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APPLICATION NOTE 4546

High-Voltage, Programmable-Gain Current Monitor

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Abstract: This circuit monitors current flow at high voltage (48V and higher) using a standard 5V difference amplifier (MAX4198) referenced to ground. It also employs a digital potentiometer (MAX5402) for gain adjustment.

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Telcom, LDMOS, automotive, and numerous other applications require the measurement of current flow at high voltages (high-side current). Often, a circuit operating at 5V must monitor currents at 48V. Techniques using costly high-voltage difference amplifiers and other special devices can measure such currents, but the circuit of **Figure 1** does it with a standard 5V difference amp, including provisions for gain adjustment.

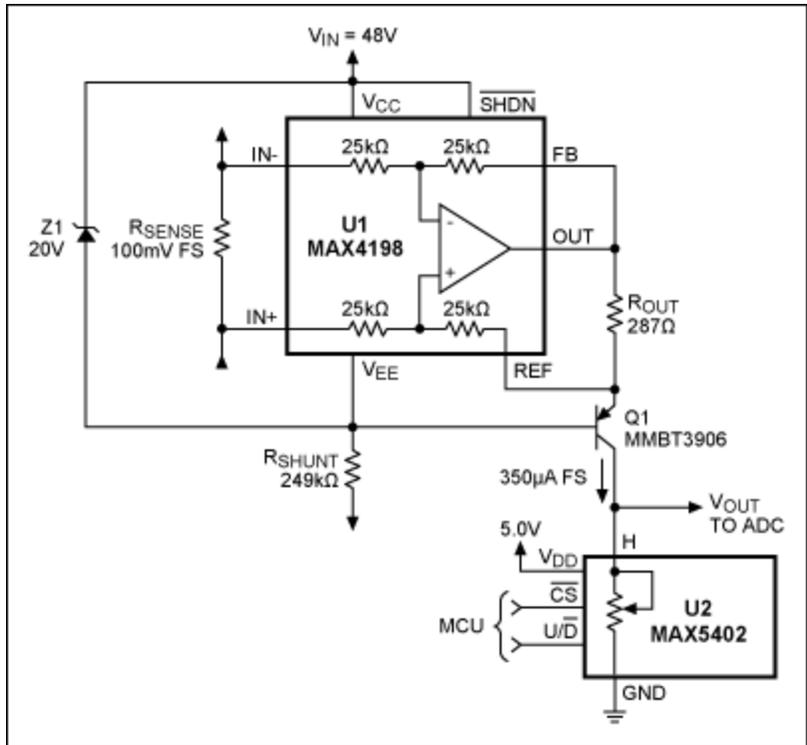


Figure 1. This circuit monitors a current at 48V, produces a maximum output voltage of approximately 5V, and includes digitally programmable gain to accommodate wide variations in the monitored current.

The difference amp (U1, MAX4198) combines gain accuracy with low-power operation, but its maximum supply voltage is only 7.5V. To overcome this limitation, the pnp transistor Q1 transforms U1's voltage output to current. Thus, Q1's current output bridges the gap between the 48V monitored current and the 5V monitor circuit. To minimize errors induced by U1's gain resistor, zener Z1 and resistor RSHUNT clamp U1's operating voltage to a nominal 3.0V. U1's maximum operating current (ICC) is 55μA, so the maximum value for RSHUNT is:

$$R_{SHUNTMAX} = (V_{INMIN} - V_{Z1MAX}) / (I_{CCMAX} + I_{Z1MIN})$$

$$= (42V - 2.7V) / (55\mu A + 100\mu A) = 249k\Omega$$

Where I_{Z1MIN} is the minimum current required for a flat zener characteristic, V_{INMIN} is the input voltage, and V_{Z1MAX} is the zener tolerance.

For the connections shown in Figure 1, the voltage drop across ROUT equals the drop across RSENSE. For a maximum full-scale (FS) voltage of 100mV across RSENSE, you choose ROUT to set the magnitude of the corresponding full-scale output current. This ROUT selection involves a tradeoff, however. Higher current minimizes the effect of error current induced by the voltage drop across the two 25kΩ resistors between IN+ and REF. The percentage error introduced by this effect is lower for higher output currents.

On the other hand, higher current levels can create over-voltage in U2, and they waste power. A good trade-off seems to be 350μA. Thus, $R_{OUT} = 100mV / 350\mu A = 286\Omega$ (287Ω is the closest standard value). At 3.0V operation, the maximum error current induced by the resistor load is $3.0V / 50k\Omega = 60\mu A$, or 17%. This may seem a bit high, but a simple calibration routine can subtract most of the effects of this error, yielding a negligible effect on the calibrated result. A common pnp transistor (MMBT3906) is chosen as

the level translator. Operating at 350µA and close to 45V V_{CE}, the transistor's power dissipation is very low (< 20mW).

The 10kΩ digital potentiometer U2 (MAX5402) adjusts the current monitor's gain. U2 has a simple up/down interface and a low value of nominal end-to-end resistance (10kΩ). Worst-case variations in the initial tolerance, supply voltage, and temperature yield a maximum end-to-end resistance of 12.5kΩ. Adding a 60µA error current to the 350µA full-scale signal current selected above yields the maximum output current from Q1: 350µA + 60µA = 410µA. Multiplying this current by the maximum end-to-end resistance yields:

$$\text{Max voltage on pin "H" of the MAX5402} = 410\mu\text{A} \times 12.5\text{k}\Omega = 5.12\text{V}$$

U2 specifies an absolute maximum voltage of 6V at pin H, so you must select the full-scale signal current sufficiently low to avoid over-voltage at pin H.

The technique presented allows use of a 5V (maximum) difference amplifier in a 48V application, and the circuit can be modified as required for lower or higher common-mode voltages. The use of Q1 to transform the signal voltage to a current allows easy gain adjustment with a digital potentiometer. The digipot shown (MAX5402) can divide the full-scale signal magnitude by factors as high as 32. Such gain adjustment is useful for automotive battery monitoring, and other applications in which the monitored current varies over a wide dynamic range.

It's important to provide separate grounds for the digital potentiometer and the op amp. It is also important not to connect these grounds to earth ground. Otherwise, that connection places the digital potentiometer in parallel with the op-amp circuit, causing the resistance at V_{OUT} (relative to ground) to vary with the voltage at V_{IN}.

Related Parts

MAX4198	Micropower, Single-Supply, Rail-to-Rail Precision Differential Amplifiers	Free Samples
MAX5402	256-Tap, µPoT Low-Drift, Digital Potentiometer	Free Samples

More Information

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