

# DESIGN NOTES

## Monitor and Protect Automotive Systems with Integrated Current Sensing – Design Note 374

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### Introduction

An automobile is an unforgiving environment for integrated circuits, where under-the-hood operating temperatures run from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and large transient excursions on the battery voltage bus are expected. In the past, electronics were part of the well-protected and centralized Engine Control Unit (ECU), but the trend is toward more distributed electronics. Electrically driven accessories and fault-protection monitoring functions are leaving the protective umbrella of the ECU and migrating directly into vehicle subsystems.

For example, many functions formerly driven by the engine—via belt and pulley or hydraulics—are now electrically driven (motorized), such as water pumps, steering mechanisms, brake actuators and various body controls. These functions can become a safety risk if they are not continually monitored for operational readiness and/or have a back-up mode of operation. In either case, real-time monitoring becomes necessary and generally involves accurately measuring the current draw of each subsystem.

### Simple Current Monitoring Solutions

The LT<sup>®</sup>6100 and LTC6101 are high side current-sense amplifiers that have been developed specifically to address the automotive designers' needs. These parts require a minimum number of support components to operate in the harsh automotive battery-bus environment.

Figure 1 shows 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  $1\mu\text{s}$  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  $1\text{mA}$  of full-scale output current into  $R_{OUT}$ , yet draws a mere  $250\mu\text{A}$  supply current when the load is off.

Figure 2 shows the LT6100 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 ( $\geq 2.7\text{V}$ ), typical of vehicle data acquisition systems, while the sense inputs monitor signals at the higher battery bus potential. The LT6100

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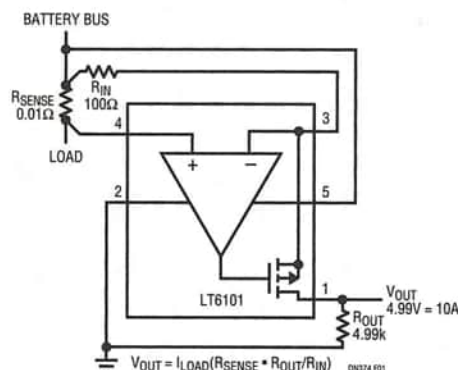


Figure 1. Simple LTC6101 High Side Current Sense Amplifier

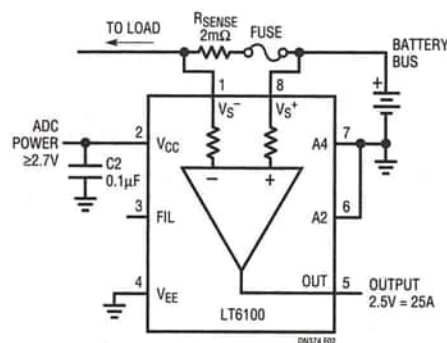


Figure 2. Simple LT6100 High Side Current Sense Amplifier and Fuse Monitor

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  $1\mu\text{A}$  max from the battery bus.

### Solving the H-Bridge Problem

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 in Figure 3. 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

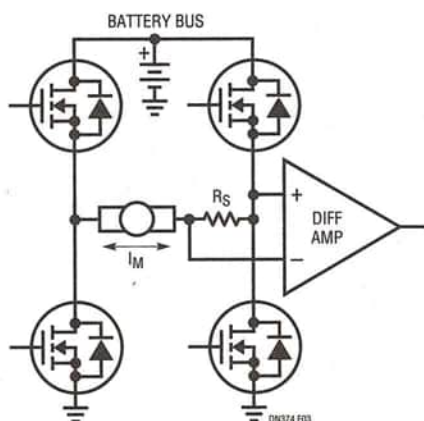


Figure 3. Limited Performance H-Bridge Current Monitor

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.

Figure 4 shows 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  $\Delta\Sigma$  ADCs. The  $\Delta\Sigma$  ADC 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.

### Conclusion

The LT6100 and LTC6101 high side current-sense amplifiers simplify designs in the automotive environment. High transient voltage tolerance (105V for the LTC6101HV) and ground-referenced outputs make it possible to improve robustness and substantially reduce the parts-count over traditional solutions.

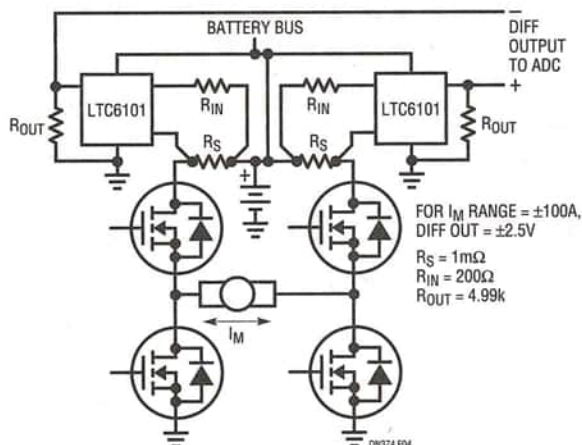


Figure 4. Practical H-Bridge Current Monitor Offers Fault Detection and Bidirectional Load Information

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