Voltage and Current Monitoring from 7V to 80V in 3mm × 3mm DFN-10

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Introduction

Accurate power supply voltage and current monitoring is increasingly important in everything from industrial and telecom applications to automotive and consumer electronics. A complete power monitoring system typically includes a sense resistor, a precision amplifier, an analog to digital converter (ADC) and a proper interface to report data to a host controller. The LTC4151 and LTC4151-1 combine all of these components (except the sense resistor) into one IC, resulting in a full featured, rugged and simple-to-use solution for accurate high side current sensing and voltage monitoring (see Figure 1).

The LTC4151 and LTC4151-1 offer the benefits of high side current sensing without any of the usual complexity. Each integrates a precision high voltage amplifier and associated level shift circuit for high side current sensing, a precision voltage divider for supply voltage monitoring, a 12-bit ADC and an I²C interface—all in small MS10 or tiny 3mm × 3mm DFN-10 packages.

High Side vs Low Side Sensing

In a power monitoring system, the sense resistor can be placed either between the system ground and the load (low side sensing) or between the system supply and the load (high side sensing). For many applications, high side sensing is desirable, but it is traditionally more difficult to implement.

Low side sensing is relatively simple in concept and design, but a low side sense resistor floats the load above system ground. Thus, the ground potential seen by the load varies with changing load current. This can result in the load seeing significant ground noise during transient spiking load currents. Worse yet, a failed or disconnected low side sense resistor causes the load ground to be charged to the full supply voltage, presenting a potential safety hazard.

High side sensing avoids these problems, but requires a number of high performance devices and interfaces. For instance, a robust high side sense amplifier is required to withstand high supply voltage or high voltage transients. Also, a precision level shift circuit is needed to accurately translate the large supply-referred signals to appropriate ground level signals for the ADC.

Full Featured High Side, High Voltage Digital Monitors

The LTC4151 and LTC4151-1 offer the benefits of high side current sensing without any of the usual complexity, plus they provide supply voltage monitoring in the same package. Each

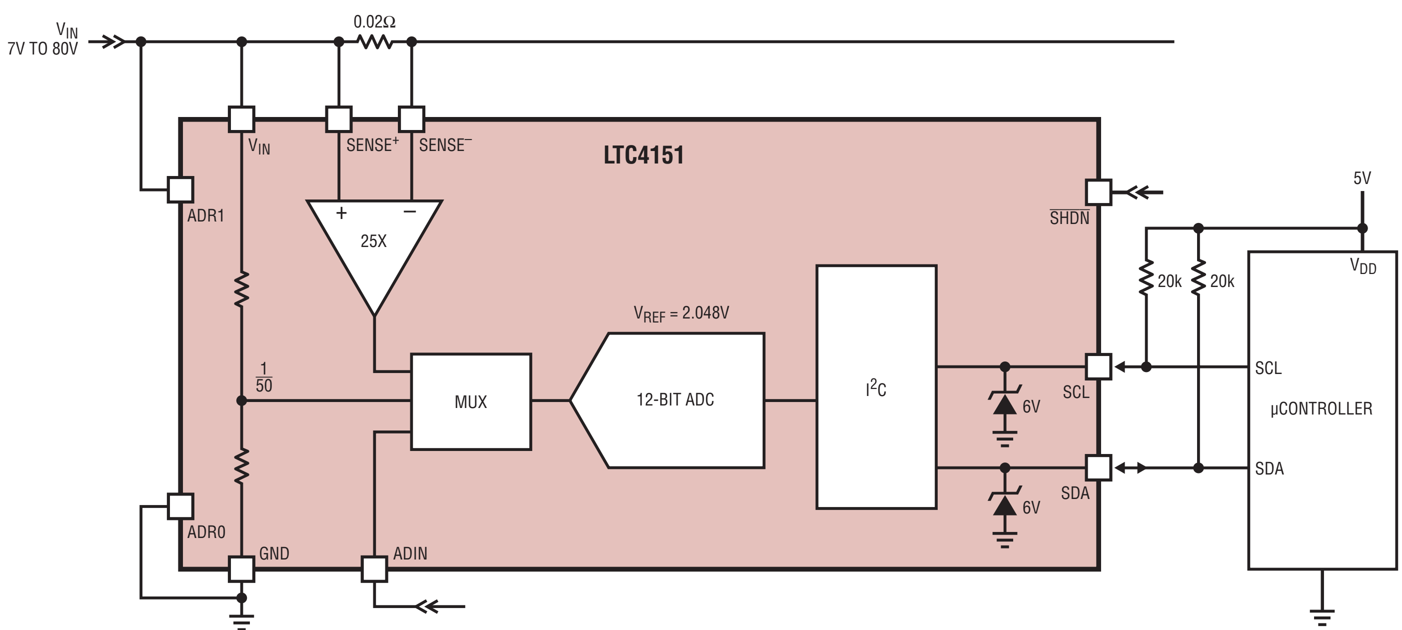


Figure 1. Full featured current and voltage monitor simplifies high voltage, high side sensing.

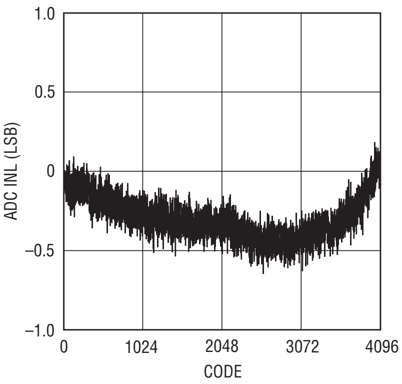


Figure 2. Typical INL error of ADIN voltage is within ±0.5LSB.

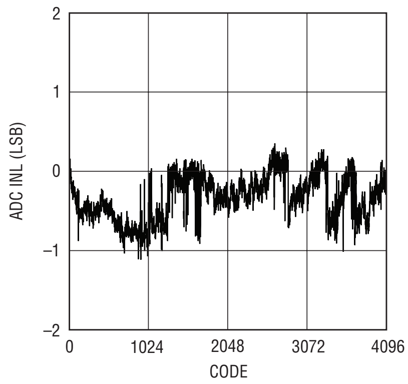


Figure 3. Typical INL error of current sense voltage is within ±1LSB.

integrates a precision high voltage amplifier and associated level shift circuit for high side current sensing, a precision voltage divider for supply voltage monitoring, a 12-bit ADC and an I²C interface—all in small MS10 or tiny 3mm × 3mm DFN-10 packages. A dedicated ADIN pin is directly connected to the ADC input for monitoring any external voltage. See Figure 1 for a simplified block diagram.

Using the I²C interface, the parts can be configured into either a continuous scan mode (default upon power up) or a snapshot mode. In continuous scan mode, the parts repeatedly measure three voltages in sequence: the differential high side sense voltage between the SENSE⁺ and SENSE⁻ pins, the supply voltage at the V_{IN} pin and an external voltage at the ADIN pin at a refreshing frequency of 7.5Hz. In snapshot mode, the host controller can instruct the parts to perform a one-time measurement of a specific signal. The conversion time of SENSE voltage is 67ms and that of V_{IN} and ADIN voltages is 33ms. Thanks to the oversampling Sigma-Delta ADC, any ripples within each conversion cycle are simply averaged out.

Easy to Use

Figure 1 shows just how easy it is to put together a complete voltage and high side current monitor. The only required external components are a sense resistor and two pull-up resistors (with the $\overline{SHDN}$ pin float and ADIN pin tied to GND).

The LTC4151 and the LTC4151-1 maintain high precision for supplies from 7V to 80V, an ideal range for applications with 12V, 24V or 48V supply voltages. The absolute maximum voltages of the supply pin and the two sense input pins are all rated at 90V, which helps the part survive high voltage transients. This wide input voltage range allows the part to be directly connected to high voltage supplies without the need of a secondary supply, unlike many other supply monitors.

The LTC4151 and the LTC4151-1 can be configured with one of nine I²C addresses via the ADR1 and ADR0 pins (high, low or open). These two pins are also rated at an absolute maximum voltage of 90V, again precluding the need for a separate low voltage supply.

Wide Dynamic Range and High Accuracy

LTC4151 and LTC4151-1 each combine a precision high side sense amplifier and a true 12-bit ADC. The result is a current and voltage monitor that offers a unique combination of high resolution and wide dynamic range. The full scale of the current sense voltage is 81.92mV with a resolution of 20µV/LSB. The full scale of the supply voltage is 102.4V with a resolution of 25mV/LSB. The full scale at ADIN is 2.048V with a resolution of 500µV/LSB. As Figures 2 and 3 show, the typical integral nonlinearity errors

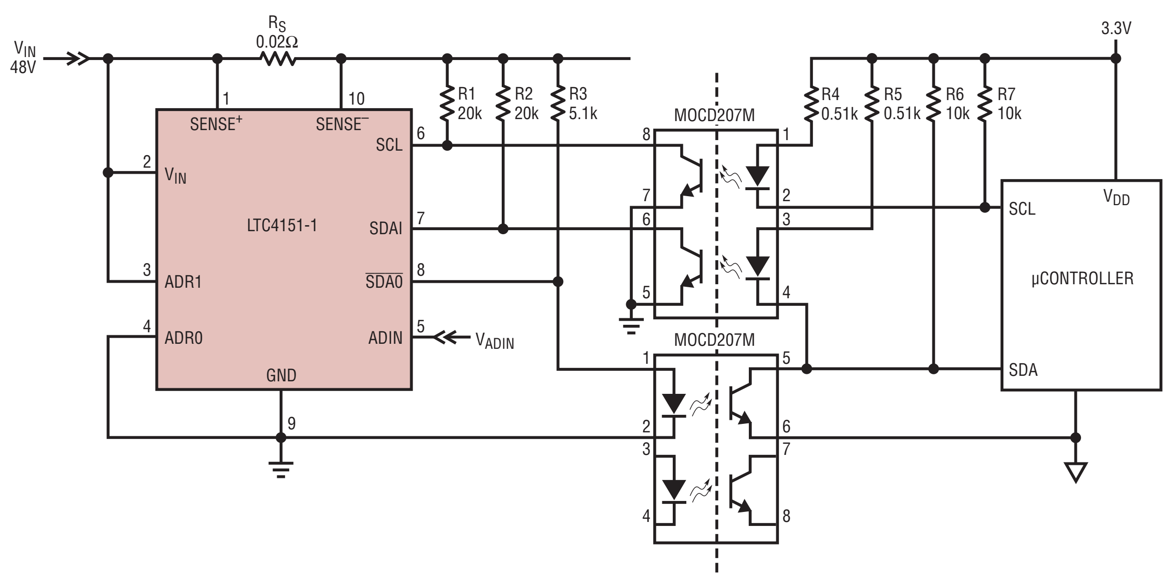


Figure 4. The LTC4151-1 makes it easy to implement optoisolation.

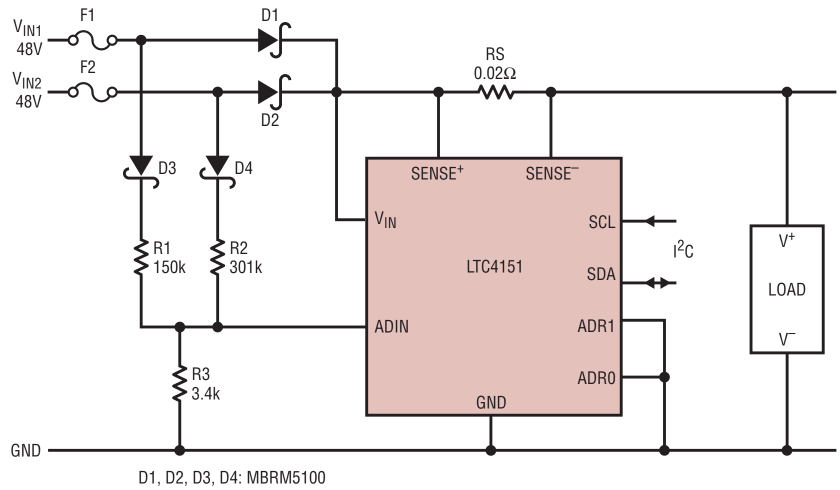
(INLs) of the ADIN voltage and the current sense voltage are both within ±1LSB. In addition, the current sense voltage, the supply voltage and the ADIN voltage are all measured with high accuracy at the full scale (1.25%, 1% and 1%, respectively) over the full industrial temperature range.

Power-Saving Shutdown or Easy Optoisolation? You Choose.

The LTC4151 features a $\overline{SHDN}$ pin with an internal 5µA pullup. When $\overline{SHDN}$ is tied to GND, the part enters shut down mode and the typical quiescent current is reduced to 120µA at 12V, about 10% of the normal operating current (1.2mA). In applications with battery supplies, one can use this pin to save power consumption.

The LTC4151-1 trades in the $\overline{SHDN}$ pin for an inverted $\overline{SDAO}$ pin to enable a simple optoisolation scheme. Optoisolation is inevitably required in applications where the host controller sits at a different ground level from the power monitor. The LTC4151-1 makes this job easy with split SDA pins: the SDAI (data input) pin and a unique $\overline{SDAO}$ (inverted data output) pin. In addition, the SCL and the SDAI pins each have an internal 6V clamp (sinking up to 5mA current).

When using optoisolators with the LTC4151-1, connect the SCL and SDAI pins to the outputs of the incoming optoisolators and connect the $\overline{SDAO}$ pin to the anode of the outgoing optoisolator, as shown Figure 4. With the outgoing optoisolator clamping the $\overline{SDAO}$ and the internal 6V clamps on SDAI and SCL, all pull-up resistors on these three pins can be directly connected to the high voltage supply, eliminating the need for a separate low voltage pull-up supply.



CONDITION*	RESULT
$N_{ADIN} \geq 1.375 \bullet N_{VIN}$	NORMAL OPERATION
$0.835 \bullet N_{VIN} \leq N_{ADIN} < 1.375 \bullet N_{VIN}$	F2 IS OPEN
$0.285 \bullet N_{VIN} \leq N_{ADIN} < 0.835 \bullet N_{VIN}$	F1 IS OPEN
(I^2C NOT RESPONDING)	BOTH F1 AND F2 ARE OPEN

* V_{IN1} and V_{IN2} differ by less than 20%. N_{ADIN} and N_{VIN} are digital codes measured by the ADC at the ADIN and V_{IN} pins, respectively.

Figure 5. A single LTC4151 monitors current, supply voltage and fuses.

ADIN Pin is Useful for Fuse Monitoring and Temperature Sensing

The LTC4151 and the LTC4151-1 feature a dedicated ADIN pin that can be used to monitor any external voltage. Figure 5 shows a simple circuit that not only measures current and supply voltage but also monitors a pair of fuses on the high side.

The fuses are monitored by comparing the voltages at the V_{IN} and ADIN pins. ADIN is connected to the two inputs after the fuses through a Y divider. Diodes D3 and D4 compensate the diode-OR D1 and D2. The voltage at ADIN varies as the status of the fuses changes, as shown in the table in Figure 5. Since the ADIN voltage is approximately ratiometric to V_{IN}, the results are independent of the supply seen at V_{IN}. The limitation of this circuit is that the two inputs must remain within 20% of each other.

The ADIN pin can also be used to monitor board temperature with an NTC thermistor as shown in Figure 6. In that circuit, V_{IN} is connected on the downstream side of the sense resistor so that the quiescent current of the LTC4151 is measured.

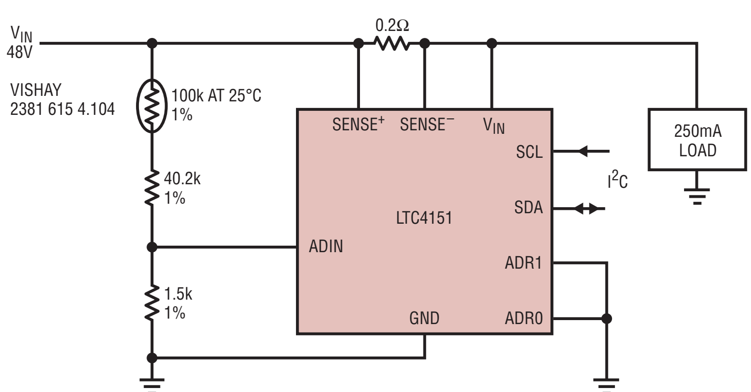


Figure 6. Temperature monitoring is simple with LTC4151 and an NTC thermistor.

Conclusion

High side current sensing and voltage monitoring could not be easier than with the LTC4151 and the LTC4151-1 supply monitors. Their wide supply range and high level of integration simplifies design, while desirable features, such as 12-bit resolution, high accuracy, I^2C interface, optoisolation support and small footprints make them an easy fit in a wide variety of applications.