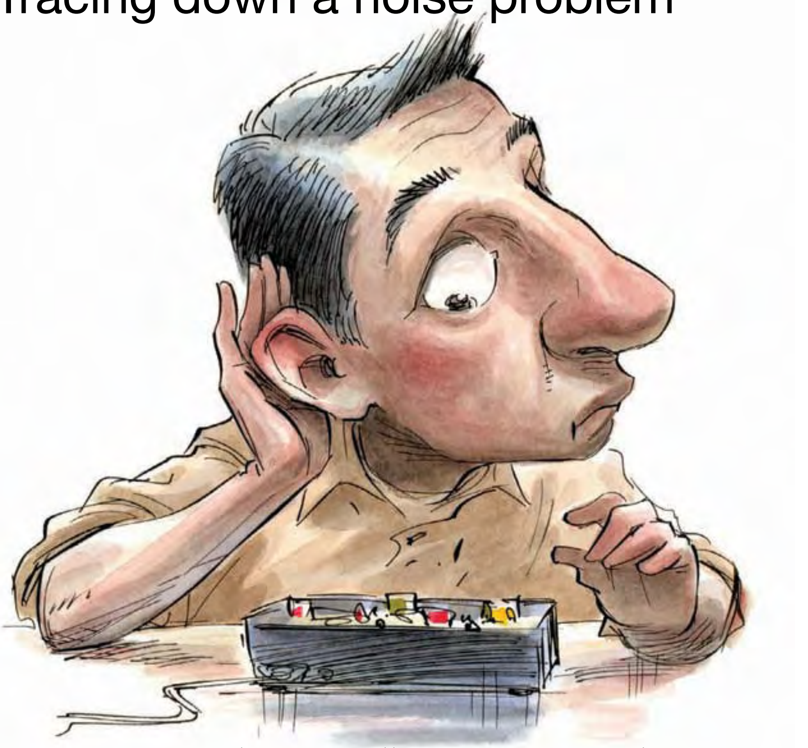
Tracing down a noise problem



My client, a small manufacturer, was having a noise problem with a new batch of 1500V-dc supplies. It had been a while since the company manufactured this product. The original engineer was long gone, and the only documentation was a schematic. The approach was a straightforward closed-loop design. An op amp controlled an oscillator that used a step-up transformer to create the high voltage, which the system rectified and filtered into dc. A small part of the output voltage fed back into the inverting input of the op amp as an error signal to adjust the oscillator frequency when necessary. The noninverting input was grounded.

The manager assured me that no changes to the design had been made between this lot and the last one. None of the old, working units were available, however, so I had to jump in cold.

Noise appeared on the output and on the error signal entering the op amp and exiting the op amp. This situation is typical of a closed-loop system, and opening the loop only causes the circuit to fail. I saw the same noise on the power supplies; that could have been either a cause of the problem or just a symptom.

I tacked a couple of capacitors across the power supplies to filter out the noise. No difference. I tried additional capacitors at different places, again to no avail.

After asking permission to cut some traces, I isolated the power entering the op amp. I inserted a 50Ω resistor in series to the positive and negative supplies and bypassed that with 100- and 0.1-μF capacitors. This lowpass filter should have removed the noise and provided clean power to the chip, but noise was still everywhere.

The result told me something important, however: The noise had to be coming from the loop itself and not from outside. The power-supply noise was a result of the problem, not the cause. The rapidly varying high-voltage output was stressing the supply too quickly for the three-terminal regulators to compensate. And because noise on the filtered op-amp supply was still occurring, that meant the op amp was drawing current erratically and causing its local power to fluctuate.

I examined the noise for a clue to its source, but it looked like just plain noise. A spectrum analyzer might have been useful, but an oscilloscope and volt-ohm milliammeter were all I had.

I cut the loop to see if something was generating the noise. As soon as I did, the noise went away, but the circuit failed—more confirmation that the noise was being generated inside the loop.

I contemplated the schematic; there had to be a point at which noise was getting into the loop. Finally, I saw it.

The noninverting input to the op amp was grounded. What if it hadn't been grounded? An open circuit here could certainly pick up noise and affect the loop. I measured that pin's resistance to ground. It was 0.23Ω, which was just the ohmmeter's lead resistance. Rats!

It did get me thinking, though. Everything pointed to the op amp as the source of the noise. If it wasn't coming from the inverting input, it had to be coming from the noninverting input.

I put the oscilloscope probe on the noninverting input; it was as quiet as a mouse. I then saw that my scope's ground lead was close to the chip. I moved the ground clip to the power-supply ground and found noise on the "grounded" noninverting input. I took some thick hookup wire and ran it directly from the power-supply ground to the noninverting input. The noise went away, and the circuit worked perfectly. Success!

Clearly, someone had made changes to the PCB; otherwise, the previous batch would have failed, too. The manager admitted there had been some PCB changes, "but the circuit wasn't changed." In other words, change is in the eye of the beholder. EDN

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