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APPLICATION NOTE 4837

Protect Current-Sense Amplifiers from Negative Overvoltage

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Abstract: Current-sense amplifiers normally operate well above ground, but a fault condition can drive the sense inputs below ground, damaging the device by drawing excessive current through the ESD-protection diodes. This circuit protects a particular high-side current-sense amplifier (MAX4080) by connecting PMOS blocking transistors in series with each input.

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A high-side current-sense amplifier typically amplifies the differential voltage across a sense resistor, and provides an output voltage proportional to the current in that resistor. The sense-voltage rides on a common-mode voltage that is rejected by the current-sense amplifier. Such devices, therefore, can be used to detect over-current faults in the load or to make system power-management tradeoffs.

Most high-side current-sense amplifiers are well suited for situations in which the range of common-mode voltage extends from ~2V above ground to more than 30V. The sense amplifier for some industrial and automotive applications requires protection against reversed-battery connections, and for some loads it also requires protection against inductive kickbacks and other negative-voltage transients. Since the common-mode voltage can go negative (below ground) during these events, it is possible to damage a sense amplifier by allowing excessive current flow through the internal ESD diodes.

For example, the data sheet for a particular high-side current-sense amplifier (MAX4080) specifies the absolute maximum voltage between ground and the RS+ or RS- pin as -0.3V to 80V (**Figure 1**). A negative voltage much larger than 0.3V below ground will draw a large current by turning on one of the internal ESD diodes D1 or D2.

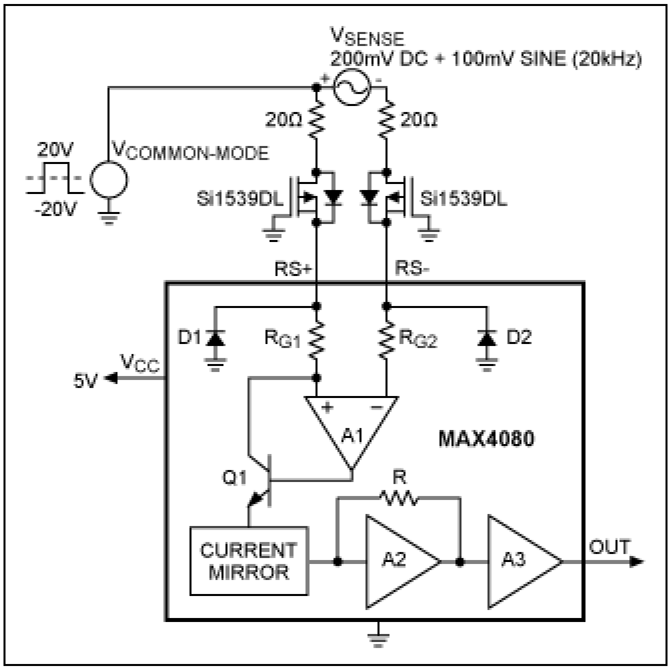

Figure 1. The two p-channel MOSFETs shown protect this high-side current-sense amplifier against negative common-mode voltages.

One method of protecting the current-sense amplifier is to connect external series diodes from the sense resistor to the RS+ and RS- pins. During normal operating conditions, however, any mismatch in the forward voltage drops of these diodes can seriously degrade the current-sense amplifier's precision input characteristics.

A better solution, then, is to connect PMOS transistors in the RS+ and RS- paths as shown in Figure 1. The PMOS switches are ON in the presence of positive common-mode voltages, allowing the IC to operate normally. When the common-mode voltage goes negative, the FETs instantly turn OFF (become open), inserting a reverse diode between the sense resistor and input pins, and thereby protecting the IC by preventing the internal ESD diodes from turning ON.

The PMOS switches have very low ON resistance: RDS_{ON} is usually a few milliohms. Because MAX4080 bias currents are also low (12µA max), RDS_{ON} causes a negligible voltage drop in its path, and therefore has a negligible effect on the IC's input offset voltage. The waveforms of **Figure 2** illustrate operation for the gain-of-20 version of this IC (other versions provide gains of 5V/V and 60V/V). The test signal applied between RS+ and RS- is differential, consisting of a $100mV_{P-P}$ sinewave riding on a 200mV DC offset, which in turn rides on a common-mode voltage that varies between -20V and +20V. When the input common mode is 4.5V or higher, the output is 100mV × 20 = 2VDC with a 100mV × 20 = $2V_{P-P}$ sinewave riding on it, as expected for normal operation.

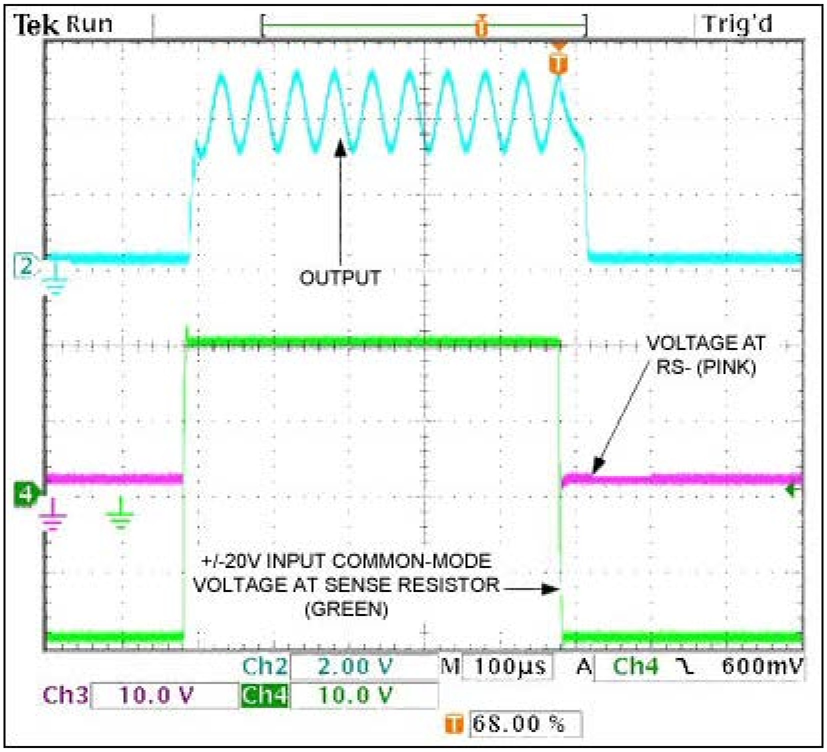

Figure 2. For the Figure 1 circuit with RS+/RS- inputs driven as described in the text, these waveforms show that the IC works normally for positive common-mode voltages up to 20V, and protects itself by shutting OFF (V_{RS-} = 0V) during negative common-mode voltages down to -20V.

When the input common-mode voltage becomes -20V (goes below ground), the PMOS switches turn OFF to protect the part, and the output sits at 0V. When the common mode recovers (i.e. above 4.5V), the IC again behaves normally. This scheme works equally well for reversed-battery protection, even if V_{CC} = 0 (as is often the case when one imposes a reverse-battery condition).

Similar protection against negative overvoltage can be implemented for other sense amplifiers, such as the MAX9938, MAX9928, and MAX4173. (The protection scheme is not required for current-sense amplifiers such as the MAX9937 and MAX9918, which are specifically designed to withstand the application conditions mentioned.)

Related Parts		
MAX4080	76V, High-Side, Current-Sense Amplifiers with Voltage Output	Free Samples
MAX9918	-20V to +75V Input Range, Precision Uni-/Bidirectional, Current-Sense Amplifiers	Free Samples
MAX9928F	-0.1V to +28V Input Range, Micropower, Uni-/Bidirectional, Current-Sense Amplifiers	Free Samples
MAX9937	Automotive Current-Sense Amplifier with Reverse-Battery Protection	Free Samples
MAX9938	1µA, 4-Bump UCSP/SOT23, Precision Current-Sense Amplifier	Free Samples

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