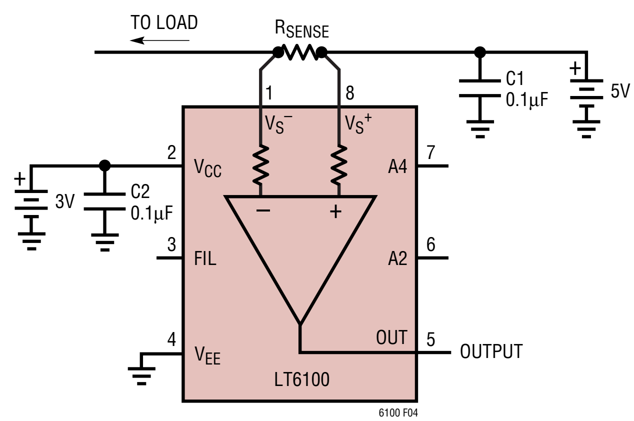
High Side

This chapter discusses solutions for high side current sensing. With these circuits the total current supplied to a load is monitored in the positive power supply line.

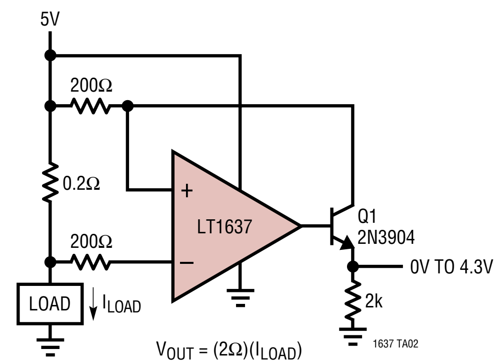
To see other chapters in this Application Note, return to the Introduction.

LT6100 Load Current Monitor



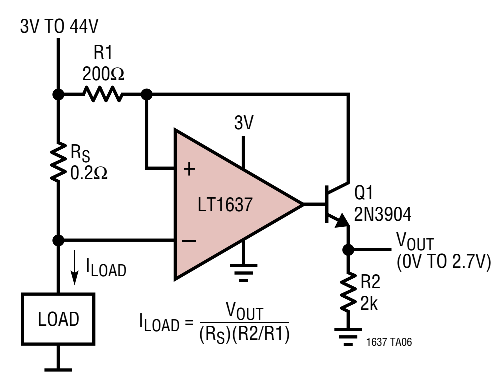
This is the basic LT6100 circuit configuration. The internal circuitry, including an output buffer, typically operates from a low voltage supply, such as the 3V shown. The monitored supply can range anywhere from V_{CC} + 1.4V up to 48V. The A2 and A4 pins can be strapped various ways to provide a wide range of internally fixed gains. The input leads become very hi-Z when V_{CC} is powered down, so as not to drain batteries for example. Access to an internal signal node (pin 3) provides an option to include a filtering function with one added capacitor. Small-signal range is limited by V_{OL} in single-supply operation.

"Classic" Positive Supply Rail Current Sense



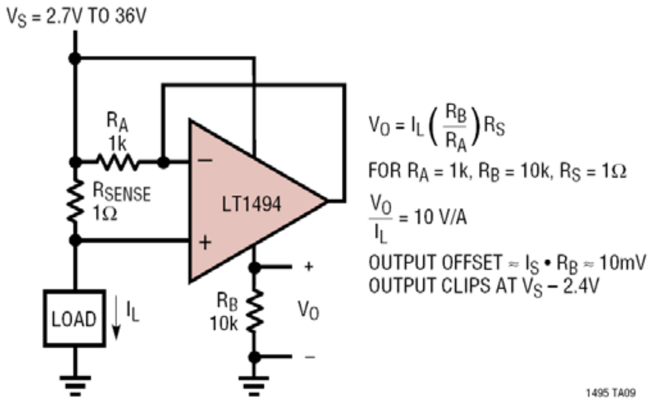
This circuit uses generic devices to assemble a function similar to an LTC6101. A Rail-to-Rail Input type op amp is required since input voltages are right at the upper rail. The circuit shown here is capable of monitoring up to 44V applications. Besides the complication of extra parts, the V_{OS} performance of op amps at the supply is generally not factory trimmed, thus less accurate than other solutions. The finite current gain of the bipolar transistor is a small source of gain error.

Over-The-Top Current Sense



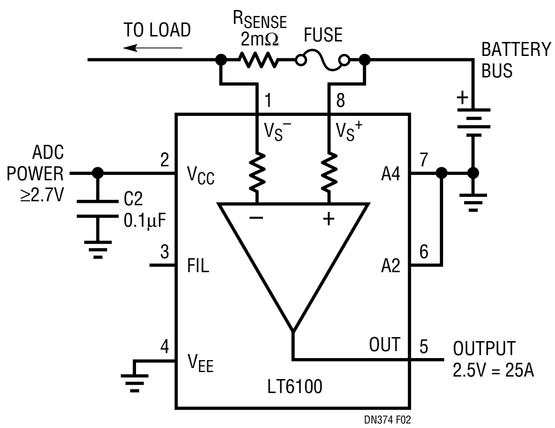
This circuit is a variation on the "classic" high-side circuit, but takes advantage of Over-the-Top input capability to separately supply the IC from a low-voltage rail. This provides a measure of fault protection to downstream circuitry by virtue of the limited output swing set by the low-voltage supply. The disadvantage is V_{OS} in the Over-the-Top mode is generally inferior to other modes, thus less accurate. The finite current gain of the bipolar transistor is a source of small gain error.

Self-Powered High Side Current Sense



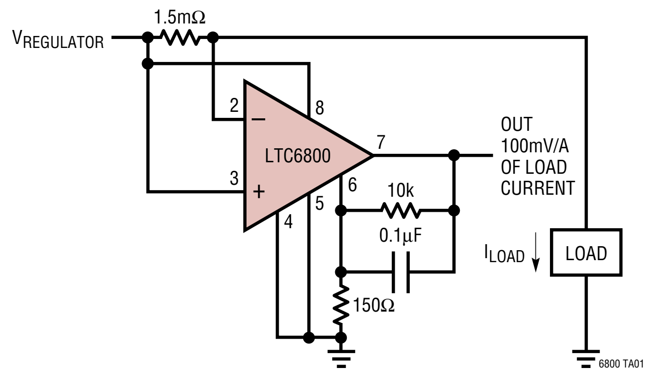
This circuit takes advantage of the microampere supply current and Rail-to-Rail input of the LT1494. The circuit is simple because the supply draw is essentially equal to the load current developed through R_A. This supply current is simply passed through R_B to form an output voltage that is appropriately amplified.

High Side Current Sense and Fuse Monitor



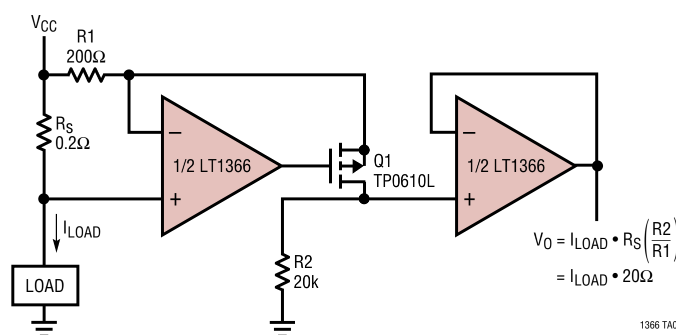
The LT6100 can be used as a combination current sensor and fuse monitor. This part includes on-chip output buffering and was designed to operate with the low supply voltage (≥2.7V), typical of vehicle data acquisition systems, while the sense inputs monitor signals at the higher battery bus potential. The LT6100 inputs are tolerant of large input differentials, thus allowing the blown-fuse operating condition (this would be detected by an output full-scale indication). The LT6100 can also be powered down while maintaining high impedance sense inputs, drawing less than 1µA max from the battery bus.

Precision High Side Power Supply Current Sense



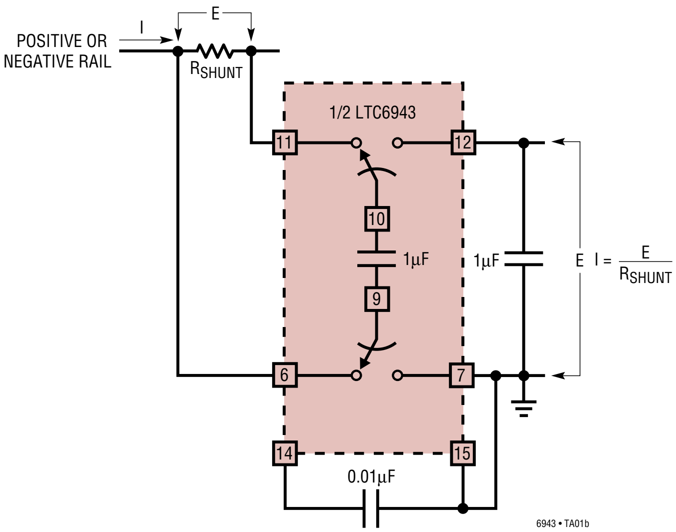
This is a low-voltage, ultra-high-precision monitor featuring a Zero-Drift Instrumentation Amplifier (IA) that provides Rail-to-Rail inputs and outputs. Voltage gain is set by the feedback resistors. Accuracy of this circuit is set by the quality of resistors selected by the user, small-signal range is limited by V_{OL} in single-supply operation. The voltage rating of this part restricts this solution to applications of <5.5V. This IA is sampled, so the output is discontinuous with input changes, thus only suited to very low frequency measurements.

Positive Supply Rail Current Sense



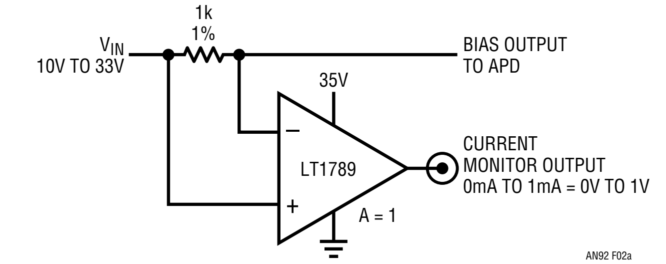
This is a configuration similar to an LT6100 implemented with generic components. A Rail-to-Rail or Over-the-Top input op amp type is required (for the first section). The first section is a variation on the classic high-side where the P-MOSFET provides an accurate output current into R2 (compared to a BJT). The second section is a buffer to allow driving ADC ports, etc., and could be configured with gain if needed. As shown, this circuit can handle up to 36V operation. Small-signal range is limited by V_{OL} in single-supply operation.

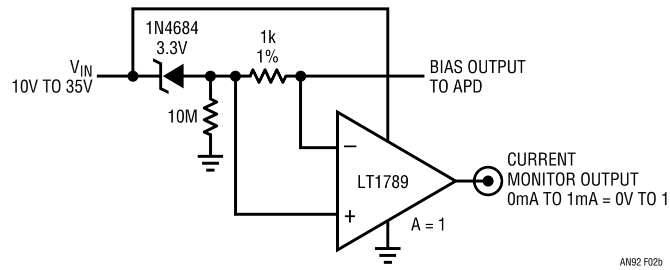
Precision Current Sensing in Supply Rails



This is the same sampling architecture as used in the front-end of the LTC2053 and LTC6800, but sans op amp gain stage. This particular switch can handle up to 18V, so the ultra-high precision concept can be utilized at higher voltages than the fully integrated ICs mentioned. This circuit simply commutates charge from the flying sense capacitor to the ground-referenced output capacitor so that under dc input conditions the single-ended output voltage is exactly the same as the differential across the sense resistor. A high precision buffer amplifier would typically follow this circuit (such as an LTC2054). The commutation rate is user-set by the capacitor connected to pin 14. For negative supply monitoring, pin 15 would be tied to the negative rail rather than ground.

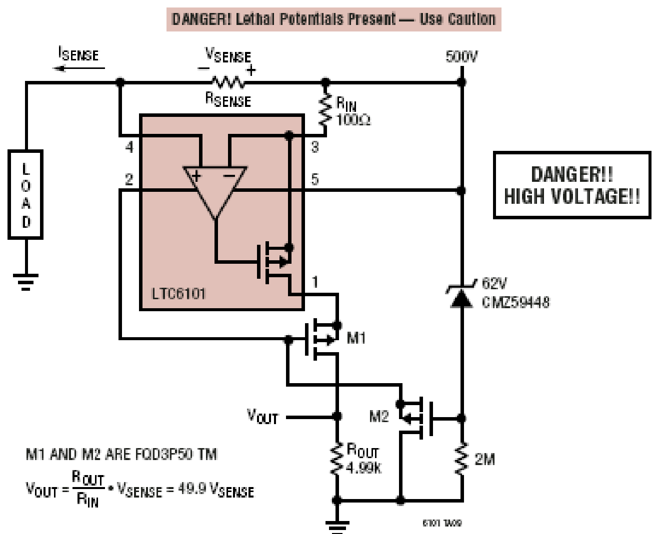
Measuring bias current into an Avalanche Photo Diode (APD) using an instrumentation amplifier.





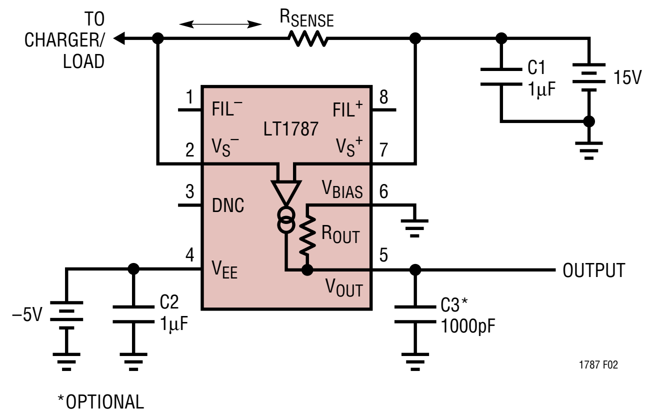
The upper circuit uses an instrumentation amplifier (IA) powered by a separate rail (>1V above V_{IN}) to measure across the 1kΩ current shunt. The lower figure is similar but derives its power supply from the APD bias line. The limitation of these circuits is the 35V maximum APD voltage, whereas some APDs may require 90V or more. In the single-supply configuration shown, there is also a dynamic range limitation due to V_{OL} to consider. The advantage of this approach is the high accuracy that is available in an IA.

Simple 500V Current Monitor



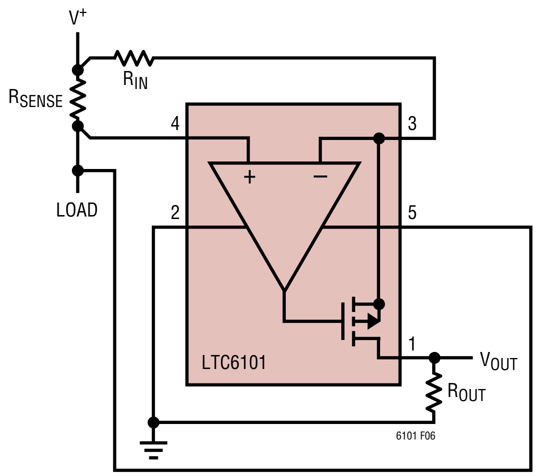
Adding two external Mosfets to hold off the voltage allows the LTC6101 to connect to very high potentials and monitor the current flow. The output current from the LTC6101, which is proportional to the sensed input voltage, flows through M1 to create a ground referenced output voltage.

Bidirectional Battery-Current Monitor



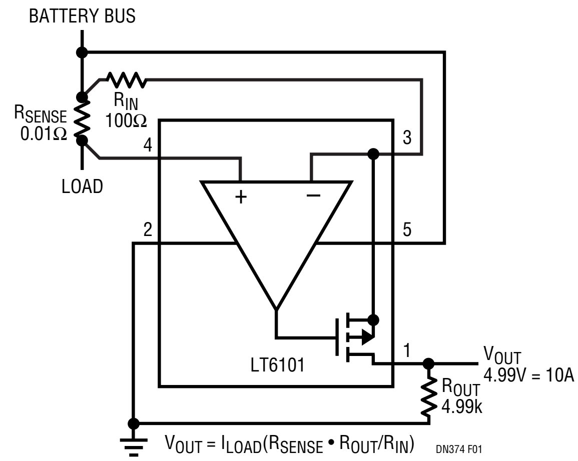
This circuit provides the capability of monitoring current in either direction through the sense resistor. To allow negative outputs to represent charging current, V_{EE} is connected to a small negative supply. In single-supply operation (V_{EE} at ground), the output range may be offset upwards by applying a positive reference level to V_{BIAS} (1.25V for example). C3 may be used to form a filter in conjunction with the output resistance (R_{OUT}) of the part. This solution offers excellent precision (very low V_{OS}) and a fixed nominal gain of 8.

LTC6101 Supply Current included as Load in Measurement



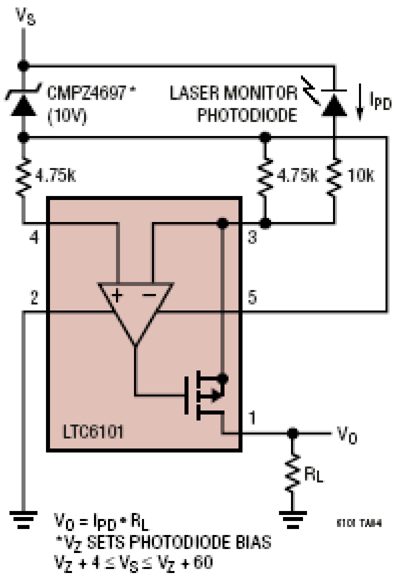
This is the basic LTC6101 high-side sensing supply-monitor configuration, where the supply current drawn by the IC is included in the readout signal. This configuration is useful when the IC current may not be negligible in terms of overall current draw, such as in low-power battery-powered applications. R_{SENSE} should be selected to limit voltage-drop to <500mV for best linearity. If it is desirable not to include the IC current in the readout, as in load monitoring, pin 5 may be connected directly to V^+ instead of the load. Gain accuracy of this circuit is limited only by the precision of the resistors selected by the user.

Simple High Side Current Sense Using the LTC6101



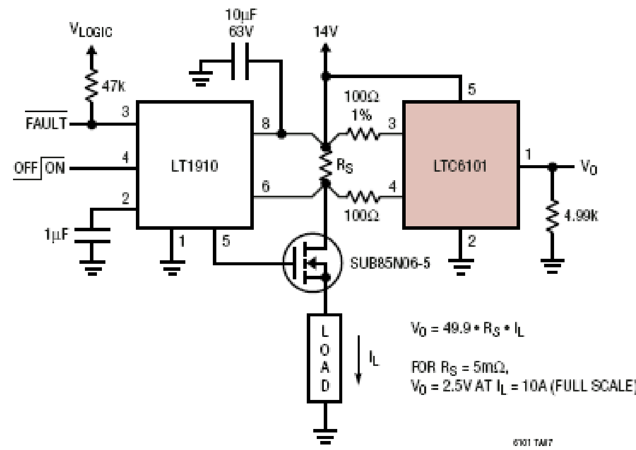
This is a basic high side current monitor using the LTC6101. The selection of R_{IN} and R_{OUT} establishes the desired gain of this circuit, powered directly from the battery bus. The current output of the LTC6101 allows it to be located remotely to R_{OUT}. Thus, the amplifier can be placed directly at the shunt, while R_{OUT} is placed near the monitoring electronics without ground drop errors. This circuit has a fast 1µs response time that makes it ideal for providing MOSFET load switch protection. The switch element may be the high side type connected between the sense resistor and the load, a low side type between the load and ground or an H-bridge. The circuit is programmable to produce up to 1mA of full-scale output current into R_{OUT}, yet draws a mere 250µA supply current when the load is off.

High-Side Transimpedance Amplifier



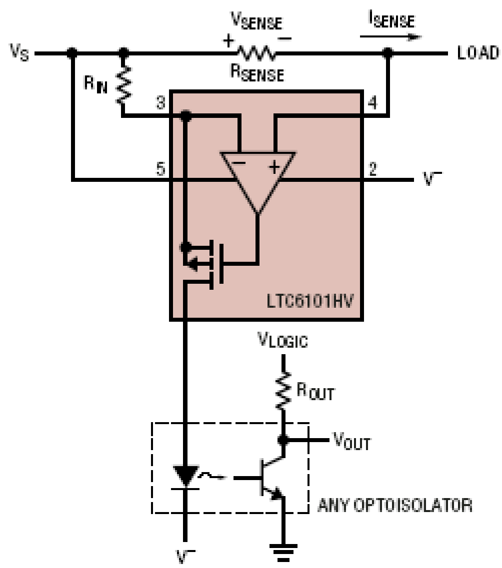
Current through a photodiode with a large reverse bias potential is converted to a ground referenced output voltage directly through an LTC6101. The supply rail can be as high as 70V. Gain of the I to V conversion, the transimpedance, is set by the selection of resistor R_L.

Intelligent High Side Switch



The LT1910 is a dedicated high side MOSFET driver with built in protection features. It provides the gate drive for a power switch from standard logic voltage levels. It provides shorted load protection by monitoring the current flow to through the switch. Adding an LTC6101 to the same circuit, sharing the same current sense resistor, provides a linear voltage signal proportional to the load current for additional intelligent control.

48V Supply Current Monitor with Isolated Output and 105V Survivability



N = OPTOISOLATOR CURRENT GAIN

$$V_{OUT} = V_{LOGIC} - I_{SENSE} \cdot \frac{R_{SENSE}}{R_{IN}} \cdot N \cdot R_{OUT}$$

6101 TA08

The HV version of the LTC6101 can operate with a total supply voltage of 105V. Current flow in high supply voltage rails can be monitored directly or in an isolated fashion as shown in this circuit. The gain of the circuit and the level of output current from the LTC6101 depends on the particular opto-isolator used.