Protect Current-Sense Amplifiers Against Overvoltage Transients

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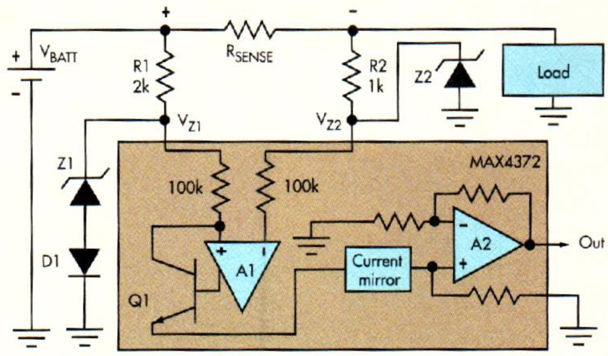
Certain current-sense amplifiers have to contend with frequent overvoltages. For example, a current-sense amplifier that monitors battery-discharge currents in an automobile must withstand high-voltage "load dump" pulses produced when loads are disconnected from the battery. This causes inductive spikes and overvoltages at the output of the alternator. If these pulses exceed the amplifier's common-mode voltage, the amplifier requires external protection circuitry.

Such a circuit needs only a pair of Zener diodes, a pair of resistors, and another diode *(Fig. 1)*. The common-mode voltage range of the example amplifier (MAX4372) is 0 to 28 V. That's more than sufficient for measuring automotive battery voltages, which vary from 6 to 18 V. Load-dump voltages, however, can reach 35 V and persist for 0.5 seconds, well over the amplifier's 30-V absolute maximum rating for input voltage. Thus, the amplifier needs external protection.

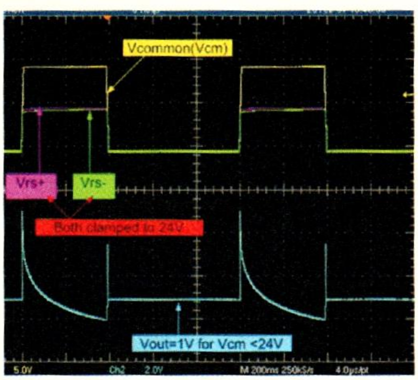
You can avoid additional errors in the input-offset voltage by using different values for input-protection resistors R1 and R2 (2 kΩ and 1 kΩ, respectively), thereby balancing the effect of the amplifier's unequal bias currents. For details on selecting these resistor values, see application note APP3888 *(www.maxim-ic.com/appnotes.cfm/an_pk/3888)*. Zeners Z1 and Z2 have 24-V breakdown voltages, plus sufficient power-dissipation capability to withstand the approximately 11-mA sink currents that flow during a 35-V peak load-dump condition. (The 35-V load-dump voltage minus a 24-V clamp voltage appears across the 1-kΩ series resistor, R2.)



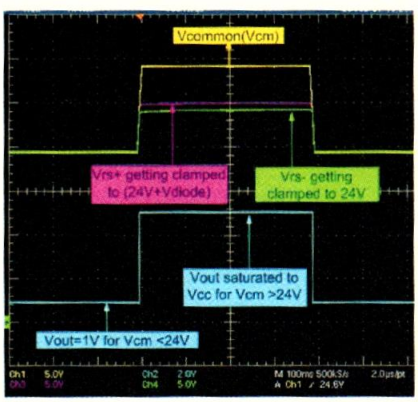
1. The handful of components added to this current-sense amplifier creates a protective circuit suitable for common-mode voltages above 30 V.

Figure 2 depicts the amplifier output in the presence of 35-V load-dump pulses without D1. With normal battery voltages applied, the 1-V output value is as expected (input V_{SENSE} = 50 mV and gain = 20). When a load-dump voltage appears, the Zeners clamp the input common-mode voltage to 24 V, and the amplifier output makes a few transient excursions before settling down to 0 V.

Because the two Zeners generally have slightly different breakdown voltages, due to part-to-part variations, and different operating currents (Z1 operates at 5.5 mA and Z2 operates at 11 mA), the quantity ($V_{Z1} - V_{Z2}$) appears as a changing differential sense voltage, which causes the unwanted output transients. You can eliminate these transients by adding D1 in series with either Z1 or Z2. The diode forces $V_{Z1} - V_{Z2}$ to be positive or negative during a load-dump, which in turn forces the amplifier output to one of the supply rails (V_{CC} or GND), thereby preventing output spikes during an input transient. Connecting the diode in series with Z1 forces the amplifier output to the positive rail *(Fig. 3)*. Connecting the diode in series with Z2 forces the amplifier output to the negative rail. **ED ONLINE 17255**



2. Without diode D1, the amplifier's output exhibits transient excursions caused by the changing differential sense voltage.



3. With D1 connected in series with Z1, the amplifier's output is forced to the positive rail.

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