 BY WALTER LINDENBACH • CALGARY CONTROLS LTD

Time bomb

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There is a failure mode that is worse than intermittent; no tests, measurements, or parts replacement will directly reveal the cause. You can test the circuit on the bench and in the field for months, and it will work perfectly. Then, within a year, a transistor fails. When you replace it, the device works well for months; then, the same transistor fails again.

I once had to fix an oil-pipeline-monitoring device with a relay driver that behaved this way. One after another, the transistor that switched the relay coil would fail within a year of installation. The relay-coil resistance was about 240Ω (12V dc at 50 mA)—by no means an excessive load for a small TO-92 transistor.

But a little 12V relay coil can produce a 200V spike. I was amazed when I saw it for the first time, and, with the scope that I had 30 years ago, it was hard to see. A transistor was switching a relay coil at about 10 times per second, and the scope triggered on the leading edge of the collector voltage. I turned the beam intensity to maximum, readjusted the focus, and, finally, after turning off the room lights, saw something going off the top of the screen! By turning the vertical sensitivity down and down again, the peak of the spike was finally visible—at 200V! That voltage was probably the transistor base-emitter-breakdown limit, not the peak of the inductive-voltage spike. A transistor with a collector-to-emitter breakdown voltage of 80V will not last long under those conditions, and, if you don't protect it from the inductive spike, the transistor will fail after some number of switching operations—in minutes or months.

The usual way to protect a transistor from inductive spikes is to place a diode across the inductive load (cathode to V_{CC}). Such an arrangement slows the relay release, but this circuit had no speed requirement so would have been satisfactory.

But I think the designer had placed a 10-nF capacitor from the transistor collector to ground to suppress the inductive spike, thus perpetrating another failure mode that looks exactly like the inductive-spike-failure mode—*invisible*! Only the transistor collector's on-resistance and the resistance in the capacitor when the transistor switches on limit the current. Now, instead of an inductive-voltage spike, there is a capacitive-current spike, the amplitude of which is independent of the capacitor size. The current spike produces approximately the same result to the transistor as the voltage spike: It continues to operate for some time and then shorts.

I decided to protect the transistor with a different modification: I placed a 12Ω resistor in series with the emitter to limit the collector-current worst-case peak to 1A. A small plastic transistor, such as the MPS8099, can easily tolerate such a peak if it is short. Then, with a 50-mA normal relay-coil current, the drop across the emitter resistor was only 0.6V, which did not alter the performance of the circuit and seemed less likely to cause repercussions than removing the capacitor and adding a diode.

Now the monitoring device worked reliably. There were no more relay-driver failures to cause users to return these units for repair. EDN

Walter Lindenbach started and operated Calgary Controls Ltd from 1970 to 1990, at which point he discovered an allergy to work and retired. Like Walter, you can share your Tales from the Cube and receive $200. Contact Maury Wright at mgwright@edn.com.