Why Appliance Designers Should Consider

Hall-Effect Sensor ICs for Motor Control

Motor control circuits in appliances, including refrigerators, washing machines, and air conditioners, need to operate more efficiently, reliably, and safely, while meeting cost requirements. With energy efficiency becoming a greater concern, appliance manufacturers should consider Hall-effect current sensor ICs for motor control.

Allegro™ MicroSystems, LLC

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Introduction

Motor control circuits in appliances, including refrigerators, washing machines, and air conditioners, need to operate more efficiently, reliably, and safely, while meeting cost requirements. With energy efficiency becoming a greater concern, appliance manufacturers should consider Hall-effect current sensor ICs for motor control.

Whether used in high-side (near supply potential) or low-side (near ground potential) applications, these current sensing devices directly improve the efficiency of the motor. These Hall-effect sensor ICs are used to determine when to apply current to the motor coils to control the motor as efficiently as possible. The ICs convert the magnetic field generated by the current flowing through the conductor integrated into the IC package into a voltage that is directly proportional to this current.

Together with current sensing, there are a host of control techniques or algorithms that are used to control the motor. This is where the accuracy and response time of the Hall-effect sensor IC are critical. In general, the more accurate and faster the current sensor IC, the better the motor can be controlled, leading to higher efficiency designs. Higher efficiency translates into the potential for smaller motors as a result of increased power output and reduced heat dissipation, which may eliminate the need for cooling devices or heat sinks in the motor.

Every appliance application is different, and is influenced by specific motor control techniques or algorithms and motor type. Therefore, designers need to ensure that they match the right Hall-effect sensor IC to their application by evaluating several key design characteristics that improve motor efficiency. These characteristics include accuracy, response time, power dissipation, and packaging. Voltage isolation is another important criterion for high-side applications. We will take a look at each of these specifications individually.

CHAPTER ONE

Accuracy Impacts a Motor's Torque

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Whether it is a high-side or low-side sensing configuration, appliance manufacturers that are designing for high energy efficiency need the current sensor IC to accurately sense the current in the motor to control motor timing and orientation. Higher accuracy directly translates into better and tighter control of the motor.

In 3-phase motors, for example, all three phases should be switched at the same time to achieve the highest efficiency. In order to operate the motors at their peak efficiency points, they need to be precisely controlled, which requires a highly accurate current sensor. Switching should take place as close to the zero current points as possible to avoid inductive switching power loss and voltage spikes. A dead time is needed for the switching transistors and so the switching takes some time and will not be completely at the zero current point.

Allegro offers innovative Hall-effect current sensor ICs that integrate the current carrying conductor and a Hall sensor IC in a single IC package. This improves IC accuracy by placing the conductor in close proximity to the Hall sensor IC, which maximizes magnetic field strength. Some examples include the ACS710, ACS711, ACS712 and ACS758.

Allegro programs these monolithic devices in-house to compensate for offset and sensitivity over temperature, which further improves accuracy and system reliability. Good zero current detection can help protect power switching devices such as MOSFETs and IGBTs from damage, as they can see high voltages and body diode currents if inductive loads are switched while carrying current.

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CHAPTER TWO

Response Time Effects Efficiency

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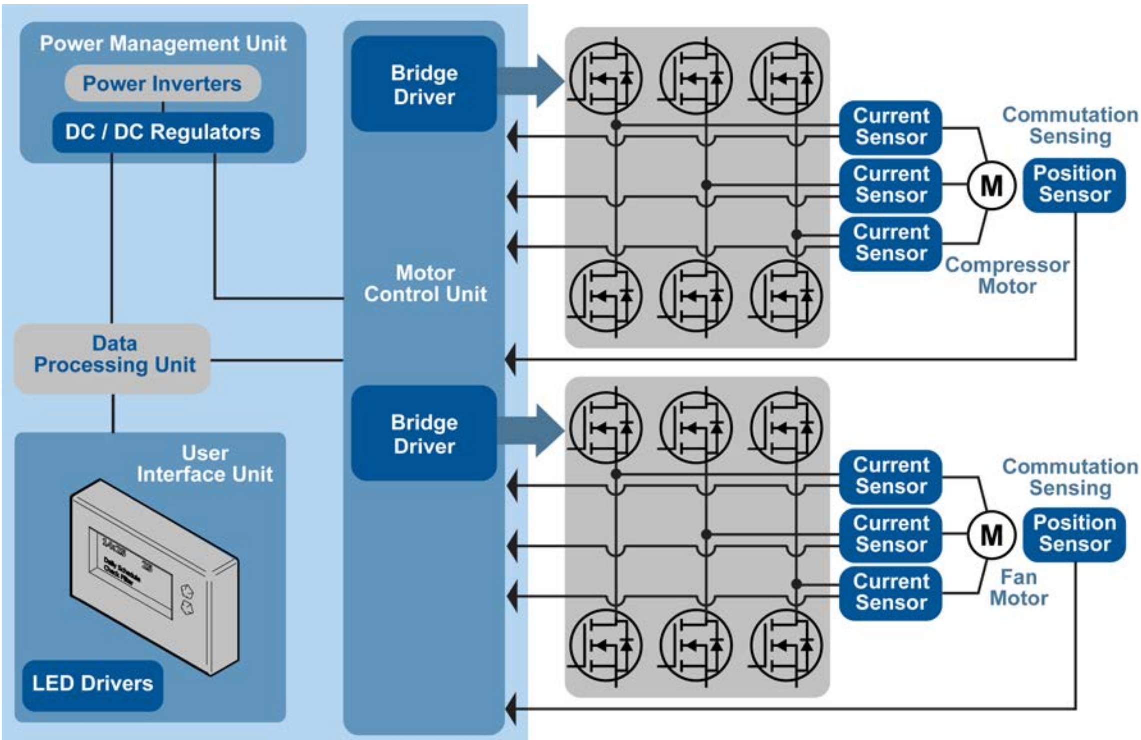
In three-phase motor applications, if motor commutation timing is not optimized then the motors will not achieve their peak torque, causing lower motor and system efficiency. Current sensor ICs that provide a fast output response time allow for a smaller control loop delay and more accurate motor control, which directly translates into greater efficiency in motor commutation.

Response times for Allegro's Hall-effect current sensor ICs, for example, range between 4 to 6 microseconds. As an example, for low-side sensing, the ACS711 offers a 4.6-microsecond response time, and offers a less-than-2-microsecond fast fault output, which helps prevent damage to IGBTs or other switching devices during a short-circuit or overcurrent condition. It can also be used as a redundant fault feature in motor control.



Allegro offers a wide selection of current sensor ICs that contribute to energy efficiency, low noise, and high reliability of air conditioning units by providing precise and accurate motor control, together with rapid detection of fault conditions to prevent system damage.

CHAPTER THREE

Lower Resistance Reduces Power Dissipation

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A lower resistance value in the integrated, current carrying conductor used in Allegro’s ICs reduces power dissipation, which improves the overall efficiency of an appliance design. Allegro's monolithic Hall-effect current sensor ICs feature low resistance conductors, which results in low power dissipation as the current to be sensed increases. Therefore, Allegro ICs provide a more efficient current sensing solution compared to alternative solutions including sense resistors. Allegro’s SOIC and QFN packaged sensor ICs have integrated conductor resistance values as low as 0.6 milliohms, and Allegro’s integrated core packages (> 50 A sensing) can be as low as 0.12 milliohms.

When designers use shunt resistors in current sensing applications it is typical to use resistor values between 5 to 10 milliohms. Larger resistance values are needed to increase the voltage that develops across the resistor when a current flows through the resistor. If the voltage across the resistor is small, then the measurement error of a shunt resistor and amplifier-based current sensing solution increases. There is an inherent accuracy vs. power dissipation trade-off when using shunt resistors, and this trade-off does not exist for Hall-effect current sensor ICs since Hall ICs sense the magnetic field around a conductor, not the voltage developed across the conductor. This feature enables very low power dissipation for Hall-effect current sensor ICs, roughly five to ten times lower than typical sense resistor or shunt resistor solutions.

Sense resistor and amplifier solutions are not typically used in high-side voltage applications, because the design becomes too expensive and complex due to the need for opto-isolators or amplifiers, which can handle large common-mode voltages. For Hall-effect current sensor ICs, since the current carrying conductor does not make electrical contact with the IC, the conductor potential can be biased at hundreds of volts and the sensor works flawlessly.

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CHAPTER FOUR

Packaging Design Improves Performance

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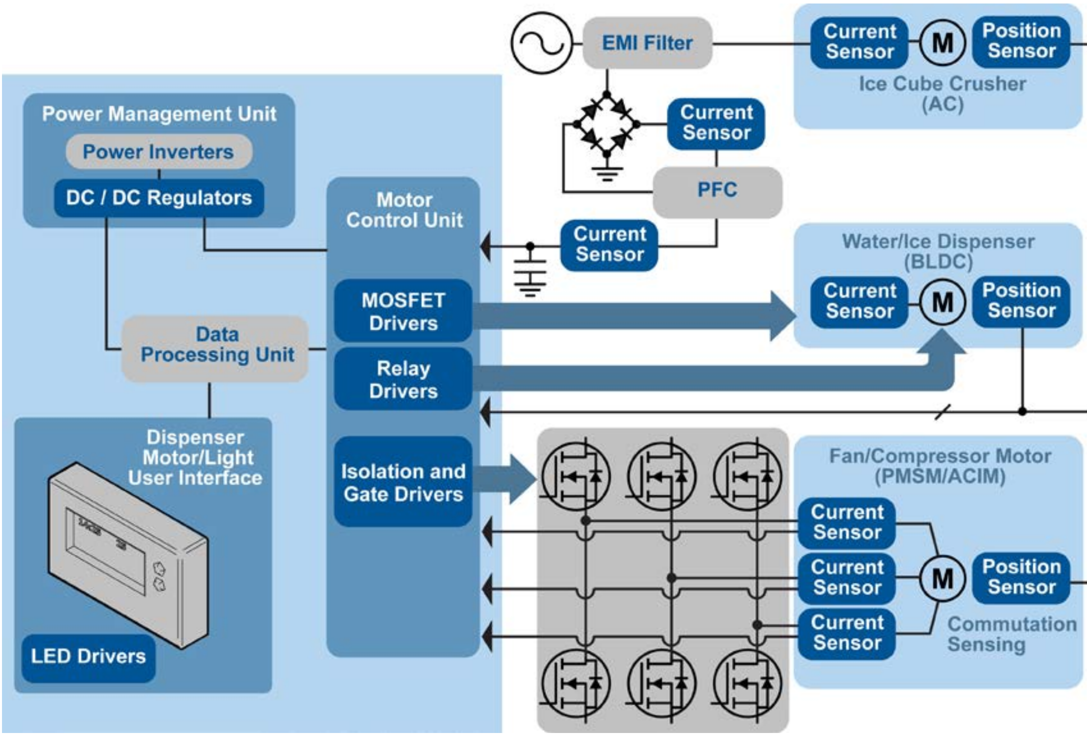
In space-constrained applications, footprint and packaging size are important. Not only does a small package size save printed-circuit-board (PCB) space, it can also reduce the overall cost of the system. Integrated Hall-effect sensor ICs, such as Allegro's ACS758, can provide a compact solution together with high-voltage isolation, replacing the sense resistor, op amp, and isolation circuitry which would be needed to perform the same function. In addition to PCB savings, a monolithic Hall-effect current sensor IC reduces the bill of materials costs compared to current transformer and sense resistor/amplifier solutions by integrating all necessary sensing functionality into one IC.

The power consumption also can be reduced with these integrated devices, such as Allegro's ACS758, because of their low primary conductor resistance (typically 0.12 milliohms), helping appliance manufacturers meet ENERGY STAR® energy-efficiency requirements.

Another benefit of the integrated solutions is that Allegro can individually test and trim the parts at room and hot temperatures to achieve the highest accuracy over the full operating temperature range. This eliminates the need for designers to do their own trimming and testing. These devices are virtually "plug-and-play," providing designers with a very fast to market solution.



Allegro's integrated Hall current sensor IC portfolio delivers performance features that meet a wide range of requirements for motor control that are critical to a refrigerator's energy efficiency, safety and reliability requirements.

CHAPTER FIVE

High Isolation Requirements for High Voltages

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Isolation is one of the most important specifications when sensing current on line voltages. Voltage isolation is required to protect the user from the mains voltage and electrical shock. In a 3-phase motor application, for example, a sense resistor/op amp solution is not well suited because a highly isolated op amp would either be too expensive, too inaccurate, or not available at the voltage rating required. Current transformers are often bulky devices taking up a lot of board real estate compared to Hall-effect current sensor ICs. Another disadvantage of current transformers is that they do not measure DC current, resulting in some design limitations.

Commonplace, Inexpensive Current-Sensing Techniques

Widely Used Sensors	Power Consumption: Insertion Loss	Power Consumption: External Power	Circuit Isolation	Frequency Range	Size	Accuracy	Rel. Cost
Sense Resistor + Op-Amp	High	Low	Low	DC - 10 MHz	Medium	±3-5 %	Low
Standard Open Loop Hall-Effect	Low	Low	High	DC - 50 kHz	Small	±5-10 %	Medium
Hall-Effect Closed-Loop	Low	Medium	High	DC - 1 MHz	Medium-Large	< ±1 %	High
Allegro Open-Loop Hall Effect Current Sensor Ics	Low	Low	High	DC - 120 kHz	Small	±2-3 %	Medium
Current Transformers	Medium (AC)	None	High	60 Hz - 1 MHz*	Medium-Large	±3-5 %	High

* Current transformers usually operate over a limited frequency range but can be designed for use from low to high frequencies.

Although there are many current-sensing methods, only three are commonplace in low-cost, volume applications. The others are expensive laboratory systems, emerging technologies, or seldom used. The commonly used techniques include: resistive, Hall-effect, and current transformers.

Housed in a small SOIC16 package, the ACS710 sensor can be used in applications that require electrical isolation without requiring the use of opto-isolators or other isolation techniques thanks to the current conduction path that is electrically isolated from the low voltage sensor inputs and outputs.

Summary

Motor control circuits for appliances need to meet energy efficiency, safety and reliability requirements at a cost-effective price point. Selecting the right current sensing solution can lead to overall improvements in design complexity, energy efficiency, and cost.
Current sensor solutions impact motor and system efficiency based on several specifications including accuracy, response time, power dissipation and resistance.

Allegro's integrated Hall-effect current sensor ICs can provide compact current sensing with high accuracy, fast response times, and high-voltage isolation to meet demands in both low-side and high-side applications. These devices also feature low conductor resistance for lower power loss, which help meet global energy-efficiency requirements.

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Learn more about the technical specifications and features and benefits of Allegro's current sensor IC family of products. Contact our sales or technical team to order samples or demo boards for your next project.

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Allegro MicroSystems, LLC

115 Northeast Cutoff
Worcester, Massachusetts USA 01606
508.853.5000
www.allegromicro.com