Using An Op Amp for High-Side Current Sensing

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High-side current sensing is used in a wide range of applications such as battery chargers or overcurrent protection. Figure 1 displays a typical high-side current sensing schematic. The shunt resistor, R_{shunt}, is placed between the bus voltage and the system load creates a differential voltage depending on the load current, which is then amplified to create a single-ended output voltage.

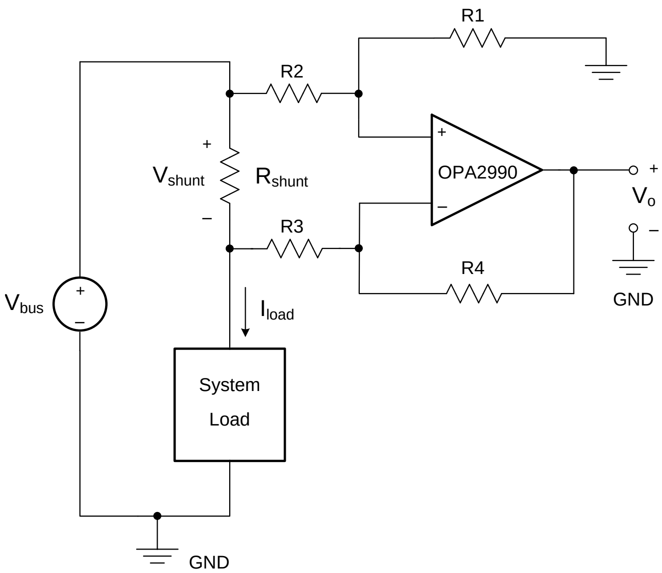

Figure 1. High-Side Current Sensing Circuit

Benefits of High-Side Current Sensing

High-side current sensing offers several advantages when compared to low-side current sensing. The first advantage is that high-side current sensing does not create ground disturbances. Ground disturbances are problematic when other circuits in a system are required to interface with the load. Placing the shunt resistor above the load, as in high-side current sensing, eliminates ground disturbances because the shunt resistor is no longer connected directly to ground. Figure 2 illustrates the differences in ground potentials between low-side current sensing and high-side current sensing. Notice the voltage potential difference, V_{ground}, between the grounds of the system load and MCU in low-side current sensing, whereas in high-side current sensing, the ground potentials are equal.

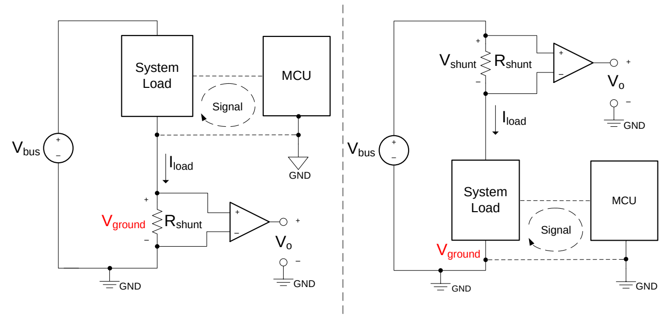

Figure 2. Ground Disturbance for Low-Side (Left) and High-Side (Right) Current Sensing

A second advantage of high-side current sensing is that it can detect a load short to ground condition. Figure 3 displays a load short to ground condition for low-side and high-side current sensing. The red line in the figure indicates the load short to ground current path. Notice that with high-side current sensing, the shunt resistor remains in the circuit and is able to detect a surge in current from a short to ground condition whereas in low-side current sensing, the shunt resistor is removed from the circuit.

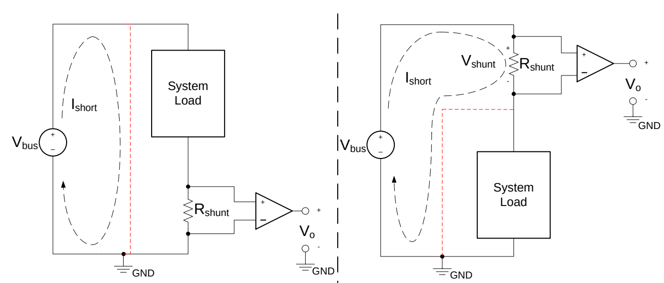

Figure 3. Load Short to Ground Condition for Low-Side (Left) and High-Side (Right) Current Sensing

Operational Amplifier Requirements for High-Side Current Sensing

The common mode voltage of the operational amplifier (op amp) must be considered when designing a high-side current sensing circuit. The common mode voltage is set by the bus voltage and the resistor divider formed by resistor R1 and R2, in Figure 1, and is calculated using Equation 1.

$$Vcm = Vbus \times \frac{R1}{R1 + R2} \qquad (1)$$

In high gain applications, such as 100 V/V, the common mode voltage of the op amp must extend to the positive supply of the amplifier. This is because resistor R1 is much greater than R2, making the common mode voltage approximately equal to the bus voltage.

In low gain configurations, such as 10 V/V, the common mode voltage range requirements of the amplifier may not need to extend to the positive supply. In a lower gain configuration, resistor R1 and R2 divide down the bus voltage reducing the need for the input common mode voltage to extend all the way to the positive supply. However, using a lower signal gain can require a larger shunt resistor to increase the measured differential voltage, which increases the power dissipation by the shunt resistor.

Conclusion

The benefits of high-side current sensing include reducing ground disturbances in a system and detecting fault conditions such as a load short to ground condition. Reducing ground disturbances allows other circuits in a design to interface with each other and ensure proper system functionality. The detection of fault conditions, such as load short to ground, prevents damage or failures of a system. In high-side current sensing the common mode, voltage is dependent on the gain of the circuit and must be considered to ensure proper operation of the circuit.

Table 1. Device Recommendations

GPN	Offset Voltage (typ)	Common Mode Voltage Range	Bandwidth	Supply Voltage	Drift
OPA2990	300 µV	Rail-to-rail	1.25 MHz	40 V	0.6 µV/°C
LM7332	1.6 mV	Rail-to-rail	21 MHz	32 V	2 µV/°C
OPA192	5 µV	Rail-to-rail	1- MHz	36 V	0.2 µV°C
OPA171	250 µV	IN to V-	3 MHz	36 V	0.3 µV/°C

Table 2. References

Collateral	Link
App Report	High-Side Current-Sensing Circuit Design Application Report
Article	A Current Sensing Tutorial – Part 1: Fundamentals
Article	A Current Sensing Tutorial – Part 2: Devices
Article	A Current Sensing Tutorial – Part 3: Accuracy
Article	A Current Sensing Tutorial – Part 4: Layout and Troubleshooting Guidelines