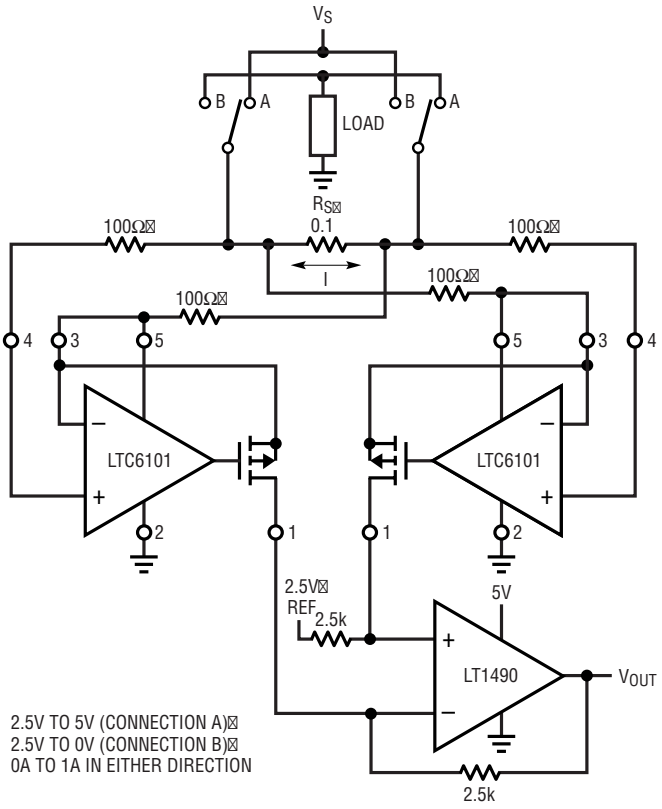
Bidirectional

Bidirectional current sensing monitors current flow in both directions through a sense resistor.

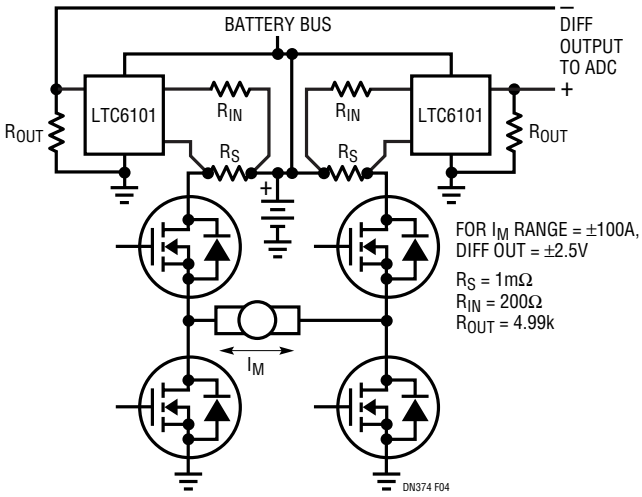
To see other chapters in this Application Note, return to the Introduction.

Bidirectional Current Sensing with Single Ended Output



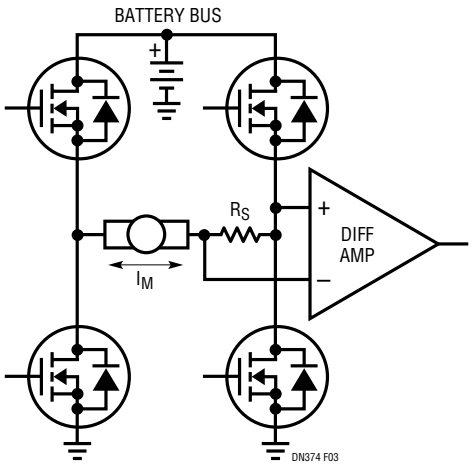
Two LTC6101's are used to monitor the current in a load in either direction. Using a separate rail-to-rail op amp to combine the two outputs provides a single ended output. With zero current flowing the output sits at the reference potential, one-half the supply voltage for maximum output swing or 2.5V as shown. With power supplied to the load through connection A the output will move positive between 2.5V and Vcc. With connection B the output moves down between 2.5V and 0V.

Practical H-Bridge Current Monitor Offers Fault Detection and Bidirectional Load Information



This circuit implements a differential load measurement for an ADC using twin unidirectional sense measurements. Each LTC6101 performs high side sensing that rapidly responds to fault conditions, including load shorts and MOSFET failures. Hardware local to the switch module (not shown in the diagram) can provide the protection logic and furnish a status flag to the control system. The two LTC6101 outputs taken differentially produce a bidirectional load measurement for the control servo. The ground-referenced signals are compatible with most ΔΣADCs. The ΔΣADC circuit also provides a "free" integration function that removes PWM content from the measurement. This scheme also eliminates the need for analog-to-digital conversions at the rate needed to support switch protection, thus reducing cost and complexity.

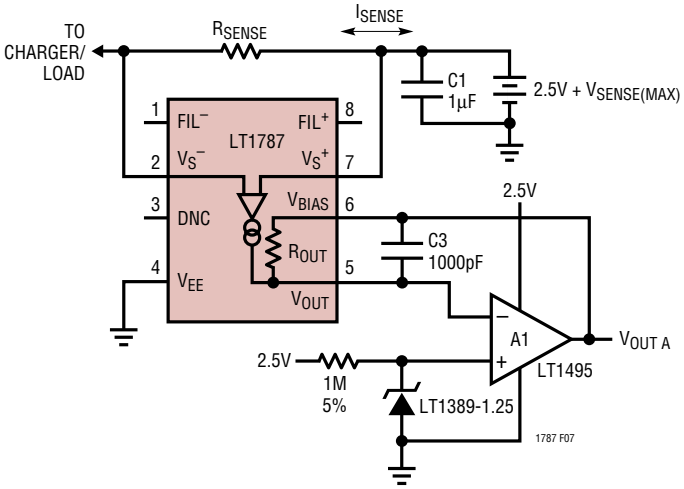
Conventional H-Bridge Current Monitor



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.

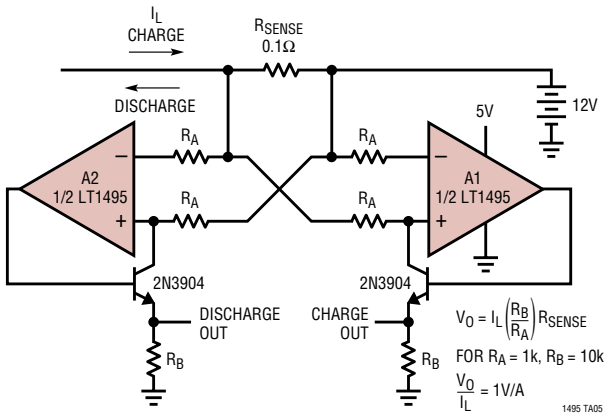
A common monitoring approach in these systems is to amplify the voltage on a "flying" sense resistor, as shown. Unfortunately, several potentially hazardous fault scenarios go undetected, such as a simple short to ground at a motor terminal. Another complication is the noise introduced by the PWM activity. 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.

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



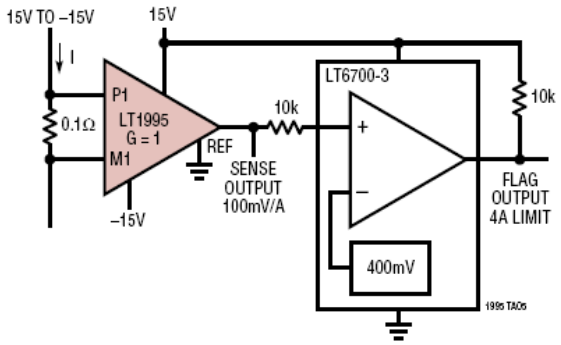
The LT1787's output is buffered by an LT1495 rail-to-rail op-amp configured as an I/V converter. This configuration is ideal for monitoring very low voltage supplies. The LT1787's V_{OUT} pin is held equal to the reference voltage appearing at the op amp's non-inverting input. This allows one to monitor 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



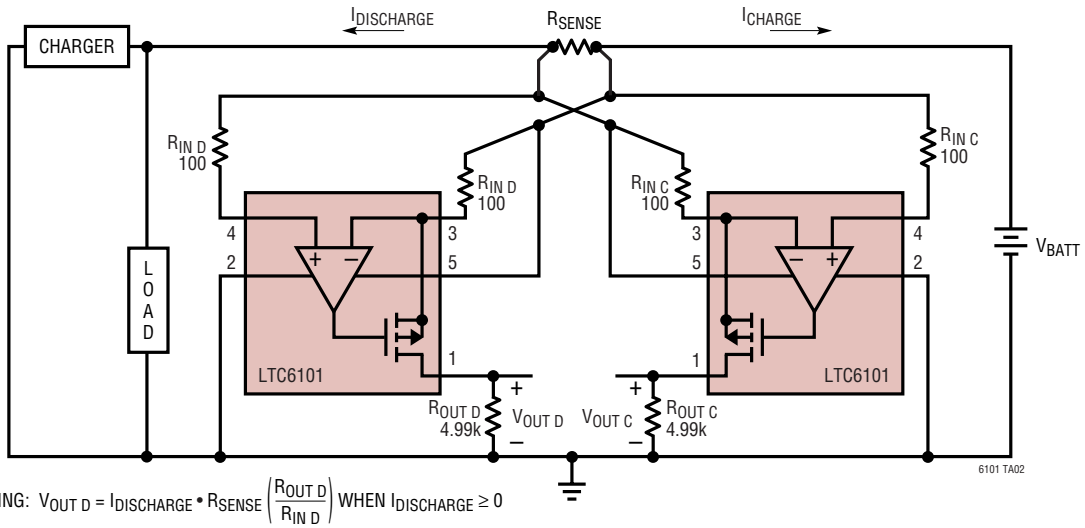
One LT1495 dual op-amp package can be used to establish separate charge and discharge current monitoring outputs. The LT1495 features Over-the-Top operation allowing the battery potential to be as high as 36V with only a 5V amplifier supply voltage.

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.

Bidirectional Current Sense with Separate Charge/Discharge Output

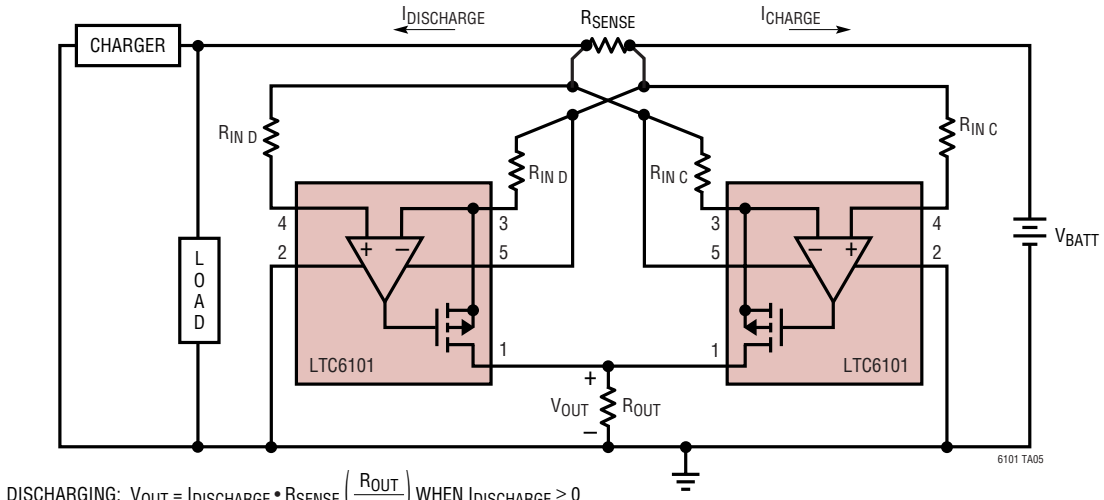


$$\text{DISCHARGING: } V_{OUT\,D} = I_{DISCHARGE} \bullet R_{SENSE} \left(\frac{R_{OUT\,D}}{R_{IN\,D}}\right) \text{ WHEN } I_{DISCHARGE} \geq 0$$

$$\text{CHARGING: } V_{OUT\,C} = I_{CHARGE} \bullet R_{SENSE} \left(\frac{R_{OUT\,C}}{R_{IN\,C}}\right) \text{ WHEN } I_{CHARGE} \geq 0$$

In this circuit the outputs are enabled by the direction of current flow. The battery current when either charging or discharging enables only one of the outputs. For example when charging, the V_{OUT} D signal goes low since the output MOSFET of that LTC6101 turns completely off while the other LT6101, V_{OUT} C, ramps from low to high in proportion to the charging current. The active output reverses when the charger is removed and the battery discharges into the load.

Bidirectional Absolute Value Current Sense

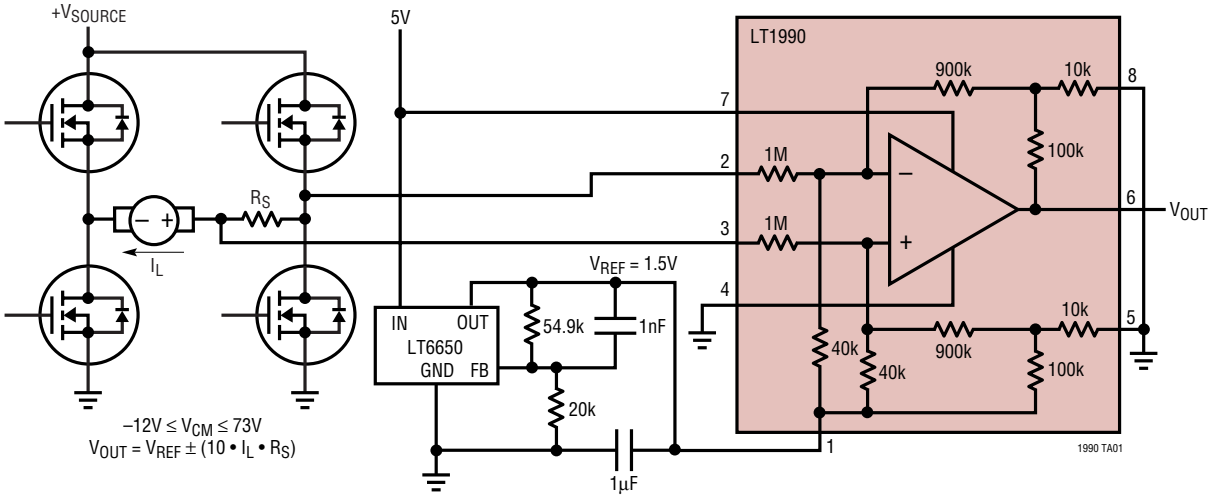


$$\text{DISCHARGING: } V_{OUT} = I_{DISCHARGE} \bullet R_{SENSE} \left(\frac{R_{OUT}}{R_{IN\,D}} \right) \text{ WHEN } I_{DISCHARGE} \geq 0$$

$$\text{CHARGING: } V_{OUT} = I_{CHARGE} \bullet R_{SENSE} \left(\frac{R_{OUT}}{R_{IN\,C}} \right) \text{ WHEN } I_{CHARGE} \geq 0$$

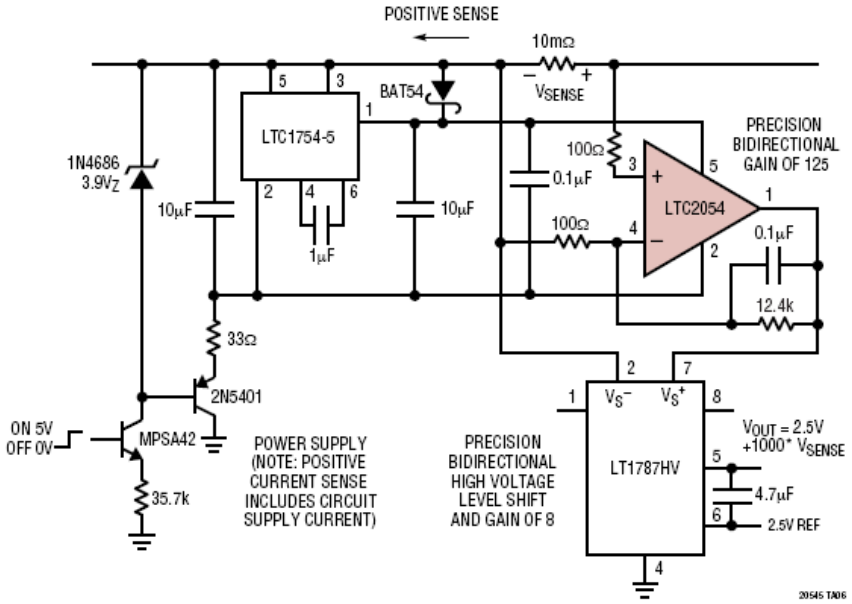
The high impedance current source outputs of two LTC6101's can be directly tied together. In this circuit the voltage at V_{OUT} continuously represents the absolute value of the magnitude of the current into or out of the battery. The direction or polarity of the current flow is not discriminated.

Full-Bridge Load Current Monitor



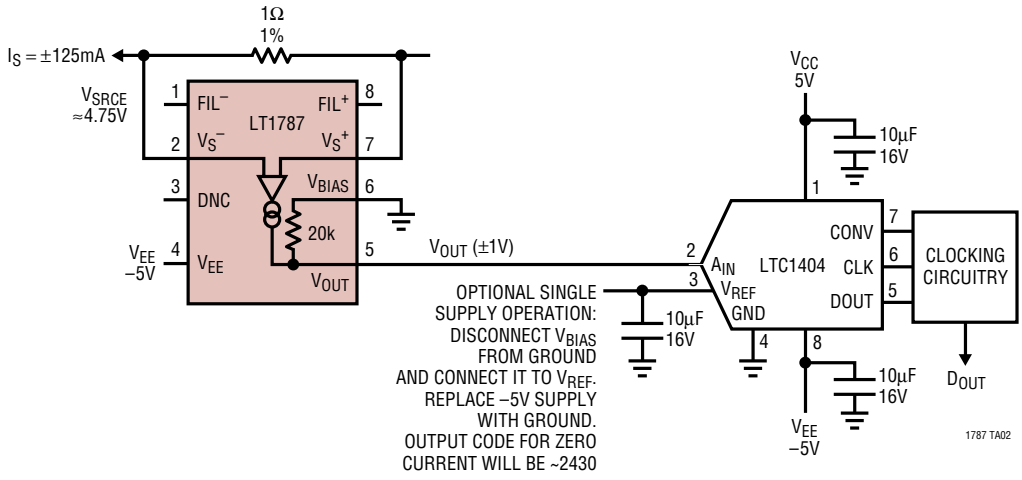
The LT1990 is a difference amplifier that features a very wide common mode input voltage range that can far exceed its own supply voltage. This is an advantage to reject transient voltages when used to monitor the current in a full bridge driven inductive load such as a motor. The LT6650 provides a voltage reference of 1.5V to bias up the output away from ground. The output will move above or below 1.5V as a function of which direction the current in the load is flowing. As shown, the amplifier provides a gain of 10 to the voltage developed across resistor R_S.

Low Power, Bidirectional 60V Precision Hi Side Current Sense



Using a very precise zero-drift amplifier as a pre-amp allows for the use of a very small sense resistor in a high voltage supply line. A floating power supply regulates the voltage across the pre-amplifier on any voltage rail up to the 60V limit of the LT1787HV circuit. Overall gain of this circuit is 1000. A 1mA change in current in either direction through the 10mΩ sense resistor will produce a 10mV change in the output voltage.

Split or Single Supply Operation, Bidirectional Output into A/D



In this circuit, split supply operation is used on both the LT1787 and LT1404 to provide a symmetric bidirectional measurement. In the single-supply case, where the LT1787 pin 6 is driven by V_{REF}, the bidirectional measurement range is slightly asymmetric due to V_{REF} being somewhat greater than mid-span of the ADC input range.