he observed that many people who now work in technical electronics were intrigued by building little planes with balsa and glue. These days, I doubt if you would get such a significant show of hands in a classroom, but still I would guess that most electronics engineers now older than 40 once had a hobby of building model planes. So, that's some of our "roots," our common heritage, and we wouldn't have known it if this guy had not asked the question.

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

Later, there was a panel session on the topic, "What do you look for when you are interviewing a person for a technician's job?" I observed that I looked for a technician or young engineer that could handle a tricky problem of a type that he (or she) has never seen before. I think that's more important than to ask a problem of a fundamental type that all students should be able to handle well. I like to ask obscure questions. I like to see what they say when challenged with a question of a sort they have never heard before. I like to hear the gears clashing and grinding inside their heads....

Then another panelist got up to propose that if he is deciding to hire a new engineer or technician, he looks for their ability to do critical thinking, because Title 5 of the California Education Code calls for all college students to be subjected to courses in Critical Thinking. Boy, did I perk up my ears! What *is* this Critical Thinking? In the simplest sense, Critical Thinking consists of teaching students to be thoughtful and reasoning and to question what they are learning. Does it do any harm to memorize that Napoleon was defeated at Waterloo in 1815? It might seem to do no harm. *But*, in every student's schedule, there is only a limited amount of time. If you waste all of your time learning diddly facts like that, you will not learn *why* things are important. *Why* did Napoleon get beaten at Waterloo? *Why* do we measure the CMRR of an op amp the way we do? If a big expensive tester says an op amp has a gain of 88 dB and we measure 112 dB on the bench, the expensive tester must be correct, right? Oh, but not necessarily so. If my boss asks me to take some data, but I detect a pattern that indicates something is broken–what do I do if my boss isn't around to give me advice? When you think of it, a large amount of your learning is involved in figuring out what makes sense, and what to do when you come up against contradictions.

When I am hiring a technician or an engineer, I am really interested in hiring a person who has good judgment, and is not afraid to question his data, or the machine that's taking the data, or even to question *me* if I ask him to do something that really has an error built into it. One of my readers recently sent me some notes about the Responsibility of the Experimentalist: [1]

"When doing an experiment, it is important for the experimentalist not to accept the data as correct without adequately questioning it:

1. If the data are semi-automatically recorded, then examine the "raw" data closely to determine whether the equipment malfunctioned.

2. After recording the data in your notebook, examine the numbers for observational mistakes. Examination of the numbers may also reveal an equipment malfunction that was not previously detected.

3. Before making use of the techniques for propagating errors through the various intermediate steps and into the final result, use *common sense* and ask yourself whether a given experimental result or error is reasonable. If it's not, there's an excellent chance that either the equipment malfunctioned or you made an arithmetic or observational mistake (note the distinction between *mistake* and *error*). A standard sample or a standard test signal may often be available for the experiment or instrumentation to give a known result. You're urged to devise tests of this sort in order to avoid this kind of mistake."

So, when you take data, or when you run tests, keep aware of how things make sense, and flag it if things don't make sense. As Tom Milligan, one of my old production test managers used to tell his test technicians, "If it looks funny, Record Amount of Funny." We call that "Milligan's Law," in his honor.

Now, getting back more specifically into Critical Thinking, I found a very good book with that title written by Dr. Richard Paul. Its subtitle read "What every person needs to survive in a rapidly changing world". I went out and bought the book, and it makes good reading.[2] In addition, the people at the Foundation for Critical Thinking sent me a nice brochure about their 11th Annual International Conference on Critical Thinking coming August 4-7, 1991 at Sonoma State University.[3] The brochure said "A critical education...appeals to reason and evidence. Students should not approach their classes as so many unconnected fields, each with a mass of information to be blindly memorized, but rather as organized systems for thinking clearly, accurately, and precisely about interconnected domains of human life and experience."

The converse may well be expressed as, "School is going fine...but I'm too busy cramming content into my skull to think about what I read, let alone develop an intelligent view. When do I get to think for myself? Am I condemned to be a memory bank of meaningless words?" Well, I should hope not. The education that I get, that my children get, that my technicians and engineers get, had better consist of a *lot* of Critical Thinking.

Recently Helen Cage, a furnace operator in National's Arlington, Texas plant, was running a special new low-temperature-oxide process. She was reading in the log books that previous operators had been logging in numbers for phosphine flow. She was surprised because she knew this operation did not require phosphine. She contacted Engineering, who investigated and concluded that the phosphine notation must have been some kind of incorrect entry. The next day, Helen was watching the gas-flow indicators on the next run–and the phosphine was flowing. She contacted Engineering again, and insisted that they find out why the phosphine was flowing when it was required to be off. When they searched a little harder, they found some kind of computer error–phosphine was being turned on for all processes, whether they needed it or not. Helen Cage, by refusing to take *Yes* for an answer, was a hero, because she didn't believe she should just follow instructions without thinking. Now, that's good Critical Thinking. I don't know where Ms. Cage went to school, but she's the kind of person I want on my team!

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

[1] From the book, *The Art of Experimental Physics*, by Daryl W. Preston and Eric Dietz, John Wiley and Sons, NY.
[2] *Critical Thinking* by Richard Paul; available for $19.95 from the Foundation for Critical Thinking, see below.
[3] Foundation for Critical Thinking, 4655 Sonoma Mountain Road, Santa Rosa, CA 95404; (707) 546-4926.

What's All This Splicing Stuff, Anyhow (Part II)

Right now, my soldering iron is hot–about as hot as it ever gets. It's a little 37-W iron, standard hobby-grade, with a 3/16-in. wide tip. I have two lengths of #12 stranded wire, so I will attempt to make a soldered splice...

Yes, I could–just barely. With no heat to spare, I was able to get a good sweated joint. If I had wire any heavier than that, I'd need at least 2 little irons, or preferably, a big iron or solder gun. But so many people have written in after reading my previous column about splicing (see ELECTRONIC DESIGN, Dec. 27, 1990, p. 72), that I just had to do a Sanity Check.

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

Several people said, "If you had a bad splice, with corrosion or poor crimping, after a while you might get audible nonlinearity and distortion from the poor connection." But the Newspaper Expert did not say, "A bad splice may hamper the sound quality," he said "a splice...."

Now, it's true that I never said explicitly, "a good splice" or "a soldered splice," but obviously it's only fair to assume that a decent splice is what we're talking about (there's no point in making any splice unless it would be a good splice).

One reader commented, "You may start out with a good splice, which becomes bad over time." I replied that, by definition, if a splice is good, it will stay good; if it goes bad, then it wasn't very good. There are lots of soldered connections in my world, both at home and at work, and I really must say that very, very few of them go bad in any given year.

Now, it's also true that in a car where there's heat, vibration, and moisture, it's not always easy to ensure a splice with good reliability over many years. So let's not say that, under extenuating circumstances, *no* splice ever goes bad. If my back porch looked out over the Pacific Ocean, the possibility of losing a speaker-cable splice every few years due to salt spray and corrosion is not negligible. But again, that's a special case.

Some people say that for the *best* splice, you should use silver solder. Maybe it would "sound better" to some people (I doubt they could tell any difference in a double-blind test), but I am very dubious. I have done some silver soldering and you need a hot torch, and if you're not an expert, it's not that easy to make a silver-soldered joint, with the borax flux and all. Besides, with the wire that hot, I would expect the wire adjacent to the soldered area to get badly oxidized and corroded, and the insulation to be badly over-heated, too. I think silver soldering is a *lousy* idea.

The other way to make a splice is with a mechanical clamp. The wire-nuts in my house wiring are quite reliable, and some of them carry more amperes in a day than my speaker cables do in a month. I don't plan to snip out an old wire-nut and check it for low resistance and low nonlinearity, but I suspect they would perform well because the whole idea of a reliable connection is the gas-tight crimp, where no corrosion can sneak in between the two pieces of metal.

If you want to argue oxygen-free copper, go right ahead. I'm not going to tell you what kind of wire to use, or what not to use. I'm just saying that you can, in almost every case, make a splice in it.

Now, it's true that you might have such a big conductor that you can't solder it or get a crimp fitting around it. If you had to bolt it, it might look *really funny* to see a lump the size of your fist under the sofa. But, hey, you really want big wires, you can have big wires.

It's conceivable that some of the ultra-high-tech wires are made with such sophisticated technology that when you buy them, the Owner's Manual tells you that soldering or splicing is impossible. But I wouldn't know about that. When I buy 14-gauge wire, it doesn't come with any Owner's Manual, but I know darned well I can solder it. With a big, *hot* soldering iron.

Recently, a reader pointed out that you can buy some splicing kits from 3M, such as Type U1R, which is recommended for general butt splicing. The little subassembly is "filled with a sealant to protect the connection against moisture." You can find this in any Newark catalog. Unfortunately, it's only specified for AWG 19-24, so most speaker cables would not find that a good match.

And when I called up 3M, they did not have any particular literature or documentation available to show exactly what reliability advantage is gained, or, under what environmental conditions you get the biggest improvement in reliability. I tried to invoke a "need to know," but they weren't prepared to show an engineer or customer any documentation. Maybe if you sound like a big customer, they might pay attention.

The March 28, 1991 issue of Electronic Design carried a neat article by Randy J. Kempf (Molex Inc., Lisle IL, 708-969-4550) about "How To Recognize a Good Conductor Crimp." He points out various procedures for mak-

PEASE PORRIDGE

ing sure that your crimping tool can do a reliable job. Even a 0.125-inch diameter brass pin can reliably carry 20 A–but that's not quite the normal connector for speaker cables. Still, Mr. Kempf has some good guidelines for determining if you're making good crimped connections to your wire.

And the IEEE Transactions on Components, Hybrids, and Manufacturing Technology (Vol. 14, March 1991, p. 214-217) discusses the technique for drawing a constant 20-mA dc "Sealing Current" through telephone circuits. Mr. Rudolf Schubert of Bellcore, Red Bank, N.J., discusses various test procedures and current biases to try to prevent a degradation of resistance in wire splices with poor mechanical integrity. The paper arrives at the general conclusion that if your wires are just loosely twisted together, and you want to prevent the series resistance from rising as high as 1 Ω, a 20-mA bias current is inadequate, and a current as high as several amperes may be required. Hey, it was still worth a try.

Personally, I think Fred Davis (of Hamden, Conn.), who wrote me after reading my original splicing column, has one of the best speaker-cable ideas. He uses multiconductor ribbon cable. Fred solders up every other conductor as *hot*, and then every other conductor as *ground*, all appropriately paralleled to get very low inductance, moderately low resistance, and very low phase shift. You don't have to use 00 gauge wire just to get good results; in fact, the fatter the wire, the more problems you have...the ratio of inductance to resistance tends to get *worse*, not *better*. I just wanted to point out, it really is *not* that hard to make a GOOD, RELIABLE splice. There are more ways than two to make a good splice.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Widlar Stuff, Anyhow?

When we got the word that Bob Widlar had passed away on February 27 at the young age of 53 (heck, I'll be up there in a couple years, if I'm lucky....), we all began to bring out stories about things Widlar had done. There are *lots* of good Widlar stories, and many of them have been printed recently. I will just try to tell here the ones that nobody else has told.

First of all, Widlar did *not* bring in a *goat* to chew down the unmowed lawns at National (when the pay to the gardeners was cut back). That would be absurd. Widlar would not do that. What he brought in was a *sheep*. I can prove it, because Fran Hoffart showed me a picture of the sheep. Widlar brought the sheep in the back seat of his Mercedes-Benz convertible. *That* would be nice to document with a photo, but Fran didn't get a photo of the sheep's arrival. However, Bob Dobkin told me that he drove up with Widlar and the sheep, after Widlar bought the sheep in Morgan Hill for \$60. Dobkin said that after the sheep was tied up to a tree in front of National's headquarters, the news photographers only took 20 minutes to show up. At the end of the day, Widlar went over to a bar and took the sheep with him. He left the sheep with the bartender.

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

That leads to another story, about the time Bob made the gardeners unhappy. Nobody remembers exactly what he did to make them so unhappy, but it must have been pretty good. One person said maybe that was the time Widlar could not find a good parking place, so he parked his convertible on the lawn–repeatedly. The gardeners retaliated by letting a sprinkler run into that area, and when he came out to go home, the car had several inches of water in it. Did Widlar retaliate after that? Nobody remembers, but even Widlar knew that sometimes, it's time to quit when you are overmatched.

Charlie Sporck, (who has just retired as the president of National) told me about the first time he met Bob. He was in a hospitality suite of the IEEE in New York City back in 1966. He was reading in Electronic News that Raytheon had just brought out an RM709 as a second source to the Fairchild μA709. Bob, who was not pleased at being second sourced, came over and, uttering a generalized profanity, set fire to the newspaper. Charlie was astonished, and threw it into a metal wastebasket. Unfortunately the fire did not go out. As they tried to extinguish the fire, the smoke alarms went off and the fire department arrived. So much for first impressions...

When I first came out to National in February of 1976, I was in a good mood, and I set about my new work whistling cheerfully–until Widlar came by. Bob reminded me that my whistling was bothering people. In fact, my whistling was annoying *him*. He came by about six times that day to remind me, and each time I assured him I was *trying* to stop whistling as well as I could, but the music (Mendelssohn's organ sonatas) was really circling around gloriously inside my head, trying to get out. He was as good-natured as he could be, and I finally broke the habit–after about a week of reminders.

There were just certain kinds of annoying sounds that he felt he didn't have to put up with, and to a large extent he was fair about that. Hacksawing large pieces of metal? Take it outside. Drilling many holes in a chassis? Wait till everybody went to lunch. Print out a huge print-out on the new line printer? Well, if Widlar could not get this noise delayed until "lunch time," Widlar would just go out to lunch with Dobkin or Mineo or both, right then. Whether it was 10 A.M. or 3 P.M., Widlar didn't need much aggravation to convince him it was "lunch time." Some days, he did indeed drink a lot of lunch. But that didn't prevent Bob from getting lots of good ideas done. It may have helped.

We still have a sign around our lab, "This is not a blacksmith shop." But there were times when Bob would discover he had wasted a day or two, just because one bad part had screwed up his circuit. He would bring this bad part–a capacitor, a pot, a transistor, an IC, or whatever–over to the vise and lay it on the anvil part. Then he would calmly, methodically beat it with a hammer until the smallest remaining part was indistinguishable from the dust on the floor. Then he would go back to work and get the right answer. He explained that it makes you feel much better if you do this, *and*, you know that bad part will never come around again and goof you up. He was right, and I recommend that you join me in doing this "Widlarizing" when a bad component fools you. You *will* feel a lot better.

One time Bob was standing up on a lab stool in the hall outside his office, taping a large firecracker to the paging system loudspeaker, when Pierre Lamond happened by. Pierre was the vice president in charge of R&D, and Bob loved to give him a hard time. Pierre asked, "What are you doing, Bob?" Bob replied, "I am going to blow out these damn speakers." Pierre used all of his Gallic aplomb and replied, "Oh," and turned and walked back out the door. Widlar lit off the fuse and hopped down. Then an M-84's blast ripped the cone out of the speaker. Bob had to repeat the blast to get the paging system to stop making noises in his lab. And poor Pierre must have been under great stress to realize Bob was setting such a bad example, but Pierre could not let on that it was bothering him.

So, Widlar was not averse to fighting noise with noise. One of the celebrated things Widlar did was to put a "hassler" in his office. When a person came in to his office and spoke loudly, this circuit would detect the audio, convert the audio to a very high audio frequency, and play back this converted sound. The louder you talked, the lower the pitch would come down into the audio spectrum, and the louder it would play. So if you really hollered, it would make sort of a ringing in your ears. Of course, if you noticed this "ringing" in your ears, and stopped for a while to listen, the "hassler" circuit would shut up. He gradually got people to stop yelling at him. I mean, Bob really was almost always a soft-spoken person. He didn't have to yell or shout to get his message across. When he did speak, and softly at that, people would soon realize that it was a good idea to listen to him.

One night Bob left the "hassler" on. The next morning, his secretary tried to do some typing, and every time she hit a key, the "hassler" would chirp. It drove her nuts until Widlar came in and turned it off.

One thing that would have made Bob gripe was to see "consultant" in his obituaries. Bob never failed to point out that he was NOT a consultant. Consultants get paid for showing up. Bob was a contractor, and contractors get paid for making things that *work*. Bob *did* get paid because his circuits *did* work. Of course, sometimes it took several masksets, and several years, because Bob was doing tasks that weren't easy.

Let me correct another error in the obituaries. The first story we heard was that Bob died while jogging on the beach, a story that got into all of the papers. Actually, he had been running up on a high ridge, and was apparently descending a steep trail down from this ridge when the heart attack hit him, and he fell in a dive and died. Not just an easy jog along the beach. Bob was, in recent years, pretty much into fitness, and he worked hard at his running. Recently, he had apparently cut down a lot on his drinking, too. Maybe the alcohol had chased away the coronaries, and the lack of alcohol contributed to the heart attack? I'm no doctor. But he did not die drunk, which may have amazed a number of his colleagues.

One time Bob was out drinking beer with his friends and he told his friend Ken Craft that he could drink a mug of beer faster than Craft could throw a mug of beer over his shoulder. At the word GO, Ken flung his beer over his shoulder in about one second flat. Widler just stood there and smiled, and then slowly raised his mug to his lips, saying, "you win."

What technical things did Bob accomplish? Well, in addition to the op amps and the bandgap references, Bob also brought out the industry's first high-power voltage regulator, the LM109. A couple of people reminded me that in the fall of 1967, there had been a big controversy about whether it would be possible for anybody to build a high-power regulator on one monolithic chip. There were little letters to the editor in several magazines, pro and con. Finally, Widlar settled the argument by writing an authoritative-sounding letter. It pointed out that the thermal gradients on a chip would make it impossible to make a high-power chip with good performance, and the features would be impossible, and the reliability would be impossible. That settled the argument. Everybody shut up, because obviously Widlar knew what he was talking about. Then two months later, Widlar introduced the 20-W LM109, and it included all those features that Widlar had said were impossible. All of the IC engineers realized Widlar had taken them for a ride, and that he had the last laugh. What a master of the art of playing games!

When the first LM109s were ready for testing, Widlar designed a tester, and Ken Craft built it up. Widlar came over to try it out. He griped, "It works OK, but the START pushbutton is on the left side, and it ought to be on the right side." The next day, Widlar came by the box and there was a big arrow, "PUSH to test," pointing at a blank area on the right side of the top of the box. Widlar, being a curious sort, decided to PUSH where it was indicated. Immediately the test sequence began and cycled through, with a green light going on. What the heck?? There was no pushbutton there, *but* every time Widlar pushed that spot on the panel, the test sequence occurred. Ken had cut away the copper foil at that place and installed a sensitive light-detector under the epoxy pc-board material. When you put your finger on that spot and blocked off the light, it would trigger the tester as a conventional pushbutton would do. Widlar was pleased that his guys would come up with a sneaky, ingenious scheme like that.

What other technical things did Widlar do? Even to the end of his career, Bob eschewed Spice and similar computer simulations. He preferred to use breadboards, all sorts of breadboards, and also "the Mexican computer." Namely, he used Teledeltos paper to make resistive analogues and simulate the two-dimensional flow of current. How many of you guys have used it? I recall we used it in school, 32 years ago, and I still use it every other year. You sketch the shape of your resistive pattern onto this resistive paper, at about 400 Ω per square (give or take 4 or 5 dB). You cut out the outlines, and paint on silver conductive paint at the border where current comes and goes. Then, after the paint dries, you shove in some currents and read the voltages and see if the ratios seem right. If not, it's cut-and-paste time again. Bob used this technique a lot to get some measure of how currents would flow. I don't think he ever actually *did* any of this work in Mexico, but I guess he could have if he had to. He never did any breadboarding or measuring down in Mexico; he would write in his notebooks and decide what circuits to try, and then come up to Santa Clara and try them. He kept very neat notebooks, and he also wrote neat script when it came to writing technical papers–some day I intend to show that George Philbrick's penmanship and Widlar's

PEASE PORRIDGE

were uncannily similar.

Of course, the stories about Widlar in a light mood were almost as bizarre as they were true. He would sometimes go to the airport, walk up to a ticket counter, and ask the clerk, "What time does your next plane leave?" The clerk would mention the time and the destination. "Our next departure is at 5:20 P.M., flight 772 to Vancouver." Then Widlar would haul out his wallet and peel off some bills and buy a round-trip ticket to this random place from the astonished clerk. In a few days, Widlar would return from his surprise vacation.

Sometimes, Widlar took one of his secretaries and picked her up by the ankles and lowered her head into a fountain. She seemed to like it. (Jim Dunkley told me this. He said her name was Nancy....)

I gave a paper at a conference in March of 1970 in Paris. Widlar also gave a paper. I recall that at the end of lunch, Widlar made sure that he got a full bottle of wine to bring back with him into the conference hall, in addition to the wine he had enjoyed with his lunch. When it was time for Bob to give his talk, he had knocked the level of the wine bottle down quite low. He always said he didn't find it easy to give a big lecture, unless he had some tranquilizer in his stomach. At this conference, Bob was well tranquilized, and he was giving a good lecture about his new circuits. But the translator (English into French) was having difficulty keeping up with all of the obscure technical phrases that Widlar was tossing off so easily and rapidly. A couple times, the translator begged somebody to get Widlar to slow down. But nobody could slow him down. Finally, the translator gave an anguished cry of distress and walked out. Bob just kept on explaining his circuits, without slowing down or speeding up. Afterwards, when conference chairman Jerry Eimbinder told Widlar he would have to speak more slowly the next time, Widlar responded, "The next time I talk here, you'd better get better interpreters..."

A year ago, Jim Williams was compiling the book "Analog Circuit Design: Art, Science and Personalities".[1] I asked Widlar if he would like to write a chapter or two. Bob gave a shrug of disinterest and kept on with what he was doing. I asked if he would like to just talk into a tape recorder and we could get it typed. No, not interested. I asked, well, surely there must be a story that ought to be told, shouldn't you tell it? He explained, with weary patience, that he really had no interest in telling any such stories. I knew better than to try to argue with a guy who obviously knew what he didn't want to do. Maybe I should have invented a trick–taken a tape recorder down to a bar and let the tape run? Obviously, if you can predict when you're going to lose a legend like Widlar, you would resort to a trick like that. But, we just saved all of the good stories we could...and the ones printed here are less than half of the good printable ones, not to mention all of the ones that could never be printed...

Obviously, there will never be another engineer like Widlar. He led the linear IC industry in many amazing new directions. I think every circuit designer has looked at one of Widlar's new circuits and said, "Good heavens. You can do *that*? If that works the way he says it does, then I could use some of these ideas to improve *my* circuits...." I found several places where I could correct or improve some of Bob's applications circuits, where he added resistors and capacitors around the IC. But I never found places to improve his ICs. This fall there will be a technical paper published in the IEEE Journal of Solid State Circuits, on the topic of substrate current flow in ICs. And everybody will read it and say, "But, of course he's right. Why didn't I think of that myself, first?" I'm not sure if Bob Widlar ever designed an obvious circuit in his life.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

[1]Published June 1991 by Butterworth-Heinemann, Stoneham, Mass.

What's All This Multiplication Stuff, Anyhow?

Several months ago, I got a strange call from a "customer" (I get a lot of strange phone calls). He said he needed a multiplier circuit to do some simple multiplying, such as 5 V X 8 V, and he needed 0.02% precision. He said he had already talked to several companies that make multipliers, and they didn't have any circuits with precision nearly that good. Then he asked if we had any ideas. I gathered that he was kind of desperate, and that he had called us *even though* he knew that National doesn't make any multipliers.

I asked, "Oh, what is the range of each of your signals?" He said, "Oh, one input goes from 5 V to 9 V, and the other input goes from 4 volts to 8 volts." I replied, well, if you want 0.02% accuracy, that's a piece of cake. I could hear his jaw dropping. "How do you plan to do that?" Ah, I replied, it's really quite easy. Your dynamic range is narrow enough, so we can do an expanded-scale amplification of your signals and feed them into a decent multiplier. Then take the output voltage from the multiplier and combine it with some constant offsets and some linear-gain signals, and add them all up with some precision resistors, and there's your output.

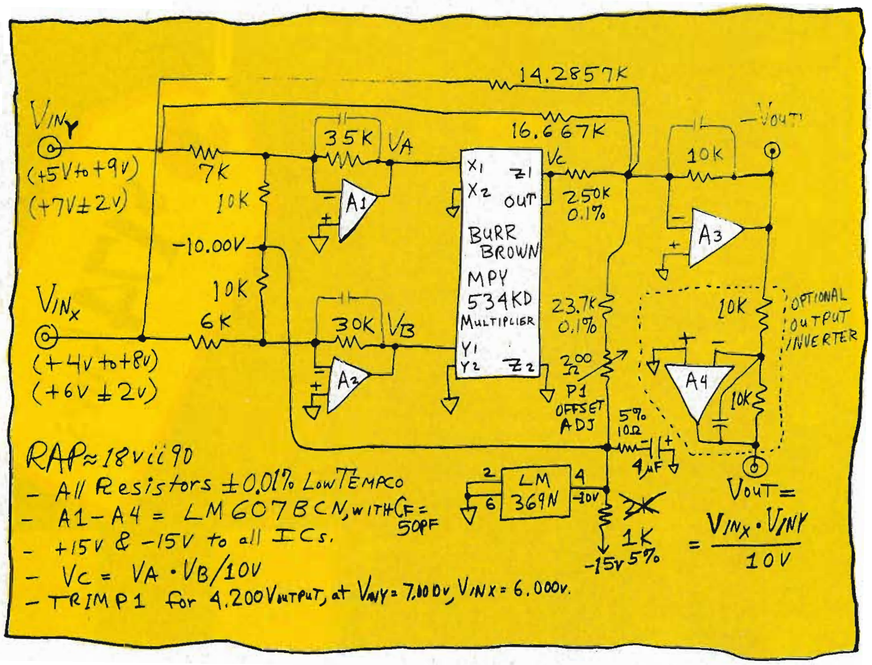
BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

He said, "Precision resistors–aren't they the ones that cost $10 each?" I said, "Heavens no, a couple bucks gets you some good ones." So the first thing I sent him was a description of how easy it is to buy precision wire-wound resistors (copy available on request with a SASE). I explained that the delivery can be quite good, because there are several competing companies (some of them are right down the road from each other, in southern New Hampshire) that can sell you resistors with excellent accuracy, 0.01% or better, and at reasonable prices. Delivery is also excellent, if you want to pay a little surcharge for that. When I need good resistors, I usually look in the EEM or the Gold Book, and shop around at two or three of the vendors to do a sanity check and make sure I have not over-specified or under-specified the resistors I need. I sent him a copy of that page in the EEM, "Precision Wire-wound resistors," so he had his choice of a dozen good suppliers.

Then I sent him a schematic similar to the one adjacent. I told him I've done something like this before, and you can't go wrong.

I never heard from him again. So I like to think that it worked okay for him. Then, as I began thinking of good topics and good ideas to write a column about, I remembered this problem. I fished a couple inches down in the file of papers on my desk and dug up the problem and the solution. Now, I had told this guy, "This is a guaranteed design. No problem." But, I'm not going to feed *you* any paper designs that have not been built and tested. I dropped by Haltek in Mountain View and bought a few of the resistors that I needed. Then I gave the whole batch to my technician and told him that it had to work. I said to come back when the output error is less than 2 mV.

Note, I don't usually tell my technicians that, because I'm perfectly capable of making mistakes, *every* kind of mistake. I usually tell the tech, "Leave extra room in case we have to change some things in the input area..." or whatever. But in this case, I just told him to leave the leads of the resistors at full length, as a sort of a strain-relief loop, so when they're soldered, it doesn't



PEASE PORRIDGE

heat up the body of the resistor.

How does this circuit work? It works beautifully (no, that's not what I meant). It works by taking advantage of the full dynamic range of the multiplier. If you merely feed in a signal in the range of (+5 V to +9 V) to the terminals of the multiplier, you're using only 1/5 of the usable range or span of the multiplier. So, let's take the signal input, subtract 7 V, and amplify it by a gain of -5. *That* signal, which we feed to the input of the multiplier, now has a range of ± 10 volts. Therefore, we're exercising the multiplier over its entire rated operating range. We do likewise for the other input. Now to get the signal at the output of the multiplier combined into the output, a gain of 1/25 is needed. The *errors* of the multiplier are also attenuated by this factor of 25–that's the key to getting the accuracy you want. Most of the signal goes through the linear gain stages, and only a little of the output comes through the multiplier.

A reasonably-priced ($40) multiplier, such as Burr Brown's 534KD (see, I told you National doesn't make any multipliers) with an accuracy spec of 0.5%, can provide a performance of 0.02% in this circuit. Now, the amplifiers are pretty inexpensive (National's LM607BN with $V_{OS} \leq 60\ \mu V$ is barely $1.20) and the 13 precision resistors are going to cost you about $30. But, they get you to a place you could not get to otherwise.

– What do we want from our MULTIPLIER?

– We want $V_{OUT} = \frac{V_{INX} \cdot V_{INY}}{10V} \pm 0.02\%$

but only in a limited range, $4V \leq V_{INX} \leq 8V$ and $5V \leq V_{INY} \leq 9V$.

– Let's define new VARIABLES:

– Let $(-V_A) = (V_{INY} - 7V) \cdot 5$
Let $(-V_B) = (V_{INX} - 6V) \cdot 5$ } and then multiply $V_A \cdot V_B$.

Then $V_C = \frac{(-V_A)(-V_B)}{10V} = \frac{V_A \cdot V_B}{10V} = \frac{25(V_{INX} - 6V)(V_{INY} - 7V)}{10V}$

So $\left[\frac{V_A \cdot V_B}{10V \cdot 25}\right] = \left(\frac{V_{INX} \cdot V_{INY}}{10V}\right) - \frac{6V}{10V} V_{INY} - \frac{7V \cdot V_{INX}}{10V} + \frac{42V^2}{10V}$

REARRANGING –

$\left(\frac{V_{INX} \cdot V_{INY}}{10V}\right) = \left(\frac{V_A \cdot V_B}{10V \cdot 25}\right) + 0.6 V_{INY} + 0.7 V_{INX} - 4.2V$

– So all we have to do is generate V_A & V_B, feed them to a multiplier, and take a summation:

$V_{OUT} = \left(\frac{V_{INX} \cdot V_{INY}}{10V}\right) = \frac{V_C}{25} + 0.6 V_{INY} + 0.7 V_{INX} - 4.2V$.

That is easy to do –

A3 sums all those voltages with the required gains – the gain from V_C to V_{out} is $\frac{1}{25}$;

– the gain from V_{INY} to V_{OUT} is $\frac{6}{10}$;

– the gain from V_{INX} to V_{OUT} is $\frac{7}{10}$;

– and the 23.7K adds in a 4.2 VOLT offset, which is trimmed for best accuracy:

When $V_{INY} = 7.000V$,
$V_{INX} = 6.000V$,
$V_A \cong V_B \cong V_C \cong 0$

so just trim V_{OUT} to 4.200V using offset ADJUST P1.

A4 lets you have an inverted POLARITY.

RAP 2 iii 91

Paul built up the circuit, and tested it at several values of V_{IN}. I must admit, he had to change one resistor value–I provided a 2k resistor to feed the LM369, and Paul figured out quickly that it should be 1k to provide 5 mA. The -10-V bus refused to regulate because the loads on that node drew more than the 2.5 mA I was providing through the 2k.

Referring to the box of data, you can see that the worst output error was about 0.7 mV or 0.007%, about 9 times better than the accuracy of the multiplier used by itself. It's always nice to know that when you tell a guy, "This circuit can't go wrong," it really does work the way you said it would.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

P.S. I was talking about this circuit with some friends, and they agreed you could do this with digital multipliers, but that would not be cheap nor easy, either. But then I countered, how about one ADC and an MDAC? (multiplying DAC)–those things can be inexpensive and quite accurate. I'll build one of those and see if it's worth writing about.

Thu, Oct 11, 1990 3:24 PM

Vin Y	Vin X	Vout	Column 5	Verror
5.0000	4.0000	-1.999399	-2.000000	0.000601
6.0000	4.0000	-2.399693	-2.400000	0.000307
7.0000	4.0000	-2.799666	-2.800000	0.000334
8.0000	4.0000	-3.199520	-3.200000	0.000480
9.0000	4.0000	-3.599620	-3.600000	0.000380
5.0000	5.0000	-2.499626	-2.500000	0.000374
6.0000	5.0000	-2.999929	-3.000000	0.000071
7.0000	5.0000	-3.499720	-3.500000	0.000280
8.0000	5.0000	-3.999440	-4.000000	0.000560
9.0000	5.0000	-4.499300	-4.500000	0.000700
5.0000	6.0000	-2.999830	-3.000000	0.000170
6.0000	6.0000	-3.600000	-3.600000	0.000000
7.0000	6.0000	-4.199930	-4.200000	0.000070
8.0000	6.0000	-4.799750	-4.800000	0.000250
9.0000	6.0000	-5.399350	-5.400000	0.000650
5.0000	7.0000	-3.500170	-3.500000	-0.000170
6.0000	7.0000	-4.200100	-4.200000	-0.000100
7.0000	7.0000	-4.900130	-4.900000	-0.000130
8.0000	7.0000	-5.600000	-5.600000	0.000000
9.0000	7.0000	-6.299500	-6.300000	0.000500
5.0000	8.0000	-4.000470	-4.000000	-0.000470
6.0000	8.0000	-4.800290	-4.800000	-0.000290
7.0000	8.0000	-5.600360	-5.600000	-0.000360
8.0000	8.0000	-6.400360	-6.400000	-0.000360
9.0000	8.0000	-7.200230	-7.200000	-0.000230

Ideal Output V

PEASE PORRIDGE

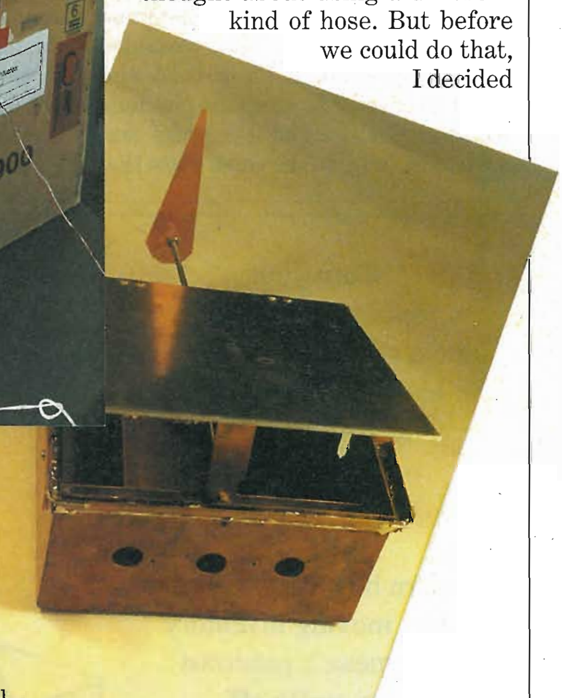
What's All This Box Stuff, Anyhow?

There are many things I do with cardboard boxes. I stow papers in some of the nice boxes we get our Xerox paper in, and we stow circuits and parts in other boxes. And when people complain that our printers are running too loud, we glue some foam rubber inside a big box and clap it over the printer. That usually makes 13 to 18 dB of improvement. The complaints are hushed, along with the printer noise.

But that's not the box I want to talk about today. I want to talk about the big (5 cubic-feet of volume) cardboard box with the Calibration Stickers on it. Most days, this box sits up on top of a tall cabinet, but about once a month we pull it down and put it to work.

About 5 years ago, we introduced a new temperature sensor IC, the LM34. It comes in a small TO-46 hermetic transistor package, and also in TO-92 plastic. And we had the production parts meeting an accuracy spec of ± 1° F, on a decent fraction of production. But how do you test a temperature sensor? And, how do you calibrate the tester? You calibrate a voltage detector by putting the same voltage into two units and making sure that you get the same answer from them. So, with a temp sensor, you have to put two (or more) parts in the same temperature environment and make sure they all give the right answer. In our case, we had several kinds of temp sensors, with a precision platinum RTD (Resistance Temperature Detector) as our primary calibration standard. It cost about $800 15 years ago, and I shudder at today's replacement cost.

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



So we put a little centrifugal blower to blow air through a piece of corrugated plastic hose and over some of the ICs and also over one or more of our precision calibrated platinum thermometers. We set up two sockets side-by-side so we could put in two units and cross-compare them with quicker response, because devices in the same package will have about the same time-constant.

After a few days, one of the technicians was trying to take some precise data in order to give them to other engineers as "Golden Units." The technician griped that he was getting inconsistent results–and they seemed to be related to when the parts were not shoved all the way down in the socket. Well, the I x R drop could change a little–but this part only drew 55 *microamperes*, and the IR drop could only be 100 nanovolts, whereas we were seeing 300 microvolts–equivalent to 0.03 degrees, for less than an eighth of an inch of movement.

We finally set up some parts with long leads, eschewing the socket, and moved the device under test around in the airstream. We found that there were temperature *gradients* in the air flow coming out of the tube. We tried a longer hose, but that did not make the gradients much better. We thought about using a different kind of hose. But before we could do that, I decided to try a big box for the air to stir around in, to circulate and mix and swirl. Then, after a while, the air poured out onto the DUT's sockets. When we looked for gradients, they were gone, at the level of 0.003°F. So we taped the whole thing together securely. But one day we saw somebody trying to take some cardboard boxes away to make the lab look neater. We realized we had to make sure *our* box would be recognized as valuable. So we made up a big Calibration Sticker and slapped one on all four sides.

Now, we could have had a stirred oil bath, but that's messy and bulky, and the settling time isn't really much faster than moving air. And when you can use a big leftover cardboard box, the price is right, and it's more fun, too.

Could we have perhaps used a somewhat *smaller* cardboard box? Maybe, but we would have to do a calibration on it, and that wouldn't be worth the effort.

Now, around room temperature, this cardboard box is fine, but at hot and cold temperatures, we normally use a little oven. But everybody knows there are terrible gradients when you run it at 125°C, or –55°, or even at room temp! So we put in a box to surround the DUTs. Small help. Then we added a metal plate (about 1/8-in.-thick aluminum) so we could strap the platinum thermometer (we had a compact one, about 8 in. long) to the same plate that the DUTs were set into. Still, there were errors. The hot air coming from the oven's duct would blow on one corner of the box and heat it worse than another side of the box. And the whole process was quite slow if you kept the box cover closed. If you want to guess how many hours of tests we ran to discover which parts really had what error at what temperature, it was *plenty*.

We finally boiled the testing problem down to two problems–we had to get a quick response when we changed the temperature, as if the box were open, and we had to get minimum gradients when we were near the final temperature. We solved the problems with a box in a box. The outside box had some small slits and baffles, so the oven's air could not blow directly on the inner box. Then we put a lever on the cover so we could open the cover to get fast response for 98% of the temperature change. After that, we turned the lever and closed the cover to get a nice slow settling

And all it took was a box inside a box, inside the oven. Could we have used cardboard for that? Well, in concept we could have, but it would get pretty flaky after just a few hours at 125°C, so of course we used copper-clad material, which was reasonably stable and easy to work with (the covers did keep warping a little bit, and we had to keep flattening them out). When the boxes were closed, the gradients between the metal plate, the 25 parts mounted in it, and the platinum sensor were really quite acceptable, <0.05°F.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Mathematics Stuff, Anyhow?

When I was at MIT, the math instructors had some famous problems. They were all about some mythical person called Little Egbert, and all of the interesting mathematical things that happened to him. I've been intending to find some more Little Egbert problems, and I even intended to ask some guys when I was at a class reunion this summer. But I guess I didn't ask the right people. Still, I remember one problem very well:

Little Egbert got a horn for Christmas, and the shape of the horn was a radius of r = (1/x) feet, from x = 1 to ∞. Egbert decided he wanted to paint his horn. (a) He decided to compute the area of the outside of the horn, so he would know how much paint to buy. Then, (b) he decided to compute the volume of the inside of the horn, so he would know how much paint to buy for that. What did Little Egbert decide?

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

If you do your integration, the first answer is the integral of 2 π (1/x) dx, from 1 to ∞. That's the natural log of x, and the natural log of ∞ is still ∞. So, (a) would take an infinite amount of paint.

But if you integrate to get the *volume* of the horn, that's the integral of pi $(1/x^2)$ dx, which works out to –π (1/x), evaluated at 1 and at ∞. That works out to barely 3.14 cubic feet of paint, or about 23-1/2 gallons—definitely a finite number for (b).

Hey, there's a neat paradox. Little Egbert can paint the inside of his horn—but he can't paint the outside. What's the math trying to tell us? Well, at any time, thinking is permitted (even if not required). If you had a horn with a diameter of even 1 micro-inch, or a thousandth of a micro-inch, you would still have to wrap two or three molecules of paint around this very thin shaft, to say that you had painted it. Then if the thin end of the horn goes on forever, an infinite amount of paint will be needed to try and cover it. Conversely, by the time the diameter of the horn gets down to a small fraction of 1 milli-inch, a molecule of paint will refuse to go any further down inside the very narrow passage. At this point, you know that only a finite amount of paint will be needed to fill it up. So, Little Egbert can paint the inside of his horn by filling it up, even though it would be impossible to paint the outside of the horn. You can philosophize about the math, or you can philosophize about the paint. Either way, the answer makes some sense.

When I was a freshman at MIT, I took the standard class—was it M21?—on Fourier analysis. I did all of the problems; I passed the tests. Then I went on to more classes in math and physics. Years later, when I was transferring into Electrical Engineering, the instructors showed you how to predict what would happen if you tried to shove a broadband signal into a wire or cable that did not have infinite bandwidth. How do you compute what kind of modified, filtered, attenuated signal comes out at the far end? Why, Fourier analysis tells you which components will be attenuated.

Well, I was astonished. You mean to tell me that Fourier analysis was *good for something*?? Why didn't they say so back in Freshman math? Nobody ever indicated that Fourier analysis was *useful*. As I got further and further into E.E., I found that a whole bunch of the mathematical techniques we had been taught were, indeed, actually good for something. These mathematical techniques had been invented to help solve a problem, and they were presented because they had the potential for being useful, even if they forgot to tell us students. So, math is a very useful science—the handmaiden of the sciences, as they used to say—and sure enough, math is still useful every day. Some people say, why learn math or geometry or calculus or algebra if it's something you will never need? Of course, in some parts of the world, you do need math every day. How will you know if you will need it if you never try it? If you have the aptitude, it may indeed turn out to be very useful.

Now, what's all this "math aptitude" stuff, anyhow? Well, I've taken a bunch of aptitude tests, and it won't surprise you to hear that I get high scores in several kinds of math aptitudes. I took tests with the Johnson O'Connor Research Foundation (with offices in 12 major cities)* and they found I'm good at Number Reasoning, Accounting Aptitude, Analytical Reasoning, Number Memory, and Structural Visualization. Now, when I took these tests, I already suspected I was good at these things, because I sure didn't get through MIT by being ultra-intelligent. I got through because I was good at taking tests, and at manipulating the data to get reasonable answers. I went to take the aptitude tests because I was curious why I was having so much fun taking tests, and the aptitude tests confirmed my suspicions. Not everybody has good math aptitudes. Only a small fraction of women have as good "Structural Visualization" scores as 1/4 of the men do. But the best women are just as good as the best men. Both of my sons have taken these aptitude tests, and both

PEASE PORRIDGE

score very high on Structural Visualization. But one son has low scores for other kinds of math aptitudes, which means he is great at geometry, but lousy at algebra and calculus (which we already knew...).

I still do lots of math in my head, or on a slip of paper. I rarely use my calculator—maybe once a week, and I use my slide rule about as often. For example, I used my slide rule to get the 23.5 gallons of paint. There's no point in knowing if it was 23.4875 or any other number, because there are still cases where "engineering accuracy" of a percent or so is quite adequate. The rest of the time, I just do the math in my head, or on paper. But I *do* use a *digital* calculator to do my taxes; I stopped using my slide rule for that. I figure it would be hard to explain a few bucks of round-off error to the IRS guys....

For example, the other day, a friend of mine wanted to know how big her old aquarium was, as she was draining it to transfer the fish to a new tank. I took a piece of graph paper and measured out the number of inches in each dimension. I did some quick-and-dirty multiplication, and then used long division to divide by 231, which is the number of cubic inches in a gallon. I told her about 30 gallons. Another guy got a foot ruler, and used his calculator to multiply the number of cubic feet by 62.4, to convert the cubic feet into pounds, and divided by 16, the number of pounds in a gallon. He got 16.18 gallons. My friend found this amusing, as she had already removed 18 gallons of water and had a good bit more to go. Of course, as we reconstructed the scene of the crime, we realized that there are about 8 pounds in a gallon, not 16, so the answer of 30 or 32 was indeed about right.

Still, when I interview a prospective engineer, I try to find out if he has any aptitude for math, and if he is rusty or on his toes. I wouldn't refuse to hire a guy who used a calculator to get the right answer, but it had better not slow him down. Math is a tool, and if we're prepared to use it with skill and ease, it leaves us more time to work on the serious aspects of our project. If a guy tells me he plans to double a resistor so he can get more current through it, it makes me suspicious because he's liable to waste a lot of time on wild-goose chases.

These days, Spice is supposed to help us on our circuit analysis, and when it does, that's nice. But many circuits don't need the full precision and power of Spice to give a suitable answer. Sometimes a good rule-of-thumb answer is just right. Then you can use that as a sanity check, to confirm that Spice is performing a reasonable computation, and that nobody mistyped anything.

When I was in the 7th grade, I got in some squabble with the math teacher. He "won" the argument. So he forced me to stay after class to memorize the square roots of all the digits from 1 to 10. What a horrible punishment!! It did take me a little time to get them memorized correctly—and to this day, they're awfully useful (with the exception of the square root of 7, which really does not get used once in a decade....). I mean, the square root of 2 and of 10 are used all the time in engineering. And the square root of 3 tells you about the side of a 30/60/90-degree triangle. And the square root of 5, about 2.236, is the voltage you see on your ac voltmeter when you add 1 V and 2 V of noise.

Come to think of it, I don't recall that he ever forced any other kids to memorize square roots. I remember a couple of kids who had good music aptitudes, and he set them the "punishment" of learning "Stella by Starlight," which he said was his favorite song. I bet they remember that, to this day, too!! I don't think I gave him much credit, at the time, for being a very bright fellow. But, maybe I ought to admit that Mr. Holmes was a pretty smart cookie, after all. Please, Bre'r Fox, don't throw me in the briar patch....

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*Call Johnson O'Connor Research Foundation, (415) 243-8074 for more information.

What's All This Copper-Clad Stuff, Anyhow?

The other day, one of our junior engineers told me enthusiastically, "I solved that oscillation problem on the new circuit. I just put down the probe on that sensitive node I suspected, and the oscillation went away." I said that's great, but how many picofarads do you think that is? He replied, "I don't know, how many?" I told him to measure it on the Impedance Bridge.

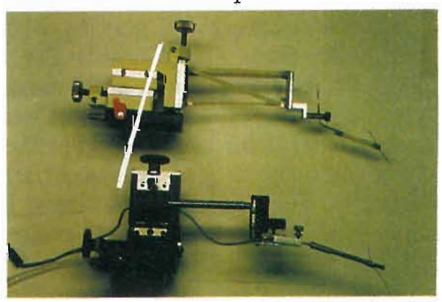
He came back in a few minutes, kind of glum, because the probe had 3.2 pF, and he knew he didn't have room to fit in that much capacitance on the chip, which was already rather crowded. I said, "Oh, don't feel bad, maybe it only needs less than 3 puffs. Try a probe with less capacitance." He went out and measured every kind of probe that we had ever bought, and they were all kind of gross, 2 or 3 or 4 puffs. I said, "No problem, try this prober with a new arm that we just made up." We fabricated the lever arm out of small strips of copper-clad, with insulation provided by peeling the copper off the glass-epoxy material. He went over and measured 0.22 pF. Then he dropped this probe tip on his circuit and it turned out that even 0.22 pF was enough to stop the oscillation. Because he had room to fit in that much capacitance, he was in pretty good shape.

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

The moral of this story has nothing to do with oscillations, but rather about copper-clad, printed-circuit-board material—glass-epoxy board material. Now, I sort of take this stuff for granted, but I realized that this rather magical stuff is extremely useful. Without it, we'd have lots of problems. I always wanted to write a story about copper-clad for Pop 'Tronics, or one of the other popular electronics magazines for hobbyists, but now that I think of it, this is a better place to write the story. I mean, we engineers can *bluff* a lot and pretend we know more than most technicians, but if we get to Crunch Time needing to produce a miracle, it's nice to know how to solve problems that even the smart technicians can't. And if we weren't aware of all the good things you can do with copper-clad, maybe we couldn't envision the kind of little fixture we will need to pull off that miracle. I'll try to list several examples of useful, valuable things you can do with it.

First, I'll mention that here around Silicon Valley, several places sell the board to hobbyists, over-the-counter, for about 1 cent per square inch. So, if you want to a make a 6-sided box about 4 in. x 4 in. x 4 in., that will cost you less than a buck—not too bad. Of course, we're talking about the conventional 1/16-in.-thick glass-epoxy material. If you shop around, though, you can get the 1/32 in. and the 1/8 in. and whatever else you need.

Next, I must admit that the tools and techniques for working with it aren't very obvious. If you try to cut up a slab of copper-clad with a saw, you'll probably dull the blade pretty fast. But heavy shears or tin-snips do quite well. Metal nibblers (I'm delighted to say they're available at every Radio Shack) are priceless. In our lab we have a big shear; it can cut precision lines across a big sheet. However, you may not need one of those.



These probe stages are commercially produced, but the upper probe tip has a capacitance of 0.3pF, 10x better than the store-bought one. Because it's easy to make truss structures out of copper-clad material, you can make an arm to any size and to any desired rigidity.

Thermal approaches are also valuable. A good hot iron (with a little solder to help the heat transfer) can easily remove a strip of copper, leaving some pretty high-grade insulator. In the first example, a strip of epoxy board 1/2 in. wide by 4 in. long, with a stripped area just 1/2 in. square, had only 0.2 pF. If we had *tried* to get low capacitance, we could have made the unclad area 1/4 in. wide by 1 in. long and then drilled holes in it, getting the capacitance down below 0.1 pF. Of course, before you peel off an area of foil, you need to cut with a good knife or saw to define the edges.

Then, of course, when you want to join two sheets together, you need a good hot soldering iron with a decent size of tip, 1/4 in. or bigger (those cute little ones with the skinny tip don't get the foil hot enough fast enough, which tends to cause delamination when you try to soak the heat in there). You can put little dabs of solder along a seam to make a mechanically strong joint. If you want to make something air-tight and water-tight, you need a good continuous bead of solder. It's possible, but a lot of work is required.

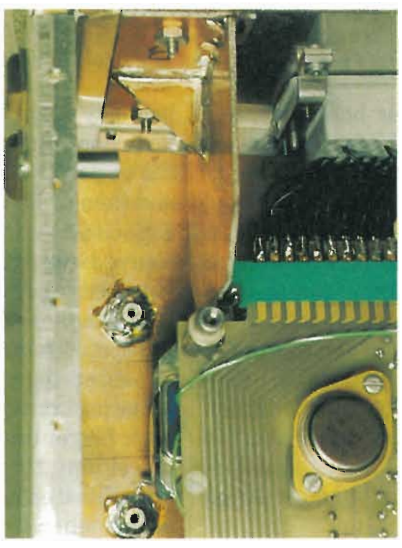
Okay—what can you make with copper-clad? You can make BOXES of just about any shape and size. Inherently,

PEASE PORRIDGE

these boxes give you good electrostatic shielding, which is an added bonus. Just remember that the copper gives you no magnetic shielding: If you put one of these boxes near a transformer, such as on a soldering iron, the magnetic flux at 60 and 120 Hz comes *booming* on in and can (temporarily) ruin a quiet breadboard. If you need shielding from magnetic flux, add some iron, or push the offending transformer away.

You can make any kind of boxes—square, L-shaped, multi-shielded with cute little compartments and walls, and holes in the walls, and feedthroughs, connectors, etc., etc. These boxes can be extremely strong if you put on a cover that bolts on tight, and/or solder them with heavy seams. You can make 3-sided boxes, or 5-sided boxes. You can bolt on real hinges, or make poor-man's hinges out of copper wire.

You can peel off strips of copper to make zones where a slab of copper is insulated. You can add heat sinks, fins, or any kind of connector. One of my all-time favorite discoveries was that you can use a metal nibbler to cut slots in the side of a sheet of copper-clad, and then slide 5-way binding posts into the slots. They look neat and sit secure; no drilling is required. You can use some of these techniques to get quick results, saving a huge amount of time compared to conventional metal-working techniques.



Here is a support for P.C. boards inside a box. Most of us don't own a welder, but we can all build neat copper-clad structures with a soldering iron.

The next major thing you can do is make structural beams—brackets, levers, cantilevers, I-beams, L-brackets, spacers, shims, push-rods, flying buttresses—just about any kind of levers or beams or supports. Cut first, solder second, drill as needed—it's an awfully creative medium to work in. The technicians in our lab all look at each others' mechanical designs and say, "That's neat." Now that reminds me of some even wilder arrangements that will occasionally be useful.

Here's a view of a wire-wrap socket, with the leads bent at various angles, for your convenience in making soldered connections.

I was recently helping a neighbor with a serious Meccano set project, and I realized that when I was a kid playing with my Erector Set, I built all kinds of structures. It was a lot of fun, but if I could have played with an equivalent amount of copper-clad and a soldering iron, I could have invented some *marvelous* machines and structures, just before I burned the house down.

Other things I like to build with copper-clad are breadboards and circuits. When people discard the 1/8-in.- or 1/4-in.-wide strips that they cut off the edge of a sheet with the shear, I scoop them up and save them and use them for little ground buses and power buses. When you solder them to cross-braces (which have insulating stripes peeled off), they're quite rigid and rugged, and very neat for op amps or logic designs.

I'm also compelled to state that some of the *cleanest, lowest-leakage* (sub-picoampere) layouts in the world use the *air* over a piece of copper-clad as the insulator. You can buy a clean polyimide board or you can get teflon pc boards or teflon stand-offs. But plain old air above a crummy piece of copper-clad is just as good an insulator, and usually better.

Another trick I like to use with copper-clad, for a quick-and-dirty applications circuit, is to use a 16-pin wire-wrap DIP socket for a 14-pin IC. I take the two pins on one end, and one of the other pins that will be grounded, and solder them to the copper-clad ground plane. All of the other pins I bend up at varying angles, for ease of soldering. I tack a couple of capacitors to the ground plane to use as power-supply bypasses. Then I tack some power-supply wires on them, and I have a breadboard in about 2 minutes, all ready for me to slap in the resistors and other components.

Now, I think you readers ought to know, I don't just sit at home on an evening and type out these ideas, then shove them into print. First I type out a good draft and make 30 copies and show them to my friends. At this point of the story, I threw copies to my Brain Trust, and invited them to show me some more things you can do with copper-clad.

Dennis Monticelli pointed out that when you peel the copper off and file down the tip, you can make a non-metallic screwdriver or a non-magnetic tool for adjusting RF circuits. Fran Hoffart explained how he uses copper-clad for shims and spacers.

And at the last minute, I recalled a little framework I had made, to hold up a 35-mm slide in front of my camera, so I could take a photograph of the slide's image and thus make my own copies of slides.

In conclusion, there are almost an infinite number of things you can do with copper-clad, pc-board materials, and I wouldn't mind hearing your neat ideas, too.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

THE MIL-HDBK-217 CONTROVERSY

It's not often that the basic precepts under which designers work get challenged. But now some industry experts are questioning MIL-HDBK-217's validity. For many years, it's guided engineers concerned with reliability. Will it continue to do so? Here are three views on the subject that highlight the growing controversy. We'd like to know how you feel about the issue.

MIL-HDBK-217: IT GETS MY VOTE OF CONFIDENCE

In the January issue of this magazine, I wrote an article discussing the techniques of design for reliability. One technique I advocated at that time was the use of stress analysis and derating in electronic-circuit design. Among the points covered in the article was the need for some method to measure the reliability of your designs on a "real time" basis as you do the design work. Therefore, you can make the necessary design adjustments to achieve the desired reliability. I recommended several methods of doing this, including using the methods of MIL-HDBK-217 in a computer-aided, reliability-prediction program to simplify the process.

This method of reliability prediction was one of several reliability design methods used during the time from October 1980 through October 1990. It was employed to improve the reliability of our products by a factor of ten and meet the challenge given to us by John Young, the President of Hewlett-Packard Co. This improvement was measured by using actual field reliability data from the beginning 6-month period compared to the ending 6-month period. It's important that you understand that reliability engineering isn't just predicting reliability and changing the design in some way to respond to the results of the prediction. It involves stress testing; reviewing field failure data; analyzing circuit variability; looking for all possible failure modes, including user abuse; and much more. For now, I will be mainly addressing the issues of reliability prediction.

ROY WHEELER
WHO RECENTLY RETIRED FROM HEWLETT-PACKARD, WAS PRODUCT QUALITY ENGINEERING MANAGER AT HP'S COLORADO CPRINGS DIVISION. HE HOLDS A BSEE FROM THE UNIVERSITY OF ILLINOIS.

After completing the work on my January article, I read two other articles relating to the subject of design for reliability that I would like to comment on. The first article was published in the October 1990 issue of *PCIM, Power Conversion and Intelligent Motion.* This recent article is the latest of several by Charles T. Leonard of the Boeing Commercial Airplane Group that criticized the use of MIL-HDBK-217 techniques to analyze the reliability of electronic circuits. In the October article, it was suggested that the MIL-HDBK-217 offers only one solution to the problem of failure rate reduction. The solution is the reduction of operating temperature. The point is that reducing temperature is accomplished at great expense in weight and total operating power by fans and other costly cooling methods. While this may be true in the data quoted in the article, it's not generally the case, and certainly not in the use of MIL-HDBK-217 predictions at the division of Hewlett-Packard where I worked.

I'm unaware of a single instance where our response to issues raised by the reliability prediction process was to reduce the ambient temperature. As I stated in my article, the appropriate response to this kind of issue is design changes to reduce the stress on the component where the stress level was found to be too high. This almost always involves reduced current, voltage, power, or increased stress rating by changing the choice of component used.

Mr. Leonard's article criticizes the modeling techniques of MIL-HDBK-217 as not realistically predicting the actual field failures of our equipment. My response is that the modeling techniques of MIL-HDBK-217 are based on millions of hours of field failure data and well known and understood principles of the physics of the failure of electronic devices. While the actual model used is a much simplified view of the actual failure mechanisms and cannot be proven theoretically, I have found by experience that this model is a reasonable and "good enough" predictor of failures to be a very effective tool. The use of the tool is to find design weaknesses without the time and expense of life testing each design.

In our modern electronic circuits, the failure rate of individual parts are generally measured in a few failures per billion hours of operation. To use life tests or field failure data to find these failure rates would take thousands of circuits tested over years of time—a completely impractical approach in the fast paced business we work in.

Let me give you a simple logical ar-

THE MIL-HDBK-217 CONTROVERSY

gument to support the use of MIL-HDBK-217 for predicting reliability. These methods just make the assumption that reliability is related in some fashion to the stress applied. I will support that argument by asking you to accept that in the limit, at Zero stress, even a faulty part will not fail. For a particular failure mode, the Zero stress environment might be dry cold storage with no voltage or current.

This is the limit condition of no stress. The other limit is at very high stress. Here, even a perfect part would fail with temperature, voltage, current, or power set so high as to melt, breakdown, cause migration of metal or doping, etc., of some critical element of the part and cause immediate failure.

All that you have to accept to give the MIL-HDBK-217 value is that these two conditions are connected by some continuous probability curve of some shape. The relationship assumed for the MIL-HDBK prediction is exponential, but this is certainly not correct for some failures. It's a reasonably good approximation of field failure experience when considered as a whole, over a lot of experience with a lot of different failure mechanisms and a lot of different parts.

Another criticism leveled at MIL-HDBK-217 is that it won't predict the failures in a well designed piece of electronic equipment. I agree. The whole point of the prediction is to design out the kind of failures the process predicts. I consider it as a success that these kinds of failures rarely show up any more in actual field experience.

I can tell you from my experience of many years of designing electronics that it's only since we started paying careful attention to the stress analysis of our designs that we stopped having these kind of failures. The prediction methods of MIL-HDBK-217 are just a tool to make sure we haven't overlooked a stress problem that will lead to field failures later.

The other problems, shown by the data in the October article as the major cause of electronic-equipment failures, are what's left after proper design has eliminated the stress-induced failures. We as designers of electronic equipment should also be working to eliminate these failures. Things like user abuse, assembly errors, no trouble found, etc., are things that can and should be addressed at the design level to eliminate the root causes of these problems. Our designs should be nearly impossible to damage by any reasonable level of abuse, so easy to assemble correctly that to assemble them incorrectly is a rare event, so well designed that to misdiagnose a problem is nearly impossible.

One more comment about this October article. While the suggestions concerning cost-effective design are valid from a thermal design point of view, it's safe to say that it's a rare circuit indeed where you can place components on the board in the manner that was suggested.

The first thing the circuit has to do is deliver the electronic performance it was designed for. This requires placing the components in the proper relationship for circuit performance, which usually severely limits placing the components to achieve the desired ideal passive cooling that was advocated.

This isn't meant to minimize the need for good thermal design as part of the design process. I just wanted to say that there are other design considerations that necessarily take priority over the placement of components for optimum passive cooling.

The March 14 issue of Electronic Design contains the second article I want to talk about. It's a very entertaining if somewhat inaccurate article by one of my favorite authors, Bob Pease. If you haven't yet read it, please do so. I think you will enjoy it. In his article, Bob took some pretty heavy hits at statistics and people that use them and also people that use MIL-HDBK-217 methods to predict reliability.

Bob and Mark Twain both agreed that statistics were the work of the devil. I have to disagree. In fact, I would go so far to say that both Bob and Mark make or made use of statistics every day in the conduct of their daily activities. Everybody does.

Bob and I are contemporaries. When he was working toward his BSEE at MIT, I was doing the same at the University of Illinois. At Illinois, and perhaps at MIT also, a course in statistics was required for graduation in the school of electrical engineering.

I wonder if Bob might just be pulling your leg a little with his comments on the subject of statistical analysis. In fact, I would go so far to say that I believe with a "99.99% confidence" (statistical talk meaning "damn sure") that his company uses statistical techniques in almost every aspect of the design and manufacture of semiconductor devices.

There's another point where I really have to differ with Bob. That's when he totally discounts the use of MIL-HDBK-217 for predicting reliability performance of electronics. Bob made the point that both statistics in general and MIL-HDBK-217 in particular were faulty because he had seen people use them and get incorrect answers.

You will pardon me if I observe that this is somewhat like refusing to use a hammer because you once saw someone hit his thumb with one. Statistics and MIL-HDBK-217 are tools. Sure they can and have been misused by people that don't take the time to understand the tool and how it works. I hope that you will look beyond the humor of Bob's article and my response to see the value in both these tools. I don't see how you can survive in a modern high-tech industry without them.

If you're interested in this topic I can recommend a good companion article that addresses the issue of reliability prediction. It appeared in the November/December 1990 issue of the *Journal of the Institute for Environmental Science* and is titled "Use and Application of MIL-HDBK-217."

Roy Wheeler
18890 Augusta Drive
Monument, CO 80132
(719) 481-3851

THE MIL-HDBK-217 CONTROVERSY

MIL-HDBK-217: It's Time To Rethink It

In the January 10th issue of Electronic Design, the article "Design for Reliability Reshapes Designing," authored by Roy Wheeler, states that its purpose is to "convince you to take another look at the way you do your job." There's no questioning the high quality of the products of Mr. Wheeler's organization, Hewlett-Packard, or of their dedication to high quality. However, his products possibly could be made better and at lower cost if some fondly held ideas are modernized. Some of his reliability improvement recommendations are similar to some that are common to the aerospace industry, where reliability is the item of first importance and virtually any cost that yields improved reliability will be accepted. However, some activities should be questioned, for they may result in unnecessary costs and actually degrade reliability because of additional complexity.

CHARLES LEONARD
AN ENGINEER FOR THE BOEING COMMERCIAL AIRPLANE GROUP, INVESTIGATES THE MECHANICAL ENGINEERING ASPECTS OF RELIABILITY-ENHANCING ACTIVITES EMPLOYED FOR ELECTRONIC EQUIPMENT.

My employer is concerned regarding the costs from following the recommendation taken from 217. We have joined with some 16 others who are equally concerned to sponsor research at the Electronic Packaging Research Center at the University of Maryland to improve the technical base. We feel that a new paradigm for cost-effective reliability is badly needed, directed mainly to packaging issues.

The sources of concern are the beliefs:

•That parts are the dominant source of unreliability. Our research indicates that properly selected and installed parts are quite reliable and cause a trivial fraction of failures.

•That parts fail in a mathematically predictable way. We find that parts fail for a reason, and when the cause of the failure is identified and corrected, the cause is almost universally one of design, application, processes, etc., and not at all something that's predictable.

•That failures are accelerated exponentially by temperature. Our research indicates this concept to be fallacious. It appears that temperature is largely a scapegoat blamed for electronic failures, a fig leaf that covers technical nakedness. The temperature effects can be accommodated by design so that in moderate ranges, temperature can be removed as a consideration for reliability. Or stated another way, reliability would not be improved by lowering the temperature. Therefore, the challenge is to remove the cause of the problem, not to lower the temperature. Elevating the temperature for design can sometimes lead to major reductions in cost, weight, complexity, and other penalties.

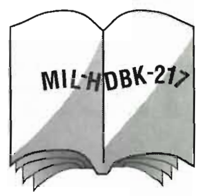
•That screened or MIL-spec parts will operate more reliably. Our research indicates this isn't necessarily true. Part supplier controls and track record of successes are far more important.

•That derating to large amounts provides improved reliability. Our research indicates this isn't the case. Derating can allow use of poorly made parts, but a better tactic seems to attack the source of the problem—manufacturing controls.

One example of the costs that can accompany the temperature ingredients of "Reliability" efforts illustrates the point. A major ground-based missile system is to be provided with a complex cooling system for electronics to improve the probability of the rocket's proper operation on demand. The rationale used by the reliability-and-manufacturability engineers was to take the specified MTBF of the boxes to be used and their coolant interface temperature, then select a new, lower, interface temperature that gives a calculated improvement to desired levels using 217's Arrhenius relationship. By so doing, a new temperature was established, and thus the operational requirement for a complex cooling system was established. All in the name of "Reliability." Never mind that there are no data concerning actual box performance, what the actual failure mechanisms are, or what stimulates them, or what role temperature plays, if any. Never mind that the cooling system itself is so complex that it's a plumber's nightmare, and weighs a ton-and-a-half!

Roy discusses examples of sources of unreliability that he has experienced. In each case, his corrective action required a design or process change. Doing the things encouraged by 217 to a greater extent wouldn't have made one bit of difference. Operating cooler, buying parts to tighter screening levels, or using fewer of them would not change anything except raise costs. These are the same conclusions as ours. Therefore, if it doesn't make any difference, why do it? And, how much of the activities that we do actually affect the end results, and how do we know? Could we do less of the expensive and complex things and not reduce reliability? These are important questions and it's time we have good answers for them. We don't have good answers now.

Roy's discussion concerning the futility of accelerated testing as a means to demonstrate reliability is puzzling. We have a good bit of information to demonstrate exactly the opposite. In fact, we're in the process of expanding our activities in this area, using the



Packaging Research Center. Maybe I'll have a full story for the readers in the future.

For another vision of the same question, Bob Pease's Pease Porridge in the March 14, 1991 issue referred to a Guest Editorial of mine ("Is Reliability Prediction Methodology for the Birds?," *PCIM, Power Conversion and Intelligent Motion,* November, 1988). The message I relayed was that Failure Prediction Methodology, FPM, (MIL-HDBK-217, etc.) is erroneously based, causing damage to those who take guidance from its concepts. Some of the actions guided by FPM may not produce desired or intended results, all the while causing increased costs, complexity, and other penalties like increased weight and volume. To use Mr. Pease's expression, "worse than useless" definitely applies to certain current uses of FPM. Notwithstanding the gross deficiencies and misleading aspects of FPM, it has become widely accepted as engineering guidance for reliability, such that it's now the single most influential document in existence today affecting high-quality electronic equipment.

Mr. Pease picked up upon a portion of my argument, which stated that one should not look to lowered temperature as a means of improving the reliability or performance of electronic equipment. The source of unhappiness with equipment that's performing below expectations may have nothing at all to do with its temperature. He refers to the "silliness of 217," a sentiment I thoroughly support, though he recognizes that those in "some businesses" must use it regardless. He then goes on to state, "...but in the industrial and instrument business, we don't really have to follow its every silly quirk and whim." From this, one could assume that Mr. Pease has, and others in his field have, escaped the damage from FPM, and that they operate at greater heights of intellectual integrity by not being befuddled by FPM.

The concepts of 217, however, have pervaded even Mr. Pease's organization. The device manufacturing industry has years of complicity in perpetuating the foundation cornerstone of 217, the notion of the exponential effects of temperature (the "Arrhenius relationship") on reliability. Devices manufactured by his company, and those of virtually all others in the industry, are sold with representations of Arrhenius-based predictions of failures versus temperature. "Base failure rate" data are gathered by device manufacturers by their operating a number of devices at a high temperature/electrical stress, measuring operating time and counting failures. Then, using the Arrhenius relationship and other manipulations, they generate and publish the well-known curves of exponential failures versus temperature.

Never mind that the failures occurring at the high stress condition are due to failure mechanisms that don't usually follow Arrhenius. And never mind that the failures that do occur are usually due to built-in defects in the devices under test, which could be eliminated by closer process controls. The high stress failures are usually attributable to failure mechanisms that don't occur in properly designed systems. Extrapolating those failures at high stress conditions to more usual conditions of use employing Arrhenius models gives a falsely pessimistic picture of the failures that should be anticipated at lower-stress usual operational condition. Arrhenius models attach undeserved value to temperature reduction by emphasizing a quick fix rather than exposing the problem.

When device manufacturers are queried concerning the technical base for their temperature/failure rate representations, the "πT factor" of 217, their usual response is to the effect that 'there's no basic for the representation, but that's what everyone else uses, so we do the same!!' They make the plea that to validate failure rates at lowered temperatures would take too long (10^6 hours is 114 years!) to be of value. In fact, the time to failure at lowered stress conditions may actually be several service lifetimes for devices that are carefully controlled in the manufacturing process, applied properly, and installed with care.

It's time we look critically into the things we do to produce our products, and to open issues that have laid dormant for years. The statement has been made that 217 is a valuable tool and 25 years of good application is behind it. I can't think of a better reason to open it up for scrutiny. We did just that, and we're quite unhappy at what we've found.

Charles T. Leonard
Boeing Commercial Airplane Group
Box 3707
Mail Stop 6U-ER
Seattle, WA 98124
(206) 477-0278

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

WHAT'S ALL THIS MIL-HDBK-217 STUFF, ANYHOW?

With all due respect to Roy Wheeler's views, I must say that I tend to agree with Charles Leonard about MIL-HDBK-217. Just because a tool once did some good doesn't mean that it's not now systematically doing harm. Designing circuits and systems to meet 217 wastes a lot of time and energy and money that would be well invested in other methods of improving reliability.

As for derating factors that are foolishly maintained in

THE MIL-HDBK-217 CONTROVERSY

systems like 217, I must say that I once heard of a request from Hewlett-Packard for op amps and other ICs to have an absolute max rating of 2 x the operating voltage. Because it's unreasonable to ask a ±15-V LM741 to have an absolute max rating of ±30 V, this leads to a system where LM741s can only be operated on ±9-V supplies. They can then have a 2:1 safety factor versus the normal ±18-V absolute max rating.

It really doesn't seem reasonable to me that LM741s operating on ±9 V will be appreciably more reliable than on ±12 or ±15 V. It also seems unreasonable to specify high-voltage amplifiers such as LM344, just to be able to run on ±15V with a big safety margin. And, I don't see much point in operating TTL ICs on a +3-V supply to give them that 2:1 safety factor.

I've also seen many customers asking, "How many transistors are in your IC?" Of course, when we ask why they need to know, they explain that 217 requires them to. Now I see that Analog Devices has even started listing the "number of transistors" in the characteristics column of some of their data sheets, so that users can get this valuable (?) piece of information without bugging the customer-service people at ADI.

Of course, if the computed reliability isn't good enough with a 42-transistor IC, the reliability would be even better with a 22-transistor IC (just choose an amplifier with the input-protection transistors omitted and the output protect/current limit transistors deleted).

And it would be even higher yet with a UA702 that has only 9 transistors, RIGHT? But, Mr. Leonard is much more knowledgeable than I am in these areas, and I will let him address these topics.

At this point, I will address some of Mr. Wheeler's questions about what I said about statistics. First of all, when I attended MIT in 1961, NO, there was *not* any specific requirement to study a course in statistics.

In similar fashion, there was no specific requirement to study a course on digital computers or operational amplifiers. We did study lots of obscure topics that were much more generally valuable, like large motors and microwave VSWRs.

Do I use statistics every day? I use many kinds of math, but almost always when I want to look at a distribution, I look at a one-dimensional distribution. Some people call them histograms, but around here we often call them "ADARTs", which is apparently an old name devised by Teradyne (I think it's an acronym for Automatic Distribution Analysis in Real Time).

I have an absolute preference for looking at ADARTS, and a well-rooted aversion to any analysis that simply says, "Average value = 1.20168 mV, sigma = 0.17357 mV." Too many evils are hidden when the data aren't Gaussian. Yes, it's *possible* to get your statistical tools to check the data to see if the distribution *is* Gaussian, but almost nobody checks that.

I mentioned in an earlier column that when the yield to a 1% accuracy spec is worse *after* trimming than *before*, somebody is being badly fooled. And letting the statisticians wield a bigger whip isn't likely to solve the problems. *No*, I eschew statistics. Yes, I use graphical methods of analysis, which I use to solve problems that other people get into when they let themselves be fooled by statistics and computers (not to mention spreadsheets that deceive and lie....). Some of our product engineers get some very good software that lets them provide two-dimensional plots (scatter-plots) that are quite educational.This I encourage...

Do other people at NSC use statistics? Well, I'm sure some people do. As long as they don't do any harm, so long as they don't do it in the streets and scare the horses, I shan't complain. But, when they screw up, well, I'm the guy they call in to fix the problem.

You ask me why I condemn statistics in my column. Well, already I'm getting letters from people who say "You think things are screwed up at *your* company, you should see how bad they are at *my* company."

Then some truly horrifying stories are spilled out. (So far, I've gotten about 150 letters about my column. A few dozen simply like my column. A few dozen agreed that Golden-Eared experts were fools when it came to splices. But many people have volunteered examples of outrageous things in the industry).

Like the guy who wrote that his boss started to chew him out for having bad averages and bad distributions on some of his older designs. When he searched into the situation, he found that the test engineers were taking statistics on the data without throwing out the dead units.

So, if there were more *shorts* one week, and more *opens* the next week, the average value would go all over the place, even though the distribution of the *good* parts wasn't moving anywhere at all.

In another case, an engineer designed some operational amplifiers that had extremely high gain, well above 150 dB. The QC people condemned the performance because they wanted to see a correlation between the gain at room temp, and the gain at hot and cold. Well, the gain was so high that you could not see any correlation at all, so they made him do 100% testing at hot and cold, even though there was no rational reason to do so. They never did find any failures or problems, but they made him perform useless, unnecessary tests that were never required on low-gain or medium-high-gain amplifiers. He was willing to list a relaxed spec at hot and cold temperatures, to give a good safety margin, and ensure that a bad part would never be shipped that failed the spec. But the QC people refused to accept that on this very-high-gain part, even though that was permitted in the past.

So, I will continue to point out that the absent-minded use of any computerized procedures, such as Spice, or Statistics, or Spreadsheets, or Analog Synthesis, or *any other mindless use of computers*, can lead to serious problems. Of course, there are absurd problems at many other places in the industry, and I'm pleased to see that many of Electronic Design's readers count me as a helpful resource when I point out these problems.

In Mr. Wheeler's column in this issue, he points out that "...it's a rare circuit indeed where you can place com-

ponents on the board in the manner that was suggested... there are other design considerations that necessarily take priority over the placement of components for optimum passive cooling." Maybe in high-powered instruments, passive cooling isn't an important consideration—you just give up on the passive cooling and throw in a fan. But, if you don't let every other engineer pull an absolute priority over the need for wise location of hot components and good thermal management, it's indeed possible to negotiate a good thermal layout without degrading other electrical specifications. Certainly on *my chips*, I have to arrange the high-power components very carefully, as thermal gradients are a critical aspect of the performance. And I don't have any option to put a tiny little blower on the hot end of my chip to prevent it from heating the precision front end. Even 5 or 10 mW can be disastrous if not properly managed.

Just last week, I had to troubleshoot a "newly improved circuit," which the engineer had carefully analyzed with Spice and other tools. The performance was awful. Finally, I spotted a strategic error in the layout. It turned out there was absolutely nothing wrong with the schematic, but the circuit's performance was destroyed by a bad layout.

Therefore, when you use statistics, as with any kind of mathematical or computerized scheme, you do so at your peril. If you use the tools wisely, that's fine.

But, if you get in the habit of letting the computer do all of the easy stuff, you may forget the basics. Then you will gradually lose the perception of when a situation is normal and when it's going very wrong. I don't think you can train your computer to watch out for every kind of "wrong." And that's my point.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

What's All This Quakey Shakey Stuff, Anyhow?

You only have to read the newspaper occasionally—*any* newspaper—to be aware of the earthquakes that occasionally rock and rattle various areas of California. People who live in the hills above Santa Cruz are VERY aware. For several years, I've proposed that we Californians need a good earthquake detector. Then suddenly I came up with 3 good ideas—three ideas with different levels of sophistication and usefulness. When a major scientific panel came up with an idea quite similar to my best idea, I asked the editors at Electronic Design to expedite this column.

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

Originally, a friend of mine, Carl Nelson, proposed to make a quake detector/recorder out of 10 cans of beans. You put one right near the edge of the pantry shelf, one further back, etc., and the last one you GLUE down to the back of the shelf. If the front one rolls off, you had a little quake; if the last one is smashed by falling beams, you know that was The Big One—and everything in between. But, you need to do this in at least 2 dimensions, in 4 directions, and most people would find this bulky, expensive, and dangerous.

So my first invention, costing as little as $1, is to set up a stack of 30 pennies, a stack of 25 pennies, and stacks of 20, 10, and 5 pennies, on a standard sheet of paper. After a quake, you can see which of the piles fell, and in which direction. I set up one of these at home and one at work. During the big 7.1 quake, at home, the stack of 30 pennies fell, and the 20, but not the 25. At work, everything fell except the 5. So, for a small investment, you can compare notes with your friends. It's not absolutely calibrated, but you can get a ballpark indication of the amount of shock in your area.

I was still not completely satisfied, so I designed another detector-recorder. It's not exactly as technically correct or elegant as a seismograph built with levers and 10,000 turns of wire, as shown in *The Scientific American*. But you can use the little circuit shown below, to be triggered by a "swaying pendulum," and make a stretched-out pulse of perhaps 60 or 120 seconds.

This pulse can turn on your tape recorder or your camcorder for a minute or two to detect the creaking or rattling of things in your house. If you hear sirens, then the neighborhood may be on fire. If it also turns on a little radio, you can hear the radio announcer say, "Oh, my Gosh, that's a big one." If all the books fall out of your book-case, that will all be recorded, too. I just got it built up this weekend. I haven't yet seen how touchy it is about false alarms, but I can live with that....

On a more serious level, I realized that every time I climb under my car to work on something, or jack up the car even to change a tire, or climb up a ladder, I wish I could get an early warning of a far-off quake. When the workers at the Cypress Structure in Oakland were using their heavy equipment to demolish the ruined concrete, they had the benefit of a little radio transmitter that would detect any quake down by Loma Prieta, the epicenter. A little radio receiver at the work site would give them 10 or 20 seconds of warning to jump off their crane, to get away from the dangerous piles of rubble, and increase their safety considerably. I don't know who engineered this, but as far as it went, it was a darned good idea. It must have made those brave workers feel a little less nervous about a quake sneaking up on them.

Well, I want to take that idea and expand it. I want to add in a bunch of features and make it available to everybody:

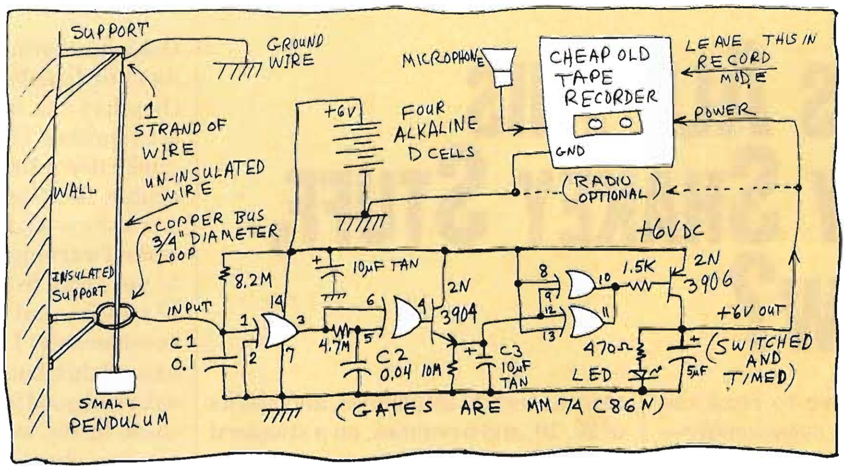
- I want to have a whole bunch of quake detectors, scattered all around the San Francisco Bay Area, located at interesting sites near and along each major fault. (Los Angeles can have their own network, and so can Tokyo).
- I want all of the sensors to transmit the warning of any significant quakes to a suitable central station, which can process the information and send it out immediately on two or more radio stations or TV channels.

The first radio station can monitor ALL quakes, large, medium, or small, and broadcast the information, and you can tune it in if you're going up on a ladder or under your car, or if you are just interested or curious. This will be a clear channel that will broadcast nothing but earthquake information and other related emergency info (tsunami reports, etc.), with an occasional tone to let you know you really are tuned in.

The second radio station would monitor all BIG quakes. Then you might just leave *this* station on all the time, even when you're asleep, so if it wakes you up with a computerized voice saying "Big one, Loma Prieta, Big one, BIG ONE...." you would have some warning to get under a table or a doorway, to grab a flashlight or a video camera, or to head for your kids' bedroom, or whatever you have decided in advance to do.

This second channel would be avail-

PEASE PORRIDGE



THE FIRST GATE ACTS AS A HI-Z PREAMP WITH INPUT NORMALLY HIGH. THE NEXT GATE ACTS AS AN "ACTIVITY DETECTOR": ANY EDGE, RISING OR FALLING, CAUSES IT TO PUT OUT A HIGH PULSE FOR 0.1 SECOND. THE NPN HELPS STRETCH THAT PULSE FOR 50 SECONDS. THE OTHER 2 GATES ARE ALSO HIGH-Z PREAMPS WHICH DRIVE THE PNP AS A SWITCH & TURN ON THE TAPE RECORDER FOR A FEW DOZEN SECONDS AFTER ANY "ACTIVITY"! NOTE, ONLY ONE FALSE EVENT/YEAR ... RAP 1990-91

able to any other radio station, for a small charge, so it could break in and give you advance warning, even if you're listening to a ball game, or the opera, or whatever. It could add onto a TV station, and break into the regular program material. The number of useful, life-saving possibilities is large but finite. You can use your own imagination.

Let's say you're listening and you hear about a quake starting in Sonoma. If you live in San Francisco, you know that's a few dozen miles away, so you have a number of seconds (at the rate of about 1.8 second per mile) to get in a safe mode. If you live in adjacent Napa county, you might have only a few seconds. So, the broadcast would have to tell you the location of the strongest shock, from a standard list of places, and you would have to be prepared to act suitably and instantly, depending on where YOU are located. You have to plan in advance, and you have to recognize all of the places on the standard list.

The sensors have to give you a very quick indication of what is the significance of the magnitude of the quake. I read in one popular scientific tabloid that some scientists were planning to set up a network of sensors and (digital) computers to analyze the data, and then give a warning in just "15 or 20 seconds." Don't look now, guys, but most of the people closest to the quake will be hit with the shock in only 5 or 10 seconds.

A perfectly computed analysis in 15 seconds would be no help at all. The key to the sensor is to have some wide-range logarithmic amplifiers and sensors that can put out appropriate signals for every size of tremor. Back in October of 1989, a friend of mine was standing in his garage, about 3 miles from the epicenter. He said, "In the first second, it knocked me on my butt". If a quake of that magnitude comes along, you can have pretty simple sensors, linear and logarithmic amplifiers, and discriminators or comparators that will get out the message "in the first second," which is the right kind of warning to save lives.

What if the quake's center is so deep underground (as it was in the Loma Prieta quake of 1989) that the shock waves hit areas several miles away from ground-zero, at just about the same time as it arrives at the sensors at ground-zero? Easy—drill a deep hole and put a few sensors down deep, to give advanced warning. Every mile of depth can help another few vital seconds.

Obviously, there are lots of practical and legal considerations. What if some driver gets the message and jams on his brakes, causing a pile-up worse than the quake damage? What if people get nervous and panicky and the first thing they do is call their lawyers? Obviously, the practical considerations aren't trivial. Still, if we plan a little, this system can be much better than no warning at all.

When I had this radio-warning idea back in December of 1989, I took it immediately to our Patent Committee at National. They considered the scheme and decided it wasn't related to any of National's business, so they told me I could do anything I wanted to with it. I sent a technical note to a couple of the major radio and TV stations and newspapers in the Bay Area. The silence was almost overwhelming.

But in late August of 1991, a National Research Panel of experts from the National Academy of Sciences proposed a similar plan to assemble a system of seismometers, computers, and radios to give people an early warning*. I immediately wrote off to the chairman, Mr. I. Selwyn Sacks of the Carnegie Institution in Washington. Soon I hope to hear more about their proposals. But you have already heard about my plans and proposals.

So, if this system gets going and it saves your life someday, you can buy me a beer. Fully-paid licenses, of course, are available at a *very* reasonable fee.

You may not have many earthquakes in your area, but you have to agree, it's certainly a fascinating and challenging set of problems to think about. Maybe you have ideas that are better than mine, or that would improve mine when added to it. You don't have to sit on top of a big fault to have good ideas.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

* "Experts Push High-Tech Quake Detection System," Warning of even a few seconds could save lives; San Francisco *Chronicle*, August 28, 1991, page 1.

PEASE
PORRIDGE

What's All This Profit Stuff, Anyhow?

Here's another esaeP's Fable. The Class of 1966 was starting to plan its 25th Reunion. The Reunion Committee went around and contacted all the alumni, until they came to Joe. Joe, as duly noted in the Yearbook, was the Person Least Likely to Succeed in Business. That had been a clear choice, back in 1966 – everybody recognized that Joe was a klutz, with no sense of proportion, no head for math nor business. But Joe had filled in his questionnaire: President and CEO of Widget Enterprises – a multi-billion dollar multi-national corporation. And Joe had just donated a new Library to the Business School. How could this be? So it was with great respect and curiosity that the Reunion Committee invited Joe to give the key-note address at the Reunion.

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

It was the same old Joe who stood up to give the speech at the Reunion. "I never was much of a speech maker. And I don't have any big secrets about how I do business. I just buy Widgets for $1.00, and I sell them for $10.00. I'm perfectly happy to take just a 10% profit." *End of Fable.*

When I started work at George A. Philbrick Researches in 1960, I observed a secret project going on – a "skunk-works" project to bring out Philbrick's first solid-state operational amplifier. Technicians were testing and grading diodes and transistors, night and day, to generate matched pairs. The data sheet was being rushed to completion. Test engineers were learning how to measure currents in the picoampere range. And Sales hoped to sell a few of these P2 amplifiers, at a selling price of $185, to pay for all this research effort.

Wow. An op amp with just 100 picoamperes input current – with no tubes, no heater power, no mechanical choppers. That must use the finest new silicon transistors. No wonder it sells for $185. But when I got to know the senior engineer, Bob Malter, a little better, he showed me that there were not any silicon transistors in the P2. There were just 7 little germanium transistors in there. *What*? WHAT??

When Bob Malter arrived at Philbrick Researches in Boston in 1957, he was already a smart and accomplished engineer. After designing several analog computer modules (which were the flagships of the Philbrick product line) he became intrigued with the concept of the Varactor amplifier, just about the time that George Philbrick, the founder and chief Research Engineer, was getting frustrated.

George had been trying to make a parametric amplifier, using varactor diodes and germanium transistor amplifiers. When the bridge started out balanced, just a few millivolts of dc input could cause enough imbalance to be amplified and then rectified (synchronously) to drive a dc amplifier. In theory, you could make an operational amplifier that way. But George had worked for many months on an elegant design he called the P7. It used 14 germanium transistors, in a little cordwood assembly with 8 little pc boards packed in between 2 mother boards. He could not get good repeatable results, not for dc accuracy or dynamics or temperature drift.

Now, Bob Malter was a very pragmatic, hard-headed engineer. You would *not* want to bet him that he could not do something, because he would determinedly go out and do it, and prove that he was right – and that you were wrong. Bob had his own ideas on how to simplify the P7, down to a level that would be practical – which he called the P2. I do not know how many false starts and wild experiments Bob made on the P2, but when I arrived at Philbrick as a green kid engineer in 1960, Bob was just getting the P2 into production.

Instead of George's 10 pc boards, Bob had put his circuits all on just two pc boards that lay back-to-back. Instead of 14 transistors, he had a basic circuit of 7 transistors – just one more device than the little 6-transistor AM radios of the day. He actually had 2 little transformers – one to do the coupling from the 5-MHz oscillator down into the bridge, and one to couple out of the balanced bridge into the first of four RF amplifier stages. (If you are really interested in the complete schematics of the P2 and P7, and other technical comments and details, you will want to buy Jim Williams' book.*) Note, 25 years ago, these would have been the center of fantastic technical espionage; but today, it's just a matter of historical curiosity – industrial archaeology – on an obsolete product. You can't buy the parts to make these amplifiers any more, and even when you could, you could build a circuit to follow the schematic, and it wouldn't work.

So what's the big deal? Here's a pretty crude operational amplifier with a voltage gain of 10,000, and an output of ±1 mA at ±10 volts, with a *vicious* slew rate of 0.03 volts per microsecond. Who would buy an amplifier like that??? It turned out that *thousands* and THOUSANDS of people bought this amplifier, because the input bias current at either input was just a few picoamperes. *Picoamperes*? What the heck is a *picoampere*?? Most electrical engineers in 1960 didn't even know what a picofarad was, not to mention a picoampere, but, they figured out it was a heck of a small fraction of a microampere. And for many high-impedance instrumentation applications, the P2 was clearly the only amplifier you could buy that would do the job. And it had this low bias current, only a few picoamperes, because all those germanium transistors were running at 5 Mcps, and their 5 or 10 μA of dc base current had no effect on the precision of the input current.

The input current was low, thanks to a well-matched bridge of four V47 varicaps. These were sold by Pacific Semiconductor Inc. (PSI) for use as varactors in parametric amplifiers, up in the hundreds of "Megacycles." The "V47" designation meant that they had a nominal capacitance of 47 pF at 4-V reverse bias, which is where most RF engineers would bias them. But Bob Malter biased them right around 0 Vdc, with a minuscule ±60 mV of ac drive. At this bias, the capacitance was 110 pF plus 1 pF per 20 mV – not an extremely high gain slope.

At this level of drive, each diode would only leak 20 or 40 pA. But Bob had a gang of technicians working day and night to match up the forward conduction characteristics and the reverse capacitance voltage coefficients, and he was able to make sets of 4 varactors that would cancel out their offset drift versus temperature, and also their reverse leakage. Of course, there was plenty of experimenting and hacking around, but eventually a lot of things worked OK. After all, when you buy 10,000 V47s, *some* of them have to match pretty well.

So, here's a little do-hickey, a little circuit made up of just about as much parts as a cheap $12 transistor radio, but there was quite a lot of demand for this kind of precision. How much demand? Would you believe $227 of demand? Yes! The P2 originally started out selling for $185, but when the supply/demand situation heated up, it was obvious that at $185, the P2 was underpriced. So the price was pushed up to $227, to ensure that the people who got them were people who really *wanted* and *needed* them.

Meanwhile, what other kinds of "transistorized" op amps could you buy? Well, by 1963, for $70 to $100, you could buy a 6- or 8-transistor amplifier, with I_{bias} in the ball-park of 60,000 to 150,000 pA, and a common-mode range of 11 V. The P2 had a quiet stable input current guaranteed less than 100 pA (5 or 10 pA typical), and a common-mode range of ±200 V. (After all, with transformer coupling, the actual dc level at the balanced bridge could be at any dc level, so there was no reason the CMRR could not be infinite.)

Wow! A $227 *gouge*. (You couldn't call it a "rip-off", because the phrase hadn't been invented, but perhaps that is the only reason....) Obviously, this must be a very profitable circuit. Every competitor – and many customers – realized that the P2 must cost a rather small amount to build, even allowing for a few hours of work for some special grading and matching and testing. So, some people would invest their $227 and buy a P2 and take it home and pull it apart and try to figure out how it worked. The story I heard was that one of our competitors hired a bright engineer and handed him a P2 and told him, "Figure out how they do this. Figure out how we can do it, too." In a few days he had dismantled the circuit and traced it out, and had drawn up the schematic. Then he analyzed it, and began experiments to be able to meet or exceed the P2's performance. But he couldn't get it to work well. He tried every approach, but he never could. After a full year, they gave up.

You see, it turns out there was some interaction between the input of the first RF amplifier and the output of the 4th amplifier, that made the P2 work, when you assembled the two pc boards close together. It would not work with any other layout, orientation, or circuit-assembly technique. So none of our competitors ever second-sourced the P2. And the P2 and P2A and SP2A remained profitable and popular even when the new FET-input amplifiers came along at much lower prices. It was years later before these costly and complex parametric amplifiers were truly and finally obsoleted by the inexpensive monolithic Bifet amplifiers from National Semiconductor and other IC makers. Even then, the FET amplifiers could not compete when your instrument called for an op amp with a common-mode range of 50 or 200 V.

Still, it is an amazing piece of history, that the old P2 amplifier did so many things right. It manufactured its gain out of thin air, when just throwing more transistors at it would probably have done more harm than good. And it had low noise, and extremely good input current errors – traits that made it a lot of friends. The profits from that P2 were big enough to buy Philbrick a whole new building down in Dedham, Massachusetts, where Teledyne Philbrick is located to this day, (notwithstanding a recent name change to Teledyne Components). And the men of Philbrick continued to sell those high-priced operational amplifiers, and popularized the whole concept of the op amp.

Then when good low-cost amplifiers like the UA741 and LM301A came along, they were readily accepted by most engineers. *Their* popularity swept right along the path that had been paved by those expensive amplifiers from Philbrick. If George Philbrick and Bob Malter and Dan Sheingold and Henry Paynter and Bruce Seddon hadn't written all those applications notes and all those books and stories, heck, Bob Widlar might not have been able to *give* his UA709s and LM301s away! And the P2 – the little junk box made up virtually of parts left over from making cheap transistor radios – *that* was the profit engine that enabled and drove and powered the whole operational-amplifier industry.

One time, I was standing around in front of the Philbrick booth at the big IEEE show in New York City. A couple engineers were hiking past the booth, and the one said to the other, nodding his head toward the booth, "...and there's the company that makes a *big bloody* profit...." Well, at that time George A. Philbrick Researches was indeed making big profits from the P2. We could never deny that. Just like Joe and his Widgets.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

**Analog Circuit Design: Art, Science, and Personalities*, by Jim Williams, about $45. Published by Butterworths (617) 438-8464 x255.

What's All This Reunion Stuff, Anyhow?

When I travel back to New England, I don't fool around. I would not go east without first visiting my mother and sisters in Connecticut. I put in a day or two, visiting and being helpful, and talking and tying up loose ends. That reunion goes back 50-odd years, since the day I was born. Then I try to get together with all sorts of other old friends.

On my most recent trip, I had a small preliminary get-together with some old friends from grade school. Now, if we wait until the year 2003, we can have a 50th reunion of when we all graduated from Broad Brook Grammar School. But nobody wants to wait that long because we'll start losing people. In the next 12 years, people are going to be *dying*.

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

So we decided it might be fun to start planning a 50th reunion of when we started the first grade. We can do that in 1995, barely 4 years from now, which is a pretty good excuse for a get-together. So, five of us got together on a warm Monday evening at the house of Helen Matulis Senk. And we talked about what happened to the people in our class, and how we could get together.

Fortunately, we won't have to hire a hall, or do fancy invitations. We'll just get on the telephone tree and pass the word around, then drop in at a neighborhood lounge that's not too dark nor disreputable to talk and gossip and sip some juices. So our little planning meeting did establish some feasibility, and surely in September of 1995, about the time of the first week of school, we'll make a reunion. A do-it-yourself reunion. No fancy reunion committee, no school authorization, no official photographer. No big deal, because there were rarely more than 30 people in the class. But there are a few problems. Some people have moved thousands of miles away, some have died, and some have moved only a few miles across town. So we haven't seen some people for years. Where is Dorothy Hearn? Where are Bobby Tyler and Allan Gallagher and Bobby Christian? How are we going to find them?

Next year will be my 35th reunion at Mount Hermon School. The school does a good job of calling us back every 5 years. We formed some close ties back in '57, and there are a number of people I write to 2 or 3 times per year. So that's always fun. But where the heck is Allan Gates? Where is Dixi Jacobs? Where is George Jacobs? Where is Dave Gillespie? Where are John Chaffee, Walter Crofut, John Hsu, Harold Jensen, John Lessard, Albert Merrill, Richard Morse, Charles Ober, J. Richard Phillips, Arnie Rolfe, Richard Van Wagner, Steve Warner? Now, I know some of these guys are perfectly willing to dodge the Alumni Fund-raising drives, but that doesn't mean they should stay out of touch. Al, Dixi, George, Dave...WHERE ARE YOU?

I just returned from the 30th reunion of MIT's class of 1961. This was not a big year; 5 years ago there were a couple hundred people at the 25th reunion, but barely 60 guys this year. Still, we ran into several old friends from '61 and from other years, and we made new friends, too. Still, there's a list of people that the Alumni Office can't locate. Hey, does anybody out there know the whereabouts of Anil Anand, Milton Clauser, Tom Laase, Peter Crichton, Gary Rosenthal, Lawrence Roven, Barry Stern, Karl Josephy, William Kleinhans, and Fred Reynard? Now, there was one guy from '61 who did not attend, even though he had been invited to give us a speech. But we were not worried – we knew *right* where John Sununu was – in Washington DC.

When we were at MIT, some of us majored in electronics or physics or chemistry. And some of us majored in Outing Club, as well as winter mountaineering, bicycling, or rock climbing. Every year or so, we have a reunion at Gardner Perry's house in Seattle, or Bert Raphael's in Los Altos. But if we knew where to find Paul Pomeroy or Brian Mokler or Bill Homeyer, we could improve our reunions even more. Also, where is Dave Berkowitz, Danny Schwarzkopf, Gloria Goldberg, Tanya Maria Atwater?

The next, and best, reunion was the Philbrick Alumni Association. There used to be a gravel bank right across the street from Teledyne Philbrick on Allied Drive in Dedham, Mass., so I told everybody to show up at that bank. Then, I explained that there was a new Hilton hotel recently built on that site, and we'd meet (naturally) in the bar.

Now, Philbrick Researches has been one of the spawning grounds of linear circuit companies, just as Fairchild alumni went off into many other semiconductor houses. So the Philbrick Alumni group has splintered into dozens and dozens of other companies – Teradyne, LTX, National, LTC, Analog Devices, Analogic, Datel, Burr Brown, PMI, Sipex, Powercube, Northrup Nortronics, Hycomp, Hybrid Networks, and many more. We can say, proudly or sadly, we got our alumni into some of the best and biggest companies in the industry. Ah, if only they could have stayed at Philbrick – but that's a

PEASE PORRIDGE

whole 'nother story.

Anyhow, people drove in from 50 miles south and 100 miles west and 90 miles north, and some people merely had to walk across the street. Others sent in their best regards by fax, from 5000 miles away. We had about 40 people there. There were people who had never attended one of our reunions before, and our Cruise Director, Al Risley of Datel, agreed that we were finally getting more efficient at inviting people. We invited some by phone, and others by mail, and our redundant techniques caused some people to get 3 or 4 invitations.

I ran into one young woman who just happened to be promoting a system for laser identification and labeling of wafers and masks – which I just happened to have a serious active need for. I mean, every once in a while, we have a project coming along great, and the wafers come out not working because somebody put on the wrong mask. It's been my pet peeve for a few years, that if every can of beans at the Safeway gets a bar code, and every other letter delivered to your door, then why can't a mask get a bar-code, too, to ensure that a computer can lock out an improper mask? So Pat Green had a real piece of good news for me, and I hope we do a million dollars of business with her company*. If we do, then *we'll* save $2 million. Of course, it will take some additional hardware and software, so that when a special engineering run needs a screwy sequence of masks, we can override the computer.

Fortunately, with these bar codes, we won't run out of legal codes very quickly. Have you ever noticed the bar codes on the front of a letter? Have you counted the *number* of bars on that? I bet you didn't notice that they cleverly inserted as many as 52 bars. The coding, of course, isn't true binary. It's a 7,4,2,1 decimal code, with a parity bit and parity word. But if it were in binary – well, 2^{52} is a VERY large number – about 5×10^{30}. With such a big number, you could have a separate mail code for your front door and another one for your back door, because there are only about 6×10^{30} square feet on the surface of the whole earth. So I don't think we will run out of codes very soon, even if we put a code on each wafer. Now, a code on each die, I'm not so sure about...

So, as with the other reunions, I ran into some nice people who had ideas that were really stimulating. Not just the enforced jollity of a group of random people forced into proximity, but the matching up of random pairs or triplets of bright people with interesting ideas. Just as, at the MIT reunion, I ran into a guy who wanted to buy a dozen copies of my new book** to pass around to his engineers and technicians. Just as I ran into artistic and talented people at other reunions. Just as I ran into a person at another reunion who was having problems with her word processor as it interfaced to her printer, and I figured out how to trick it into giving her the correct margins.

So, in addition to the good news of the bar-code business, I found this reunion business a good success. For instance, there may be a person that you associated with, years ago, and that person may have been (so you thought) a boring or useless or unpleasant person. But (after a number of years) that person suddenly becomes interesting, skilled in a field that just happens to be fascinating to us, as we listen and learn.

I mean, once upon a time, we were all kids. But as we grow up, we become better rounded individuals; and other people do, too. So, if you're deciding whether to attend a reunion, I would recommend that you really should. You may run into some fascinating ideas, some pleasant memories, even some good business – but you won't be bored, not for very long.

And the best part is, if you want to call a reunion, you can figure out how to do it yourself. I have attended Amelco Semiconductor Alumni Reunions, and reunions of National Semiconductor's ALIC group, and I have also heard about some good Fairchild reunions. All it takes is a park where you can gather and picnic, or a local bar where anybody who will buy even a ginger ale is always welcome. No matter where you worked, you can run your own reunions. I won't say that the art of getting everybody found and invited and actually in attendance is trivial, but you can figure it out.

Here's one technique I've used to find a person who seems to have dropped off the earth, and I used it to locate the former owner of my house. An insurance company kept sending her statements about the value of her policy, but I had no idea where to forward these letters. But I did have her social security number. So I sent a polite note to the IRS, asking them to forward the note to the person with this social security number, as there was this valuable information that I wanted to forward. Shortly she wrote to me from Baltimore, thanking me for getting this material sent to her.

So if you know somebody's social security number, I'm sure you will admit there are some people who can always find their man! And they're willing to help you forward a little note; whether the person wants to write back is another matter.

Ah, that reminds me – even at the Philbrick reunion, there were people we could not invite because we had no address for them. Where is Louis Watson? Where is Bob Boyd, Dave LeVine, Brian O'Brien? Suzanne McGovern, Adele Fata, Ann Havey, Sue Taipale, Jeanne Finnert? Brad Vachon, Everett A. Day, Ralph Daigle, Dan McKenna, Dick Hewson, Bob Squarebriggs, Maurice Goldwater, James Royer, Dick Davis – where are these guys? Unfortunately, we don't know the social security numbers for these people. So I'd appreciate it if my readers will just remind these guys, all of these missing persons, and anybody else that ever worked for Teledyne Philbrick or George Philbrick Researches, that we really do want their addresses, so we can invite them to the next reunion. If we can get most of them to show up, we can make a really *great* reunion.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*Computer Identics, 5 Shawmut Rd., Canton, MA 02021

***Troubleshooting Analog Circuits*, Robert A. Pease; published by Butterworths, (617) 438-8464.

What's All This Reflex Response Stuff, Anyhow?

I must have been quite small when I learned that if I dropped something heavy, I should jump so as to pull my feet out of the way of the falling object. For example, if I dropped a brick that fell toward my right foot, I didn't have to worry about my left foot, but my right foot had better clear out quickly. Obviously, just about everybody learns this early enough that you have no recollection or memory of how you learned it.

At a somewhat later age, I learned that if I dropped my glasses, or my watch, or any delicate object, it was pretty easy to swing one foot underneath that object. Even if I could not entirely prevent my glasses from hitting the floor, I could deflect them so it would only be a glancing blow. And I have developed that knack, so it's pretty automatic for me.

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

Then, the other day – in the summer of 1990 – I dropped something, and I did not move my foot either to catch nor to avoid the object. Well, I asked my leg, what is this that you're so blasé about? I reached down and picked up – a stick of butter. My leg had apparently made a decision that a 4-ounce stick of butter was not worth worrying about, one way or the other. Smart leg!

I mentioned this at work, and a friend (who has a lot of experience as an auto mechanic) said, "Okay, here's the fourth situation – the fourth quadrant. Let's say you are working on a Porsche, and you leave the starter motor up on a bench. Suddenly you notice that the starter has just rolled off the bench and is on its way to the floor. It weighs 30 pounds. It costs $900. NOW, what do you do with your leg?"

After some consideration, I figured that I would try to kick the starter with my toe, pretty hard, about 16 inches off the ground, so my toe would not get crushed, but it would have a chance of slowing down that heavy object. But I haven't gone to try it out.

Now, there's a very good and very serious application for this kind of pre-planning, pre-judging what kind of a reflex reaction you will make, instantly, in a particular situation. Let's say you're driving along a freeway, and suddenly you spot a dog in front of you. You may blow your horn, but some dogs really don't pay much attention (some of them are deaf, and others are stupid enough, they might as well be deaf). Okay. What do you do? You might hit the brakes, but if there were a truck on your tail, he could do *lots* of damage to you. You might swerve. That's a better way to avoid the dog (unless the dog dodges in the same direction as you do – I've seen that happen). But what if there's a car passing you? You could easily wreck your car and any number of other cars, too, depending on how many cars are around you. Or, if you dodge really hard, you could go off the road and cause additional trouble. A woman was observed trying to dodge a dog on Route 93 in Medford, Mass., about 20 years ago. She missed the dog but went off the road, down an embankment, and was killed. Bad move.

Now, I'm not suggesting that you just hit the dog. In many states, if you hit a dog, you have to file a report with the police, and you might have to cart in an injured animal to the vet – no fun at all. Nobody really wants to cause pain to the dog, even if the dog is out where it shouldn't be. So, it's worth some effort to try to avoid the dog. But, what is the right answer?

The answer, I'm convinced, is to keep aware at all times of how much traffic there is behind you and beside you. If you're convinced there's nobody beside you, you can cut the wheel hard and avoid the dog. If the road is empty, you can also brake. Just try to avoid losing control. You might damage your car if you hit a big dog, but you might wreck it if you lose control completely.

And if you know there's heavy traffic all around you, well, you can try squeezing to one side of your lane to give the dog a chance to miss you. And all of the time you must have your thumb on the horn. Maybe the dog isn't deaf, just a little hard of hearing. And, after all that, if you do hit the dog, you have tried your darnedest to avoid hitting it. You did your best. But you can't do your best without being aware of traffic, and without planning in advance.

Now, if you're really aware of what's around you, you will also be prepared to dodge a deer, or a concrete block, or a loose wheel – or a child. Obviously, it's worth a lot to try to avoid a deer, because at 50 mph, almost every car will have several thousand dollars of damage if you nail that deer. And you'll be lucky if you don't wind up with the deer in the front seat with you. As for dodging a child – I hope you never have to do it. But just in case, I hope this column helps you to plan what to do. I know that in Massachusetts there's a truck line (the Crystal Freight Co., Wakefield, Mass.), and on every truck they have painted a scene with the caption: "Crystal says: After the bouncing ball... comes a running child." The scene shows a kid about to chase a bouncing ball out into a busy street. I used to laugh at that because it seemed so far-fetched. Then one day, *two*

PEASE PORRIDGE

times, a bouncing ball sprang out from behind a parked car, into the street, right in front of me. In each case, a kid stood hesitantly by the car, wise enough not to run into the street. But I stopped laughing at Crystal and her silly sayings after that.

Here's another angle on safe driving. Suppose you think you see *something* up ahead in your lane, and you're not sure if it's a blob of cardboard, or a dog, or whatever. As soon as you get at all suspicious, bring your foot over and give the brakes a tiny *tap* and start looking around for a clear lane behind you or on one side. If there's somebody behind you, it will catch their attention pretty quickly, so if you *do* have to hit the brakes hard, the driver behind you will be alert, too. Sometimes this is called defensive driving, and it sounds a little silly, but if you can use these techniques on the rare occasion there really *is* a dog or large object blocking your lane, you won't feel so foolish about tapping your brakes a little early, before you get all your plans made up.

When the N.Y. Giants played the S.F. 49ers in December 1990, the football experts said that Giants quarterback Phil Simms was playing much better that year. He had learned to throw the ball away or take a sack, rather throw into a crowd. Now that's a sensible reflex reaction. But on the game's last play, with the Giants losing 7-3, Mr. Simms could not find an open receiver and wound up getting sacked. The wisdom of refusing to throw into a crowd is imperfect if there's only one play, and you don't have any other chance to win. Every habit should be accompanied by an awareness that there are times when it doesn't apply.

Now, at this point, I wanted to give you some sage advice on how to use pre-planning and reflex response to help you in the electronics business. I had written this far, and could not think of a good example. But Frank Goodenough read my first draft and came to the rescue. He pointed out an old saying, "Never try to catch a falling knife." No matter how fast you think you are, it's very unlikely that you can grab for a falling knife 10 times without getting your hand seriously sliced at least once. Even if the knife isn't moving very fast, your hand is coming over rapidly, and it's astonishing how deep a cut you can make in that situation. In other words, it ain't worth it, and you had best plan your reflex response in advance so your head will automatically tell your hand, "Don't try it."

In the electronics business (see, I told you I would get there eventually) there's a good analogy: "Never try to catch a falling soldering iron." The odds are about as poor as trying to catch a falling knife, and the payback is equally painful. So, it's worthwhile to have a holster where the iron can be kept safely without likelihood of falling. Then drill the idea into your head, that if the soldering iron *does* fall, well, *let it.*

Frank related the story of the technician who was kneeling on the floor in front of his bench, looking for a part he had dropped. When he found it, he reached up and set it on the bench. Then, being an agile and sprightly fellow, he decided to *spring* to his feet. He put his hands on the bench, and gave a great LEAP – followed by roars of pain. He had inadvertently put one of his hands down really hard on the business end of his soldering iron, which was not in any holster. He was lucky to get out of the heavy bandages in a few weeks, but he got a very painful lesson about leaving hot items where they can be contacted accidentally.

Frank also proposed that I extend the analogy to a stack of lab equipment – a pulse generator on top of three power supplies on top of a scope on a cart. If you live in California, you know there's always a 0.05% chance of having your set-up topple in case of a 'quake. Even if you don't work out here, somebody could stumble and bump into the cart. And then you have the privilege of diving to see if you can *intercept* a couple of those valuable pieces of equipment before they hit the floor. It's a little outrageous, but valuable things do sometimes take a dive. Just make sure that your head *automatically* decides that if there is a soldering iron, *that* is not a good thing to try to grab. And perhaps you could set up your equipment so that the stack is unlikely to topple. Maybe you can wire it together, or tape or strap it up so it cannot fall.

Once upon a time, when virtually all electronic equipment ran on vacuum tubes, it was easy to remember that you could easily get a shock from almost any node of a circuit you were troubleshooting. So the rule developed: When probing or trouble-shooting a circuit, *always* keep one hand in your pocket rather than hold onto a chassis or rack. Then if you brush against a high voltage, it will not cause a lot of milliamperes to flow *right past your heart.* The odds of being electrocuted used to be greatly reduced by this simple precaution.

These days, the new transistorized circuits are all at low voltage – except when they aren't. There are line-operated switch-mode power supplies, and high-voltage boosters that can put out ±80 volts – and suddenly that old precaution of keeping one hand in your pocket is beginning to look pretty smart again.

So, whenever I start work on a high-voltage circuit, I tack in a neon lamp in series with a 100k resistor across the high-voltage busses. Then when I see the neon's glow, I'm graphically reminded that this really *is* a high-voltage circuit, and that the power is still ON (I don't care what the power switch says) and I should revert to the mode of High-Voltage Cautions. If I grab onto a really hot wire, the shock might not injure me, but I might convulse and jerk backwards. That's not a good idea if I'm standing on top of a ladder, for instance. So, looking for the glow of a neon lamp is a way to remind me to be serious, and I recommend it for you, too.

Please do try to keep aware at all times while you're driving, whether there's anybody beside you or behind you, so if you do have to make an emergency swerve, you will know if it's safe. It may save your life, or it might save your car. Be careful out there! And, keep one hand in your pocket when working on high-voltage circuits.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

What's All This Negative Feedback Stuff, Anyhow?

Once upon a time, I worked as Director of Development at Philbrick Researches in Boston. I was reporting directly to George Philbrick himself. (I'll have more stories to tell about him another day.) One day George asked me, could I name the earliest example of a system with feedback? I thought for a few seconds and then conceded, "No, I couldn't."

George proceeded to tell me about some master clock builders who had designed many beautiful high-precision clocks back in the 14th or 15th century (I'm trying to give you this story from memory after a full 20 years). They had a tedious procedure for trimming and adjusting the rate of the pendulum for each new clock, to bring it up to the correct speed so that it agreed with a master clock.

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

But one of the master workman decided to get smart and lazy. He added a little mechanical detector so if a new clock's pendulum were to fall behind the reference, it would trip a cog which would then rotate the screw on the new pendulum and shorten it up, making it run it faster. Conversely, if it ran ahead, the screw would be turned so as to lengthen the pendulum. Of course, this was operated as a sampled-data system – it did not exactly work in real time. So if the pendulum's speed was too far out of synch, the servo would not work. But the lazy fellow was able to do some first-order tweaking and then go home. When he came to work in the morning, the new clock's pendulum would be perfectly matched with the reference.

WOW! Let's give a cheer for 1550s technology. This is not only a feedback loop – it's also one of the world's first PLLs (phase-locked loops). That would, of course, be the first if there's any truth to this story. I've searched a little and have not been able to confirm its validity, though. But maybe there's an element of truth in there. Maybe I don't have the century quite right. But, it's an impressive story, and George did tell it to me.

The next week, when it was time for our meeting, I told George that I had an example of feedback that was older than his, by a large margin. He looked at me quizzically and I explained. When the ox or bullock was first tamed and domesticated thousands of years ago, it was found that if you put a ring through the nose of the ox, you could easily lead it with a gentle tug, and the beast would follow you closely. At first, the ox would follow closely to avoid pain in his sensitive nose, but eventually he would learn to follow because it was his job and habit.

Even a small child could learn to lead an ox pulling a heavy cart or sledge, by tugging lightly on a thin cord. So here is the original Unity-Gain Follower, with a *high* input impedance, and a *low* output impedance. Even if the ox didn't pull the load quite far enough, he was still under control "inside the loop," because even a child could tug a few more inches on the cord to get the load pulled up to exactly where he wanted it. I can't tell if that feedback goes back 5000 or 6000 years or more, but it surely is a good old example, and George had to concede that.

In the early 1800s, steam engines were developed to a rather high degree of sophistication. To maintain speed, the governor was invented. The centrifugal force on a couple of rotating fly-balls was coupled into a linear motion that could open or close the throttle. The basic governor had finite gain, so if a load was applied, the engine would slow down and then work its way back up a little – but not all the way back, due to the finite gain. To obtain substantially perfect speed regulation, governors were devised with tricky mechanical linkages so that they had infinite gain. But some of these were unstable. Finally, improved designs had infinite dc gain, but a well-controlled dynamic response, to help keep the loop stable. To think all this stuff went on back in the 1880s! I can look up a whole bunch of these old designs in my old Encyclopedia Britannica, the 1891 edition. YES, *1891*, not 1981!

Now, come to think of it, George Philbrick told me of a saw mill he designed when he was young. He said he designed it to idle at a moderately slow speed, to save on fuel and energy. But when a load was applied, it would speed up smoothly, so as to apply maximum power when the load was heaviest. Of course, any *simple* governor could not do this, because if it sensed the inertial load of the saw blade, it would speed up as it sensed the torque being sent to speed up the inertial load. It could not easily distinguish this from a lossy load, such as a log being cut by the saw teeth. This loop would normally oscillate with a vengeance, back and forth from the highest speed to a stall speed.

But, of course, George claimed he had designed a detector that could distinguish the difference between a dynamic load and a lossy load, and he could servo the loop with adequate stability. In theory, one could indeed do this. But when George was young (in the 1930s and 1940s), I doubt if the tools were easily at hand. Still, I would not want to bet him that he did not or could not do it. After all, in 1970 I designed an analog-to-digital converter that could easily have been built in the

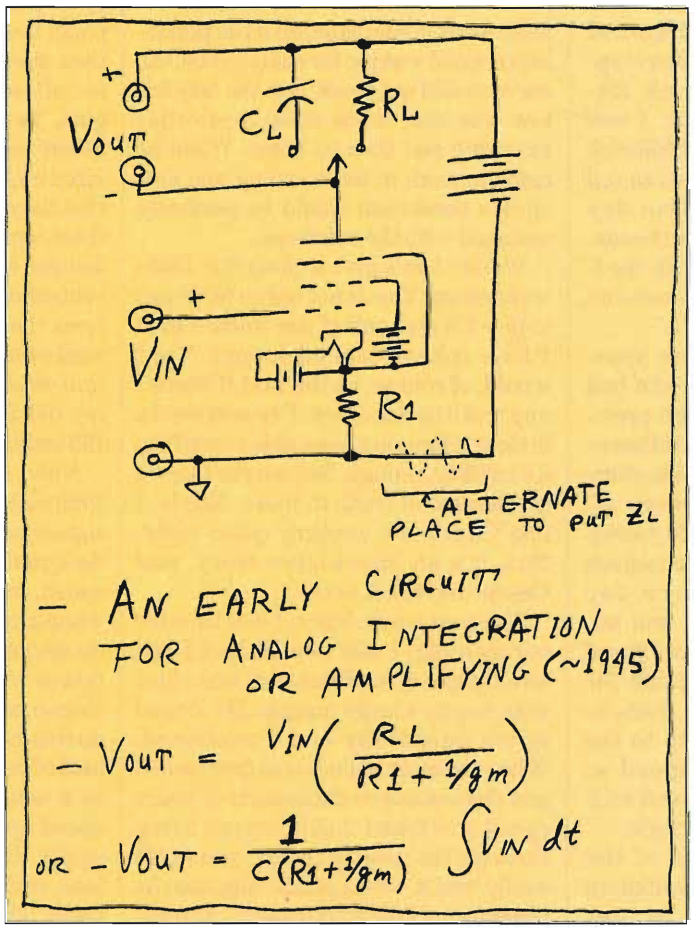
1940s or earlier. But I still think George was pulling my leg.

In the 1930s, Mr. Harold S. Black devised his famous theories about negative feedback at Bell Labs. The best amplifiers of the time still had excessive distortion. When you cascaded 40 or 60 stages of amplifier, as you might do in a long-distance telephone line, the distortion kept building up. With the aid of feedback, the amplifiers' distortion could be cut to negligible levels, even after many cascaded stages. The story of how Black became aware of the advantages of negative feedback, while crossing New York harbor on a ferry-boat, was recounted a few years ago in the *IEEE Spectrum*, and makes fascinating reading....

It was only a matter of time before this led to the analog computer and the operational amplifier. Now, we all know that a basic operational amplifier can integrate a signal. But in the early days of analog computation, even a single pentode could perform integration *(refer to the sketch)*. George Philbrick worked with many things of this type – crude, imperfect, but inspiring. Who invented the operational amplifier? Nobody argues that there was only one inventor, but there were groups of engineers who helped convert those crude, unidirectional current pumps into the familiar op-amp functions we know. And George was one of those pioneers.

During World War II, George worked with analog computing systems, training gunners to do a better job of aiming their guns at fast-moving planes. He found that if you inserted a controller circuit between the man and the gun, it could be tailored to improve the response and accuracy. He could also tailor this response to make the job more difficult, more awkward. He added lags to make it really very difficult to aim the gun. Then after some more practice he removed the lags, and the gunner was now quicker and more accurate than ever. So this was used as part of the training.

George also devised controller networks that, under favorable conditions, could aim a gun at the correct angle ahead of the plane's image – the "lead" – better than a human could. He designed controllers that were very good at adapting to any changes in the dynamics of the gun-aiming circuits.



However, there was one situation George said he could not handle with his controllers: If the gain reversed – if the knob that was supposed to make the gun go to the left made it go right – he could not accommodate that. These days, of course, you could design a computer that would detect this reversed response and then make it work right. But back in the 40s, it wasn't so easy.

Now *that* reminds me of one of my pet experiments. Somebody told me that if you're riding a bicycle, and you cross your hands on the handlebars, your servo will goof up and you will crash. I tried it. I crashed. I will concede that if you think *really hard* and lock up your shoulder with your arms, you may be able to steer the bike to servo things and not crash. But if you just let your arms push and pull, as if they were not crossed, well, I warn you now, it's easy to crash a bike. Please do not hurt yourself. You do not really have to try it; just think about it. But if go ahead with this endeavor, try it on a soft lawn where you won't get ruined when you crash.

These days, there are so many examples of negative feedback, that it's almost preposterous to try to count them. If you have a VCR, the motors are driven at a precise speed by a loop controller. Radios have AFC and AVC loops. A refrigerator's thermostat is a crude, bang-bang controller. Kids' toys act as robots with feedback.

A single op amp may have 2 or 3 feedback loops. When we are driving our cars or riding our bicycles, if we get off center in our lane, we servo back to where we want to be. If the car's speed errs from the bogey value, the speed control pulls it back to the right speed. There's almost no limit to the amount of negative feedback that we use in a given day. And the more we think about the Good Old Days, the better we can appreciate how things work, and how things got to be this way.

Now, I'm only writing about Negative Feedback. I was not intending to write about George Philbrick. Imagine what I'd have said if I had intended to write about George.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

WHAT'S ALL THIS CUSTOMER SATISFACTION STUFF, ANYHOW?

Let's start off with another esaeP's fable. Once upon a time, there was a King who told his Courtiers, "Send up the Royal Wizard." The Wizard promptly came running up, asking, "Sire, what is your desire?" The King said, "Make me invisible." So the Wizard went down to his cavern, got his book of potions, brought up an Eye of Newt, a Wing of Bat, and all of the other good things he needed, and went to see the King. He sprinkled the right potion and incanted the correct phrase and, presto, the King was INVISIBLE. The King's robes and crown kept moving around the throne room, but the King himself was invisible. The whole court was impressed. Good stuff! Good magic!

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

The next morning, the King awoke early and roared, "Get that lousy wizard up here." The Wizard came running up, in fear for his life, as soon as he got the word. "Sire, what is the problem?" The King replied, "Dammit, I asked you to make me invisible, but I'm still bumping into things." *End of fable.*

Think about it. The Wizard did what he was asked to do, yet he didn't get a satisfied customer. The King specified what he wanted, yet when he got what he asked for, he was unhappy.

Does this ever happen with your customers? How can we avoid this in the future? It sure takes much better communication than the King had with his Wizard. Perhaps the Wizard should ask what the King was trying to accomplish. What did he really want?

Here's something to think about: Do you ever ask your customers what they really want? And are you then prepared to give them what they really want, rather than what they said they wanted?

For example, once an engineer at company A went out for a bid on a signal conditioner circuit, and he defined the function he wanted. "This function must consist of an input filter followed by an amplifier/comparator. When you put in 200 mV pk-pk at 100 kHz, the output must give a TTL signal at 100 kHz. When you put in a 4-V pk-pk signal at 5 MHz, the output must not respond." His intention was to specify a steep roll-off of the frequency response, but he never really said that. He just specified a couple of tests that a good part ought to pass.

The Marketing Engineer at Company B looked at this specification and figured out, "If I put a 200-mV clipper or limiter on the input stage, I can meet that spec with a simple 2-pole roll-off." Sure enough, this approach gave a very simple and low-cost circuit. Company B won the bidding with a low price that many would consider a low-ball bid. They began production and had no problem meeting the incoming inspection tests. But when these signal conditioners were put into service, some worked well. Others, though, worked very badly if they happened to be in a noisy environment (which was the whole reason behind having a filter anyhow).

After some side-by-side comparisons, the circuit with the limiter was found to perform quite differently from the intention of Company A. The filter circuit passed the specified tests and fulfilled the spec. But it failed to meet the intention of Company A, because they never spelled out what they really wanted. They really wanted to be able to put in BOTH the 5-MHz noise and the 100-kHz signal and get a 100-kHz TTL output, while rejecting the 5-MHz noises. The circuit from Company B passed all of the specified tests, but it did not meet this unwritten spec. So, most users found that circuit unusable, and the business fell apart, even though the units met every spec. But, YOU would never get caught making that kind of mistake. Would you?

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Dear Bob,

Your reasoning on the Little Egbert problem in the Sept. 12, 1991 issue is wrong. Consider a horn whose radius is $1/x^2$ instead of $1/x$. Both its area and volume are finite. Yet by your reasoning, an infinite amount of paint would be required to paint the outside, since the surface is still infinitely long. On the other hand consider a horn whose radius is $1/x^{1/2}$. Both its area and volume are infinite. Yet again by your reasoning, only a finite amount of paint is required to paint the inside, since there will be some point at which a single molecule will no longer fit. Thus the math tells us nothing about the real-life situation because it is improperly applied.

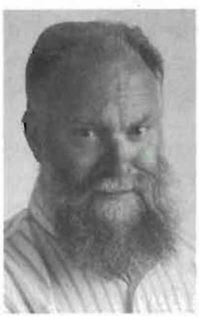
NORMAN D. MEGILL
Lexington, Mass.

I appreciate your restraint in puncturing my ad hominem arguments. You're correct and I apologize.-RAP

What's All This Dead Car Stuff, Anyhow?

Every year, in January, I compile a list of all the Dead Cars I've seen along the highways over the last calendar year. If you want to see a copy, send an SASE and I'll mail it. This year will be the 22nd annual list, going back to when I lived in Massachusetts in 1969. It lists every car according to their manufacturer, and sometimes by type.

For example, I try to keep the GMC cars separate from the Fords or the Chryslers, but I can't possibly segregate the Chevys from the Buicks – for all I know, they have the same engine anyhow.



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

I do separate the Volkswagens from the Saabs, which was my original intention. Back in 1969, I was trying to show some of my buddies that the Saabs of that era were less reliable than VWs, even though the Saab engines had "only 7 moving parts." I found that there were lots of dead or abandoned Volkswagens along the roads, but there were also quite a few dead Saabs. It seemed that there were more Saabs than one would expect from the number of Saabs on the road. Over the years, I kept on listing all of the cars I saw, dead or abandoned, foreign or domestic.

Now, what's the significance of these lists? Do they prove that one car is more reliable than another? No, not really, because even though you could tell how many cars are registered in any state, that doesn't tell you the number being *driven.* But I have had a lot of fun keeping notes on the Dead Cars. And my friends find it amusing to look at these lists.

Just the other day, I was writing down the data for one dead Mercedes Benz and one abandoned Ford with a flat tire. My passenger asked, "You mean, every time you see an abandoned car, you write down a note?" I replied, "Sure... doesn't everybody?..."

In the last five years, I began to keep a list of the cars I saw with no brake lights. I carry an envelope that I can hold up to warn a driver, "YOU HAVE NO BRAKE LIGHTS". I really don't like to see cars driving around with no brake lights.

It's all too easy for them to collect an innocent car on their rear when they hit their brakes and the following driver can't make this out all that well. So an accident can happen, and in my neighborhood, insurance rates go up even though many of us have had no accidents at all.

On the other side of the placard it says "YOU HAVE ONLY ONE BRAKE LIGHT". After one brake light burns out, what happens next? The other one burns out, and the car is left with none. So I like to warn these guys to get their brake lights fixed. In 1990, I notified 69 cars that they had no brake lights, and 144 cars that they had only one brake light.

There were about six guys with no brake lights that got away – sometimes they turn off in traffic before I can catch up with them, or sometimes a light changes against me. I hate to let a car with no brake lights get away. Still, I think I'm doing something useful, even though my wife sometimes gripes that I beep my horn too much just to tell a guy he has only one brake light.

But think about this: A guy has only a right brake light. He starts to signal for a right turn. Then he hits his brakes. In many cars, the brake light and the blinkers are connected to the same bulb, so when he hits the brakes, no change occurs. In some cases, one brake light burned out is as bad as no brake lights at all.

What do I do about brake lights? On each of my four cars, I've rigged extra brake lights up high so that they're really noticeable to the drivers behind me. If 1 or 2 bulbs burn out, I still have a couple left. Best of all, I can look in my mirror and see if the extra bulbs light up when I hit the brakes, so I can tell if the brakes' pressure-switch is working. Now, with a broad pen and a blank envelope, or a piece of paper taped to an envelope, *you, too,* will be able to warn drivers: "YOU HAVE NO BRAKE LIGHTS" and "YOU HAVE ONLY ONE BRAKE LIGHT".

Just what kind of car do *you* drive, Pease, to get good reliability? Ah, yes, I drive a car with exactly the right amount of modern electronic, computerized equipment – a 1968 VW Beetle (my wife drives a newer car, a 1969 Beetle).

Now, as an engineer, I suppose I should say good things about all of the fancy electronic fuel injection and spark computers and diagnostic computers and Lambda sensors. But I get 31 mpg and the car goes just as fast as I want, and that's good enough for me. The bottom line is that I prefer a car that has proven itself by running reliably for 244,000 miles. In fact, until a couple months ago, it was still running on the original engine, and the original crank and pistons and cylinders (though it's true I had replaced the cylinder heads).

Sometimes I do connect a Heathkit electronic ignition system to minimize wear and tear on the breaker points. But right now it's on the blink, so I just went back to the old conventional (Kettering) ignition system, points and coil and distributor and "condenser". I set my own timing and I adjust my own valves. That's one good thing about old, simple cars – if something does go wrong (which is rarely) you can fix it yourself.

Do you ever count your own car, Pease, when it's dead? Yes, but that's not very often. One time my coil burned out. One time my distributor got loose and lifted out of its spigot, and it took me a full hour to figure out that when the engine turned, there had to be a reason why the distributor and its rotor did not. Another time a fuel hose fell off, but I fixed that and got going quickly, so I only counted it as 1/2.

There are several cases where I count a car as 1/2. For example, if a guy with a Volvo is talking to a guy with a Datsun, and they both have their hoods up, I may count 1/2 Datsun, 1/2 Volvo, 1 Helper. I count people who are obviously helping out as a Helper, not as a Dead Car. If I'm not sure it's a Rabbit on the other side of the road on a rainy night, I may count 1/2 Rabbit and 1/2 Modern Boxy Car (1/2 Modbox). If I can't even tell if it was probably foreign or U.S.-made, it gets scored as "1 car".

Do I think that electronic systems are going to improve the reliability of vehicles? Well, maybe. I recall the story of one of the first trucks that had an anti-lock brake system. They were driving innocently down the road when a nearby driver keyed the transmitter on his CB radio and the truck immediately locked up all its brakes. It turned out somebody had decided it would *hurt* the reliability to add bypass capacitors across all of the sensors and the inputs of the sensor amplifiers.

That's what you learn from MIL-HDBK-217...remember? So when the transmitter went on, all of the amplifiers went berserk. Oh, the *amplifiers* were perfectly "reliable," but the system had not been engineered properly. It was a miracle that nobody was behind the truck when it locked up all its brakes.

Are the new electronic systems better for the environment? Maybe so. Maybe a new sedan can travel down the road emitting even less smog and emissions than my VW, so long as its computer is working right. But in 10 years, what happens when you can't get parts for the computerized systems? My car will still be running just fine. I think I'll stand pat.

After all, I have all of the tools and techniques I need to keep old VWs running forever. Forever? Well, there are old VWs around here that are over 35 years old, and if I can keep my good new beetles running 35 more years, they may outlive me. You would not want to bet that I can't keep them running. Meanwhile, if I see another VW broken down along the road, I stop and see if I can help.

Sometimes I have a tool or a gallon of gas, or the spare part they're in need of – a fan belt, or some points, or a clamp for a fuel hose. So I try to help solve their problem. If we can't figure out what's wrong, I leave them a SASE so they can write to me and explain what was the problem once they find out.

For example, one guy sent me a letter stating that the 1969 bus he had just bought was merely out of gas. The gas gauge was broken, but the previous owner, of course, had not warned him about that.

So, when I see a dead, abandoned, or broken-down car along the freeway, I score it. I categorize and count it. Now, if a guy is just changing a tire, or pouring in a spare gallon of gas, I list that problem, but I don't count the car as dead or abandoned. In 1990, I saw 24 people that ran out of gas, 139 with a flat tire, 211 pulled over by a cop, and 16 with a broken drive shaft (remember, none of my cars has a drive shaft). I counted 293.5 GMC cars, 146 VWs, and one Citroen. What are the corresponding totals for 1991? I'll let you know as soon as I have them all added up.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Sir:

I love you! (Do not get your hopes up, I am 50, overweight...and male). I was beginning to think I was the only engineer left in the world who still thought there was merit in breadboards, or common sense designs for that matter.

I am fighting a losing battle against the invasion of simulated labs (plastic labs as a friend put it). Recently, the administration at the engineering school where I teach was talked into replacing our logic design laboratory (undergraduate) with a network of workstations.

I have been trying to convince everybody that such an action was a huge mistake, and that the only people who should have (limited) access to such tools were *experienced* designers who could instinctively know when they were being fed rubbish. But I have been sadly outgunned by those (almost all) around me. The main argument against me and my position has always been: "that is how INDUSTRY does it."

My contention that such machines are a hindrance to learning and should be banned from a learning environment was always received with total disbelief, because "those are the tools REAL ENGINEERS use to improve their productivity."

I also got *absolutely nowhere* when pointing out that those engineers who do derive advantages from such tools are people who learned their trade *without* these machines. They use them to *supplement* their knowledge and abilities rather than *replace* them.

It gives me immense pleasure to see that someone else (with maybe a limited knowledge of the real world, not an academic type like myself) seems to be fighting the same battle. I might not win the war, but I shall not be alone in my abject defeat.

What can we do? These people will not read (at least not seriously) such "sour grapes" prose as yours. After all, they *know* that is how INDUSTRY does it. I sometimes get the feeling technology is shooting itself in the foot. By using technology to replace thinking, we are freezing it at the state the software engineers used to design their wares. And I sense that, a generation or so from now, when everyone else has forgotten how a transistor works, and the computers start to die off, nobody will be left to fix them or design new ones.

Are we seeing the last technical generation? Will the computer simulations do to creativity what the calculator has already done to mental arithmetic? I fear it might, and I am at a loss on how to stop it. Taking a hammer to the darned things will only divert more funds to fixing and protecting them. Maybe a more direct plea from people such as yourself to university planners would help, since it is not "politically correct" to criticize computers within our walls. People were less defensive of their religion during the Spanish inquisition than they are of their computers these days. Anything you can do would be greatly appreciated.

GEORGES-EMILÉ APRIL
Professor of Electrical Engineering
École Polytechnique de Montréal,
Montréal P.Q, Canada

I hear you! I agree.—RAP

Dear Bob:

I enjoyed your article "What's All This Spicey Stuff, Anyhow? (Part III)" in the October 10, 1991 issue. Unfortunately, the main idea of the article expressed with a Russian proverb "Trust, but verify" was somewhat turned upside down for me, because *Proverai no doverai* means exactly the opposite: "Verify, but trust." The reason for this confusion is that you misplaced two words. This proverb should read *Doverai no proverai*. Being a recent newcomer from Russia to the U.S., I couldn't help but notice this little mistake.

MIKE KORKIN
Development engineer
Fischer Imaging Corp.
Denver, Colo.

I sorry. Thanks for the correction.—RAP

Dear Bob:

Gee, I wish we had more sensible people like you. One of my young engineers came to me with the plaintive cry that his SCR R/C snubber circuit was oscillating!

He had set up the circuit in Tutsim, or something of the sort, and kept juggling component values in an effort to "stabilize" it. He had not even examined what he was doing far enough to realize he had a passive circuit oscillating. The problem, of course, was the default step size on the canned program.

KEITH H. SUEKER, PE
Engineering manager
Robicon Corp.
Pittsburgh, Pa.

Exactly my point!—RAP

Dear Mr. Pease:

I have read your article in the October 10, 1991 issue, "What's All This Spicey Stuff, Anyhow? (Part III)", and I find that I agree with most of what you say.

The current debate on the extent to which universities should rely on simulation in the teaching of electronics has an interesting historical parallel. Twenty years ago, many universities replaced their electrical machine labs with analog (and later digital) simulations. The "old school" regarded this as a backward step in the education of practical electrical engineers.

PEASE PORRIDGE

There is one part of your article on which I would appreciate some further elaboration: the paragraph on metastability. Since this is a statistical phenomenon, a deterministic circuit simulation is not going to give much directly usable information, even if there were no artifacts due to numerical problems.

However, the probabilistic model for the metastable behavior of a latch is simple, and has been thoroughly tested over a number of years. The circuit design problem is finding the parameters to use in the statistical model, and then to optimize the circuit with respect to its metastable operation. Here, the use of Spice can help. (Many papers have been published on this topic, not all from universities.) Obviously, the only model in which you can have full confidence is the breadboard. But CAD can help, in my opinion. Any comments?

MARTIN J.P. BOLTON
Inmos Ltd.
Bristol, England

Spice can develop the facts you need to study metastability, but can't do it directly.—RAP

Dear Bob:

Thank you for writing all those great articles. I save all of them and share your views of this linear world.

Would you believe that strain-gauge power supplies are now extinct? I sure wish I could still buy one, but have been unable to find a single vendor that still sells them. I think we need to raise a hue and cry about this. I have always considered them one of the true basic building blocks and are about as close to batteries as you can get. Too many power supplies today have high capacitance between windings and they transfer line noise right into the circuit we are trying to clean up. Once in a while, we can find a simple foil shield between windings. But almost no one will tell us about it, much less give any specs on the strays.

When you specifically buy an isolation transformer, the single shield seems to be added by the vendor as an afterthought, and there are no specs. And to add insult to injury, it is arbitrarily grounded at the case and/or returned to the third wire on the line cord.

I am convinced that nobody makes decent power transformers anymore. Any bench supply should have carefully isolated windings with adequate shielding from the power line. A little care in that area would save us hours later on when the noise hunt begins.

In the meantime, I'm going to be watching for old strain-gauge supplies in the junk stores. There should be a lot of them out there, unwanted and unused. Maybe it's about time to rediscover what they can do.

NEIL IVERSON
Boeing Co.
Seattle, Wash.

Can anybody recommend where to buy good, well-isolated supplies; or a good transformer so you can make them?—RAP

Dear Sir:

Please keep up the good work. I have read trade publications for ten years now and have never regularly read a columnist. But now I read your column.

The pictures and handwritten captions are great. I have also never written a letter to a columnist, which means I'm enthused about yours.

I want more of the black magic of analog engineering. Things like why amplifiers oscillate, and why oscillators amplify. I'd also like to see more of your circuit breadboards. I teach "communications" here; we build (my students and myself) RF amps, VCOs, mixers, etc., on breadboards. I want to see how you do it.

Send a copy of this letter to your publisher and ask for a raise.

DAVID D. DRAPER
Electronic Technology Dept.,
Utah Valley Community College
Orem, Utah

I'll hire your kids a lot quicker than guys who can only drive a simulator.—RAP

PEASE
PORRIDGE

What's All This Applications Engineering Stuff, Anyhow?...

...Or, Why Being an Applications Engineer is Sometimes Like Being Nibbled to Death by Ducks.

When I first started to work for National 16 years ago, I thought I was going to learn how to design good monolithic ICs. And I did, eventually. But the very first day on the job, Pete Lefferts gave me National's new 1976 Linear databook, with a list of 10 ICs taped onto the front cover. "These are the ICs that our group is responsible for. In our group, we design engineers also handle the applications engineering for our parts," Lefferts said.

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

Well, that setup sounded pretty good to me, because up to that time I had been pretty much an expert at applying ICs. I soon figured out how to field and answer most of the calls cheerfully. Of course, there were some calls too technical for me to know the answers. So, I just took good notes and then got some help from other more knowledgeable guys. I learned how to steer the customer to the right op amp (whether we made it or not). I learned how to explain to a customer that a TO-3 regulator could dissipate 20 W, *but* only if attached to a heat sink. I even learned to refer to an LM741, rather than a μA741.

The most important thing I learned was that if you want to avoid lots of "dumb" phone calls, you should write a very good, clear, comprehensive data sheet. When customers ask for needed information that wasn't included, it's not a *dumb* question, but rather a *dumb* data sheet. At least 30% of the calls were caused by a lack of sufficient information in the data sheet. So I learned to put *lots and lots* of good info, necessary info, into my data sheets. The penalty for not doing so is having to answer "dumb" questions forever.

That reminds me of the Quality Control procedures for the "riggers," the people who pack parachutes. Obviously, packing parachutes is a very serious, very responsible job. How do you make sure that the guy packing 'chutes never gets sloppy, never goofs off? Ah, very simple: At the end of every month or so, each parachute rigger is invited to select one chute at random from a pile of all the chutes he has packed, and then he goes up and jumps out of a plane. Ah, if only there were QC procedures as good as that one, one that we could design for other jobs! If only we could all have such a good incentive to do perfect work. But in general there is not...if you can name one, you tell me.

Anyhow, in the last five years, our Linear group has moved further away from the concept of having every Design Engineer do applications engineering, too. This certainly makes some sense. There are some people who are really good at designing silicon, and it's not fair to tell them they can't do it if they're not also good at talking with customers on the phone.

So now we have gone into a little bit of specialization. Unfortunately, it often means that an apps engineer gets on the phone to discuss a big project, and soon needs "a band-aid to put on his ear." There are times when an hour on the phone is needed for a special case, and that really is tough on the ear. In other cases, an apps engineer gets on the "MAC," and works on several data sheets for a sprint lasting several days. I don't think I would enjoy that. Still, there are detailed technical problems that are appropriate for me to answer, and I still help out on specialized facets of applications engineering. I just don't get to take so many "cold" calls.

But what is the crucial thing about the applications engineer's job? I guess it's that he (or she) is an *interface*. Whenever the design engineer wants to design a piece of silicon to make a customer happy, the apps engineer should help facilitate the process, by showing the best way to teach the customer how to apply the circuit. He has to write a clear data sheet, list all of the features and specs, spell out cautions, and show what new applications are suitable.

What if the proposed silicon is lacking a necessary feature? Then the apps guy has to holler "WHOA!," until the need for that feature (or the lack of that feature) is resolved.

One time I was doing a redesign of a regulator, and the apps guy wanted me to add in protection so all of the pins would be ESD-proof, up to 2000 V. But I argued that if we added that protection, the circuit would not work in some existing sockets. Finally we compromised. I agreed to add all of the ESD-proofing I could so that the part could work in existing sockets. We wound up with a part that would pass only 800 V by itself, but when plugged into a usage circuit, its ESD tolerance was improved up to 2 kV because some pins linked together.

Other times, when a customer has difficult questions about an IC, the apps guy acts as a filter to make sure that all of the relevant questions get asked. Then the design engineer has all of the information he needs before he starts to work on the problem. The apps engineer is quite valuable when he gets all the facts lined up for the experts. Of course, most of the time, the apps engineer gets the facts and solves the problem by himself – he is the first-line expert.

What other things do apps engineers do? They design and evaluate circuits. They write and rewrite data sheets and applications notes. They teach other people by giving seminars and writing magazine articles. They communicate with every kind of user, from the grouchiest to the nicest, from the laid-back to the desperate ones. Their customers include op-amp experts, and also expert chemists who need a little advice about how to interface simple op-amp circuits to their systems. They hold the customer's hand. They won't let him fail.

Apps engineers act as a psychologist, and sometimes as a psychiatrist – they cajole and debate, and they know how to convince people to do things. They also breadboard things. And they run computers. They simulate things. They interpret ideas and data and people's wishes.

Do they get rich and famous? Usually not. Most of the time, they get (at best) begrudging thanks from the customer who did not like to be told that he needs a heat sink to keep his 20-W regulator from getting hot...or from the IC design engineer who is mad that his project is delayed because the apps engineer talked him into redesigning his output stage to add a necessary feature.

On top of everything else, the apps engineer has the thankless job of deflecting and absorbing a thousand complaints. Like an offensive lineman in the National Football League, the best he can say is that he didn't let the quarterback get sacked today, despite the opposition's best moves. Maybe he even has the chance to make a brilliant play. But most of the time, people just beat on him, as if they were trying to wear him down. They ask every kind of picky, niggling, quibbling question. They bring his sanity into doubt. Sometimes they make his day less than fun. Sigh.

Apps engineers don't just get steamrollered. Sometimes they get nibbled to death by ducks. They may even get ulcers. But usually they have a personality that lets them survive these stresses. After all, just because we put all of the info in the data sheet – does that mean that people READ That Fine Data Sheet? If all else fails, call the Apps Engineer? If all else fails, read the data sheet? Never happen!!

I recall one friend, Jim, who had been an apps engineer for many years, and he gradually decided that he was not in a mood to talk to customers on the phone. One day his phone was ringing and he was sitting at his desk trying to ignore it, when his boss walked in. After a few more rings, the boss said, "Jim, do you know who is on that phone?" Jim replied that he did not. The boss said, "Jim, the guy who is calling you on that phone, is *me*". And he went on to explain why an apps engineer really *has to* answer the phones. Jim was able to talk his boss into not firing him outright, but he was given a month to find a job he could agree with.

There's still one last thing that apps people do, and I think it's the most valuable: They listen to people tell them what they "need" and what they "want." Then they try to figure out what the customer *really needs* to make him happy. That may be *quite* different from what the customer *says*.

Sometimes the customer is unrealistic. Sometimes the apps guy is "lucky." Sometimes there's no brilliant or easy answer. But when I was doing a lot of apps work, I considered it my most valuable privilege to hear 19 people ask "simple" or "trivial" or "nasty" questions, and to answer them the best I could, just so I could hear *one* customer ask a REALLY GOOD question.

Sometimes the question points out a deficiency in a data sheet, leading to an improved data sheet, so every user gets the advantage. Sometimes it leads to an applications note, or a magazine article. Other times it leads directly to a new product. Other times it leads to a debate, or an argument with your boss, or a screaming contest. Out of that argument often comes some better way to do something. But you never can tell which caller will be asking the really valuable question. Sometimes it's the op-amp expert—and sometimes it's the chemist.

My boss will probably be pleased to hear that the amount of time I'm "wasting" on apps engineering is less than a couple hours a week. But when someone asks me to put on my Applications Engineering hat, the calls I get are really some of the most interesting and valuable ones. That time isn't "wasted" at all.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

And now, here's a comment from Kerry Lacanette, Applications Engineer for Data Acquisition Circuits at NSC:

Bob, I don't think the customers are as bad as a reader might infer from your discussion. I can think of lots of those annoying "duck" calls in which a series of customers would ask "why don't you build a...?", or, "Do you have an ...IC with a pin that does...?" or some other question that we *thought* we had spelled out clearly in the data sheet. While we may have been annoyed by some of these calls at the time, or we carefully explained to the customer why they couldn't have what they wanted, these customers were really voting – voting for features, products, and better data sheets. We have occasionally counted these votes, and brought out better products because of them.

"Nibbled to death by ducks?" Yeah, I feel that way on a bad day. But would I prefer to take only the "good," "intelligent," or "challenging" questions? Nope. – Kerry.

Kerry, I agree with you completely! You have helped me complete what I wanted to say. Another way to look at it may be that just because a question is "dumb," it doesn't mean the "answer" is dumb. The answer may be challenging or complicated or valuable – and vice versa. Thanks for your comments.—RAP

Bob's Mailbox

Pease Porridge—A Neal Certificate Winner

ELECTRONIC DESIGN is pleased to announce that Bob Pease's "Pease Porridge" has been honored by the Editorial Committee of the American Business Press with a Jesse H. Neal Certificate in the category of Best Regularly Featured Department or Column. ELECTRONIC DESIGN's Chief Copy Editor Roger Engelke shares the honors with Bob.

Robert:

...I especially enjoyed the article in the Sept. 26, 1991 issue regarding copper clad. One application which I would like to add to your excellent collection is that of RF stripline design.

Being an old RF Dawg working in the area of 300 to 1000 MHz, I used to buy single-sided copper-clad boards of various thickness to do stripline design. This was accomplished with a roll of 3M copper tape and an Xacto knife with plenty of spare blades for trimming the tape once it was on the board. When my careful calculations were done, I would lay out a board using the copper tape and experimentally determine the effects of inter-trace spacing and trace shape. Using this technique has saved my company lots of square feet of copper clad over the years, and lots of prototype pc-board layout.

LAWRENCE O. RICHARDSON, P.E.
Senior development engineer
Halliburton Logging Services
Houston, Texas

Sounds neat! And versatile for breadboarding.—RAP

●

Dear Bob:

That was a great article on copper-clad board. I use it to make microwave horn antennas. You just need a big soldering iron, a pair of shears, and a waveguide flange.

TOM WEBB
Texas Instruments
Dallas, Texas

Honk if you're a horn expert! I'm not much of an RF man myself.—RAP

●

Hi Bob:

...Having just finished your column on the many uses of pc boards, let me add another trick. Find the local store that deals in materials for STAINED GLASS. One method for joining glass panels is sticky-back copper tape, available in several widths and very solderable. Wrap that around the corners of a pc-board box, run a bead of solder along the seams, and I bet not much will get past that boundary.

There is a certain art to soldering copper foil using a big iron (>200 W). With practice, a pool of solder is formed and the iron is lifted slightly off the foil. Then, as the solder is drawn along the foil and solder is fed in simultaneously, a very beautiful bead forms that's as smooth as silk. Copper-sulfide crystals dissolved in water and rubbed over the solder will return it to its copper color. This might be useful for a "presentation" box. Oxalic acid is the standard stained glass copper flux.

PETER DOHERTY
Address unavailable.

Neat ideas. Pretty, too!—RAP

●

Dear Bob:

...On the top floor of a department store called Seibu Loft in Shibuys, Tokyo, they sell lots of "artsy" stuff at exorbitant prices to Japanese yuppies and yuppie-wanna-bes... I was in Japan recently on a business trip and lo and behold, they were selling lamps and clocks that used surplus pc boards (without any components on them) for the shades and faces. Even more amusing were the prices – some were as high as 50,000 yen for a lamp. Why didn't I think of that?...

...While I lived in Tokyo, I found myself in desperate need of a major project to keep from going totally bonkers, so I decided to try building some electrostatic speakers. The speakers not only sound good, but due to the voltages used (about 1200 V dc with peak ac voltages that approach 4000), they also make great bug zappers. Needless to say, good insulators are essential. That's where FR-4 circuit-board material comes in. The stuff works great! My most recent project uses FR-4 as the insulating frame, which keeps the diaphragm under tension and supports the perforated metal sheets...

...Unfortunately, I didn't realize how difficult it is to saw FR-4 until after I bought it. What a horrible job that was! I ended up cutting the stuff with a carbide hacksaw blade, which I modified to fit my electric scroll saw. You may want to warn your readers about the unhealthy effects of breathing the dust generated by sawing epoxy-fiberglass board.

MARK REHORST
Fremont, Calif.

Good info. I prefer using heavy tin snips to sawing (or see Duncan Moyer's letter below).—RAP

●

Hello Bob:

What's all this penny a square inch stuff, anyhow? Being a long-time practicing frugal engineer, I was very intrigued by your article on copper-clad innovations. I typically have to pay 10 times your mentioned price for the stuff when I can find it. So PLEASE

PEASE PORRIDGE

Pease, give me some tips or clues or contacts on your sources.

Thanks for the great column. It's always refreshing to observe a member of our profession in firm contact with the real world.

JOHN K. CARTER
Norman, Okla.

For approximately 36-in.-by-4-in. strips of good G-10 at 1¢ per square inch, call Halted Specialties Co., 3500 Ryder St., Santa Clara, CA 95051; (408) 732-1573, VISA/MC. For virgin 3-ft.-by-4-ft. sheets of FR-4 at 3¢ per square inch, call Advance Electronics, 1661 Industrial Way, Belmont, CA 94002; (415) 592-4550.—RAP

●

Dear Mr. Pease:

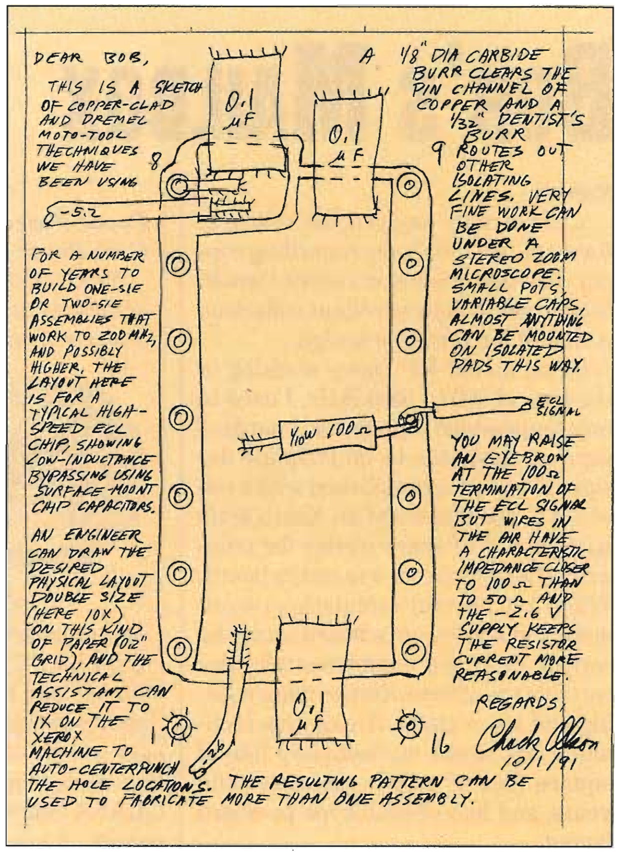
...We use a small paper cutter for cutting circuit board. There is a tendency for the board to be pulled into the blade so square cuts are difficult, but not impossible.

We also use the paper cutter to cut thin aluminum. Cutting both these materials does not destroy the edge on the cutter and we are still able to cut paper quite well.

We obtain, for free, scrap circuit board material from our local board fabricator. He has a good supply of material that is, for the most part, too small for his use. He does see a return, though, because he does our board manufacture.

Larger pieces of braid (outer braid on coaxial cable) make good hinges. Solder-wick also works well for hinges, although it's difficult to keep solder from wicking into the hinge.

DUNCAN MOYER
Technical services manager
Radio Systems Technology Inc.



Grass Valley, Calif.

Good techniques—thanks for sharing.—RAP

●

Dear Mr. Pease:

...Yes, copper-clad board is very useful to me as well. I thought I'd add one more use to the bag of tricks. When I need to epoxy two things together, I use a 2-in. square piece of copper-clad board as an epoxy palette. The epoxy I use has resin and hardener in separate tubes, so I squirt the stuff onto the board and mix it with a hunk of 14 AWG bus wire. Copper-clad palette is great because it's so plentiful (around here) and the surface is clean as opposed to paper products.

I suppose it would work just as well for artistic painting.

DONALD J. DELZER
Electronic design engineer
Tektronix Inc.
Beaverton, Ore.

That stuff sure has many uses!—RAP

EDITORIAL

Taking The Responsibility

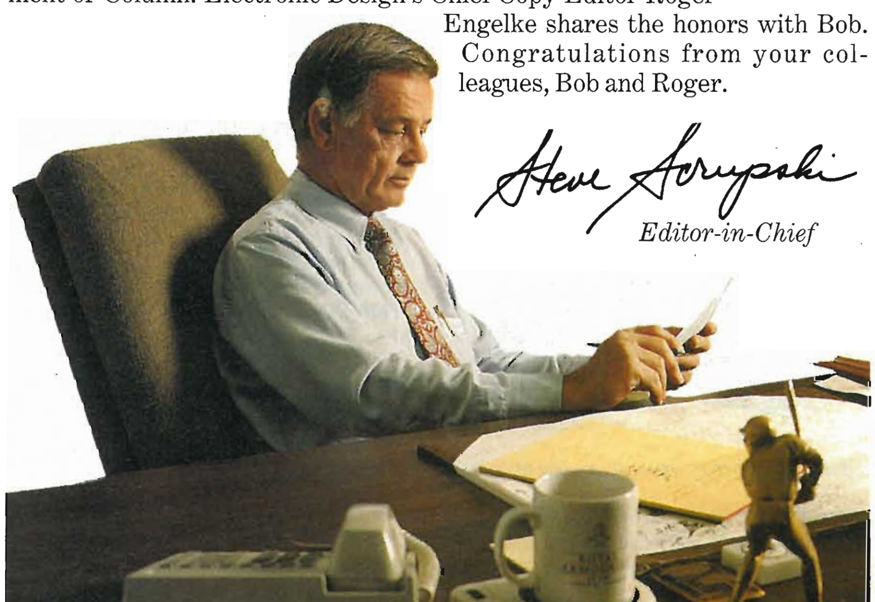
For as long as I can remember, the secret of successfully designing and marketing a product has been "Find a need and fill it." Some slick marketers may have altered this to "Create the perception of a need and then fill it." In either case, the advice carries an implicit recommendation for a pro-active approach. It essentially says "Don't just sit there, go out and do something if you want to succeed." And, conversely, it means that if something goes wrong, you have no one to blame but yourself. Controlling one's own destiny is the American way, at least until recently.

These days, that individualism is being replaced by a "it's not my fault" mode of thinking. There always has to be someone else to blame for our woes. This trend is exemplified in our judicial system, where an overwhelming amount of litigation is burdening the court system. Whenever misfortune befalls someone, it seems the first reaction now is "Whom do I sue, because this obviously could not have been my fault." This litigation craze has even reached the extent that a cab driver in San Francisco gets sued – and loses – because he injures a mugger while restraining him after a crime. We also see this pass-the-blame approach in our schools, where teachers push responsibility onto the parents for a student's poor performance.

"Our principal problems are within and not without...To remain great we must again emphasize politically, economically, and socially those basic methods that made us great in the first place." These two points are made in a recent insightful newspaper ad sponsored by George Romney, former Governor of Michigan and CEO of American Motors. In international trade, Americans can complain about unlevel playing fields, but while we're expending our energy doing that, competitors steadily improve. In today's world, you simply can't afford to wait around for government to redress inequities and expect that to solve competitive marketing problems. It's far better to focus on correcting our own problems, from short-sighted management to a barely coping educational system.

A Neal Certificate For Pease Porridge

On a happier note, Electronic Design is proud to announce that the Editorial Committee of the American Business Press has bestowed a Jesse H. Neal Certificate of Merit on Bob Pease's column, "Pease Porridge." The column was honored in the category of Best Regularly Featured Department or Column. Electronic Design's Chief Copy Editor Roger Engelke shares the honors with Bob. Congratulations from your colleagues, Bob and Roger.



Steve Scrupski
Editor-in-Chief

PEASE
PORRIDGE

What's All This Calculator Stuff, Anyhow?

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

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

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

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

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

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

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

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

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

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

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

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

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

I hope this peek into calculator theory will dispel the blind trust in calculator and computer results, and in all that complex digital stuff. Now that you've been alerted to a future of continuing digital problems, you will not be surprised when your naïve colleague's new 17-digit calculator sinks into Digital Nirvana when trying to pin down the penultimate digit. You will know that calculators, like everything else, face limits. The Digital Illusion can't shelter us indefinitely. Although the affable, warm-hearted analog engineers have used all of the technology at their disposal to stretch the Illusion over the last 40 years, their numbers dwindle, and the digital engineer's age of innocence must end. A moment of silence, please, for those generous analog folks who have worked so continuously and indiscreetly during these long, hard years.

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

And, lastly, April Fool!

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Dear Mr. Pease:

I have been able to tolerate your vilification of Spice as that of an uninformed user. However, your publication of a letter from another such user forces me to respond.

Check the words leading to the acronym Spice sometime. A review of the original treatise by Vladimirescu and Liu might be informative. See anything about board design? If you are going to use a tool for a purpose other than what it was intended for, you had better understand how to apply it. The custom *Integrated Circuit* designs that I have done performed as well or better than indicated by Spice simulation.

There is no reason Spice can't be used for board design, if you pay attention to how the program converges, and why it converges to a particular solution. Any professional who uses public domain versions gets what they deserve. The program was developed for those of us that *can't* breadboard a design, not those so foolish not to.

KEVIN J. McCALL
Custom Analog IC Design Engineer
Leominster, Mass.

What irritates me is when people say I am uninformed and Spice has to be telling the truth—when the truth turns out to be vice versa. I'm delighted Spice works for you.—RAP

Dear Bob:

I particularly enjoyed your article last year about your calibrated cardboard boxes. I work for a well-known temperature-controller company. We were having customer problems with C-type thermocouples and chasing every last tenth of a degree. Needless to say, it wasn't the customer's fault or our fault—the compensation cable didn't match the thermocouple table. It turned out that the errors of an earlier instrument matched the bad cable better than the new one that 0had smaller errors!

...However, my fingers started to rattle the keys after reading one letter in your mailbag. Namely the guy from Boeing looking for some strain-gauge power supplies.

Well, "my own bit on the side" just happens to be precisely that. I sell them, at the recommendation of our National Physical Laboratory, to people wanting very high stability for precision force measurement. Now, I took a lot of care to develop a circuit that would give Kelvin buffering to both the positive and negative outputs, and add minimal errors to the basic reference.

I haven't taken that much care over the noise immunity and earthing that Mr. Iverson is looking for. However, I've checked a few details and can quite easily get shielded transformers specially for him. So if anyone else is after stable 10-V power supplies – mine will put out up to an amp, making it a good laboratory reference, too. Please pass them my address.

And now while I'm writing to you, here's a poser that bemuses me. If I, as an engineer, wish to start up my own business at home while working for someone else, it causes all sorts of chaos. "Company loyalty, design rights, conflict of interests" – you name it and it's there. But now, if having left that company, I apply to a new company for a job, and openly declare my own private business, I'll be greeted by enthusiasm. "This man has initiative..."

JIM EDWARDS
Quiet Electronic Designs
60 Clayton Rd.
Selsey, Sussex P028 9DF
Tel: (0243) 602132

That's a good conundrum. Thanks for the info on good supplies.—RAP

Dear Mr. Pease:

I enjoyed the Pease Porridge about splices in speaker wire. It reminded me of the philosopher Paul Thagard's essay about astrology. He says the thing that really marks astrology as a pseudoscience is not that astrologers don't *know* why it should work; it's that they don't care why it should work.

The same could be said for the speaker-wire cult. If these people had really found an empirical correlation between splices and poor audio quality, they'd be scrambling to find a physical explanation. But no. Like Peter Pan, "ya gotta believe" (and, in this case, pay money).

MICHAEL A. COVINGTON
Assistant to the Director
The University of Georgia
Artificial Intelligence Programs
Athens, Georgia

A good point, nicely worded.—RAP

Dear Bob:

Re: What's All This Reflex Response Stuff, Anyhow? ...This is in response to dropping a very small important item (also valuable in terms of inconvenience if lost), such as a 1-mm left-handed screw from a "grungle plunger." Don't try to catch it or deflect it. *Just watch where it goes!*

The reason? Small items often bounce and roll a long way. If you lose sight of it, it can take a frustratingly long time to find because it's small.

JOHN FLEMING
Research technologist
Department of Midwifery
University of Glasgow
Queen Mother's Hospital
Glasgow, Scotland

In your business, when you drop something, you darned well better watch to see where it rolls! – RAP

Dear Bob:

Sometimes I have a hard time getting my colleagues to take a simple path to an end. But if I remember correctly, you are currently collecting other people's common-sense stuff for your next book. I know I will have more luck getting my cohorts to try this trick if it appears in your book first. So please accept this widow's mite.

People who design electronic projects often need to be concerned about temperature. Hot spots accelerate degradation of materials and thereby cause premature (whatever that means) failure. So how do we find hot spots? If we really care about temperature uniformity, for example in a precision analog instrument, we set up a tangle of thermocouples on a sacrificially modified prototype, and wait. A long measurement period in which we collect lots of data is followed by hours of disagreeable evaluation, culminating in dubious conclusions.

If all we want to do is find hot spots, though, we can use a simpler approach – liberal use of mercury-in-glass fever thermometers. Fever thermometers have a number of favorable characteristics for surveying hot spots in electronic systems.

First, remember how you have to initialize a fever thermometer? It's a peak recorder. You have to shake it down to the arrow points before you use it. You can shake down a few thermometers and then leave them in the system for as long as you like. You can operate the system in all it's various modes, some of which certainly generate different temperature distributions than others.

At the end of the exercise you simply take the thermometers out and look at them, and learn what the worst peak temperatures were in all of the spots you monitored. There is no excess data to discard.

Second, the fever thermometer's temperature range, 94° to 106°F, is near ideal for surveying commercial equipment. By testing your equipment at room temperature ambient, you can learn about an internal 25° to 35° rise. If it turns out to be less than 25°, it's safe and you don't care to know any more about it. If it's more than 35°, you need to understand it better and will want to investigate it in more detail.

Third, a fever thermometer is self-contained, tiny, and (unless you break it) electrically insulative. You can insulate it right where you want it and secure it with sticky tape. Compared to the average thermocouple wire, a glass thermometer is an easily tamed instrument.

Fourth, the mercury bulb of the fever thermometer offers a small, well-focused sensitive target. If located in a convective plume above a heat sink, a fever thermometer will give a surprisingly high (but accurate) reading.

If you think you want a larger target to average over a larger area, wrap the bulb end of the thermometer with several thicknesses of 1-in.-wide aluminum foil, and insulate with clear tape before installing in the system. Or, survey the plume with three or four thermometers all at once.

DOUG RAYMOND
Teradyne ATWC
Walnut Creek, Calif.

The temperature of a hot spot is the room ambient plus its rise above ambient. If you want to resolve large rises, work in a cold room. To resolve small rises, start in a warm room. So, your thermometers are even more useful than at first glance.—RAP

WHAT'S ALL THIS VICE-VERSA STUFF, ANYHOW?

Well, I always did want to write a column about vice-versa stuff. As my old friend Dave Ludwig likes to say, "In this world, it's dog eat dog – or vice versa." As I already mentioned in my column about negative feedback, it's nearly impossible to ride a bicycle with your arms crossed, because the arms get their tasks all figured out *one way*, and then you can't tell them to do the job *vice versa*.

So I wanted to write a good column about other vice-versa stories, and along came Jack Fogarty, Darryl Phillips, Doug Grant, and Gunnar Englund, who beat me to the punch. At this point, there's nothing I can do better than to shut up and let you read their letters:

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

Dear Mr. Pease:

Enjoyed your Jan. 9 column on negative feedback. Let me add one thing about crossed-arm bicycling.

If you try to balance a bicycle while rolling backwards, you'll crash. *But*, if you can cross your arms, hold them rigid and steer with your *shoulders*, you'll find you can balance – at least for a little while.

If you *think* about what you're doing, you'll crash, but if you let your automatic balance prevail, well, surprise! It works.

JACK FOGARTY
Professional Engineer
Columbia, MD

And I say, that's marvelous. I believe it. I haven't tried it yet, but I will. Next:

Hi Bob:

You sure hit a nerve with your mention of riding a bike with crossed hands. Of course you're right, and there are implications that go beyond a showoff stunt.

Probably more ingrained in our genetic servo wiring is control of our feet. From the first creatures, the left foot has pushed off to go right. This may actually be the reason the brain lobes are crossed.

We take walking so much for granted it's difficult to even discuss the mechanics, so consider roller skating. You push with the foot opposite to the desired turn. It's equally true on other machines. Sit any kid on a sled, give him a start down the slope, and he will steer it fine with his feet. Push with the left foot to turn right. Can you think of an exception?

There is one. The airplane. The rudder pedals are hooked up "backwards" (you push left to turn left), and it cause the same cross-control problems you alluded to. One of my joys is giving first rides to kids, often in the 8- to 13-year-old group.

Most of them really take to flying, they do better than the typical adult. But taxiing for the first time is a nightmare. Invariably they go the wrong way, and make some comment that it's hard to steer with your feet. They're too overloaded by the unfamiliar surroundings to realize the obvious: the pedals are backwards.

Over the years, I've mentioned the problem to many pilots, and I've yet to find one that agrees. Usually they give me a look that says, "Well, buddy, I don't know about your rudder, but mine is hooked up just fine!"

The human is a very adaptable creature. We learn to fly and do okay most of the time. But within the brain, training is pulling one way and instinct the other. And when things suddenly come unglued – and millisecond response is needed – instinct sometimes wins and the wrong foot is used. It would be better to have the two forces aiding rather than opposing, but it's hard to make the changeover. Anyway, I wanted to share this with someone who understands.

DARRYL PHILLIPS
The Airsport Corp.
Sallisaw, Okla.

Now that's a scary thought. Yes, a sled is easy to figure out how to steer. And yes, an airplane is feasible to control, and many people figure out how to fly it quite easily, after you think about it a little. But I never thought of its controls as being backwards or vice versa....

Now let's go on to a story about British Flying Officer H. M. Schofield, who was a pilot for racing seaplanes in 1927: "He took the Short-Bristol 'Crusader' out for a trial flight on Sunday the 11th. No sooner had he lifted off the water when he did a jerky half-roll and slammed back into the sea again. The impact tore the aircraft to bits and ripped off most of Schofield's clothing, smashing his goggles against his forehead. Bewildered, half-drowned, and infuriated, he was carried off to the nearby Italian Naval Hospital. When his aircraft had been reclaimed, it was found that the aileron control cables had been reversed! The best-laid plans...." *

So, just as George Philbrick pointed out that it was impossible for the automatic or "computerized" controllers of his day to accommodate a reversal of polarity – you can be completely gefoozled, even as a skilled human, if somebody springs a surprise change on you. As the seaplane's airspeed began to rise, the pilot saw the right wing dropping. When he moved the stick to the left to try to bring the wing up, things got worse so fast he never had time to realize that the controls were reversed. Now *there's* positive feedback for you!

It's the same situation as the technician who was trying to mount a gyroscope on the bulkhead of a missile. It was kind of inconvenient to get it bolted down, so he decided to mount it on the other side of the bulkhead – it fit much better using the same mounting holes.

But when the missile was launched, the controls went "haywire," and of course, it also crashed, with controls full-over against the stops. Both of these cases are just like the next story, which you can appreciate without being an airplane pilot:

Dear Bob:

Your column on "Negative Feedback" reminded me of a real-life example of positive feedback described by one of my profs at Northeastern.

The example deals with a dual-control electric blanket, where the controls have ended up on the wrong side of the bed. From any initial condition (for example both set at "5"), the system soon goes unstable. The husband is too cold so he turns "his" control up. The wife, of course, gets too hot and turns "her" control down. This makes the husband colder, so he turns his side up more, causing her to turn hers down. Eventually, both controls end up at the stops and the humans end up at each other's throats.

DOUG GRANT
Wilmington, Mass.

Exactly! Now I'll finish up with a letter about a ship that was moving MUCH slower than 100 mph, when it crashed, and crashed... and crashed repeatedly:

Dear Bob:

It's kind of a privilege to have an opportunity to write to you. I look forward to someday passing the casual remark to my grandchildren, "...and then I told Bob Pease..."

This brings me a little bit closer to the subject. When I was a child myself, me and my friends did just that – bicycling on a lawn with our arms crossed. You are right, it is very difficult and it hurts, too. Some of us got rather good at it, and I recall that the girls adapted faster than the boys. Is there a lesson to be learned?

The experiment has been repeated here in Sweden recently. Or rather between Sweden and Denmark, on the water separating Swedish Helsingborg from Danish Elsinore. Remember Hamlet?

A clever person decided to make the new ferry more efficient by allowing it to go both ways, without having to turn around each time. The idea isn't very new, but this time the clever person decided to save some money by using the same steering wheel for both Denmark-bound and Sweden-bound traffic. A steering wheel and an old-fashioned machine telegraph seemed to be a bad idea, so the two were combined into one joystick.

Now there was some real confusion: The difference between starboard and backboard is tricky enough, but now you also had to separate Swedish and Danish starboard and backboard. If that's not enough, it seems there were different forwards and backwards as well. One set for Sweden and one set for Denmark.

All good experiments have results. In this experiment, we use the word "consequence" instead. The consequences were: heavy damage to both harbors, heavy damage to the ferry (both ends), damage to cars, and people injured. The experiment went on for some time. Obviously, the experimenters were anxious to rule out random and systematic errors. After some time, with consistent results, the experiment was evaluated. We're still waiting for the report. Moral: Know your polarities, and stick to one set of definitions.

For someone who knows anything about northern Europe, astronomy, and folklore, it comes as no surprise that the name of the ferry is Tycho Brahe.

GUNNAR ENGLUND
Granbergsdal, Sweden

Well, Mr. Englund, some skiers and some drivers are just "an accident looking for a place to happen," and that ferry boat was, too. Note, Mr. Englund observed that it was appropriate for the ferry to be named after the great 16th-century Danish astronomer Tycho Brahe. Brahe published a list of "bad-luck" days – the "Tycho Brahe days" – when a great project or journey should not be initiated, because it will come to a bad end. Mr. Englund did confirm that no correlation had been found between the Brahe days and the ferry accidents or the boat's launching date. Perhaps the people who designed the control system for the ferry will propose a 4-lane vehicular tunnel between England and France – with no center divider. So, where do the drivers change over from driving on the left to driving on the right? Any time they want to! – whenever the mood strikes them! Now, there's a vice-versa situation!

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*Excerpted from *The Great Air Races* by Don Vorderman, Bantam Books.

BOB'S MAILBOX

Dear Bob:

Thank you for writing all of those very informative and enlightening articles. They are both educational and bring back memories of my forty years in electronics. I have clipped every one to date for further reference. I believe I have a very good source for high-isolation power transformers, both linear and switching types, for Mr. Neal Iverson of the Boeing Co. His letter was in the February 20 issue. The company is: Glen Magnetics Inc., Third Avenue, Alpha, NJ 08865; tel: (201) 454-3717; fax: (201) 454-2702.

Mr. Iverson should contact Mr. Emil Badway, who is the vice president of engineering. They have made many extremely critical transformers for companies I have been employed by.

GLENN A. THOMPSON
Penn Yan, N.Y.

Thanks for the info.—RAP

PEASE PORRIDGE

BOB'S MAILBOX

Dear Bob:

Congratulations on your Neal Award.

It's one thing to excel in circuit design, but now in your column too! That's a very rare combination. Your column is a refreshing departure from the stuffy, lightweight fare normally encountered. Keep up the good work.

Also, thanks again for plugging our multiplier in that earlier column.

JERALD GRAEME
Manager, Instrumentation Components Design
Burr-Brown Corp.
Tucson, Ariz.

Let's all promote analog stuff, even if it's not linear. —RAP

Dear Bob:

Congratulations on the Neal Award Certificate of Merit. Your columns are great. No matter who won, in my opinion you should have.

Don't belittle such certificates. They come in handy for covering ugly places on walls. And they can buy credibility with persons otherwise not sufficiently intelligent to listen to you.

No money, too bad; you could have used it to buy some superconducting speaker wires!

RONALD A. ROHRER
Director of the Center for Computer Aided Design
Carnegie-Mellon University
Pittsburgh, Pa.

Thanks, but I would have trouble splicing them. —RAP

Dear Bob:

I very much enjoyed your article in the March 5th issue describing Applications Engineers. I think you have described our profession perfectly. When "Field" is added to the title of Applications Engineer, it adds another dimension to the job. You can no longer let the phone ring in the hopes that the customer will give up. They *have* your number (pagers, voice mail, *my home number*). There is nothing quite like getting pinned to the coffee bar in a customer's lobby to be nibbled upon by the ducks.

I envy the inside position of being able to go down the hall to get the right answer to a question. And who can find time to write the Great American App. Note when half the day is spent being chased by the ducks on the customer's factory floor. But at the same time, there is a great sense of satisfaction that comes with being able to solve the customer's problem on the spot while looking for the next design-in opportunity.

Being in the field is a terrible job and a wonderful career all at the same time. I wouldn't trade my position in the "duck pond" for anything! Keep writing your column. I always look forward to a good sanity break.

GREG JURRENS
Compaq Field Applications Engineering Specialist
NEC Electronics Inc.
Houston, Texas

It's fun being an Apps. Engineer, but it's good to be able to take a break occasionally! —RAP

Dear Bob:

Just read Pease Porridge in the February 6th issue. Since the late '60s, I have had 25 W of power amplifier in seven cars with a speaker behind the front grille.

I use this to tell drivers of faulty lights, no right turn where necessary (left turn in your case), "move over dum dum," etc. In case of retribution, I usually look around to see where the voice originates. " 'Allo darlin' " to an old lady makes her day! "Oi mate!" makes pedestrians turn round, etc., etc. Great fun!

DAVE ST. GEORGE
St. George Electronics
London, England

A great idea! Even in California you can do this legally, but don't blast too loud. Check your local ordinances! —RAP

What's All This Bachelor's Degree Stuff, Anyhow?

Recently I got a letter from an "engineer" with a problem. "Dear Mr. Pease: In my company, engineers who don't have a bachelor's degree were recently demoted. I am, unfortunately, one of those "demoted" engineers, as I possess a non-traditional BSEET degree. The lack of a conventional degree is stated to be the only reason for the demotion. I have gathered the following information as ammunition to fight this tyranny:

1. Per my past performance reviews, my supervisors have indicated that my work has been very good, with performance recognition.

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

2. Other departments affected by these new rules have "grandfathered" their current employees. Only the Engineering department has had demotions.

3. Several years ago, I chose to pursue the BSEET degree because it was, at that time, accepted by my company as an engineering degree. Also, I could attend classes in the evening (which I could not do for any school that awarded the traditional BSEE). This was supported by my company; in fact, they even offered incentives in the form of partial tuition reimbursement.

So it has come about that due to the "type" of degree I possess, I no longer have the title of electrical engineer, nor the work responsibilities, even though my work assignments remain the same. I do the work, and then another engineer with a "real" degree approves it. I now have a project engineer who receives all of the credit for my work.

What upsets me the most is the fact that I dedicated over twelve years of my life to this company, working my way up from test technician to electrical engineer, and now some bozo demotes me to a technician with no opportunity for advancement. And there's no reasoning with the Chief Engineer who made these decisions.

Maybe by discussing this subject in your Pease Porridge column, we can heighten the awareness of people. And maybe even bring about some change.

Maybe this isn't an isolated case. If it's not, how should we deal with it, and where should we turn to? Most people advise me to look for another job. Eventually I will do that, but first I want to explore my options. Meanwhile, I appreciate your comments on this difficult problem.

(signed) Mr. X. (Address withheld)."

Well, I'll share with you here the ideas I quickly fed to Mr. X to help him resolve his problem.

First of all, I talked with some people in the Human Resources field. They had never heard of this "demotion" happening to engineers, anywhere. But on the other hand, they thought that it was probably not illegal.

Then I suggested that Mr. X get in touch with the IEEE. It's not entirely clear if anybody in the IEEE would want to get involved, but they might be able to show what happened in similar past cases.

I also gave Mr. X the addresses of several organizations that have taken over the work of Irwin Feerst—the American Association of Concerned Engineers and the American Engineering Association. They surely would be concerned and interested, whether the IEEE was interested or not.

I suggested that while he may want to eventually hire a lawyer, he should do as much research as possible by himself, as it will be less expensive *and* more effective.

I pointed out that even though this is very sad for him, and for everybody else at his company, it's also sad for his company's customers, and he will be doing the profession of engineering a service if he can solve this problem.

I also pointed out that, while he can quit at any time, he can postpone his departure until he has all of the conditions right for him—he may even be able to line up his next job. OR, he might decide to outlast and outsmart the Chief Engineer. If nobody else has run into this problem, it may just be a matter of time until that stubborn, unfair boss discovers he has to change his mind. I noted that there are lots of *very good* design engineers who never got an engineering degree—or any other degree.

Now, I respect the Bachelor's degree because it shows that a student has a lot of perseverance to complete a big project. But exactly the same is true of a BSEET. On the other hand, I've seen reports that claim there is indeed a correlation between an advanced degree and creativity—a NEGATIVE correlation. And that's consistent with many people I have met. Some of the most creative engineers I know never even get through a year or two of engineering school. I don't have to name any names.

So I sent off a letter to Mr. X, suggesting he do a lot of homework. A couple of weeks later, I was talking this over with Frank Goodenough in Boston. Frank insisted I write up this column, to tell the story of the problem and my suggestions for a solution just in case anybody else in the world has this problem. As I began to re-read his letter, I spotted one more element and quickly banged out a letter to Mr. X pointing out this: When he embarked on his BSEET studies, his company encouraged him to consider this an equivalent of a conventional BSEE degree. Now the company is trying to change the rules in the middle of the game. Quite unfair!!

So I encouraged Mr. X to quickly do as much homework as he conveniently could, on the outside chance that something good would turn up, but mostly to get a large mass of facts and information. Then he should hire a lawyer to explain politely but forcefully to the president of the company that in view of this rule changing in the middle of the game, the president had better rescind that rule PRONTO, with apologies for all, or be slapped with a MASSIVE lawsuit.

I haven't heard back from the engineer yet. But I have no doubt that he will prevail. After all, every company has employees who are occasionally capable of doing something truly stupid and/or wrong. Fortunately, in most cases, someone has the wisdom and perseverance to correct the mistake. How about you?

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Dear Bob:

I just wanted to write and say thanks for writing your Pease Porridge column, "What's all this Applications Engineering Stuff, Anyhow?" A colleague dropped a copy of this on my desk the other day and I gobbled it up. I thought I could've written it myself. Everything you say is so true. Having worked in both Design and Applications, I can say that there are benefits and disadvantages.

Coming out of Cornell in 1984 with an M.Eng EE, I started as a design engineer with a company in Sunnyvale, Calif. My entry into Applications was not by choice. Nine months into my design career, I was told that I was laid off but they had an opening in Applications. Was I interested? Wanting to continue to eat and pay my rent, I said sure, I'll do it. Hence my introduction into the Apps world.

Here is where I found out about the toughest part of Applications. Lots of times, you are expected to become the instant expert for a product line. At least, that's what is expected from the poor soul on the other end of the phone line begging for help. In my case, I was supposed to support a video product line (consisting of about 150 products). Believe me, for someone who was just getting familiar with diff amps, bandgaps, current sources, and emitter followers, becoming an expert on sync strippers, CRT drivers, NTSC to RGB converters, and Genlock converters was a bit of a leap.

Unfortunately, there's just not enough time to go to the lab and play with the parts to become an expert on all of them. Many times, the customer knows the part better than the Apps guy. Why? Because he focuses on that one part, spending endless hours in the lab trying to get it to work. And finally, when he can't do anymore, he picks up the phone and calls yours truly to get some kind of tip to make his circuit work. Talk about frustration!

After three and a half years in Applications, I took an opening back in the IC design group and worked on a project with two more senior designers on a fiber-optic postamplifier. My applications background came in handy, because I understood most of the system issues involved in proving the part worked in a full fiber-optic receiver test system. This approximates more closely the case you described in which the design people become their own Apps engineers.

For a year and a half, it was a good time being in the design group until the division marketing manager saw all the good work I was doing on the *applications* side of design. I was moved into the group full time. This was the second time in five and a half years I was forced out of design and into Apps! So I left the company and joined Elantec in Milpitas as a Design Engineer.

I thought, "Now I can be a Design Engineer again." After about a year, the current Applications Engineer left the company and they had an opening they wanted *me* to fill. So, for the third time in nearly seven years, I moved out of Design into Apps. As my wife says, "Maybe somebody is trying to tell you something. Maybe you should stick to Apps. You seem to be suited for it, otherwise why would they keep putting you there?"

So here I am doing Apps for the last year and a half. Sometimes you don't get any respect from the designers because you aren't actually designing ICs. To the marketing people, you're just another engineer.

I believe, however, that I'm one of the most important people for the designers *and* the marketers. For the designers, I debug lots of the chips by solving the customer's problems, and try to make sure changes get incorporated into the next design revision. For the sales and marketing people, I'm golden. I get called by many sales guys because they might lose a lot of design-ins if the customer can't get the part working properly.

One of the biggest advantages of Apps over design is that there a lot of daily victories. In design, an IC could take 4 months to design, 2 months to layout, 2 to fab, 1 to characterize, and 1 to release. So from the beginning of a project, it may be a year before the previous work gets justified. In Apps, you multiplex so many problems, you sometimes forget how many good things you actually get done because they're not a concrete thing like a part in a databook.

So Bob, thanks once again for bringing a little publicity to those guys in the trenches saving designs.

Michael J. Sadayao
Applications Engineer
Elantec Inc.
Milpitas, Calif.

Applications Engineers make up a good team with the Designers. Sometimes they can't even tell which hats they are wearing.—RAP

PEASE PORRIDGE

BOB'S MAILBOX

Dear Bob:

I recently read your article on application engineering. I thought it was a great piece. I enjoy reading your columns in each issue because they tell it like it really is in the trenches. You write from your heart and experience, which is rare in technical journalism. I always learn something from your articles because they cause me to think and feel.

The reason I wrote to you about this application-engineering article is that my first job was an entry position in Central Applications at National Semiconductor in the late 1970s. I was one of those young kids who came to you for help with questions I couldn't handle. I remember the first time I saw the awesome filing system on your desk.

Thanks for the help you so willingly offered back then and thanks for the insightful article on the role and importance of AEs today.

I now work for Cadence Design Systems. Our products are design automation tools for electrical engineers, but your view of the AE role is just as valid in our business as yours. We have over 300 AEs in Cadence today, with more coming in the future.

They are as vital to our business in providing service and product direction as you mention. I am going to pass your article on to our AE managers, sales managers, and general managers because I think it offers a great perspective. It is good advice for AEs and an important wake-up call for those who may sometimes take AEs for granted.

JOESPH B. COSTELLO
President and CEO
Cadence Design Systems, Inc.
San Jose, Calif.

I'm glad we agree on the value of Apps guys! –RAP

Dear Bob:

Much appreciation for your April editorial that provided a nightmarish peek into the mind of an analog engineer. I read it with prayer and thanksgiving that I, a digital designer, am spared the futile struggles that must be endured daily in that Slough of Despond called "analog design," where nothing is as it seems, and where there is no bedrock except in pitiless physical laws like Planck's Constant, Heisenberg's Uncertainty, and Rejection Ratios by Power Supplies.

One useful fact did manage to percolate through Mr. Kuzdrall's erudite April foolery. To wit:

The fundamental minimum energy requirement for an analog computer is directly proportional to the amount of actual information handled by the system. In a digital computer the fundamental minimum is proportional to the log of the information handled, n'est pas?

Aside from the clear superiority of digital over analog in every field – acquisition, control, computing, simulation, image processing, etc., etc. – there is the outstanding fact straight from the Creator: The entire Universe in all aspects is *digital* to its foundations, e.g.

1) Time is digital because all clocks tick. Even streak cameras have s/n digital limits.

2) Space is digital because there are "forbidden zones" at the atomic level.

3) Matter is digital (as Democritus suspected 23 centuries ago) because it is in fact atomic.

4) Thought is digital because it is a sequence of synapse snappings.

5) Life is digital because the information for every living cell is carried digitally within its DNA.

6) Sound is digital because all organic perceptors have digital design.

7) Acoustic "waves" are digital at the molecular level where they are a sequence of bumpings.

8) Electromagnetic radiation is digital via photons.

9) Color is digital because each and every color in every shade is a digital ratio of R, G, and B.

10) Imagery is digital because all perceptors have pixels, whether organic or inorganic. The pixels in old-fashioned video are defined by digital numbers like "s/n" and "lp/mm." The Pointillists were right.

11) Optical images themselves are digital at the diffraction limit.

12) Even snowflakes and tree shapes are digital, since the recent discovery of fractals.

"Analog" in any sense is simply an illusion of ignorance. The wise analog engineer, living in the late 20th century, will recognize that the time has come to replace his warm heart with a cool head, bit by bit.

PETER R. VOKAC
Digital Engineer
Tucson, Ariz.

I shan't bother to rebut your extreme claims that all the world is digital, though readers may wish to do so. But the next time you need an analog voltage or circuit, and you refuse to use it, I'll feel sorry for you. What power supplies <u>do</u> you run your computers on, anyhow? –RAP

Dear Bob:

Enjoyed your "dead car stuff" article in the Feb. 6 issue. You may not be aware of it, but you have pointed out the need for a new product: a solid-state tail/brake light bulb.

My son owns a commercial trash company, and I assure you a burned out light bulb is no trivial matter today. After being stopped, the truck is subjected to a safety inspection and paperwork inspection, which often uncovers minor leaks and drips, minor adjustments, and incorrect this or that.

Loss of time/money/income can run into the hundreds of dollars for each problem because of the barbaric 1920s-designed light bulb with archaic socket connections.

The major reason for this problem is severe vibration of the heavy truck. Even new bulbs last only about a month or so.

PEASE PORRIDGE

Several years ago, I "thought" I saw an LED replacement tail-light bulb. If you have the contacts, could you please ask if anyone makes them. I feel a cluster of LEDs grouped together would have enough light to pass as marker lights and tail lights. The brake light would probably still need the old-style light bulb? I also feel the truck owners would pay $15 each for replacement tail-light bulbs or marker lights *which would not burn out.*

DENNIS BRIGANCE
Vitro Corp.
Silver Spring, Maryland

PS: If you can't find this thing, ask National to make it. I'll be your East Coast sales rep.

NSC quit selling LEDs several years ago. But a smart guy could easily assemble redundant strings of LEDs with ballast resistors and antireversal diodes. Then the dirty, rusty, bent socket becomes the unreliable element! Good Luck! —RAP

Dear Bob:

This letter is in response to the letter from Neil Iverson of the Boeing Company (February 20, 1982), stating "...nobody makes decent power transformers anymore."

Grand Transformers Inc. is a designer and manufacturer of custom-built power transformers. If Mr. Iverson will send us specifications, we will build him a transformer with single or multiple shields, grounded or brought out to an external termination.

And they will be built to comply with any UL, CSA, VDE, or IEC Standard he wishes. We have built units exhibiting interwinding capacitances as low as 0.05 pF.

The letters in the same issue responding to your article, "What's All This Spicey Stuff, Anyhow (Part III)" (October 10, 1991), was also very interesting to me.

We see the same situation in the transformer field, where so-called "engineers" only know how to "design" transformers on a computer. I am old enough to say that my first few years were spent using a slide rule. Today I do use a computer, but only to save computation time. The designs are still worked out from scratch on paper, and more importantly we still build prototypes to check out the design. *Doverai no proverai!*

KEITH L. WILLIAMS, P.E.
Senior Design Engineer
Grand Transformers, Inc.
Grand Haven, Mich.

I'm delighted that you still design transformers the right way—by thinking! Now, if you stocked and sold a "well-shielded F91X" as a semi-standard product, would anybody buy them? —RAP

PEASE PORRIDGE

What's All This Taguchi Stuff, Anyhow?

A couple of years ago, some friends suggested I join them in a seminar on "the Taguchi method." It's the hot new method to optimize a manufacturing process, they assured me. So I hiked over to building 27 and watched the lecture on a video session. At first, I was just making notes in the workbook and on scratch paper I had brought along. But soon I found myself getting suspicious and angry.

The first example was a special "widget" amplifier in which the basic design, we were told, did not meet its specs with a good yield. The professorial lecturer assured us the problem was because the betas of the transistors were too low and too variable, leading to sloppy tolerances on the finished product. What to do? The lecturer claimed that the solution was to specify higher beta (by just a factor of two) on the transistors, so that the sensitivity of this circuit to beta was greatly decreased to virtually zero, and the production spread got narrower. Ah, I thought, very nice, but what exactly is that circuit? WHY, exactly, did doubling the beta cause less problems and a tighter production spread? Why did tripling or quadrupling the beta cause problems to recur? I vowed to find out.

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

Then the video lecturer went on to study the problem of a high-pressure molding machine that could make little plastic spoons. There were several variables – the temperature of the plastic, the pressure, the mold time, etc. Now, if you've never studied the Taguchi method, I think I can safely say that its analysis method is primarily geared to design several tests that combine changes of the variables. Then you can analyze the test results to see which variables are causing the most harm, and which ones you should tweak to optimize the centering of the output and achieve the best, tightest distribution. In theory, you can't argue that a plausible, logical, methodical approach like this can go wrong.

But I began to get more and *more* suspicious. Why did all of the data have nice, simple *round numbers* as results? Why was there no NOISE on the measurements? Why did all of the data come out nice and LINEAR? Where I come from, I do not expect the data to be perfectly linear and noise-free, and to come out in round numbers.

It looked to me as if somebody were laying down some funny data to make it easy for us to analyze. That made me pretty nervous and suspicious, so I was on my toes looking for any other suspicious statements.

The lecturer then belittled the operators of the machines – "Joe thought he knew how to run the machine better than anybody else, but the Taguchi method found an optimum operating point that Joe never thought of...." Again, I was suspicious, because that might be true, but maybe Joe knows something that the computers don't. For example, it's easy to prove, by math or by computer, that in many cases you can get the best acceleration and performance from a car if you slip the clutch a lot. All very true, until the clutch burns out.

As soon as I saw the full glory and simplicity of the Taguchi method, I spotted its first, deadly serious weakness. The advantage claimed for the Taguchi method is that it proposes a MINIMUM number of tests, the analysis of which will indubitably lead to an optimum solution. But these methods only check the design-center zero point and the design-center full-scale point *once*.

The Method implies you can check the design-center zero offset in the morning, and the design-center full-scale of the meter at noon, and take data all day long. And you'll never have to recheck the design-center zero reading or the gain, because that would be wasteful and redundant.

Mr. Taguchi, pack up your "methods" and get out of my lab. DO NOT TALK to any of my engineers or technicians. Do not suggest any other ways to be more "efficient" or "optimized." Just get out.

When I have my technicians taking data, they all know to record some design-center or "reference" zero data and gain data, at the beginning and at the end, and a few times in the middle. And when they're just sitting around sipping a cup of coffee, they tend to keep their eyes on the experiment. If it has any drifty tendencies or "jumpy" habits, they can spot that. And, as a "sanity check," they normally repeat some of the early tests, down near the end of the testing, to make sure the data are more-or-less repeatable. Is that "efficient?" Well, it's the right way to take data, and that's the important thing. One of my old supervisors, Tom Milligan, used to tell his technicians, "If you see something funny, Record Amount of Funny." And we call that Milligan's law, in his honor. So, I suspect Mr. Milligan would have thrown Mr. Taguchi out of *his* lab, too.

Back to Taguchi, the lecturer pointed out that they would manipulate the variables they could control – the temperature of the plastic, the pressure, the molding time. But they would not worry about the viscosity of the incoming plastic material, because they didn't have any control of this. So they would ignore it. Good Heavens!! If there is a big variable, (like the sun coming up in the morning?) and you have no control over it, that doesn't mean you should not monitor it and try to compensate for it. Let's say you're trying to mold little plastic spoons, and the Taguchi method has told you an optimum setting for the time, temp, and pressure. Suddenly a new batch of plastic material comes in with a much lower viscosity. Are the optimums going to change? You bet! And if I keep monitoring the viscosity, I can look up in my "cookbook" to see where I should start searching for a new optimum. The Taguchi method sets a very poor example – there are no plans for keeping track of the viscosity and its changes, or compensating for it.

Early on in the lecture, we were told that the Taguchi method tries to minimize the "loss to society." We're told that widows and orphans will suffer if we don't make things correctly; that is, with the highest reliability. But then every example we were given was simply a procedure to maximize production yields and lower the production cost. Suddenly it began to rankle me that we were first motivated to be nice to widows and orphans, but at the end of the day, it turned into another pitch to improve manufacturing costs. I'm in favor of both objectives, but I don't like to see the approaches muddied with unclear thinking.

As I went along through the rest of the lecture, I spotted other discrepancies. I noted them all in my workbook and prepared to ask the lecturer some serious questions. First, I had to find his address – apparently nobody expected anybody to ask any real questions. But I did find his address, at one of the respected eastern technical schools. I sent him a nice letter. A month later, I sent a second copy in hopes of getting a response. I really did want to find out about that Widget circuit that allegedly worked better with moderately high beta.

But the professor responded with platitudes, just congratulating me on my perceptions. He answered none of my questions. So I wrote again, requesting that I would like to know the circuit of the Widget amplifier, and the answer to several other questions.

The professor claimed I had asked so many questions that he could not answer them all. So he answered none of them. I wrote *again*, asking just one question – exactly what is that Widget circuit?

Again he responded in platitudes. He observed from my business card that my title was "scientist," and scientists don't have to follow the teachings of Mr. Taguchi as engineers should (hogwash). And he still evaded my question, and he still didn't include a schematic.

I wrote back politely, stating that if he expects us engineers to accept all this Taguchi method on his say-so, on faith, and to never question anything, he was probably going to find some massive rejection. I explained that maybe in other parts of the world, you can sell engineers simplistic solutions as profound enlightenment. But around here, we don't just buy something on faith – we compare it to other methods that have worked well in the past.

I explained that I could not possibly let my engineers or technicians use the Taguchi method. Our measurement methods are much more skeptical, and they have a chance for working despite nonlinearities and noise, something I would never trust the Taguchi method to do. I also explained that if I found anybody else pushing the Taguchi method around my area, I would sit them down and explain the weaknesses and disadvantages of the method. And I would specify that I believed the Taguchi people were trying to sell them an optimization technique for a "Widget" amplifier – one that apparently never existed. After that, I never heard from the professor again.

So, I caution you – if any new whizbang method promises results that sound too good to be true – maybe they *are* too good to be true. Recently, the announcers on National Public Radio promised that there would be a special program at 11:00 P.M., with "incredible" new political developments. At 11:00, John Hockenberry told about how Richard Nixon was entering the 1992 political races.... yes, it was so late at night that it took me several minutes to realize that only 23 hours of April 1 had passed by, and there was still one hour yet to go! Yes, the announcer was right – it really was "incredible"... absolutely unbelievable!

One of the people who reviewed my first draft of this subject, Dan Callahan, had some experience with Taguchi studies, and he agreed that I wasn't just imagining my complaints. He suggested a book by William Diamond, *Practical Experiment Designs for Engineers and Scientists**. I immediately hiked over to our library and checked it out, and it's quite thoughtful indeed (especially by comparison). This book allows for the possibility of different types of noises, nonlinearities, errors, and glitches in the data. It advises the experimenter how to deal with many of these aspects of reality. "The best experiment design results from the combined efforts of a skilled experimenter who has had basic training in experiment design methods, and of a skilled statistician who has had training in engineering or science. The statistician alone cannot design good experiments...." That makes sense to me. I can't say I understand everything in it – I'm a little rusty on my statistical mathematics – but I like everything I understand. Much better!

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

(The opinions expressed herein are those of the writer and do not necessarily reflect the views of National Semiconductor Corporation.)

**Practical Experiment Designs for Engineers and Scientists*, William Diamond. New York: Van Nostrand Reinhold, 1981 (347 pages).

PEASE PORRIDGE

Bob's Mailbox

Dear Mr. Pease:

I've been reading your articles in Electronic Design since they began and I just wanted to say that I've thoroughly enjoyed them. Their content is certainly interesting to me, but not nearly as interesting as the thoughts they provoke. It warms my heart to read the thoughts of someone who seems to believe, as I do, that our best problem-solving instrument is not on the lab bench but right between our ears. The biggest thing I learned at M.I.T. was not any specific knowledge but rather how to think. There are plenty of bright people but not enough is done, in my opinion, to teach these gifted people how to leverage their intelligence into setting up and actually solving problems (both everyday problems and professional problems, such as in engineering).

I believe your articles really encourage your readers to use their brains more effectively by showing them your thought processes. You show how to use what I would call "non-traditional" thinking.

Your article in the April 1 issue was quite funny. I rapidly surmised the thrust of the column but I was chortling nevertheless. It reminded me of an April 1st issue of some electronic journal I read a few years ago. It had an article about fuzzy logic, a concept that was totally unfamiliar to me. Well, as I got further into the article, I said to myself that fuzzy logic was an amusing subject for what was obviously a spoof. I was rather chagrined, though, to find at the end of the article that fuzzy logic was quite real. When I see consumer products like camcorders mention fuzzy logic in advertisements, I feel doubly chagrined. It's here to stay. Perhaps my reaction has been a typical one, which explains why fuzzy logic has been so hard to catch on here – everybody laughs at it because it seems to challenge (but really doesn't) some of our basic engineering teachings. I recall a similar reaction to "sequency" theory the first time I was exposed to it. As I get older, I am far less quick to make value judgements on new ideas as we obviously have only scratched the surface in explaining and controlling our physical universe.

Your February 6 column that mentioned dead cars was of special interest. I used to have a 1970 Saab 99E, which became a part of the case files of the Attorney General's Office and the Federal Trade Commission. It was the ultimate lemon (until I saw the repair records for a friend's Ford Tempo). One relative called my car the "slob" instead of "Saab." After I was able to extricate myself from my Saab folly, I became interested in how many Saabs were disabled alongside the road. I was curious as to whether Saab had improved their quality since my car was built. I didn't actually count Saabs, but I sure saw a lot of them with their emergency flashers on and their hoods up! I think I saw more than you would expect from their market share in New England, but possibly that is simply wish fulfillment.

You are truly a credit to our alma mater. If you're ever in the New England area in January for a week, you should consider giving some sort of Independent Activities Period course at M.I.T. I think the students and M.I.T. community would love hearing you for an hour or two a day for a few days or a week!

ROBERT A. PIANKIAN
(another RAP!)
Consultant
Brighton, Mass.

Yeah, I've thought about writing "What's All This Fuzzy Logic Stuff, Anyhow?," but nothing I could write would be as funny or weird as what I read in technical journals. –RAP

Dear Sir:

The proposal of Mr. Doug Raymond about finding "hot spots" with a mercury-filled fever thermometer (April 16 issue) is an interesting and working approach. BUT spilled mercury from a broken thermometer nicely distributed through the interiors of an electronic assembly might move more than an eyebrow from a quality or security inspector!

The rough facts: Mercury is a conductor and its vapor deposits are also conductive. Also, it slowly vaporizes and vapors are poisonous.

However, we spend fortunes to market our temperature recording labels in the U.S.A. and other countries worldwide, and here comes Doug Raymond who hits my head with his proposal...

Does anybody these days read small ads anymore? Companies with smaller budgets and smaller ads get lost and the readers might miss interesting products and technologies.

Readers: Small ads may also carry very useful contents.

DIPL. ING. ERNEST SPIRIG
Rapperswil, Switzerland

You are quite correct; mercury thermometers are kind of dangerous, and I should have said that. But fever thermometers filled with red alcohol are safe enough. The little temp-sensing dots sold by Spirig are, of course, even smaller and faster. And they are good for wider ranges – but with less resolution. –RAP

Dear Bob:

Your recent "Vice-Versa" column plus a prior column on having people accountable for their work reminded me of an incident when we were leasing hangar space from an aerial photography company near Dallas. Whenever their aircraft were serviced, the owner made the service mechanic ride along on the first checkout flight. During service to a helicopter, the tail rotor pitch cables were reversed. The tail rotor is an antirotation mechanism, with the pitch (angle) of the blades determining the amount of thrust to counteract the natural tendency of the helicopter body to rotate with the main rotor. As

PEASE PORRIDGE

they lifted a few inches off the pad, the body began to rotate. The pilot applied what he thought was thrust to counteract it, and as I'm sure you realize, the rotation just sped up. The pilot was quick-witted. He put the main rotor back to neutral pitch and the helicopter smacked down onto the pad, bending a landing strut. But there was no other injury, other than to his pride. I also recall the animated discussions with FAA inspectors over whether this was a flying or taxiing accident and the effect this would have on their insurance premiums. Sorry, I don't know how that was resolved.

MARVIN T. ANDERL
Richmond, Va.

Wow, what a sharp pilot! I like that the mechanic gets to go along on the test flight! —RAP

Hello Bob:

I've enjoyed your articles on feedback and polarities. There is a common machine in which the polarities switch depending on the situation. Operating the typical, three clutch "caterpillar" tractor uphill, one releases the clutch on the side of the direction to be turned. However, going downhill, with gravity and the load pushing the tractor, one releases the clutch opposite the turning direction. On hilly terrain with many obstacles, it is not at all intuitive.

THOMAS LAKIA
Coastal Designs
Los Gatos, Calif.

Hey, that's a real vice-versa switch, enough to make George Philbrick nervous! —RAP

Dear Bob:

Your column on vice-versa stuff reminded me of a friend who used to win drinks with motorcycle and bicycle riders by betting them that when they pressed their right thumb on the right handlebar, a right turn would be initiated. Of course, you had to let the thumb go down and then come back toward you to keep from falling over!

That front wheel is a classic gyroscope. Turning the handlebar left causes precession to tip the wheel, and the bike to which it's attached, toward the right, thus initiating a right turn. It's not initiated by leaning to the right as most believe, because you unconsciously push the handlebar first. Try this when there is room to spare and you are moving at least fast enough to keep your balance without effort.

LEE SEELIG
Senior Staff Engineer
TRW LSI Products Inc.
La Jolla, Calif.

Come to think of it, to make a bike LEAN left, you first STEER right. To make it STOP leaning to the left, you steer MORE to the left. Maybe that's why it's hard for kids to learn. —RAP

What's All This Muntzing Stuff, Anyhow?

Recently, a young engineer wanted to show me a circuit he had been optimizing. We reviewed the schematic and the breadboard, and we studied the waveforms on the 'scope. We realized that one of the resistors was probably doing more harm than good, so he reached over for a soldering iron. When he turned back to the circuit, the offending resistor was gone! How did it disappear so fast? Ah, I said, I always keep a pair of small diagonal nippers in my shirt pocket. And when I want to disconnect something, it only takes a second to snip it out or disconnect it on one end – just like Earl "Madman" Muntz. The kid looked at me. "Earl WHO?" And I explained.

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

Back in the late 1940s and early 1950s, television sets were big and expensive and complicated – a whole armful of vacuum tubes, lots of transformers and rheostats and adjustments that had to be trimmed, and many complicated circuits for signal processing. And all to drive a crummy little green-and-white 5-in. or 7-in. picture tube, where the whole family could crowd around to watch.

Earl Muntz was a smart, flamboyant businessman. Anybody who could make a success of selling used cars in 1939 or 1946 had to know something about salesmanship, and Muntz had built up a $72 million business in Glendale, Calif.

For example, Muntz would advertise a particular car with a special price as the "special of the day" – a car that *had* to sell that day. If the car was not sold by the end of the day, Muntz vowed to smash it to bits with a sledgehammer, personally, *on camera*. Needless to say, with tricks like that he was able to generate a lot of publicity and interest, and sell a lot of old cars, too.

So when Muntz started his plans to sell TV receivers in 1946, it was obvious that he would be looking for a competitive advantage – in other words, he had to have an *angle*. He wanted to get the circuits simple – the manufacturing costs low – and he knew he needed a lot of promotion.

He realized that a receiver designed for "far-fringe reception" (40 or 50 miles out) had to have at least 3 or preferably 4 Intermediate Frequency (IF) stages (with a pentode for each stage, *plus* a transformer, 5 capacitors, and 3 resistors), and loops to hold the frequencies stable even when the signals were very weak.

Muntz decided to relinquish that "fringe" business to RCA and Zenith and other established manufacturers. Instead, HE would design for Manhattan and other urban areas, where you could look out your window and *see* the doggone transmitting antenna on top of the Empire State Building, or equivalent.

HE knew he could get engineers to design television receivers that would be very inexpensive, very simple, and would still work quite satisfactorily in these strong-signal areas. Then he could get away with *two* IF stages, and they would not need fancy loops, and the tubes could all be biased up with cheap-and-dirty biases.

As the circuits shrank, the power supply shrank. And as the price shrank, his sales volume began to grow, leading to still further economy of scale in manufacturing. Muntz dropped his prices so fast, so low, that his competitors again accused him of being a madman, cutting prices and competing unfairly.

When people watched Ed Sullivan or other pioneering programs of the era on their tiny 7-in. screens, who came on at the end of the hour to promote his new, low-priced 14-in. (diagonal measurement) TV sets? Why, Earl "Madman" Muntz himself!

"You can have TV in your home tonight," he would say. "Your living room is our showroom." And, wearing red long johns and a Napoleon hat, he would vow, "I wanna give 'em away, but Mrs. Muntz won't let me. She's crazy."

Muntz was a smart merchandiser, and he knew that his competitors' jibes could be turned to work to his advantage. He knew that his TVs were not built of cut-rate parts – in fact, his receivers were carefully engineered to be at least as reliable as the competitors' sets that cost twice as much – and they would perform just as well, so long as you stayed in a strong-signal area.

And how did Muntz get his circuits designed to be so inexpensive? He had several smart design engineers. The story around the industry was that he would wander around to an engineer's workbench and ask, "How's your new circuit coming?"

After a short discussion, Earl would say, "But, you seem to be over-engineering this – I don't think you need this capacitor." He would reach out with his handy nippers (insulated) that he always carried in his shirt-pocket, and snip out the capacitor in question.

Well, doggone, the picture was still there! Then he would study the schematic some more, and SNIP....SNIP....SNIP. Muntz had made a good guess of how to simplify and cheapen the circuit. Then, usually, he would make one SNIP too many, and the picture or the sound would stop working. He would concede to the designer, "Well, I guess you have to put that last part back in," and he would walk away. THAT was "Muntzing" – the ability to delete all parts not strictly essential for basic operation. And Muntz took advantage of this story, to whatever extent it may have been true, and he publicized his "uncanny" ability to cut his costs – in yet more televised advertisements.

For several years, Earl Muntz kept impressing his engineers to build in only the circuits that were essential, and for those years, his TV receivers were competitive and cost-effective. All because of his "Muntzing," he would say in his ads. But really, that was just one aspect of good sharp engineering. And of course, he had to know where to start snipping. Although he was not a degreed electrical engineer, he was a pretty smart self-taught engineer, and his marketing and advertising campaigns capitalized on the story: He knew how to engineer what people needed – right down to a price.

For example, only in the last 10 years has Automatic Fine Tuning become universally available on UHF as well as VHF tuners, so that manual fine tuning is unnecessary. But as early as 1958, Muntz TV bragged that there was no fine tuning on their best receivers, on all 12 channels. Did Muntz build in AFT before his time?? Heck, no – he just left out the fine tuning knob. The tuners were all tuned up at the factory. Then if the tuning drifted on a hot day, or the tuner components aged, you just had to call in a serviceman to tweak it with a special screwdriver.

So, Muntz had the gall to leave out an important feature, and then he bragged about the apparent simplicity! You can fool some of the people some of the time....

Muntz got rid of the Horizontal Hold AFC circuit to cut costs. He got his engineers to use a straight Hold circuit, which actually worked well under strong signal conditions and was easier to troubleshoot than the temperamental AFC loops of the day. He pioneered and took advantage of the Inter-carrier sound (Parker System) so that audio tuning was automatic and no separate tuning was needed. This was a necessity before he could drop the fine-tuning knob....

For some production adjustments, his test technicians would clip a trim pot onto the circuit, twiddle it to get the alignment just right, and then remove the pot and solder in a fixed resistor of the required value. All very fine, AND inexpensive, but as the carbon resistor aged, and the circuit aged, the TV receiver would go "on the fritz." Then the TV repairman would have to make a special trim, much more expensive than just tweaking a pot. The repairmen were happy to get all this repeat business, but eventually the customers figured out that a low initial cost was not necessarily the best investment....

Finally, as the TV receiver business matured, Muntz realized he had sold all of the cheap sets he could, and he got out of the manufacturing business. After a brief bout with bankruptcy in 1954, he got back in the business of selling TV and electronics, "HiFi and Stereo," in a Los Angeles store, until his death in 1987 at the age of 77. The store is still open, operated by his family and heirs.

These are SAD days, because kids don't get a chance to build their own TVs or radios or FM tuners. Heathkit used to make it easy to build their kits. I myself built three Heathkits and a Knightkit 10-W amplifier, as well as a couple other kits. And I helped some of my friends when they were having trouble with their Heathkits. NOT because I was an expert on circuits in those days at MIT, because I was really pretty ignorant of electronics – I was a struggling would-be physicist then, in Course 8. I just thought this electronics stuff was kind of fun! But I was interested because these kits were such *interesting* stuff.

These days, you can hardly buy a kit. Heathkit went out of the kit business in January of 1992. The kits were more expensive than the assembled circuits you could buy from any number of stores. BUILD your own TV? How bizarre! The Japanese could build them, with very high quality and very low cost, and even if you threw in your own labor for free, a Heathkit cost more to buy!!

Let's go back to the scene where Mr. Muntz was trying to justify which parts could be safely left out of the TV set. If he snipped out a resistor that appeared to be unnecessary, but it was actually needed for operation on low line voltage, or when the frequencies shifted on a hot day, then I really believe Mr. Muntz would not prevent the designer from justifying it on a real need basis. But frivolous circuits – *they* were too expensive to keep.

Now let me make some observations about adding features and "frivolous" circuits, which is what I tend to support. An example: If I design a new circuit with 8 new features, I may argue to the marketing expert that these features will surely sell lots of these parts to new markets.

He may ask, "Bob, which of those 8 features will make it sell so well?" And, I'll admit, I have no way to guess exactly which ones, but I believe that 2 or 3 of them will be very popular. No matter how much he grills me, he can't shake me loose from my ignorance – I really do not know which of the 8 added features will make the basic chip a great seller.

BUT, things have changed from the days of Earl Muntz. Today, I can add 5 transistor functions here, and 8 there, and 14 here, and 27 there, and altogether they will not add 2% to the area of the chip, nor the cost, and they won't hurt the yield.

They may not even impact the test time all that much. They will surely have no affect on reliability if I design them properly. In Earl Muntz' day, though, NONE of these statements were true. Things sure keep a'changing, don't they??!!

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

Bob's Mailbox

You readers already know how I feel about the correlation between a BSEE, a BSEET, a PhD, and the ability to be an electronics engineer. I laid out my opinions in the column about Mr. X, a BSEET who was "demoted" by his boss for not having a BSEE (What's All This Bachelor's Degree Stuff, Anyhow?, May 28). Many readers wrote in to say that they agreed with me – up to a point – and then expanded on their opinions. Here's a good sampling of some of those opinions and suggestions....

Dear Mr. Pease,

I just read your article in the May 28 issue of Electronic Design, which was about Mr. X with a BSEET who was demoted from being an engineer back to a technician by his company.

You mentioned the American Association of Concerned Engineers (AACE) in your letter as one possible place Mr. X could contact. I am an AACE member myself, and brought your article to the attention of the AACE Board members.

The plight of Mr. X isn't new or unique to his company. It's just another example of how many companies mistreat engineers and technical people. It is not widely known, but many companies are doing similar things to engineers and technical people over about age 35. That is if they don't down right lay them off. And let's call things as they are, a "layoff" at least implies the person could be called back to work when things pick up. Laid off for someone over 35 usually means *fired*, because a snowball in the hot place has a better chance than these "middle-aged engineers" do of being called back.

It could well be that what Mr. X's company is trying to do is encourage Mr. X to quit his job. Then they can state he left of his own accord, etc., and they're free and clear of any age discrimination problems. I wholeheartedly agree with you about companies (or employees) not changing the rules. This, however, also applies to governments that arbitrarily change the rules. It happened here in Ohio with the Workers Comp deciding that people they had *signed contracts* with were suddenly no longer qualified to receive payments. I believe this came down from the governor's office during his efforts to balance the state budget.

I've been making my living in the electronics/electrical field for just over 23 years now, and I know I'm experiencing the "glass wall" of age discrimination. I started "consulting" just over four years ago after being *laid off* from a well-known company that closed the facility where I worked. In that layoff, some 350 employees lost their jobs while another 150 people (all *under age 35*) were offered similar jobs at other company facilities.

As I started into my job hunting, I did the usual things of getting registered with several employment agencies, mailing out lots of résumés, etc. That first 12 months I personally sent out over 100 résumés, plus I was registered with about seven technical employment agencies. In that same time frame, I got less than five interviews, and NO job offers once I attended the interview. So I've been consulting since then to generate at least some income.

Your article came at an interesting time, too. I sent out some more résumés about two weeks ago, looking for a full-time job. After all, consulting doesn't have paid vacation or medical benefits. I felt perfectly qualified for one job with an area company that advertised it wanted someone with a minimum 10 years experience in industrial controls, PLCs, and custom circuit design; all of which I've done for at least 15 years. Their ad also stated they preferred an EE, but would consider comparable technical education and experience.

The company personnel manager called and left a message on my answering machine *hinting* he wanted to go over my résumé and get me in for an interview to cover the opening I applied for, which was a full-time design person. I called him back yesterday, and while we talked, he asked if I had at least 10 years working with PLCs, motion controls, etc.

He also asked why I was a consultant, and I told him my reason was I liked to eat and pay my bills, and consulting allowed me some income while looking for a good full-time job. He was reading through my résumé, and noticed that I graduated tech school in May of 1969.

His next reply was to state that that gave me 23 years working in electronics now, and pointed out my age should be around or over 40 now, and then asked if that was correct.

I'm not going to lie to the man. I said YES. He paused a while, then said, "Well John, I'd like to get you in here to talk about possibly doing some *consulting work* for us. Would you be interested in that?" Funny how the tone and direction of the conversation changed when my age became known for sure.

Another area where AACE is very much concerned is Bill #1706 in the U.S. Senate (which is how I learned about AACE to begin with). The bill would ban electronics, electrical, and computer people from being consultants, period. We could not have our own business, and would HAVE to be an employee of a company. If passed, it could make my little consulting business illegal. This kind of thing, in my opinion, just kind of reinforces the third big lie. You may remember them: #1 - The check is in the mail, #2 - Your part is on backorder, and #3 - I'm from the Government, I'm here to HELP YOU. Well in this case, the government is at least thinking of helping several thousand technical consultants out of work.

NAME AND ADDRESS WITHHELD

We should all be thoughtful of such problems, which may vex us if we are guilty of living long and growing old. AND watch out for preposterous notions like that Bill #1706 – that would prohibit consulting?!!? – RAP

PEASE PORRIDGE

Dear Bob,

What's all this B.S. about the BSEE degree? I'll admit it, I'm prejudiced because I have no degree (quite a few years as a physics major at five universities and colleges). I preferred working to school; the part-time jobs I got as an electronics technician or field engineer were always so much more fun than school. I always ended up chucking school to work full time. I do regret it at times, because I wasted so many years working as a bright tech for really dumb engineers! Only a few were like you (if there were more, I probably would still be working as a technician). I finally started my own company so I could do engineering. I love it.

Tom Edison didn't have a degree, and if I remember right, he didn't do too badly. (Although ac power theory did seem to be too much for him, as it is for me. So what!) As the owner of H&L Instruments, I've had the pleasure (?) of hiring degreed and non-degreed engineers, and I can't tell the difference. My ex-partner (a BSEE whom I considered to be a very good hands-on engineer) tells me that he thinks I am a better engineer than he is. I'll take his word for that.

I've just been promoted to be a Senior Member of the IEEE after spending almost 20 years as an Associate Member (because I had no degree). Apparently, I finally had enough experience (age) to make up for a four-year degree. Senior and Fellow Members recommended me and the board had to vote me in. It was (and is) an honor, especially if you could have seen my college G.P.A.

Mr. X should quit working for those turkeys and go where he will be appreciated. Forget the lawyers, the company will only hate him for making a stink. If there is one thing I've learned in my 30-plus years of work, you should try to be where you will be appreciated. Money is great, but being appreciated (and respected) is greater.

BOB LANDMAN
H&L Instruments
Burlingame, Calif.

If you're not having fun at your job, something's wrong. Being appreciated is the key. —RAP

Dear Bob,

I just finished reading your advice to Mr. X, holder of a BSEET "degree." If all of the details are correct, then I agree that Mr. X's company has treated him badly and deserves what it gets in the form of retaliation. Generally, however, I don't think that someone with a BSEET should be considered an engineer. If engineering is ever to be truly regarded as a profession (right now we're just technical laborers), then I don't think it should be encouraged.

If you had really read Irwin Feerst's newsletters and those of the groups that followed him, you would not suggest that he contact them. He is not likely to find a sympathetic ear among those trying to abolish the BSEET.

Nor should you advise him to contact the IEEE, which has a history of doing nothing in such cases.

I find it difficult to believe that there is a negative correlation between advanced degrees and creativity. You did not cite any references. If true, then PhD engineers should be the lowest paid, not the highest.

In my opinion, you neglected to give Mr. X the most important advice that he could possibly have: Get a BSEE (at least). If he's indeed qualified, it shouldn't be that difficult. Without it, he will be stuck at one company and be forced to endure a lifetime of frustration and the type of shenanigans described in your article.

STEPHEN D. ANDERSON
ANSCO Inc.
Minneapolis, Minn.

For Mr. X to go back and get a BSEE would be a retreat from his principles and a waste of time for a good engineer. AND, PhD engineers get paid for many other things besides creativity. —RAP

Dear Bob,

I just read your column regarding the engineer who was demoted because his company lost respect for his work and his BSEET degree. It made my blood boil. During my career, I have worked for five companies. At each of the last three — Avion, GE Valley Forge, and Hughes Aircraft Company — some of the best work was done by *engineers* who had no degree whatsoever; we even had some highly competent engineering managers who lacked formal college degrees! So, I am happy to report that leading companies like Hughes and GE look at ability as well as sheepskin. Incidentally, at one company I worked for, a rather inept "engineer" had a PhD!

No, I am a degreed engineer, so it is not a personal axe I am grinding. I still get mad when I see the idiocy going on in the industry, even though I am now retired. By the way, I wonder if the case of the demoted engineer is not a mis-directed case of belt-tightening by the company (I assume that their salaries have also been reduced). In any event, somebody out there deserves a spanking.

GERARD L. ZOMBER, PE
Venice, Calif.

I'm glad to hear that some smart managers appreciate smart non-degreed workers. —RAP

Dear Bob,

While my personal situation is not exactly like the one you wrote about, it's close enough to send you my tales of woe.

I am one of those non-degreed engineers you talk about, and I think I am very good at what I do — designing power supplies.

I earned my ASEE degree the hard way (at night) from Lowell Technological Institute in Massachusetts 25 years ago. I worked at several military-aerospace companies that circled Route 128 around Boston. A major laser company hired me as a project engineer and moved me to the state I currently reside in. I stayed with them for ten years, then went on to start my own company, which I ran for ten more years.

I have stayed pretty current with the trends in electronics design. I sold my company to another similar electronics firm, with the agreement that I would do the design and technical support, and they would do the sales and marketing.

Well, here is the real zinger. My "boss," owner of both companies for three years, just announced that effective right now, my salary will be cut exactly in half. There was no discussion, or any opportunity for me to dis-

PEASE PORRIDGE

cuss this pay cut. This has sent my head spinning. This is less than the going rate for technicians in this area.

I don't know what to do. Like other places, our state is overpopulated with unemployed engineers from the military and government agencies. In addition to working every day "full speed ahead," I do most of my computer design time at night. So I put in a very long day, typically 60-70 hours a week.

Obviously, the company is in financial trouble. But I certainly think my technical skills shouldn't be reduced by 50%.

NAME AND ADDRESS WITHHELD

If your boss must suddenly offer you a 50% pay cut, somebody was asleep at the throttle. And if your company doesn't even offer you stock or paper for the other 50% of your pay, as an incentive for you to help the company, they aren't very bright. —RAP

Dear Bob,

HOORAY for your response to Mr. X in the May 28 issue. I can't believe any company could give in to some prima donna and demote engineers, BSEE'd or not, without regard for engineering performance. As you pointed out, there are engineers everywhere, without *any* degree, engineering or otherwise, who are as creative and productive as most of the rest of us.

So how can a company justify demoting employees because they just figured out what degree they have? I think that the company needs to do some real soul-searching: With an attitude like this, they either have a cozy government contract, or they don't care about being competitive in their market. Obviously, their first concern is the paperwork, not the product or the people.

I have a BSEET from Capitol College in Maryland. My experience has been mixed regarding my acceptance as an "engineer." I have recently started working toward an MSEE at a local university. I'll be driving about 30 miles each way for classes (after work). There is a college about two miles from work, where I am taking some classes to transfer to the other school. When I applied at the closer school, I was (I thought) prepared to defend my academic background. I brought course descriptions and most of the books I used for the engineering and math classes. So I plopped my stack of books on the desk of the department chairman, and he proceeds to tell me how impressed he is with them (he seemed to be familiar with most of the books). Then he announces, "...too bad we can't accept any of these class credits..." After some discussion, the final result was that I must first obtain a BSEE from the school before being considered for graduate work.

That's OK, but as it turned out, they wouldn't accept credit for any technical or mathematics classes from my BSEET. It was clear to me that they didn't want an EET in their graduate school.

About six months after this, a coworker of mine taking classes at this school showed me that the instructor for a junior year circuit design class was using a paper that I had written as *required reading*. The paper was a mathematical derivation, and was published by an engineering magazine. After being booted out of the graduate admissions office a few months before, this was a real surprise.

So now I'm taking classes at this school to transfer to another. I'm taking the same classes that other engineering students take, and my grades are above average. I'm satisfied that I'm academically redeemed, but as with Mr. X, a lot of other people are still in the position of having to defend their choice of an undergraduate curriculum. Just as there are engineers with non-engineering degrees, there are people in all sorts of jobs with degrees in other fields. I have always thought that college prepares and trains us to learn how to learn: In the real world of engineering, we must keep learning new things. It's the ability to adapt and to apply what we learn that makes a good engineer.

DANIEL N. MEEKS
Lead Engineer
Q-Bit Corp.
Melbourne, Fla.

A school is a place to learn how to learn. Later on, the challenge of learning keeps you on your toes, not the fear of flunking. Good bosses respect that, not any mere diploma. —RAP

What's All This Spreadsheet Stuff, Anyhow?

Sometimes people ask for my opinions on Spreadsheets. I usually reply that they are perfectly fine on beds. If the people persist in further inquiry, I ask them to show me a definition of the word in a dictionary. Of course, that slows them down a little, because that's a word too new to be in most dictionaries. But when they try to explain what a spreadsheet is, I say, "Oh, yeah, that's one of those computer programs that makes mistakes, and lies a lot. We used to use those, but they made too many errors." Which, alas, is partly the truth.

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

At one time we had a procedure for computing Return On Investment, using pencil and paper and maybe a calculator. It worked fine. It actually took you 3 or 4 minutes to crank through a whole set of numbers, and if you changed one input, you could modify the rest of the computations in 2 or 3 minutes. Then a new guy showed up one day, and he said he had computerized the whole thing. Just plug in the numbers, push a key, and out come the results. If you wanted to try a different set of numbers, just plug them in and, Bingo, you get the new results. You could print out a dozen different versions on a stack of paper that weighed only 2 or 3 pounds....

About a year later, one of the managers, a singularly suspicious fellow, asked why the spreadsheet's outputs did not match with the numbers he had calculated at home at midnight. After a good bit of checking, he found that the Spreadsheet was doing it wrong – some kind of systematic error had been programmed in, and all of the ROIs for the last year had this error, and nobody had ever questioned it. Sigh... so much for people who always trust a computer, because nothing can go wronx..?!? Fortunately, we did not have to go back and correct all of those errors, because those ROI numbers don't mean anything, anyhow....

Even last month, a guy showed me some figures on a frequency synthesizer. He said he had optimized the numerators and denominators for the circuit, so as to get the output frequency as close as possible to 60 Hz. I told him, "That's funny, how come my optimization gives better optimization than yours did, with different numbers? I used a slide rule, and when I checked it, I used a hand-held calculator. We can't both be wrong. Go back and check your stuff."

He went back and checked – he told me, "no errors in my work." I got mad and did it by LONG DIVISION. I told him he had better throw out his computer because I was in no mood to put up with any more lies. He went back and discovered that his spreadsheet was doing some rounding off – obviously a misapplication, because a spreadsheet should not be asked to do scientific or engineering computations if the round-off errors can cause false answers. People shouldn't use computers when a simple calculator does a better job. But it's the same as saying that people should not drive a 3400-lb. car down the block just to pick up a loaf of bread. Now, if the calculator is broken (or if the rain is pouring down), the Spreadsheet (or the car) may make some sense. But just remember where to bring in a sanity check.

The worst thing about Spreadsheets is they get you out of the habit of thinking. Just as I said back in my column on cost accounting – if you let an oversimplified formula or computer program tell you what to do, and that defines your policy, then what are you going to say when your policy forces you to do something *truly stupid*? You will then find that you have been doing stupid things for a long time, but not stupid enough to notice. Some people can have a Spreadsheet multiply 2.99 × 3.01 and they'll never complain when the answer pops up "6." Unless, of course, it applies to their paycheck – and even then they won't notice it for a year.

I'm supported in my wrath by Michael Schrage, who writes about technology's impact on our lives for the Los Angeles Times: "The most dangerous, hideously misused and thought-annihilating piece of technology invented in the past 15 years has to be the electronic spreadsheet."* And he's barely warmed up.

He details many other aspects of foolishness in people's trust of spreadsheets. He argues that planners should plan out the future in terms of scenarios – a little story that argues, "what if this happened?" In the past, planning by scenario was used by wise managers to imagine some unpredictable situations.

However, "Companies are more comfortable in the formal sense with simple quantification because it reduces the apparent complexity of the problem," says Peter Schwartz, president of Global Business Network, an Emeryville-based think tank and consulting firm. "I use the word 'apparent' deliberately... Most managers believe that if they get the right spreadsheet, the right formula, the right methodology, all that complexity will disappear." But, of course, it

PEASE PORRIDGE

will not go away.

People who style themselves as "executives" can always pretend that complexity and risk do not exist. But when they do so, they're just fooling themselves.

Schrage explains, "They're just increasing the risk and turning themselves into gamblers, not businessmen. Because real businessmen understand risk." But you won't understand the risk (not to mention, manage or reduce it) by manipulating it within the framework of a spreadsheet. "You need techniques that let you creatively explore risk and vivisect it," he says.

Asking a spreadsheet to deliver a best-case scenario is hopeless, because the spreadsheet is inherently capable only of linear thinking. Now, I like operational amplifiers because they can be very linear when you want them to be. I enjoy building and studying linear circuits.

But the business world is not a linear place. You can't predict the future by extrapolating linearly from the past nor the present. So whenever you get help from a spreadsheet, you're envisioning a world that has no more imagination than an old history book. Can a history book tell a child how to guess and predict what will happen in the future? Probably not, and neither can a spreadsheet – even if it doesn't make any numerical errors. That's because the spreadsheet doesn't help you understand the significant aspects of a problem.

You don't develop a feel for what's important if you let machines do all the work. Spreadsheets, especially. But, I say the same thing about SPICE.... what's new?

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

*"Spreadsheets Endanger Corporate Health," by Michael Schrage, *San Jose Mercury News*, April 15, 1991, page 4F.

Bob's Mailbox

Greetings Mr. Pease,

Re: "All This Taguchi Stuff"

Right on! Another pot of snake oil exposed for what it is. My favorite skunks (changing metaphors) these days are:

1. Concurrent engineering – as if that is new. All projects, if done sequentially, will take too long. Under time-to-completion pressures, parallel paths will be taken. The skill and art of management is to keep the relative rates of progress balanced. This management challenge existed before the Egyptians built the pyramids.

2. Scheduling – as if dividing a project into a million little tasks, and arranging those tasks on a time-phased chart, means that the project's understood and can be managed. My experience is that schedules will be generated to management's request. The real job is to get the guys to think through what they do not understand about the project and what they are afraid to admit even to themselves. Once that is accomplished, the project will take on a form and direction that makes the previous scheduling exercise impossible to relate to except in very broad strokes.

Keep it up man!

LAUREN MERRITT
Sunnyvale, Calif.

Experts are always bundling up a package of old stuff with new buzzwords–and sometimes it is of some value. –RAP

Dear Mr. Pease,

Recently, in a minor reorganization, I came across a few periodicals that had been set aside into a "later" pile over a year ago. It included an *Electronic Design* magazine with one of your triple-column commentaries. I regularly enjoy reading your works because, although your circuits display great practicality, your mind often tends to stray toward whimsy. Most of us could do with more doses of levity, interspersed with handy hints. Thank you.

The subject of that triple column was splices in wires to loudspeakers. That brought to mind related facets of Esoteric Audio, like the perceived need for Litz wire run to loudspeakers. The increased surface area of Litz wire is believed to reduce distortions, which would result from the use of Gigantic SuperFlex Cable (from your local Audio and Welding Center).

Those who engage in Esoteric Audio are far from united in their beliefs. Like many other religions, the truth is often misinterpreted. War may result. One splinter group currently prophesies that the physical shape and relationship of the conductors colors the sound; they believe that the interconductor capacity is more important than the Litz-believers' surface conductivity. As a result, they have developed rectangular conductors. These are parallel strips of copper foil, laminated between insulating films, like an extended flexible circuit board. This facilitates few farads per foot, while maintaining reasonably low dc resistance. It should be noted that this splinter group has, perhaps unwittingly, contributed greatly to the aesthetically satisfactory installation of loudspeakers in the home environment. However, it is not due to the measurably minuscule interconductor capacity, but rather to the fact that speaker wires can be placed under carpeting with no visible ripples. Zip cord may be doomed...

On a more scientific front, splices in speaker wires may cause grief, but only if they're poorly done. Loose connections tend to transmit audio intermittently, and may oxidize. Copper oxide is used to make low-voltage rectifiers for meters. A rectifier in a speaker lead can produce nasty-sounding "crossover" distortion (a discontinuity when the current is reversing direction). However, anybody who believes he can hear a proper splice is likely more artist than scientist.

Now on to a phenomenon for which I seek an explanation: Several years ago, I was cautioned that the use of tantalum capacitors for audio could or would result in perceivable distortion. I placed that into my Esoteric Audio fact file, and proceeded. A few years later, I was developing yet another audio circuit. It needed a coupling capacitor, and I had suitable value tantalum handy. The circuit measured reasonably near perfect. As is my practice, I listen to my circuits while I'm developing them, as the ear is often much quicker to detect a flaw and suggest a solution than are bench instruments (besides, this is audio; the ear is the ultimate judge of quality). That circuit did not sound clean on orchestral program material. But it sounded normal on signals from my oscillator.

I monitored the circuit at various points. There was an obvious change in program quality when I monitored before and following the tantalum capacitor. The polarity was correct. I replaced it with a similar tantalum. No improvement. I replaced it with an aluminum electrolytic. The program sounded normal. Disbelief. Then I replaced it with a different brand and style tantalum. Bad again. I repeated frequency response, THD, noise measurements. Sine, square, and sawtooth waveshapes did not appear different than normal on the oscilloscope at any frequency or amplitude. The meters gave the same numbers with either capacitor type. But the program sounded slightly distorted, unclean. Then I replaced it with another aluminum, different brand. Good sound again. I repeated the same measurements, and they were essentially identical.

The sound of orchestral music (from any good CD) was unquestionably altered by the type of capacitor. I do not enjoy phenomena that are observable, but not measurable with my instruments. Obviously, I didn't make the appropriate measurement. I do not have access to an audio spectrum analyzer, perhaps that might show something. Have you any experience with the good-measuring, bad-sounding tantalum coupling capacitor?

KEITH RAUCH
Senior Engineer
ACD Services
Santa Ana, Calif.

Someday I'll set up an A-B comparison of audio amplifiers with electrolytics vs. tantalums. A side-by-side comparison will show us the difference. But does anybody out there know the answer already? –RAP

Dear Bob,

Lee Seelig's interpretation on why one steers right to turn left (which is called counter-steering in the motorcycle safety courses) is interesting. I have another interpretation. When you steer left, the tires move left. When this happens, the center of gravity is to the right of the roll axis (the line between the contact patches of the tires). This causes the bike to fall to the right. To keep from falling, you have to start turning right so inertia (centripetal force) holds you up. Fortunately, the geometry of the forks and steering head naturally turns the front wheel in the correct direction. To get the bike back upright, you turn harder. This causes inertia to raise you up and also causes the tires to try to get back under the bike. You can actually see this happen if you watch someone take a quick turn on a bike or motorcycle. The tires actually move a bit to the left just before a right turn. Understanding this was a boon to the designers of racing motorcycles. They used to think they needed to keep the weight low to get fast handling. Now they know they need to keep the moment of inertia low (along a front to back axis) so the tires can get out from under the bike quickly.

Of course, you can steer a bike without counter-steering (remember "Look Ma! NO HANDS!"). Leaning right causes the bike to fall right and the fork geometry causes the wheel to turn right, catching the fall. You can see this, too. Just walk your bike by just holding the seat.

I wonder what would happen if the geometry were set up such that the wheel turned left when the bike leaned right (ouch!).

CARL G. HAYSSEN
Principal Engineer
Ungermann-Bass
Andover, Mass.

I still think a bicycle will work if you use tiny wheels (like a roller skate) or an ice skate blade where there's no gyro effect –RAP

Dear Bob,

I read your article on the BSEET degree with considerable interest. I happen to work for the government and make occasional recruiting trips for engineers. We have an interesting policy on hiring engineers – if they take and pass the EIT examination, we can hire them as engineers. There is a considerable pay differential and greater opportunity, so it is quite an incentive to do so. This might also work in the case of "Mr. X," but I agree with you he should pursue the "changed rules" path first.

...You also mentioned creativity versus education. I more or less agree with you, but feel it is more a function of what type of school the engineer has attended. I attended a technological school, and got my MS from a similar school. Had I opted for more theoretical schools, I doubt I would be as creative or effective as I am. My father, a chemical engineer, referred to my schools as "nuts and bolts" schools. We learned to get our hands dirty, and never lost our desire to do so. I work with a number of engineers with lots more textbook knowledge than I have, who are unable to apply it in their jobs.

And this applies to Professors as well. I had a chance to teach for a year at Cal Poly in San Luis Obispo, in the EL/EE Department. As I looked around at my fellow instructors, I noted that the ones who were the most popular (and effective as well) were often the ones *without* PhDs.

MARK S. HUTCHENREUTHER
Computer Engineer (Yup, times have changed again..)
Oxnard, Calif.

I'm with you; I like to get my hands dirty and operate in the "can do" mode. If we can't apply theoretical knowlege, why have it? –RAP

Mr. Pease,

Over the past year or more, I have read "Pease Porridge" with a sense of anticipation, and pleasure. You have an outlook that is quite refreshing in its humor, realism, and style. Please keep dishing out the porridge.

I read your May article *"What's All This Bachelor's Degree Stuff, Anyhow?"* and felt that your comments were reflective of "real world" conditions. I think the "engineer" in this case is getting screwed and should stick to his guns. Your comments about "very good engineers who never got engineering degrees" hit home like a smart bomb. In short Mr. Pease, "Encore!...Encore!...Encore!"

As you have probably guessed by now, I am a technician, with an associate degree in applied science, that has been in the "real world" for twenty years. I have a long history of working with engineers (BS's and MS's) and have known both good and bad, but that's not what this letter is all about. I would like to know what your readers (BS's, MS's, AAS's and tech school grads) feel about technicians and their role in the industry today.

I would also like to see information presented for technicians much like it is now presented for "Titled Engineers." The "Career Survey" is good information and helps keep me current.

For the past ten years I have filled an engineering position where I have had sole responsibility for all technical duties, and feel that I have done as well as any "Titled Engineer." I like to call myself a "Pocket Engineer" – that is an engineer in every way except the money in my pocket. Is this a commonplace occurrence and if so, does this reflect a trend in the industries?

I want to thank you for you comments about the "Negative Correlation" and "Most Creative Engineers," and please thank Frank Goodenough for giving you encouragement. I know that technicians are not engineers, but in many cases we "Techs" are the ones that make things work.

NAME AND ADDRESS WITHHELD

Technicians are not only extensions of my hands; they are receiving antennas and filters for info which they help digest, and pass on to me. Good ones are very valuable. Comments, guys? –RAP

What's All This Unavailability Stuff, Anyhow?

I had been waiting for this phone call for some time. I knew it would come soon, I just did not know exactly when. Then on the line came a would-be customer, Mike Grimes (not his real name).

"I've been trying to order some LM78MGCPs, and the distributor said I can't place an order for them".

Quickly I checked in the big price list. The LM78MGCP was listed there. Hmmm – that's usually a pretty good indication that the part really is available. I asked him, "Did the distributor say you couldn't get delivery by any particular time?"

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

"No, he just said I couldn't get them," the wistful customer said.

I asked, how many did he want to buy – answer, 25. That's not unreasonable. I mean, some times a guy wants to order 2 pieces, and sometimes 200,000, and in each case there may be a reason why it's inappropriate for the distributor to book the order. Then I hit Mr. Grimes with the sucker punch.

"Exactly who was it that said you could not get the parts?" He did not know. "Which distributor was it that said you couldn't get them?" He could not recall. So I explained patiently that I could pin down the problem and get him a good answer, and I would like to educate the distributor's inside salesman to be helpful.

But I could do that only if we knew who that was. So I asked Mr. Grimes, "You find out who it was, the distributor and the name of the guy, and let me know, and we will educate him. I will go and find out what is the real availability on the LM78MGCPs. Okay?" And he agreed.

As soon as I got off the phone, I went over to Applications and asked if Wanda could get on the SWISS computer and tell me the availability of this part. No, she could not, because she did not have access to that computer. But she was a good sport and wanted to see how it came out. So she volunteered to get the info for me, which was a good thing because I was trying to empty out my office in preparation for a move, all 130 boxes and 5 file cabinets, or about 3 tons. And I set back to work at my packing business, grumbling, "I wonder what the problem is *this* time????...."

About every 5 months, I get one of these phone calls.

"Your distributor says I can't buy LM324Ns any more."

"Your distributor told me the LM741 has been discontinued...."

And when we inquire, "Who told you that?," the would-be customer *never* has the name of the salesman. So I patiently explain that it's kinda hard to help if you can't tell me who it was that told you this story. Then we go off and investigate, and we find the most amazing stories.

Sometimes, the guy talked to a distributor who is *not* a distributor for NSC. Still, there are distributors who aren't authorized distributors for NSC, and amazingly these people will sell you *some* NSC parts, and yet refuse to take orders for others. I still haven't figured out exactly how they do that, but it happens occasionally. So, as soon as we find out which distributor it is, we can solve that problem, pretty well, by referring him to a proper distributor.

Other times, the guy asks for the wrong part number, or an obsolete part number. No, the salesman can't accept an order for LM324Hs, even if that sounds like a perfectly rational part number, because we don't sell a quad op amp in an 8-lead TO-99 package. Other times, there's a typo in a data book, and he tries to order a part that doesn't exist.

When it's our error, we owe the guy an apology. Sometimes when we make an error, we print a line in our price list, explaining that even though this looks like a legal number, it is not, and we suggest what the customer really might want.

But the people who guard our price list are usually trying to keep everything as simple as possible, so these explanations often don't get into the price book.

For example, NSC discontinued the LX5700 temp sensor about 10 years ago, but the LM3911H-46 is the same chip in the same TO-46 package, with slightly looser specs. I've tried for many years to get a cross-reference in there, so if you ask for the one, it refers you to the other. But I guess I can give up on that since there haven't been so many requests for the LX5700 recently.

Other times a guy wants to buy some LM114s. But, it turns out we discontinued the LM114 about 13 years ago because business was negligible. The fact that a guy wants to place an order for some LM114s despite the fact that neither he nor anybody else has bought any for 13 years is lost on him.

He wouldn't care if our stock sits there and nobody buys any. *He* just wants his parts, when *he* wants them. Fortunately, we have people who are good at trying to explain things to people like that....

Sometimes, there really is a computer error, and we have to fix that. In years past, a salesman would be working out of an old or obsoleted or falsely-marked-up price list that was printed on paper.

Back then, we actually had to send somebody to impound the offending document. In the 1990s, though, most such facts are contained in an on-line computer, so if there's a mistake, it can often be corrected from a master terminal. But there are still more parts that we sell than can fit into the memory of the on-line computer. As a result, the availability of many low-volume products is still defined by paperwork – and the correctness of that paperwork is still threatened by all of the potential errors that can lurk in paperwork.

Ah, but there is one marvelous exception: Here at NSC, over the years, we've had so many enthusiastic people who wanted to get their hot new product onto the price list (so that it could be officially listed for sale) that we had to establish a set of interlocks to prevent any one wild man from putting the product on the list before everybody has agreed. Consequently, it takes an Act of Congress – a sign-off sheet signed by every cognizant party – before the clerk is authorized to put the new product on the list. I guess that's fair.

But if a part is to be obsoleted, any number of people apparently have a way to single-handedly, unilaterally drop a part off the price list. And no good safeguards exist to prevent an accidental banishment. Sometimes a single inadvertent keystroke has banished a perfectly good part, pushed it right off the page, with no guardrail to prevent it.

Then if a part is discovered to have been dropped accidentally, it takes a long time to get all of the signatures and put it back on, despite the triviality of the error. So sometimes we have parts in Box-Stock, and nobody can buy them because some absent-minded keystroke caused that part to fall off the price list, and then it takes a whole huge bureaucratic procedure to get it back on....sigh.

In other cases, the customer wants to buy 100 pieces "right away," and when the salesman explains that the parts aren't in stock, the unfortunate Purchasing Agent goes bleating to his boss that these parts "are not available" from NSC. Now, I'm a bug about Availability and Delivery, and that's a whole 'nother story which I plan to write some day.

Anyhow, what we often find is that the P.A. asked if he could get his 100 pieces right away, but when the answer was no, he did not ask, "OK, what *is* the delivery?" Sometimes the answer is 2 weeks, or 5 weeks (or sometimes 18, which I happen to think is not a good way of doing business). But if the P.A. neglected to ask "What is the actual availability?," then he's not helping matters when he complains as if the part had been stated to be completely unavailable.

There will be times when the guy says he needs 5 pieces of LM109. For production? No, for a breadboard. OH well, if you're just using it for a breadboard, you can use LM309s, and they will work just as well, and you can put in your LM109s later...sometimes that solves the problem. And sometimes you can substitute a more expensive, tighter-spec part.

When I showed the first draft of this column to our Sales people, they griped, "Why does Pease have to hang out all our dirty laundry?" But, of course, I bring out *our* conflicts because these are the ones I see most clearly.

Anybody who shops at many places can tell his own horror stories about miscommunication and confusion with other salesmen. But if we tried to pretend that other companies' salesmen had problems and that *we* never have communications problems with *our* customers, people would begin disbelieving anything I said.

So I talked a few hours with some of our sales managers about all of the problems we have had and the improvements we're making in the order-entry business. And finally we agreed that this column will be a definite part of the solution, helping to improve communications.

Going back to this particular "unavailability" case, Wanda returned in 10 minutes with the fact that these 78MGCPs were available with 6-week delivery. Hamilton Avnet was running an active market in ordering and scheduling to ship these parts, so there should be no problem there. Also, the computerized price list had nothing that would lead anybody to say the parts could not be ordered or obtained within a reasonable amount of time. So I called the customer pronto and told him the news that if he placed his order, he could get the parts fairly soon. And I assured him that we really did still want to find out exactly *which* salesman from *which* distributor had told him *what*. So, maybe we will be able to get to the bottom of this, in a few more weeks.

Meanwhile, I want to remind everybody out there that if you're talking to *any* salesman, make sure you scribble down his name. When you have been waiting on the line, on hold, for 3 minutes, and finally the voice says "This is Joe," you may be so relieved that you will immediately start to tell the salesman your story. But before you go off half-cocked, note down JOE adjacent to the phone number that you dialed to get in to the distributor. Then if he tells you a story that you don't like, or a story that you *do* like, but that somebody tries to deny it later, then at least you'll be able to say "It was JOE who told me that." Without that identification, you have no corroboration for your story.

And whenever somebody tries to tell you something unreasonable about the availability of a part, try to get all the facts you can before you complain to the experts. Obviously in any area of human endeavor, where strangers get together to try to do business, there's a myriad of ways that misunderstandings and miscommunications can occur – some hilarious, and some pitiful. If you want to cry on my shoulder, that's OK. But the real question is, can we solve and prevent these problems? If everybody jots down a note that he was talking with "JOE," that's a good first step.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

BOB'S MAILBOX

Dear Mr. Pease:

Your anonymous reader's letter that opened your column in the August 6 issue contained some information that was incorrect and may be misunderstood by the author of the letter.

He referred to a "Bill #1706," which would ban consultants in certain electronics-related fields. He was not complete or accurate in his description.

The "Bill #1706" that he referred to is Section 1706 of the Tax Reform Act of 1986. That section of the Act, sponsored by Senator Dan Moynihan, was proposed to offset a $60 million tax reduction of another section of that Act – all amendments had to be tax revenue neutral.

Section 1706 specifically applies to "an engineer, designer, drafter; computer programmer, systems analyst, or other similarly skilled worker engaged in a similar line of work." The Act subjects them to common-law standards for determining who is an employee and who is an independent businessperson. Previously, a "safe harbor" provision of the law permitted them, as independent contractors, to be exempted by the IRS from treatment as common-law employees with less generous tax benefits.

In the six years since the passage of the Act, independents have found that it has not affected them as seriously as first expected and has certainly not made the profession illegal. What has occurred is that in order for independent consultants to be considered businesses, they must look like businesses and not employees.

Independents are regarded as a business by:

- acquiring a business license
- controlling the methods of doing the work
- being in a position to lose money – that is, not work hourly
- working when and where will get the job done most effectively, not necessarily where your client wants you to work
- using your own equipment in your own office

There are many more of these points and it's generally agreed that no consultant can fulfill all of the points all of the time.

In addition, there's a bill currently pending in Congress to repeal Section 1706.

Bob, I assure you consulting is alive and well.

MARK C. DIVECCHIO
Vice President, San Diego Chapter
Independent Computer
Consultants Association
San Diego, Calif.

Thank you for educating us and getting the facts straight. Many of us part-time consultants should get on your mailing list. – RAP

Dear Bob:

I enjoy your column a great deal. Your offer to rebut Mr. Peter R. Vokac's claims in the June 11 issue that all the world is digital was too tempting to pass up.

In the real world, every digital circuit I have ever seen is made up of analog circuits, with analog constraints, and even analog surprises. When I hire a digital engineer, one of the important skills I look for is the applicant's ability to understand important analog concepts. Without this skill, it is chancy to try to design real digital systems! Perhaps Mr. Vokac was just having some fun teasing his analog engineer friends.

JOHN DARJANY
Griffin Technology Inc.
Rancho Domingues, Calif.

I agree that most digital guys must have some expertise in various analog aspects of digital circuits! – RAP

Dear Mr. Pease:

I very much enjoyed your piece on "Muntzing" in the July 23 issue. It reminded me very much of an occasion in the mid 50s while I was newsman, chief engineer, announcer, etc., at a S.F. Bay area radio station. We had a popular disc jockey who had a habit of acquiring all sorts of goods by means of what later came to be called pay-ola.

I was invited to dinner at the DJ's home, full well knowing that he wanted me to "have a look" at a slight problem he was having with his TV/Hi-Fi set. He mentioned that the TV didn't hold on vertical and that he had "TIGHTENED UP ALL THE LITTLE SCREWS THAT CAME OUT OF THE LITTLE CANS."

At that point, I almost refused to go, but he said that the picture seemed to be just as good as before he "adjusted" the set. I was curious and succumbed to the invitation.

As you would guess, the set was a MUNTZ – the first I had ever seen – and sure enough the least critical as to adjustment. It had a minimum of tubes, about half what I would expect compared to an RCA 630 chassis or other quality set. The trouble as I recall was a bad 6SN7, which I had in my tool box.

So my duty was done, the TV worked – not the best definition, and retrace lines were a little evident, but the owner was happy with the four local stations on VHF. After dinner, he had the nerve to ask me to fix the record player before dessert. It wasn't of MUNTZ origin, but rather a Webcor turntable with a GE variable reluctance cartridge courtesy of the station. That was my evening – MUNCHING and MUNTZING.

BOB MORRISON
Kensington, Calif.

I understand why you couldn't decide to visit this guy: A clear-cut case of variable reluctance! – RAP

Dear Bob:

A while back you wrote a column about having people accountable for their work. Here is an incident that follows that theme.

I was on an airplane in Albuquerque, New Mexico. The plane was performing pre-flight tests when a malfunction

PEASE PORRIDGE

occurred. The flaps would not go down, so the pilot taxied back to the gate.

Then the ground maintenance crew performed some tests. They managed to get the flaps to move, but I could hear a sickly sounding hydraulic pump.

We had to wait six hours before the plane was repaired!

I could overhear two people discussing what was wrong with the aircraft in some detail. One of the gentleman was the mechanic who made the repair.

The mechanic and his son got a free round trip ticket to St. Louis. I think this was how the company rewarded his efforts. However, he would "pay the price" if his work was inadequate. I felt much more relaxed knowing the mechanic was willing to ride on a plane he fixed.

MIKE SUTTON
Fairborn, Ohio

I'm glad to see how some incentives really do help guarantee excellent workmanship. And they instill confidence in the customer, too! –RAP

Dear Mr. Pease

After reading the letter from Robert A. Piankian in your "Mailbox" in the July 9 issue, I couldn't resist sending you my own thoughts on "fuzzy logic."

1. Fuzzy logic is nothing but the multi-valued logic first enunciated (I believe) by Alfred Korzybski in the 1920s (?).

2. Fuzzy logic, as it is practiced today, is actually an attempt to do analog computation by digital means. As a result, it gives a limited number of discrete results, rather than a continuum of results, such as a true analog system would.

It is unfortunate that the originator of the name (in an attempt to be "cute"?) didn't choose a more accurate name, such as "continuous logic" or "analogic," or even the original "multi-valued" logic. That choice has undoubtedly led to a lot of (probably subconscious) reluctance to use – or even to investigate – "fuzzy logic," because of the implications of imprecision. A similarly unfortunate choice of a name was made in the case of the computer language LISP. When one stops to think about it, doesn't the word "lisp" carry a connotation of immaturity ("All I Want for Chrithmath ith My Two Front Teeth")?

Afterthought: I wonder what the literal translation of the Japanese term for "fuzzy logic" might be?

You might be interested to know that I "cut my computer teeth," so to speak, on the electromechanical, *analog*, fire-control computers that were used in the B29, P61, and A26 aircraft of WWII.

ROBERT J. NEDRESKI
Owner
Nedreski Industrial Service
Erie, Pa.

Thanks for your comments and insights into the history of such logic. –RAP

Dear Bob:

Re:Pease Porridge and fuzzy commentary:

Pease Porridge hot
Pease Porridge cold
Pease Porridge in a pot much too old

Pease Porridge please
open up your eyes
something with a silly name
doesn't mean it flies
Fuzzy logic is not fuzzy
nor a fuzzy wuzzy was he
Fuzzy logic is making money
and to some that's sure nice honey

Pease Porridge hot
Pease Porridge cold
Pease thinking has gone to pot
because fuzzy logic is gold

The poetry is not perfect, but I think you get the idea. Your thought is highly respected, but for such an uneducated comment referencing fuzzy logic (July 9 issue) to escape from your pen, well, it is unfortunate.

CAMERONE A. WELCH
Director, Corporate Communications
Togai InfraLogic Inc.
Irvine, Calif.

You have piqued my interest, and when I figure out what to say about fuzzy logic, I'll be sure to let you know. –RAP

WHAT'S ALL THIS CZAR STUFF, ANYHOW?

But first, an esaeP's Fable.... Once upon a time, the Lion woke up in an especially powerful mood, so he started out through the jungle. He met a hyena and roared, "Who is the Lord of the Jungle?" The hyena replied, "You are."

The Lion met a wildebeest, and roared, "Who is the Lord of the Jungle?" The wildebeest replied, "You are." Further along, the Lion met a monkey, and again roared, "Who is the Lord of the Jungle?" And the monkey confirmed, "You are."

Then the Lion met an elephant, and he asked the same question. Without a word, the elephant grabbed the Lion, hoisted him over his head, and SLAMMED him to the ground. After a few seconds, the Lion collected his wits, and struggled to his feet, and proceeded to slink down the trail.

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

But he called back over his shoulder, "Well, you don't have to get sore just because you don't know the answer." *End of Fable.*

About 6 years ago, I declared myself the Czar of Bandgaps. I stated that anybody at National Semiconductor who was designing a bandgap reference must clear his design with me. Sure enough, since that time, I've been fairly busy in my spare time, checking the circuits *and* the layouts for new bandgap circuits.

Recently, a reader wrote that he thought that Paul Brokaw at Analog Devices was the Czar of Bandgaps. I wrote a nice reply, and said that I had never heard Paul claim to be the Czar of Bandgaps, and Paul had never slammed me to the ground. But if Paul wanted to claim to be the Czar of Bandgaps, well, I wasn't going to argue with Paul. However, if anybody had the right to claim to be the original Czar of Bandgaps, it could have been the late Bob Widlar, since *his* LM113 and LM109 circuits came first. But Bob Widlar never slammed me to the ground. And he never challenged me about my Czardom – for good reason!

First of all, why would anybody make the claim to be the First Czar of Bandgaps?? I was the first to do so, as nobody before me had ever been stupid enough to make that claim. I only made that claim because my boss and his boss were unhappy because several new bandgap-reference circuits had been observed to not work properly, and the mistakes were the same as old mistakes made years ago. It's always a shame when you make a mistake, but it's especially sad when you repeat an old mistake like that. It's akin to the old saying, "Those who do not remember history are condemned to repeat it."

I figured I was pretty good at noticing and remembering things, and as I was a veteran of over 10 years at National, I had a good chance of doing more good than harm. At the time, I had made a bunch of mistakes in my own circuits, but I had never yet made the same mistake twice. So I made this outrageous bluff, and I promised to be helpful to make sure that no old, foolish, unnecessary mistakes were made, and not too many new ones, either.

So far, I think I've done a pretty good job of catching the mistakes in the bandgap references brought to me – at least half of them. I've encouraged the engineers to think about worst-case design, and good layouts and good testing. Our references and regulators have been coming out with fewer dumb old mistakes, although a some brand new mistakes still creep in (which we keep learning from). In a few months, I will demonstrate a few good bandgap circuits that you can't buy, but that you can make for your general amusement and edification.

Additionally, we decided, after a while, to establish a couple other Czardoms: we have a Czar of Startup Circuits, a Czar of Computer Goofups, and a Czar of Czener Czaps. Now, that would ordinarily be spelled, Czar of Zener Zaps – that is, the expert on trimming of circuits, using fuses and "Zener Zaps." But we decided the alliteration was a little too good to resist. Also, we have a Czarina of Linear Data Sheets. And, oh, I almost forgot, I also declared myself to be the Czar of Proofreading. I am the best Proofreader I know, and I have a very bright eye for typo errors. I've caught typo errors in the telephone book, in the Sears Roebuck catalog, and in the Holy Bible (RSV). But that does not say I'm perfect at catching all of the errors in my own work – I'm NOT perfect when it comes to my writing, because every writer is too close to his own work.

In Dec 27, 1990, I used the word *tendency* twice in one paragraph of my column, and it was spelled two different ways. The English language is flexible, but not *that* flexible. Bob Milne graciously conceded that he had put the wrong "tendency" in there, at the last minute, so late that it never had a chance to meet the spell-checker. And when he faxed a copy to me, I didn't spot it. It just goes to show that even a Czar can miss an error if he's too close to it. I regularly have fistfights with the spell-checker in my word processor. And Mr. Milne and Roger Engelke, *Electronic Design's* chief copy editor, have been known to shake their heads at some of the odd spellings that I think are perfectly correct....

What else have I done as Czar of Bandgaps? I gave a 40-minute Tutorial at the IEEE Bipolar Circuits and Technology Meeting, back in September of 1990, not just about how to do it *right*, but, more interesting, how to do it *wrong*. I mean, you can look in any number of data sheets to see a circuit

PEASE PORRIDGE

that works, but looking at a circuit that DIDN'T work is more educational. I can't give away every secret so that every engineer can copy any circuit with impunity, but it's not to anybody's good to have everybody making all sorts of dumb old mistakes.

For example, at National, when we engineers have a circuit laid out as well as we can (at least to the best of our knowledge), we invite all our peers and colleagues (engineers *and* technicians, too) to see if they can detect any errors in the circuit's layout. If they find a significant error, they win a mug of beer, to be paid off later. That's why we call it a Beer check. It's much cheaper for me to give away a few pitchers of beer, with pizza to match, than to have my circuit crash and burn just because of a dumb oversight on my part. As I mentioned above, I can easily overlook a dumb error on my circuit because I'm too close to it. I can let through a mistake in my circuit that I would surely spot if it were in somebody else's circuit. Isn't that true for *you*, too?

So if you think there are certain classes of errors that cause excessive trouble, well, *you too* might declare yourself (with your boss's approval) the Lord of the Jungle, or the Czar of Thingamabobs. Just don't be too surprised if somebody doesn't understand and tries to slam you....

Recently I was giving a lecture, back East, and I asked the engineers, "Do you have any Czars in your company?" A week later, I got a nice letter from a senior engineer who realized that his company *did* have several Czars, experts in a particular niche, who didn't get enough recognition or appreciation. He said he was planning to give them a little extra responsibility and appreciation, as Czars. Maybe I'm on the right tack after all! So, I will ask the same of *YOU*, whether you have previously recognized them or not: Do *YOU* have any Czars in your company?

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

PEASE PORRIDGE

Bob's Mailbox

No other Pease Porridge column has generated more reader response than "What's All This Taguchi Stuff, Anyhow?" which appeared in the June 25 issue. Bob's hot on the trail of those elusive Widget amplifiers, and will be devoting another column to the Taguchi method in the near future. In the meantime, here's a sampling of our readers' opinions on the subject.

Dear Mr. Pease:

Your article "What's All This Taguchi Stuff, Anyhow?" is refreshing reading. I suppose one could look at the Taguchi issue better if distinctions are made among: (a) Taguchi the Master, (b) Taguchi Methods, (c) Taguchi Preachers, and (d) Taguchi Disciples. Then it would be clearer which are the ones that ought to get out of real labs that deal with real systems, and be asked not to sell any more magical data and beautiful parables concocted supposedly for the salvation of engineers.

I am doing research on this Taguchi phenomenon, and would like to keep in touch with you and everyone else that has experience with the "Taguchi Methods."

T.N. GOH
Professor
National University of Singapore

I, too, am concerned about those magical data and miracle cures and I'll share my ideas and letters with you. More later. —RAP

Dear Mr. Pease

Wrap it up! Your two-page put down of Taguchi only puts me off my Porridge.

The Taguchi approach explores the whole design space and enables many factors to be evaluated for the significance of their contribution. Confirmatory test work is always recommended.

Please recheck your own signal-to-noise ratio.

RICHARD W. GILBERT
Product Engineering Manager
Basingstoke, England

I've been checking my work. My S/N ratio is fine. It just bothers me when people think they can use Taguchi's methods on nongaussian data, just because they see Dr. Taguchi doing it. —RAP

Dear Bob:

I just read your article on the "Taguchi Stuff." It is very well written and hits the nail directly on the head. I thought I was the only one on the planet that was suspect of this whole thing.

As a senior process engineer for a company that does injection molding, occasionally I'm involved with troubleshooting extremely difficult parts to injection mold. The more time I spent in our process development lab, the more I saw of this "Taguchi Stuff." It had become a monster from the simple little method that it was originally intended for (I personally think it would be good for making pancakes if you had no recipe, just the Bisquick, eggs, and some milk).

On a serious note, the type of molding machinery we have is some of the most sophisticated in the world and has many closed-loop feedback systems that deal with outside disturbances, such as material viscosity. I found out that our process technicians were trying to do these "Taguchi Tests" that were designed by quality engineers. In order to run these tests, though, they had to "fool" some of the closed-loop systems. In short, they generated information that could never be used in manufacturing or the test wouldn't even run.

I asked a lot of technicians and process engineers around the company if they ever ran a Taguchi test that lead to a better process than the one they had. The answer was "Yea, once" but only because one of the tests itself was a better process (I'd call that luck).

The tests still go on, but not on any of my projects. I believe strongly that common sense, intuition, logic, reason, and experience bring much more to the party than this "Taguchi Stuff" will ever bring.

EDWARD J. DEVAULT
Sr. Process Engineer
Nypro Inc.
Clinton, Mass.

Obviously we agree on most aspects. There are many good ways to optimize a system. But the Taguchi method does not provide me any insights. Thanks for your real-world observations. —RAP

Dear Mr. Pease

I was sorry to read about your negative feelings concerning the Taguchi Method. I was, however, pleased to note your scientific curiosity as well as your desire to learn a new method.

I have been working in the field of the Taguchi method, also known as the Robust Design method, for the last twelve years and I have seen it work in a wide range of industries: telecommunications, microelectronics, xerography (electrophotography), aerospace subsystems, defense electronics, steel making, software testing, and software development. These applications range from early stages of technology development, product design, and manufacturing process design, to fire fighting in manufacturing operations. Of course, it goes without saying that Robust Design is not a tool that solves all problems. Selecting an appropriate tool and applying it correctly are essential for getting good results. When applied correctly in appropriate situations, it has yielded excellent benefits. The same thing can be said about statistical methods. They, too, have yielded excellent benefits.

I would like to suggest a few references for you. Keeping modesty aside, I would like to refer you to the book *Quality Engineering Using Robust Design*, by M. S. Phadke, Prentice-Hall, 1989, for a clear explanation of the Robust Design method. It also has some case studies relevant to the microelectronics field. The book *Quality by Design: Taguchi Methods and U.S.*

Industry, by Lance Ealey, ASI Press, 1988, describes the experiences of several industries in the United States and other countries in applying the Robust Design method.

DR. MADHAV S. PHADKE
President
Phadke Associates, Inc.
Tinton Falls, N.J.

I am definitely interested in learning about other people's ideas and books for "robust design." Engineers have been designing mechanical and electronic products for many years. Sometimes good "robust" results were achieved. How did we ever do this before Dr. Taguchi came along? —RAP

Dr. Mr. Pease,

Regarding Taguchi, I couldn't agree more and I'd like to relate a similar experience. My company is putting all of its employees through "Five Lambda" training as part of its quest for a well-known quality award.

In this class, we were shown a video tape in which a PhD type from another company (from which we purchased the course) showed us how to use Five Lambda techniques to optimize the design of a stopband filter.

He chose one leg of the filter. First he said his technique would eliminate the archaic "tweaking" capacitor (he never followed through with this). I contend that most filters have to be tweaked because of unpredictable effects, like mutual coupling between components, putting the lid on the can, etc. Second, he went to great lengths to show that the value of the *resistor* had little effect on what he called the "Robustness" of the circuit. The idiot didn't even realize that there was no actual resistor in the circuit, just the resistance of the coil wire. Third, he optimized (by statistical methods) the value of L and C for best input impedance and passband insertion loss. These are not the parameters that define the "Goodness" of such a filter.

I pointed all of this out to the instructor and suggested that this man and his company's very expensive course have no credibility with me.

NAME WITHHELD
Silicon Valley, Calif.

Some of these "experts" take themselves terribly seriously. They claim to be experts in EVERYTHING, even topics they really do not understand. —RAP

Dear Mr. Pease:

In regard to "What's All This Taguchi Stuff, Anyhow?," your article really misses the point. You have clearly demonstrated a total lack of understanding of the process. As a case point, the Taguchi method is just one tool in a toolbox of tricks, but you treat it as though it totally replaces everything in the lab, including common sense.

No, Mr. Pease, that won't work in my lab. Take that Pease Stuff and shove it in the round file. I don't need that

PEASE PORRIDGE

Pease dividend or any others like it.

On a more positive note, I'd like to hear more about the "Pease Stuff." If you don't use the Taguchi method as one of the tools in your arsenal, what do you use? How do you perform process optimization, design for higher yields, and process control?

CHARLES JACKSON
TRW
Redondo Beach, Calif.

Ah, but peddlers of the Taguchi method don't say it is just one tool in the toolbox. They claim it's the only tool you'll ever need. Myself, I optimize my work using 2D scatter plots. I use my eyes, skeptically (not any mindless computer) to look for correlation, trends, troubles, and solutions. –RAP

Dear Mr. Pease:

I hope that all readers of your column and those who have attended similar Taguchi lectures are equally as skeptical. I have attended several such lectures and have come away from each with a great deal of frustration because the Taguchi method seems to oversimplify things and seems so quick to ignore and discount things that would 'muck up' the application of the method.

Similarly, the examples used are always nonrealistic scenarios (such as the magic widget amplifier); and the solution could be easily figured out without the Taguchi Method.

One other shortcoming that you may wish to point out to your readers is that the Taguchi Method (as it has been explained to me) completely discounts the use of random samples and tests of processes and their outputs because it is assumed that the process is always under control – therefore nothing random can happen. So! Our processes are therefore completely under control – we have just *chosen* lousy yield tolerances? We need the Taguchi Method to tell us to tweak things to get tighter SPC? I don't think so!

Finally, there is a ray of hope for those who like to use a methodology in their quest for better quality control: "*Design of Experiments*," by Keki R. Bhote, is a method I have found to be much more logical and scientific as well as simple to learn and apply.

STEVEN J. VORNSAND
Audio Engineer
Dukane Corp.
Saint Charles, Ill.

Isn't it funny how these gurus set up a simple problem, to demonstrate the superiority of their methods. And when the methods, after massive amounts of work, give useless or misleading answers, then what? –RAP

Dear Mr. Pease:

You are clearly very frustrated with the poor presentation you got on the Taguchi method. You also mentioned the ridiculous attitude of the professor you contacted. Your criticism mostly centered around the inappropriate examples cited during the lessons and the frustrated interactions you have with the professor. Lastly, you do not understand the techniques and you do not allow your people to practice the techniques in your area.

However, from a scientific view point, that criticism doesn't seem applicable to the Taguchi way of experiment design per se. Moreover, I cannot agree with you on the following arguments:

(1) You wrote: "The method implies you can check the design-center zero offset in the morning, and design-center full-scale of the meter at noon, and take data all day long. And you'll never have to recheck the design-center zero reading or the gain, because that would be wasteful and redundant." And you wrote that your people always include a sanity check.

To my understanding, the Method does not mean what you said. The "sanity check" can be included by simply putting it in as an extra factor in the Noise Matrix. In this way, you can ensure the corresponding repeatability in your data, and at the same time not expand the number of experiments.

The Method is just providing us with some techniques which may or may not be useful, depending on the particular situation. If people do not understand them, and use them wrongly, obviously they will generate wrong data from the experiment. Similarly, if people are using calculus wrongly, and it generates wrong results, this only means there's a problem with the way they are applying it. It's nothing to do with the calculus itself.

(2) In another paragraph you wrote: "...they would manipulate the variables they could control – the temperature of the plastic, the pressure, the molding time. But they would not worry about the viscosity of the incoming plastic material because they didn't have any control of this. So they would ignore it."

I think this is seriously violating the spirit of conducting experiments and as far as I know, is not found in Taguchi's literature. The Method provides a new way of designing experiments, but it's not a substitute for the basic skills of conducting experiments. This might be a mistake or misquote from the professor you mentioned.

I cannot see why you developed the hostility towards the use of statistical methods, although I agree with you that there will be problems if designs of experiments are "dictated" by statisticians, or scientists, or engineers... This is not the time to talk about discrimination against a particular profession or race. The world functions well through the cooperation of different professions and people instead of unhealthy hostility.

I think a new method should be judged on a merit basis. If it does not violate scientific principles, then it is a sound method to use, whether it also concentrates on reducing "manufacturing costs" or "loss to society."

To what I see, the Taguchi method is one way of doing DOE (design of experiments). It is a sound and practical method. It also gives us efficiency by adopting different techniques from various fields, such as orthogonal matrices, graph theory, ANOVA, and so on.

The fact that you do not understand the technique does not mean that the method is no good. This only means that you have to work harder. Maybe consulting a better source will give you more enlightenment.

WALLACE YONG
Advanced Engineering
Seagate Technology International
Singapore

Ah, but we refuse to use it because we understand it all too well. And soon, enlightenment will be provided for all. –RAP

What's All This Floobydust Stuff, Anyhow?

First of all, I should explain that "Floobydust" is an old term that was invented here at National, a phrase coined by Dennis Bohn, meaning "miscellaneous" or "potpourri" – a "Mixed bag." A catch-all phrase. And that's what we have this month. For example:

• Several people have asked, "Why do we now have a Pease Porridge column only every *other* issue?" Well, I LIKE to write a column every issue, twice a month. But after putting out more than 40 columns, I am finding that all of the *easy* ones have been written. The ones I am writing now take *more* research, *more* breadboarding, *more* special permissions and approvals, *more* time, *more* work. I'd rather write just one column per month and get it *right*. Meanwhile, because there are so many excellent letters from readers, I'd feel bad if we couldn't get a lot of them printed. Running a good batch of letters once a month helps keep me from burning out on writing columns on tough subjects. And I hope you are enjoying the letters, too.

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

• Also, I just learned recently that my column is being translated and published in the Russian-language version of *Elektronics*. A knowledgeable friend assured me that the translation is quite good, retaining much of the style of the original. So if anybody is studying the Russian language and would like a few copies, hit me with a 52-cent SASE and I'll send you some good columns in Russian.

• Recently, I got a letter from Michael Ellis, Research Engineer at the U.S. Army Corps of Engineers, Vicksburg, Miss.:

"Dear Mr. Pease, I have enjoyed your commentaries on Spice, and your own articles have enticed me to personally explore Spice. Since Spice obviously solves for circuit voltages using numerical techniques, I presented a circuit to Spice for simulation. This particular circuit represents the simplest case of a mathematical class of differential equations known as 'stiff' equations. The significance is that there is no known *stable* solution to 'stiff' equations using numerical techniques *(see the figure)*. The 1000-μF capacitor C1 is assumed to have a 1-V dc charge as an initial condition; then it is discharged by the 1-kΩ resistor. Spice is asked to simulate the voltages V1 and V2 over time. My Spice file is:

```
R1 1 0 1K
C1 1 0 1000UF IC=1V
EAMP 2 0 1 2 10E5
.PRINT TRAN V(1)  V(2)
.TRAN 1S 100S UIC
.END
```

The Spice solution is compared with the exact solution $V = e^{-t/RC}$ at a few points *(see the table)*. The solution continues to degrade and the percent error will increase to well beyond 1000% as time goes on. One might ask why such small voltages are significant. However, in many areas, including radio astronomy, a signal of nanovolts in a very narrow bandwidth might be of utmost importance. This particular Spice simulation uses an ideal op amp and still gives the wrong answer (the op amp works fine since V(2) tracks V(1) exactly). At time = 20 seconds, the voltage V(1) is negative, which in reality is impossible for any real or theoretical circuit with an initial condition of +1.0 V dc on the capacitor. It would also be impossible for any manufacturer to guarantee the Spice model of his op amp in such a case because the errors are entirely due to the passive components."

Obviously I found this letter intriguing, especially as I am such an expert with Spice. (That's supposed to be a joke.) I set up the circuit in Spice, and in a couple minutes I got a solution. I fooled around some more and got several other solutions. After some thought, I constructed this answer:

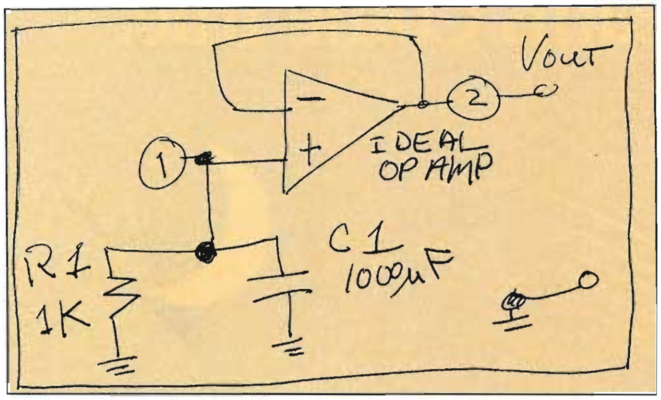
No, you can't just blame the errors on the passive components. It is a set of computational errors, and like any other computer problem, you should ask the computer a question for which you know the answer, exactly as Mr. Ellis has done. THEN if you don't like the answer, you trick the computer into giving an answer you like.

In this case, I merely guessed that if I broke the question down into smaller elements, I could get finer computations. On my initial computations, I got an error of just −20% at t = 20 seconds – rather less error than the −137% Mr. Ellis did. So on my next run, I asked for .TRAN 0.1S 20S UIC, namely, I asked the computer to compute the answer for each 0.1-second in-

SPICE VS. EXACT SOLUTION

Time	V(1)	V(2)	Exact Solution	Percent Error
1 sec	0.3815	0.3815	0.3679	3.702
2	0.1253	0.1253	0.1353	-7.415
5	5.542E-3	5.542E-3	6.738E-3	-17.75
10	2.723E-5	2.723E-5	1.234E-4	-40.02
20	-7.605E-10	-7.605E-10	2.061E-9	-136.9

PEASE PORRIDGE



not found any documented example that goes back that far, but I did get a letter from Owen Gallagher, Stratus Computer, Marlboro, Mass. He sent me an excerpt from a book about *The Origins of Feedback Control,* translated from

terval. (I decided to truncate the problem at t = 20 seconds, because when the output is smaller than 0.001 ppm of the input conditions, I really don't care any more. Even radar sets that transmit in kilovolts and then receive in microvolts don't need much more dynamic range than that....) The computation time then stretched out from 0.25 seconds on our mainframe to 1.2 seconds, a mere factor of 5 extension. And the accuracy at t = 20 seconds improved to 2%.

Hey, that's pretty good engineering accuracy. That's reminiscent of the scientist and the engineer who were both put into a room with a beautiful woman. They were told that each second, they would move 1/2 the distance to the woman. The scientist moaned, "I'll never get there." But the engineer just smiled. "I'll get close enough."

I also bounced this Spice question off Dave Hindi, a real Spice expert. He countered that when you really want tighter relative accuracy, you should ask for a tighter RELative TOLerance of the computation:

`.OPTIONS RELTOL=1E-08`, which is much tighter than the normal (default value) of 0.001. Indeed, this did tighten up the computations. But Dave was running his computations on a small, powerful PC, and asking for such a small `RELTOL` did cause the computation to slow down. And, his answers were not all as precise as mine. Still, this indicates there are two ways to sweet-talk the computer into giving very good computational accuracy.

• In my 1991 column on Negative Feedback, I observed that according to an old story George Philbrick told me, somebody invented a clock-adjuster back in the 1500s or 1600s – a big old slow phase-locked loop. So far, we have not found any documented example that goes back that far, but I did get a letter from Owen Gallagher, Stratus Computer, Marlboro, Mass. He sent me an excerpt from a book about *The Origins of Feedback Control,* translated from the German version (1969) and published by the MIT Press, Cambridge, Mass., in 1970.

First you should note that the flyball governor was probably invented by Matthew Boulton about 1788, and constructed in James Watt's workshop about 1789.

In chapter XI of this book, credit is given to Abraham-Louis Breguet, a skilled French-Swiss watchmaker living in Paris, for inventing a watch-synchronizer, along nearly the same lines as I recited in George Philbrick's old story. This invention was documented by a letter dated June 29, 1795 – just a few years after the centrifugal governor attributed to Watt. So, even though the story I gave you was off by a century or two, the basic concept has been confirmed.

• Lastly, I'll comment about old cars. Several readers questioned me pointedly: Even if I can keep my old 1968 VW Beetle running reliably and economically (now at 260,000 miles), is it right to keep this old car running when it is "obviously" polluting the air much worse than modern cars?" A fair question....

I checked on some of the data on smog tests taken on my VWs in recent years. In California, these old cars do not have test limits on pollutants at running speeds, only at idle speeds. BUT the service stations took the 2500 rpm data anyhow:

Hydrocarbons:
102 ppm, 185, 188, 148 ppm.
Carbon monoxide:
1.14%, 1.15%, 0.36%, 0.64%.

The corresponding test limits that I have seen for modern cars are 220 ppm of hydrocarbons and 1.2% CO. My old car was passing these test limits without any special effort. Just because a car is old or "obsolete" doesn't mean it is necessarily smoggy or polluting. Besides, I am getting 29 mpg, and the percentages are based on a total exhaust volume that's obviously smaller than for larger cars that burn more gas and air.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

BOB'S MAILBOX

Dear Robert,

I have enjoyed your articles since they began, because I have been an analog circuit designer for about the last 30 years. Normally I am in full agreement with you, but your article on spreadsheets surprised me.

I have used spreadsheets for about the last 10 years and have found them to be very useful as an engineering instrument. Notice that I say instrument because they must be built very carefully, tested very extensively, and used with common sense and care in mind, just as we would use an oscilloscope or a voltmeter.

There are about a dozen fairly simple spreadsheets that I regularly use for engineering calculations and estimates. They work because they were very carefully designed and tested using many examples checked by old-fashioned methods and double-checked by several other people.

The spreadsheet is just another instrument/tool, maybe similar to Spice, which must be used with a lot of good engineering judgment and care. Regular calibration checks are needed and circuit modifications are made with the greatest care and patience, followed by rigorous testing.

ROBERT L. YOUNG
DuPont
Parkersburg, W.V.

Like any other calibrated instrument, a calibrated spreadsheet is a lot more valuable than something uncalibrated, untested, and unconfirmed. –RAP

PEASE PORRIDGE

WHAT'S ALL THIS INCANDESCENT STUFF, ANYHOW?

A couple months back, I was reading one of the alumni bulletins from Northfield Mount Hermon School, which I attended 35 years ago. I was poring through a whole bunch of not-too-interesting social stories about people whom I did not know when suddenly I ran across a technical story written by Mike Hannon, another NMHS alumnus who lives in Lompoc, Calif. He was explaining how some new incandescent lamps manufactured by GE, Philips, Sylvania, and others are now able to provide high efficiency as well as improved life. And how do they achieve these advantages?

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

Well, first of all, they are halogen lamps. Instead of the filament boiling off, it boils off and then back on, so the filament has a good chance of lasting several thousand hours. This is good technology, but nothing new. The real kicker is that the filament is enclosed in a new dichroic filter, which is selective to energy at long (infrared) vs. short (visible) wavelengths. Every lamp's filament generates some energy in the visible wavelengths, and a lot more heat (radiation in the infrared region). If all this energy is allowed to radiate, the bulb puts out a lot more heat than light. You have to dissipate 100 W, for example, to keep your filament hot while you get a mere 6 or 8 W of visible light. However, if we had a specially engineered coating to let the visible light *out* and reflect the heat radiation back *in*, we might be able to keep that filament hot with only 70 or 60 or 50 W, yet still keep the same light output. That's not necessarily more efficient than a fluorescent lamp, but if you want a bright, intense lamp rather than a wan, weak light source, then there may be places where these new halogen-plus-IR lamps have real advantages. GE deserves a lot of credit for engineering these improved "dichroic" lamps and bringing them to the market-place.

AND, Mike Hannon deserves a lot of credit for trying to educate people on a real opportunity to save money and energy. I mean, I've been trying to keep an eye out for these bulbs ever since I first heard of the concept about 6 years ago, but I had not found them until Mike pointed them out to us.

Mike didn't just recommend buying these lamps; he did a lot of evaluation on the best ways to apply them. He studied the tradeoffs of lamp life vs. brightness. Of course, most people are aware that if you want the highest efficiency, you run the lamp at a fairly high voltage. But this degrades the life of the bulb according to a 12th-power law. If you take a 115-V bulb and run it at 125 V, your brightness is *way up*, and the efficiency (lumens per watt) rises significantly, too, but the bulb life is *way down*. A couple of times, I have lived in a house where the line voltage was up near 124.5 V. It was not uncommon to lose two light bulbs in one day. I kept a calibrated ac voltmeter and I would check the line voltage quite often. The line got up ever so close to 125 V—but it never exceeded it. If the voltage got as high as 125.1 V, I would have complained to the Light & Power people and forced them to come out and adjust the taps on their step-down transformer.

Conversely, if you want to get really *long* life from incandescent bulbs, you run them at relatively low voltage. The easiest way to do that is not by fooling around with Triacs or transformers, but rather to put a single silicon rectifier in series with the bulb. This cuts the power dissipation by about 65% and the light output by about 82% (19 dB), and bulb life is extended enormously. This is what you may want to do if lights are located in really rotten, inaccessible locations.

The disadvantage of poor efficiency will be well offset by the savings from the reduced frequency of bulb replacement. Some of the new halogen bulbs are also available with 130-V ratings, which is another good way of matching your requirements to the available power.

Mike did many experiments in this area. He found that some of the new bulbs had problems with singing, vibrating filaments, an often annoying problem that can cause early bulb failure. He found that putting a full-wave bridge in the lamp wiring can feed dc with a lot less ac component to the filament, banishing the vibrating filament problem.

However, with one particular lamp, the Sylvania CAPSYLITE, the lamp brightness seemed to go *way up* with the bridge. He took measurements and confirmed that the power drain was greatly *increased*. What's going on here? He figured out that in this lamp, a single rectifier was already built-in. In normal operation, the lamp ran on half-wave rectified power. But when you inserted the full-wave bridge, the lamp ran nearly twice as much average current—extremely bright and *extremely* hot.

Mike also observed that some of the cheap "miracle button" rectifiers aren't very reliable, and can fail in a mode with bad local overheating. So if you buy some of those inexpensive rectifier disks that get stuffed down in the socket, keep an eye on them for the first few hours....

Mike also did lots of research on the startup characteristics of these lamps. Because the filaments run SO hot, the dc resistance when cold is even lower than on ordinary incandescent bulbs—as low as 1/12 of the hot value. So the in-rush current can be *quite* large, say, 6 A on a 50-W bulb. This can slightly shorten the life of the bulb.

Again, the solution is fairly simple. You can buy In-rush Current Limiters (ICLs) from Keystone Carbon Corp., if you want to buy OEM quantities of them. Or if just a dozen are needed, you can order them from Digikey (call 1-800-344-4539) for about $1.39 each (part number KCL013L-ND). These thermistors come with ordinary leads, rather like a fat ceramic disk capacitor, about 0.42 in. in diameter. To install them, you have to solder them carefully into your lamp's wiring. This particular model, which I find suitable for 50- to 100-W bulbs, provides an in-rush current of barely 2 A, so the lamp takes many milliseconds to warm up gradually. I am buying a dozen of these, because they will improve the life of every 100-W bulb in my house.

When we add this ICL to the new halogen lamps, that should improve our lamp life out from perhaps 2000 hours toward 3000 or 4000 hours, in normal service. That's a rather good thing because right now these lamps cost somewhere from $7 to $11 at retail. If we can make them last 6 times as long as an ordinary 100-W bulb, the cost of the halogen bulb (per hour) is still relatively high. Then why bother? Answer: for the improved energy efficiency. If I can run a 50-W halogen bulb at 42 W and get slightly more light than a 100-W bulb, then over a 3000-hour lifetime it can save 3000 hours × 58 W, which costs (at 8 cents per killowatt hour) about $13.

So there's where you will break even, and even start to save money. Eventually, when manufacturing costs fall, these halogen/dichroic lamps will be even more cost-effective.

Of course, nothing competes in a vacuum (pardon the expression). The modern fluorescents have already come down in price. The recently announced Philips magnetic-induction bulbs will be coming along the learning curve, too. Five years from now, will there be a clear-cut winner for every application? Maybe, maybe not. But it will be fun to see how the competition works out!

So, you should run right out and buy a dozen of these GE Halogen-IR 60-W 60PAR38/FL/HIR bulbs (GE's part number; product order code is 18626), or the slightly more compact 50-W 50PAR30/FL/HIR, or a Sylvania CAPSYLITE, at your corner hardware store, right? Heck, no. First of all, if there are two in stock, you'll be lucky. If there are none, you may be able to wave this column at the manager and convince him to special order some for you, and to stock them. But, will you need a whole large number of them?

If you leave a light on many hours per day, that becomes a good candidate for installing a (relatively) expensive high-efficiency lamp. If you leave it on all the time, your break-even time on the investment can be as short as six months. But if there's a lamp you use just a few hours a week, you will not get your investment paid back for several years—no point in fooling around with that. So, until the price drops, you might want to buy just one or two to check out the situation. If you find the light from the fluorescents adequate, these lamps are already well developed along the learning curve.

On the other hand, do you dislike the idea of electronic ballasts humming in your ear as you sit reading? Then the newer halogens may find favor. I have a couple of each. I'm trying to evaluate where my preferences lie.

I must point out that right now the best halogen/dichroics are in the form of a floodlamp, with a 38-degree beam. I'm still trying to get some lenses to spread out the beam to be more like an ordinary lamp's spread. The floodlight is not, by itself, exactly the light pattern I want.

If, as you shop, you see some that are semi-spot or spotlights (Model /SP/), don't buy one unless you're prepared to use an 18-degree cone of light. One engineer says you can spread out the light to a wider pattern by sandpapering the face of the bulb. This might give a nice diffuse source, but I would not sandpaper any glass that sees that much stress and heating. However, placing a *separate* piece of frosted or sandpapered glass in *front* of the bulb should do the trick. I'll try that soon.

An additional caution: The bulb's shipping box has a rather weak warning, which states that if the outer glass bulb breaks or cracks at all, you should throw the bulb away, even if it appears to work okay. Why? Two reasons: the inner halogen capsule emits lots of ultraviolet rays, and you could get a bad sunburn, or go blind if the light shines right on you. Also, the failure mode of the halogen capsule can sometimes be a blow-out, and you need the outer glass for protection.

Additional comments—Mike Hannon points out that using a dimmer is one of the nicest things you can do with one of these lamps. As you turn it on, the lamp intensity comes up gradually, which is ideal for its life. You won't need any ICL. These halogens *do* like to run on a dimmer, which fluorescents refuse to do. However, if you turn down the dimmer *too* far, and the capsule gets *too* cool, lower than 250°C, the filament material will refuse to reevaporate back onto the filament. A dark film will then appear on the inside of the capsule, and you'll have to turn the voltage back up to get the bulb back to full efficiency again (that's a reversible mode of degradation of efficiency). This might even happen if you use a half-wave rectifier—the capsule might not run hot enough for proper halogen action. Further, running a filament on dc can help accelerate a failure mode called "notching." This causes the boiling off of the filament to be localized rather than uniform, so the actual increase of filament life at low line voltages isn't as great as predicted theoretically. So when the magic rectifier peddlers claim, "extends bulb life 100 times," they're just blowing smoke, as you suspected. They're extrapolating into regions where they have never taken any data....

On the other hand, if you're doing industrial lighting, you may be lighting stairwells or hallways, 24 hours per day, and if the lights are virtually never turned off, an ICL would have no advantage (however, the extra couple volts dropped in the ICL will cause the halogen bulb to run a little cooler, for a little longer life).

I went researching at a Radio Shack.

PEASE PORRIDGE

They don't sell thermistor-type ICLs, and they don't sell little rectifiers assembled in the magic-button format. What they DO sell is a little Triac assembly, (Part # 61-2726, two for $4.25). It claims to save 10% of power for an "undetectable" decrease of brightness. But it does start up the SCR with a small (55%) duty cycle, so it effectively acts as a current limiter. After it warms up, the Triac fires at a high duty cycle, so the lamp runs at substantially full voltage. So, there's one more game you can play to improve longevity.

I guess it would be fair for me to say that at this state of application, these new high-efficiency halogen lamps are, like 'most every new product, still in need of some planning, engineering, and experimentation. But in the long run, there will surely be other formats, other shapes, other products, that will be very convenient and appealing *and* efficient. Saving electricity by buying more efficient lamps is one of the easiest and most effective ways we can save energy and money, and the opportunities to do this are expanding rapidly. I'm getting my feet wet now (of course, when changing bulbs, you do not *literally* want to have your feet wet....), starting to find out which places in my house can benefit from more light with less electricity. I'll be darned if I buy *two* 22-W fluorescents just to throw a decent amount of light on my workbench. And people who already use a lot of flood lamps for institutional lighting can, *right now*, start taking full advantage of these products to save on energy and on the cost of lamp replacement. If these are used in an air-conditioned location, every watt of heat saved means your air conditioner will have an easier job, too! And, unlike the magic-button rectifiers that improve the bulb life while ruining the efficiency, these new halogen lamps provide long life plus dazzling improvements in efficiency.

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

Address:
Mail Stop C2500A
National Semiconductor
P.O. Box 58090
Santa Clara, CA 95052-8090

CLASSIFIEDS

EMPLOYMENT OPPORTUNITIES

Engineer, I.C. Design. Resp. for design & implementation of logic & integrated circuit designs; duties incl. generating design feasibility estimates, logic & circuit design, generating logic simulation & test vectors, physical floorplan layout & verification, participation in initial debug, production test, implementation & customer liaison. Reqs. an M.S.E.E. or a B.S.E.E. +3 yrs, exp. in I.C. design of microprocessors & related circuits. Also reqs. knowl. of I.C. circuit & logic design incl. underst. of microprocessors & peripherals, knowl. of impact of process parameters on device performance & modeling in SPICE; knowl. of CAD tools incl. simulators, layout entry & verification, schematic capture & SPICE; knowl. of Assembly, Pascal & C. Hrs: 8 am - 6 pm, M-F; salary: $37,008/year. Job & intrvw site: Nampa, Idaho. Send this ad & your resume to Idaho Department of Employment, ATTN: Job Order Number: ID6093812, 317 Main Street, Boise, Idaho 83735. Must have legal right to work.

SOFTWARE

Season's Greetings!

All of us at Penton Classifieds wish you a Happy Holiday Season! We look forward to working with you to make this a Prosperous New Year!

FAX YOUR ORDER!
To Advertise in
Penton Classifieds,
FAX: (216) 696-1267