What's All This Bridge Amplifier Stuff, Anyhow

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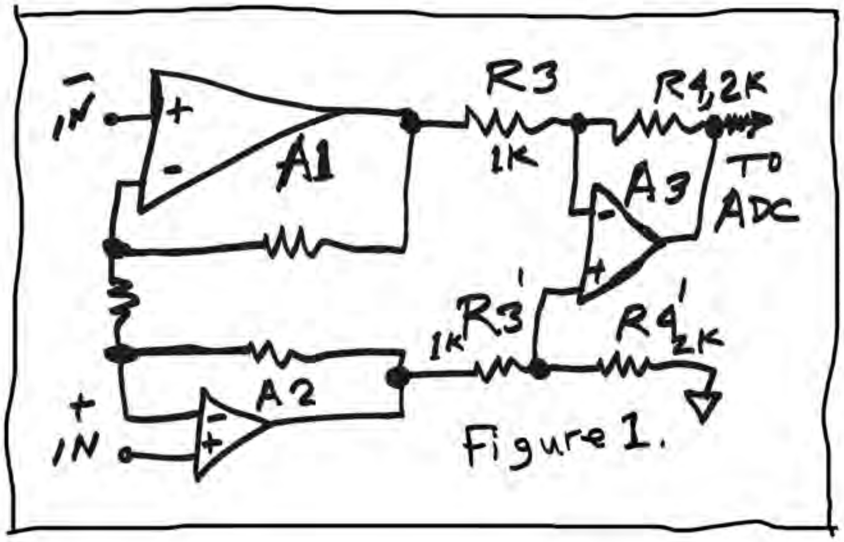
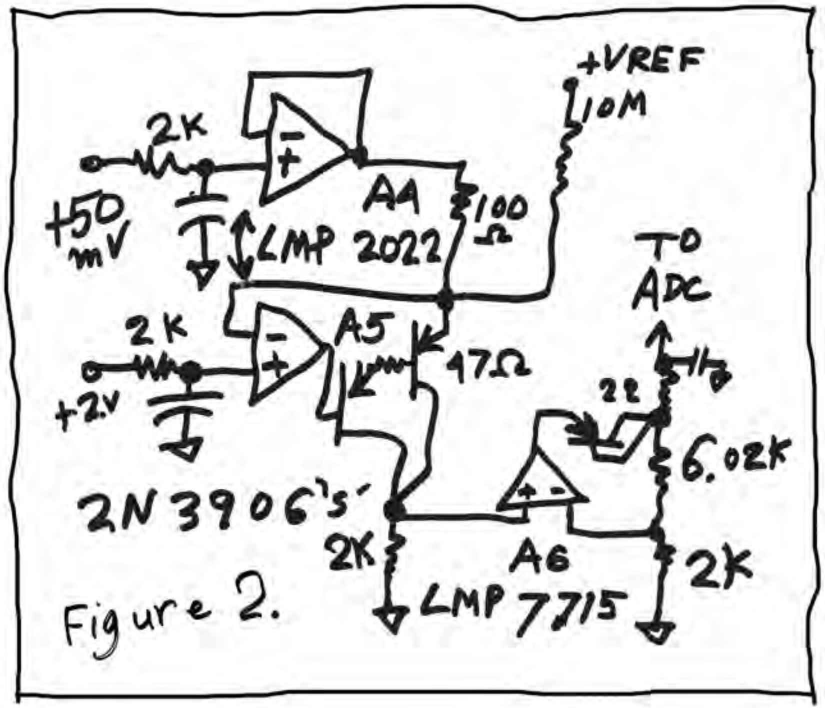
I was helping some engineers working on a strain-gauge preamp not too long ago. We had it functioning, but there seemed to be some bad linearity problems. We even set up a little calibrator and tried to get it linear, yet we kept getting odd errors, using the conventional amplifier setup per Figure 1.

The guys said, "We don't have to worry about precision or calibration because we're calibrating it in software." I went in with a digital voltmeter (DVM) and started measuring real signals.

One of the major problems turned out to be the zero-point calibration. The strain-gauge was nicely trimmed for zero output at zero force, and the first preamps (LMP2022) had zero output. But





the second amplifier stage output was then nowhere near ground.

Oh, yeah. They had been using the third amplifier as a "rail-to-rail" amplifier. These so-called "R/R" amplifiers don't really go to the rail, though. Maybe within 10 or 25 mV? It turned out there were three problems.

THREE PROBLEMS

First, to run the third amplifier, they set up its input/ feedback resistors as 1k/2k. They woulda been a little better off at 100k/200k. Second, the amplifier won't go to the rail, but just close. And third, they had put in the resistors at 1%. They were still saying, "We don't need precision amplifiers or resistors, as we'll be calibrating in software."

I'm beginning to get grouchy about such people. I explained that using 1% resistors, the common-mode rejection ratio (CMRR) of the third amplifier can be as poor as 37 dB with respect to the input or 31 dB at the output. They said they were assuming there would not be much CM noise.

I pointed out that that's not a safe assumption. Plus, the center of the bridge is at about 2.2 V, so there's 1.5 V of VCM. Using 1% resistors, the output may go to +60 mV or –60 mV, per my comments on error budget (see *"What's All This 'Error Budget' Stuff, Anyhow?"*). Since there's no way the output can go to –60 mV, this is doomed! What if we put in a couple bucks to buy 0.1% resistors? The whole project is still in trouble. Now jump to Figure 2, which is based on my error budget circuits.

Input differential voltages from 0.00 to 50.0 mV will be converted to a current, which flows through the Darlington, down toward ground, with 0.01% accuracy and even better linearity. The op amps' low (5 µV) offsets will provide very good precision. Then A6 (LMP7715) can easily magnify the signal up to the +4.0-V input that the analog-to-digital converter (ADC) would like to see. And the whole thing will swing close to ground.

So even in real-world conditions, we don't have to "assume" that an "R/R" amplifier can "swing R/R." It takes good strategy to get this. And now, the "software calibration" will surely work well. So the engineers said, "Good! Now we are ready to do 11 and 12 bits of accuracy and resolution!"

I responded, "Like heck you are! Show me the error budget on your V_{REF}, which as a bandgap surely has a lot of voltage noise!" We went over this and added some filtering. And, we put the same amount of filtering on the signal fed to power the bridge. They finally figured out that wishful thinking does not lead to good S/N. Good engineering can.

One of the engineers said, "It looks like you're just solving the problems by throwing a lot of silicon at the problem." I pointed out that the silicon is very cost-effective. It's the screw-ups that are expensive, as well as the ability to get something good enough to ship consistently. "It's bad product design that's expensive," I said.

I may no longer work full-time for NSC, but I know how to use good NSC amplifiers to do precision work—not just wishful. ■

RAP/Robert A. Pease/Engineer

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