

# DESIGN NOTES

## Dual Current-Sense Amplifiers Simplify H-Bridge Load Monitoring

Design Note 407

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### Introduction

The H-bridge power-transistor topology is increasingly popular as a means of driving motors and other loads bi-directionally from a single supply potential. In most cases there is great benefit in monitoring the current delivered to the load and utilizing this information in real-time to provide operational feedback to a control system. In most new designs, pulse-width-modulation (PWM) techniques are used to provide highly efficient variable power-delivery, but this places extremely fast voltage transitions at both terminals of the load and therefore complicates the instrumentation problem. New high side current sense amplifiers from Linear Technology can simplify this problem.

### Measuring Load Current in the H-Bridge

The classical approach to load monitoring is to place a small value sense-resistance in series with the load that can develop a measurable voltage drop representing the load current (see Figure 1). The difficulty here is that with PWM activity, the common mode voltage at the sense resistor has nasty voltage transitions that can corrupt the sense amplifier operation with high frequency hash. While this hash can be filtered to recover useful low frequency information, the ability to provide fast fault protection is then lost. Additionally, this “flying” sense resistor configuration is unable to monitor switch shoot-through current, leaving many important fault modes undetected or unmanaged (failed switch function, for example).

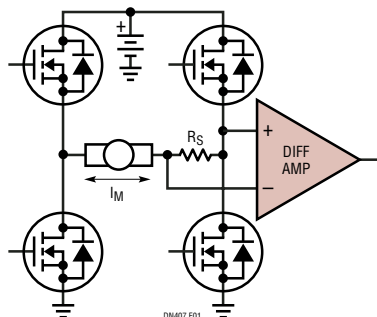


Figure 1. Classical Load Sensing Problematic with PWM

A far more practical method is to monitor the supply current fed to each half-bridge as shown in Figure 2. This scheme provides several benefits that simplify and improve the circuit performance. The main improvement comes from having the sense resistors at a relatively constant common mode voltage (i.e., the power supply voltage) so that fidelity of the PWM current waveform can be preserved. Additionally, by monitoring each half-bridge individually at the supply side, both failed power device operation and load shorts to ground are readily detected and manageable.

By using PWM logic that generates “sign-magnitude” control, one of the half-bridges is in a 100% pull high condition (depending on the direction or polarity of drive). The load current equals the current delivered through the 100% (fully on) switch, unaffected by the duty cycle of the PWM activity on the other half-bridge. This permits simple reconstruction of the load current waveform using suitable high side sense amplification techniques.

### The Simple Solution

The LTC6103 and LTC6104 dual high side sense amplifiers are ideal for performing the H-bridge monitoring function. Both parts include two current sense input channels and

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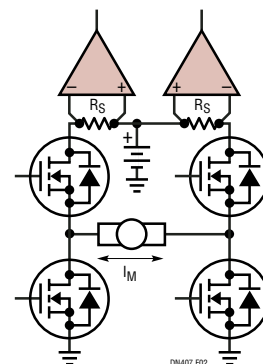


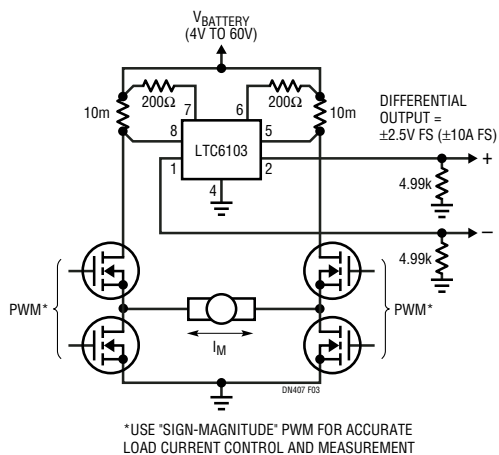
Figure 2. PWM-Compatible H-Bridge Load Sensing

furnish either two unidirectional outputs (LTC6103) or a single bidirectional output (LTC6104). Since each current sense channel operates in a unidirectional fashion, only the current from the fully on half-bridge is monitored.

Since the current pulses in the other half-bridge are in the opposite direction, that amplifier channel remains in a cutoff condition and does not impact the reading. This means that the output signals only reflect the fully-on half-bridge current, which is identical to the controlled load current.

With their fast (microsecond level) response times, these parts also offer overload sensing, thereby providing the ability to signal power device protection circuits in the event of fault conditions. Both parts are furnished in tiny MSOP-8 packages for compact layouts and can operate with up to 60V power supply potentials. With their 70V transient capability, the need for additional surge suppression components is eliminated in harsh automotive applications.

The dual outputs of the LTC6103 can be used individually to provide overload detection, and/or may be taken as a differential pair to provide a bidirectional signal to an analog-to-digital converter (ADC) for example. Figure 3 shows a typical circuit for a generic H-bridge application. The power devices may be complementary MOSFETs, pure N-MOSFETs, or other switching devices. When the



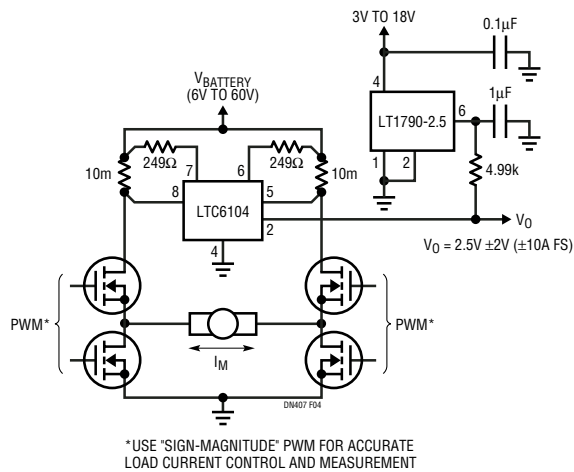
**Figure 3. LTC6103 Provides Bidirectional H-Bridge Monitoring with ADC-Friendly Differential Output**

bridge drives the load (a motor assumed in the example shown), one of the LTC6103 outputs rises above ground, while the other remains pulled down to ground, thereby forming an accurate bidirectional differential output with a common mode voltage that never falls below ground. The selection of output resistance (4.99k in the example) can be scaled to satisfy the source-impedance requirement of any ADC.

As an alternative, the output structure of the LTC6104 provides a single bidirectional signal. The output connection can either source or sink current to a load resistance, depending on which input channel is sensing current flow. A negative-going output swing remains linear as long as Pin 4 ( $V^-$ ) is lower than the lowest expected output level by at least 0.5V. This condition is met if the load resistance is returned to a suitable reference voltage while Pin 4 is grounded (as shown in the Figure 4 example). The output resistance could also be returned directly to ground to form a true bipolar output if Pin 4 is tied to a suitable negative supply, such as  $-3V$ .

### Conclusion

Designing a load current monitor for an H-bridge power driver is not difficult if you have the right amplifier. The LTC6103 and LTC6104 fit the bill. They include dual sense inputs and a choice of two different output configurations—features that reduce complexity and printed circuit area.



**Figure 4. LTC6104 Provides Bidirectional H-Bridge Monitoring with Single-Ended Output**

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