

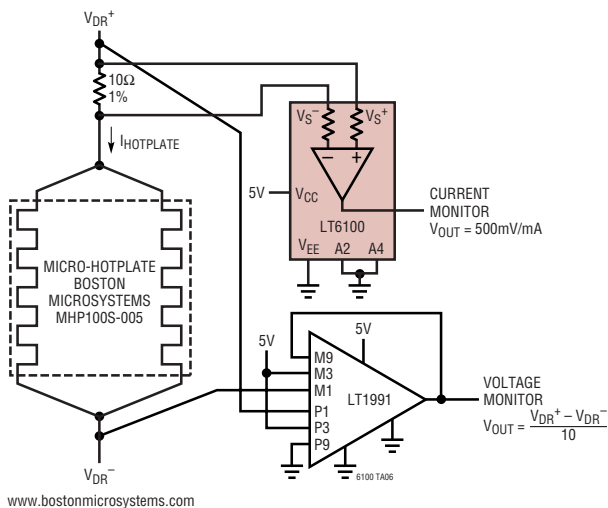
APPLICATION NOTE 105: Current Sense Circuit Collection

DC

DC current sensing is for measuring current flow that is changing at a very slow rate.

To see other chapters in this Application Note, return to the [Introduction](#).

Micro-Hotplate Voltage and Current Monitor

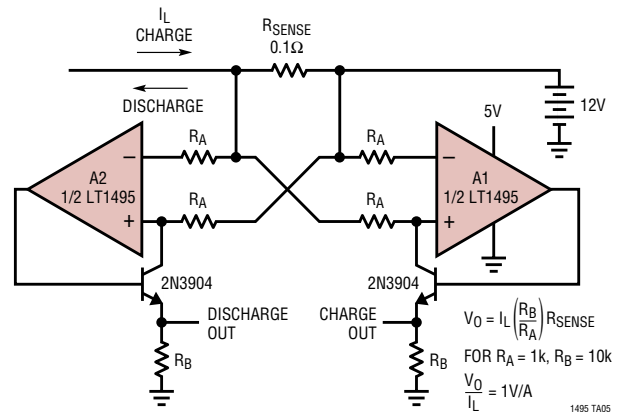


Materials science research examines the properties and interactions of materials at various temperatures. Some of the more interesting properties can be excited with localized nano-technology heaters and detected using the presence of interactive thin films.

While the exact methods of detection are highly complex and relatively proprietary, the method of creating localized heat is as old as the light bulb. Shown is the schematic of the heater elements of a Micro-hotplate from Boston Microsystems (www.bostonmicrosystems.com). The physical dimensions of the elements are tens of microns. They are micromachined out of SiC and heated with simple DC electrical power, being able to reach 1000°C without damage.

The power introduced to the elements, and thereby their temperature, is ascertained from the voltage-current product with the LT6100 measuring the current and the LT1991 measuring the voltage. The LT6100 senses the current by measuring the voltage across the 10Ω resistor, applies a gain of 50, and provides a ground referenced output. The I to V gain is therefore 500mV/mA, which makes sense given the 10mA full scale heater current and the 5V output swing of the LT6100. The LT1991's task is the opposite, applying precision attenuation instead of gain. The full scale voltage of the heater is a total of 40V (±20), beyond which the life of the heater may be reduced in some atmospheres. The LT1991 is set up for an attenuation factor of 10, so that the 40V full scale differential drive becomes 4V ground referenced at the LT1991 output. In both cases, the voltages are easily read by 0V–5V PC I/O cards and the system readily software controlled.

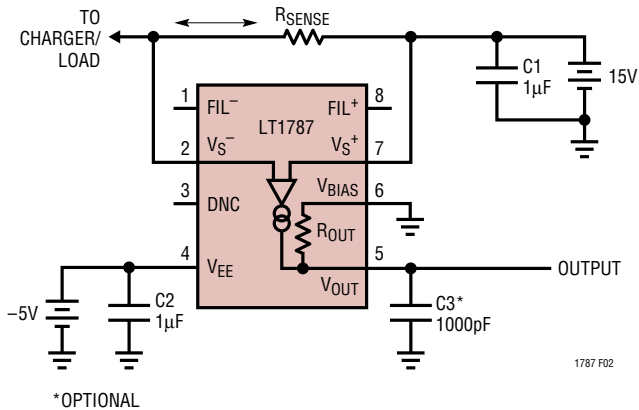
Battery Current Monitor



One LT1495 dual op-amp package can be used to establish separate charge and discharge current monitoring outputs. The LT1495 features Over-the-Top operation allowing the battery potential to be as high as 36V with only a 5V amplifier supply voltage.

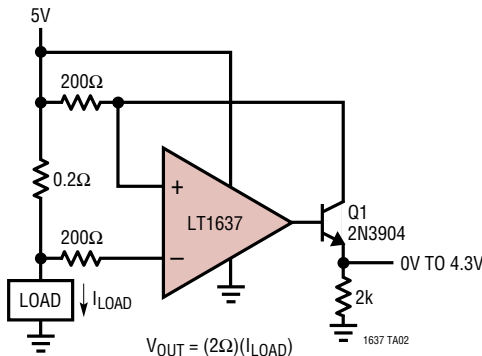
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Bidirectional Battery-Current Monitor



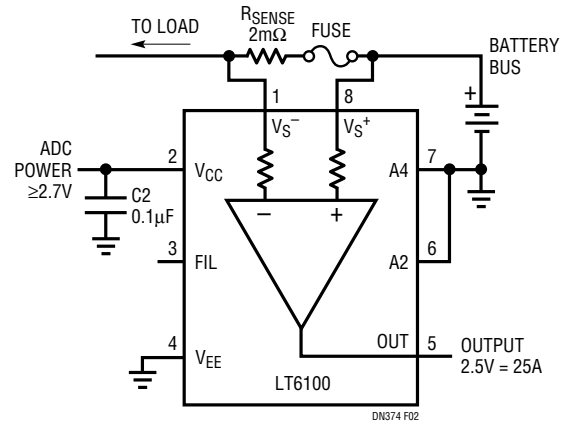
This circuit provides the capability of monitoring current in either direction through the sense resistor. To allow negative outputs to represent charging current, V_{EE} is connected to a small negative supply. In single-supply operation (V_{EE} at ground), the output range may be offset upwards by 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.

“Classic” Positive Supply Rail Current Sense



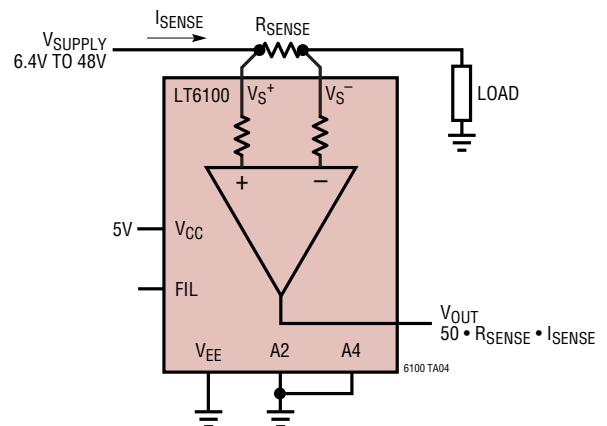
This circuit uses generic devices to assemble a function similar to an LTC6101. A Rail-to-Rail Input type op amp is required since input voltages are right at the upper rail. The circuit shown here is capable of monitoring up to 44V applications. Besides the complication of extra parts, the V_{OS} performance 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.

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 ($\geq 2.7V$), 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 $1\mu A$ max from the battery bus.

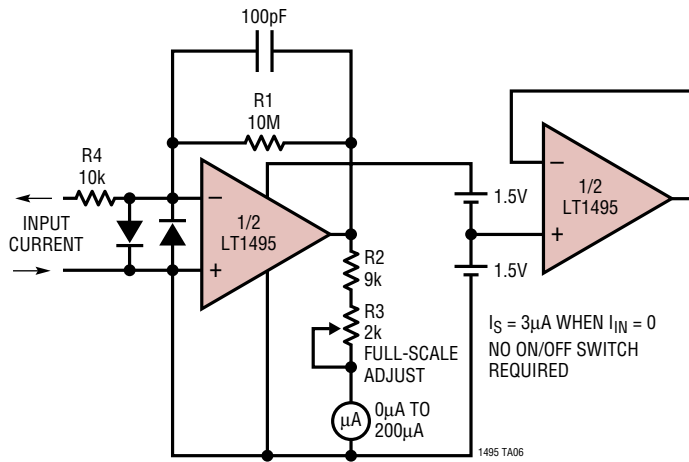
Gain of 50 Current Sense



The LT6100 is configured for a gain of 50 by grounding both A2 and A4. This is one of the simplest current sensing amplifier circuits where only a sense resistor is required.

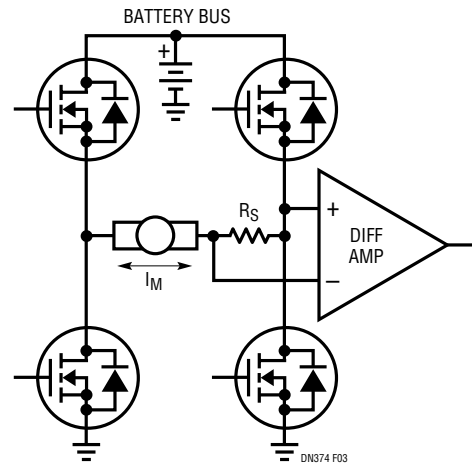
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0nA to 200nA Current Meter



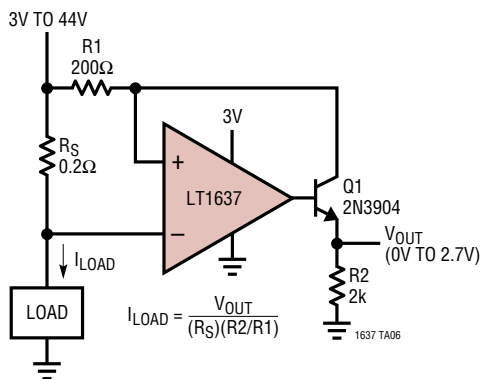
A floating amplifier circuit converts a full-scale 200nA flowing in the direction indicated at the inputs to 2V at the output of the LT1495. This voltage is converted to a current to drive a 200μA meter movement. By floating the power to the circuit with batteries, any voltage potential at the inputs are handled. The LT1495 is a micro-power op amp so the quiescent current drain from the batteries is very low and thus no on/off switch is required.

Conventional H-Bridge Current Monitor



Many of the newer electric drive functions, such as steering assist, are bidirectional in nature. These functions are generally driven by H-bridge MOSFET arrays using pulse-width-modulation (PWM) methods to vary the commanded torque. In these systems, there are two main purposes for current monitoring. One is to monitor the current in the load, to track its performance against the desired command (i.e., closed-loop servo law), and another is for fault detection and protection features.

Over-The-Top Current Sense

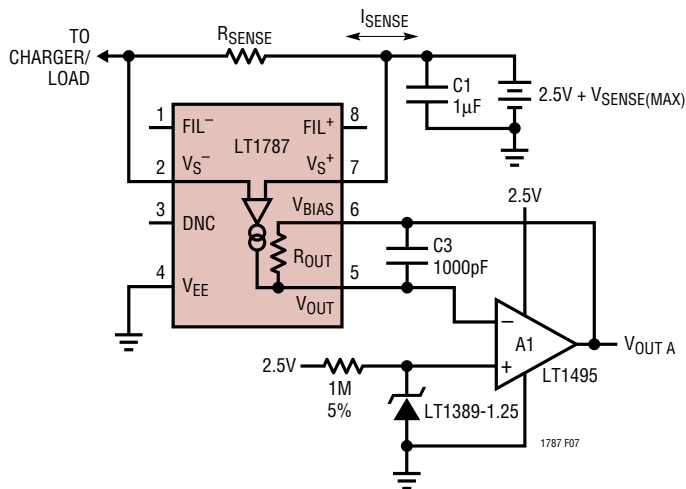


This circuit is a variation on the “classic” high-side circuit, but takes advantage of Over-the-Top input capability to separately supply the IC from a low-voltage rail. This provides a measure of fault protection to downstream circuitry by virtue of the limited output swing set by the low-voltage supply. 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.

A common monitoring approach in these systems is to amplify the voltage on a “flying” sense resistor, as shown. Unfortunately, several potentially hazardous fault scenarios go undetected, such as a simple short to ground at a motor terminal. Another complication is the noise introduced by the PWM activity. While the PWM noise may be filtered for purposes of the servo law, information useful for protection becomes obscured. The best solution is to simply provide two circuits that individually protect each half-bridge and report the bidirectional load current. In some cases, a smart MOSFET bridge driver may already include sense resistors and offer the protection features needed. In these situations, the best solution is the one that derives the load information with the least additional circuitry.

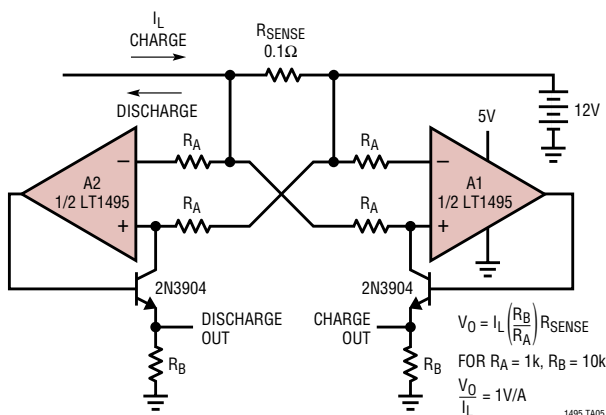
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Single Supply 2.5V Bidirectional Operation with External Voltage Reference and I/V Converter



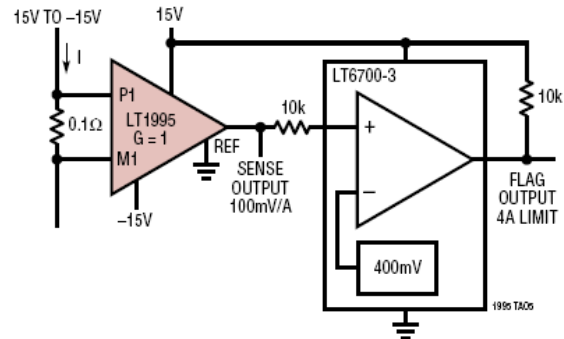
The LT1787's output is buffered by an LT1495 rail-to-rail op-amp configured as an I/V converter. This configuration is ideal for monitoring very low voltage supplies. The LT1787's V_{OUT} pin is held equal to the reference voltage appearing at the op amp's non-inverting input. This allows one to monitor supply voltages as low as 2.5V. The op-amp's output may swing from ground to its positive supply voltage. The low impedance output of the op amp may drive following circuitry more effectively than the high output impedance of the LT1787. The I/V converter configuration also works well with split supply voltages.

Battery Current Monitor



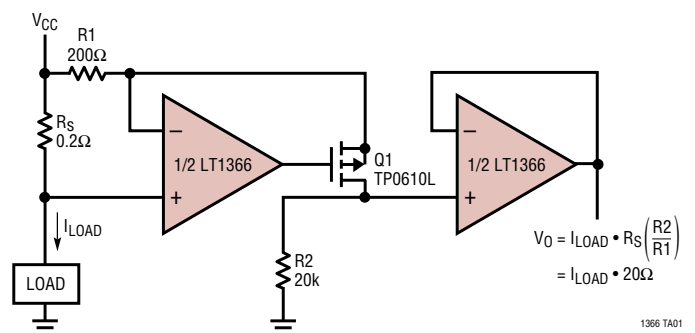
One LT1495 dual op-amp package can be used to establish separate charge and discharge current monitoring outputs. The LT1495 features Over-the-Top operation allowing the battery potential to be as high as 36V with only a 5V amplifier supply voltage.

Fast Current Sense with Alarm



The LT1995 is shown as a simple unity gain difference amplifier. When biased with split supplies the input current can flow in either direction providing an output voltage of 100mV per Amp from the voltage across the 100mΩ sense resistor. With 32MHz of bandwidth and 1000V/usec slew rate the response of this sense amplifier is fast. Adding a simple comparator with a built in reference voltage circuit such as the LT6700-3 can be used to generate an over-current flag. With the 400mV reference the flag occurs at 4A.

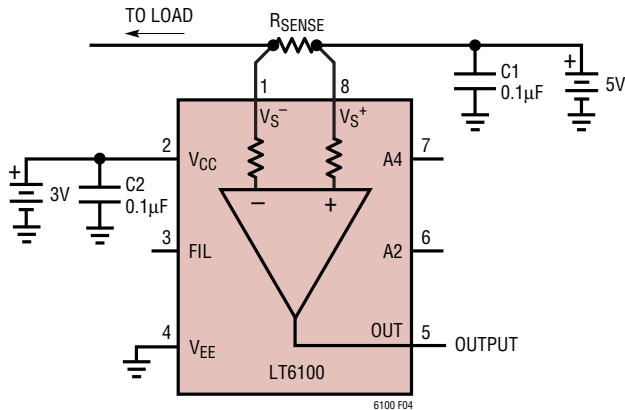
Positive Supply Rail Current Sense



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 R_2 (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.

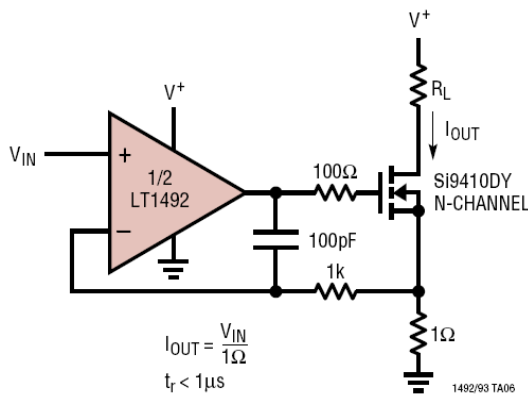
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LT6100 Load Current Monitor



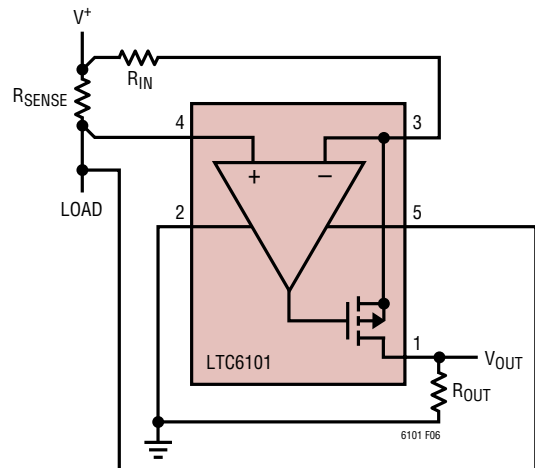
This is the basic LT6100 circuit configuration. The internal circuitry, including an output buffer, typically operates from a low voltage supply, such as the 3V shown. The monitored supply can range anywhere from $V_{CC} + 1.4V$ up to 48V. The A2 and A4 pins can be strapped various ways to provide a 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.

1A Voltage-Controlled Current Sink



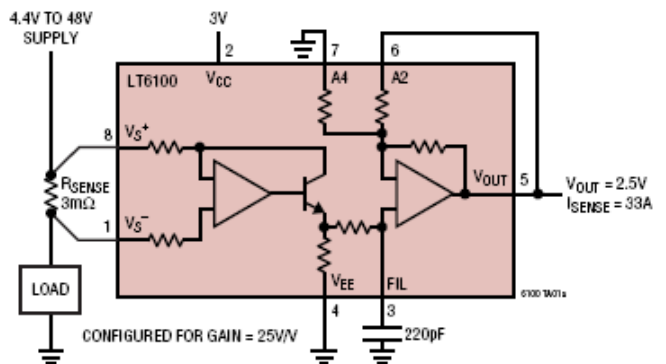
This is a simple controlled current sink, where the op amp drives the NMOSFET gate to develop a match between the 1Ω sense resistor drop and the V_{IN} current command. Since the common-mode voltage seen by the op amp is near ground potential, a “single-supply” or Rail-to-Rail type is required in this application.

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.

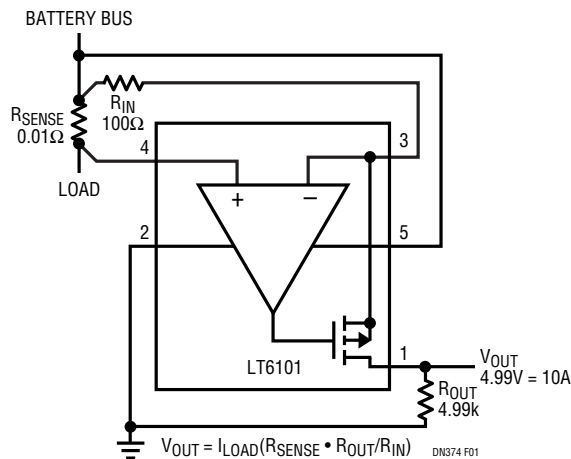
V+ Powered Separately from Load Supply



The inputs of the LTC6101 can function from 1.4V above the device positive supply to 48V DC. In this circuit the current flow in the high voltage rail is directly translated to a 0V to 3V range.

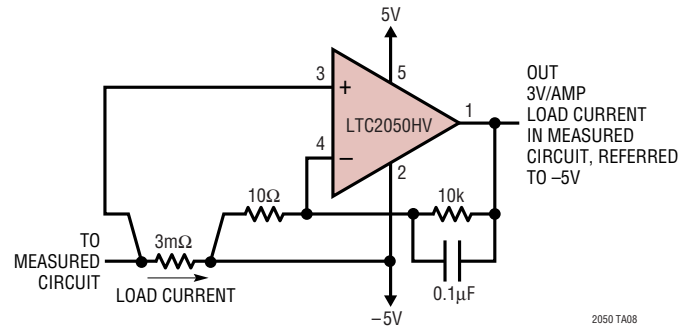
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Simple High Side Current Sense Using the LTC6101



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 $1\mu s$ 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 $250\mu A$ supply current when the load is off.

“Classic” High-Precision Low Side Current Sense



This configuration is basically a standard non-inverting amplifier. The op amp used must support common-mode operation at the lower rail and the use of a Zero-Drift type (as shown) provides excellent precision. The output of this circuit is referenced to the lower Kelvin contact, which could be ground in a single-supply application. Small-signal range is limited by V_{OL} for single-supply designs. Scaling accuracy is set by the quality of the user-selected resistors.