Application Information

Hall-Effect Current Sensing in Electric and Hybrid Vehicles

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The automotive marketplace is transitioning from mechanical actuation and timing methods to electrically driven systems. Hall-effect devices are proven to be uniquely suited to these applications. This application note provides a review of the implementation factors.

Introduction

Improved energy efficiency in HEVs and EVs can be attained by using electrically driven actuators instead of belt-driven and hydraulic actuators. For instance, in traditional internal combustion engines a fan belt drives the cooling fan, which operates continuously while the engine is running. The same applies to power-steering pumps and other belt-driven loads.

Technology Replacement Benefits

Replacing belt-driven actuators with electric motors, as shown in figure 1, improves energy efficiency and allows for greater control of the actuators. Precision, high-speed current-sensor ICs provide the bandwidth, response time, low noise, and accuracy performance necessary to optimize motor performance. They also allow quick detection of malfunctions by reporting overcurrent conditions and triggering protection circuits.

Allegro Hall-effect current sensors ICs are factory-trimmed to provide uniform sensitivity and minimize offset voltage through the entire operating temperature range. The small footprint of these packages, along with designed-in galvanic isolation, facilitates high-side and low-side current sensing while saving PCB area, and particularly when compared

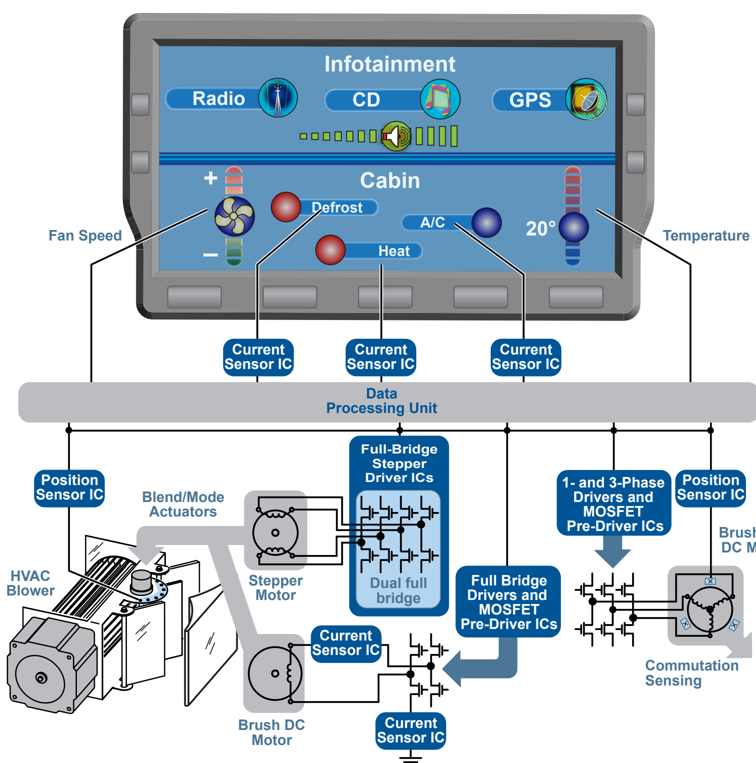

Figure 1. Power-efficient electric actuators

with the traditional sensing solutions based on sense resistance and operational amplifier current, such as that shown in figure 2.

The SOIC package shown is typical of a Hall solution. In the Allegro ACS714, one of the product lines that use this package, a low-resistance integrated conductor serves as the path for the sensed current (figure 3, left panel), bringing it into close proximity to the sensing elements while maintaining galvanic isolation. This minimizes power loss and facilitates the high accuracy measurements required by advanced HEV systems.

Case in Point: Smart Batteries

An increasingly relevant example of low-side current sensing implementation is charge current monitoring for smart battery systems. As shown in figure 3, in addition to the two battery terminals, these battery systems typically have two diagnostic signals: a single-wire data line for battery health, and a single-wire thermistor output for battery temperature monitoring. These diagnostics are referenced to the negative terminal of the battery.

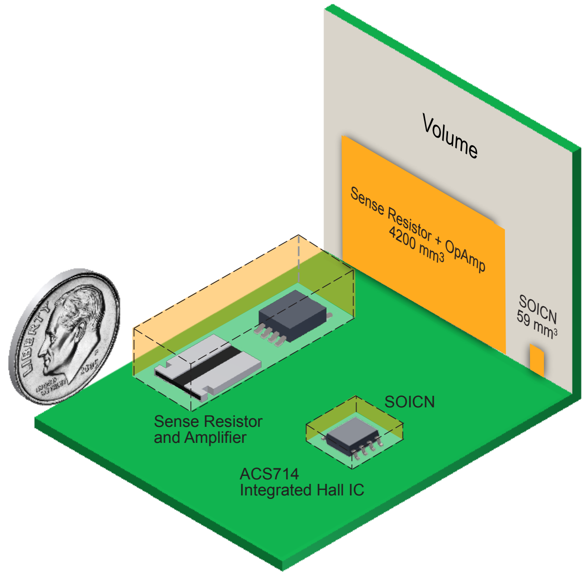

Figure 2. PCB volume comparison of typical Hall current sensor ICs versus traditional sense resistance and operational amplifier current sensing

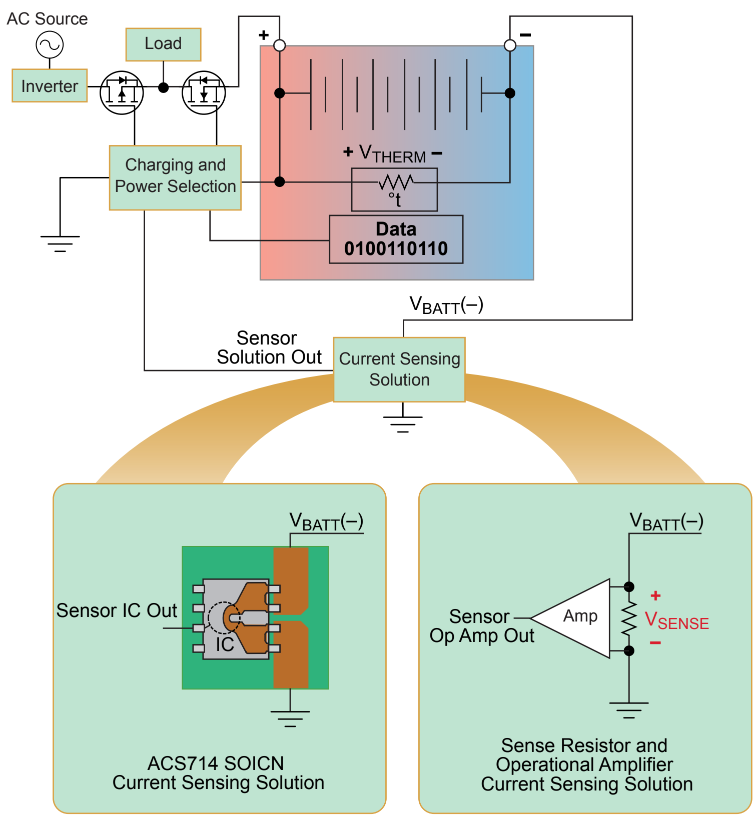

Figure 3. Smart battery current sensing. The Illustration on the left shows the integrated primary sensed current path featured in the ACS714.

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The design complexity of the seemingly simple sense resistance solution has a direct effect on the efficiency and accuracy of the sensing decision. When using a sense resistor in this application, the design engineer must take into account a variety of critical error terms. Primary among these is that the resistor will dissipate a significant amount of energy from the battery as heat, making the system inefficient and requiring extraneous thermal transfer structures in the application.

Second, the thermal phenomena also affect the sense voltage, V_{SENSE} in figure 3, that will be developed across the sense resistor. Further, the sense resistor-op amp solution requires that V_{SENSE} be superpositioned on the thermistor voltage, V_{THERM}. This escalates the voltage seen by the charge controller, such that:

$$V'_{SENSE} = V_{SENSE} + V_{THERM} ,$$

resulting in an enhanced error factor in the monitored battery temperature. This hampers the charging control of the battery system and thereby eventually undermines battery life, which is a crucial component to the success of HEV and EV systems.

To contrast the Hall-effect sensor IC solution, begin with the most basic consideration, conductor resistance. The integrated conductor current path resistance is simply and substantially lower, as low as 100 μΩ. This greatly reduces overall application power dissipation.

Another essential consideration is that practically zero voltage develops across the terminals of the integrated conductor loop. Minimizing the voltage to trace levels increases the accuracy and integrity of the thermistor diagnostic signal (V_{SENSE} is driven to its lower limit).

A fundamental advantage that distinguishes Hall-effect technology is the reliance on magnetic coupling between the current flow and the induced signal response. This is because the current-based magnetic characteristic being sensed is not thermally-dependent at practical temperature ranges. Not only does this ensure overall linearity of response with current level changes, but advanced Hall-effect devices can incorporate logic circuitry making them highly customizable and provide programmable temperature offsets, further enhancing performance.

This simplifies the overall system design challenges, and places Hall ICs in stark contrast to the relatively brute-force sense resistance-op amp method with its complex component dependencies for conductor resistance versus accuracy. When a sense resistor-op amp approach is used, a low resistor value must be used to minimize power consumption. However, a low resistance also has a contrary effect, degrading the accuracy performance because a very small voltage will be sensed. Advanced Hall ICs can operate at very low voltages, as mentioned before. In addition, the device backend stages can output conditioned data signals to match application system requirements without affecting the superior accuracy and low power dissipation of the integrated solution.

Practical Sensing Solutions

Allegro MicroSystems has developed a line of fully integrated Hall-effect current sensor ICs that provide highly accurate, low noise output voltage signals proportional to an applied AC or DC current, bidirectional or unidirectional. The basic categories of devices are displayed in figure 4.

Allegro proprietary integrated Hall-effect devices employ advanced IC and packaging techniques for sensing current from 5 to 200 A. Even larger currents can be measured using a Hall IC and an external magnetic concentrator or core. Allegro current sensor ICs allow design engineers to use Hall-effect based current sensor ICs in new EV and HEV applications where increased energy efficiency or new operating features are required. Wherever current sensing is needed, an integrated Hall-effect IC can provide a solution.

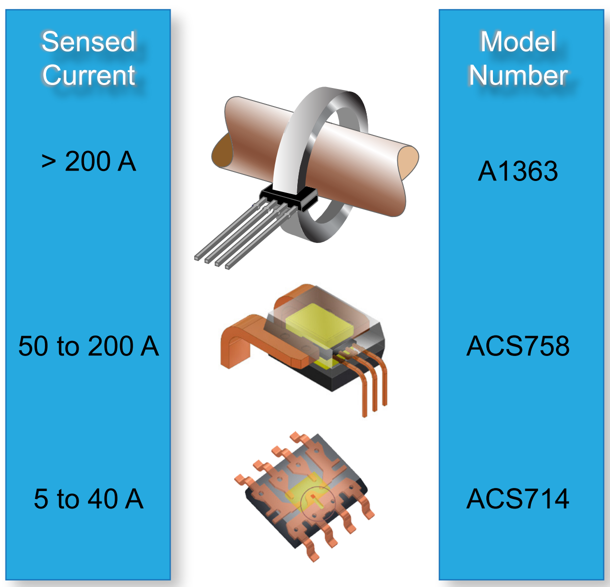

Figure 4. Allegro Hall-effect current sensor IC typical package categories

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REVISION HISTORY

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2	November 7, 2022	Corrected application note number (changed AN296106 to AN29610)

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