How ICS Performance Can Open Up New Perspectives for System Design

Four reasons why integrated current sensors offer the ideal solution where accurate control, efficiency and protection are essential

Current sensing is a crucial function in a wide range of electronic devices, including power supplies, battery management systems, e-motor drives and renewable energy networks. For them to be protected and operate efficiently, accurate and reliable current sensing is essential.

By Charles Flatot-Le Bohec, Global Product Manager for e-mobility, LEM

However, there are challenges around current measurement as the power density of devices increases and the goal is always to do more with less, including having minimal circuit board footprints. Within this environment of space constraints and high power density, integrated current sensors (ICSs) have a vital role to play.

Ideal for a range of automotive, industrial or residential applications, ICSs are Hall-effect based current sensors that incorporate the current conductor, sensing elements, signal treatment die, some dedicated features such as fault detections and the isolation in a single package.

Hall-effect sensing is one way to achieve contactless measurement of the current-induced magnetic field. The Hall cell is the sensing element that converts a change in the magnetic field into a change of its resistance and when a constant current goes through the Hall cell, it will give a voltage output change proportionate to the magnetic field.

As a leader in electrical measurement for 50 years, LEM is continually developing new technologies to fit customers' changing needs in the sectors it serves, which is why the company chose to invest in its own ICS design function and is now in the process of building a complete ICS range.

There are four key benefits that illustrate why LEM believes integrated current sensors represent a sound investment.

Coreless design

Traditional Hall-effect current sensors use a ferrite core around the current conductor and the sensing elements to concentrate the magnetic field. This core also brings protection from undesired external magnetic fields and noise. Differential measurement makes it possible to remove the ferrite core, using two sensing elements (the Hall cells) which both receive the magnetic field to be measured – one with a positive factor, the other negative. The difference of the two fields allows for the cancellation of any additional unwanted magnetic fields.

Integrated current sensors take advantage of differential measurement to avoid using a ferrite core at all. Removing the core delivers several advantages in embedded applications. For example, the cost of the device is reduced, the power density on the sensing side is mechanically increased (up to 75A in 800V applications for LEM ICS products), and measurement is not affected by magnetic hysteresis (when an external magnetic field is applied to a ferromagnet and the atomic dipoles align themselves with it). Finally, frequency and bandwidth are not limited by the inherent saturation of the magnetic element of the core.

Embedded Isolation

Some systems needs specific isolation to protect the final user, which means the user interface has to be physically separated from the high-voltage (HV) network and cannot share the same voltage reference level. An ICS integrates the isolation function inside (galvanic isolation) and outside (creepage and clearance distances) the device, meaning there is no physical connection between the primary conductor where the HV current flows, and the secondary circuit with the application specific integrated circuit (ASIC) chip and the secondary pins. These two sides communicate only through the magnetic field produced by the flowing current.

The ASIC in the ICS is produced using the CMOS semiconductor manufacturing process which allows specific features to be integrated into the component without adding any hardware. For example, all the analogue and digital elements required to sense, amplify and process the proportional voltage signal are manufactured on a single die with semiconductor materials, which also ensures low consumption and power dissipation.

Over-current detection (OCD) is also an important factor. With internal OCD, when the current crosses a threshold it internally triggers a signal output sent to a dedicated fault pin. This allows the microcontroller of the application to receive the alert information with minimal delay. Otherwise, the action would have to be done internally and based on the current level sent by the sensor, which would take much longer.

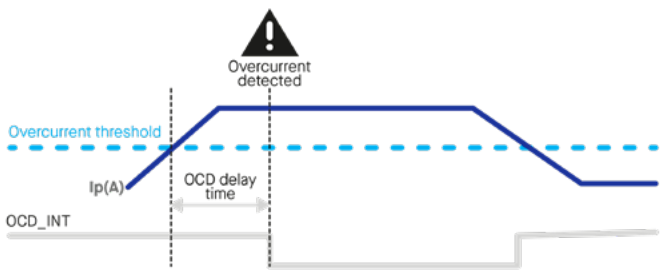

Figure 1: OCD enables microcontroller to react to overcurrent with minimal delay

Compensation and additional integrated functions

As for stress and temperature compensation, if the ASIC die is subject to mechanical stress from the package, this can create sensitivity drift (the same can occur with temperature variations of -40°C to +125°C). Internal sensors in the die of the ASIC compensate for this drift to guarantee a linear and accurate sensitivity over a large range of conditions. In a discrete-based design, the temperature of the shunt varies widely with resistive losses, requiring an extra design step in the microcontroller to compensate for this accurately. By contrast, an ICS solution is plug-and-play.

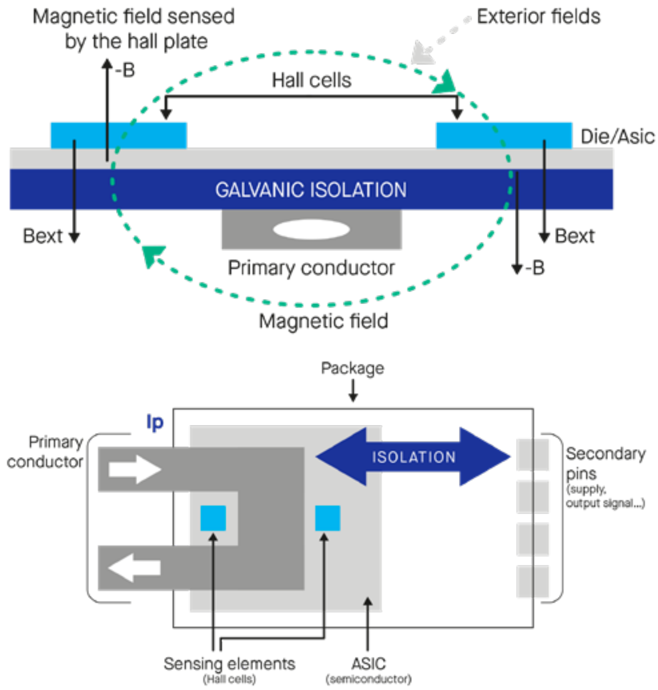

Figure 2: ICS embeds the primary conductor, 2 sensing elements on a die, etc

Traditionally, the voltage output is always proportional to the measured current but there are two possible reference voltages. In ratiometric mode, Vout is expressed as a percentage of the voltage supply Vcc and requires a stable voltage supply. In fixed (non-ratiometric) mode, Vout is compared to an external reference voltage Vref. The proportional signal is then Vout minus Vref but when the current to be measured is 0A, Vout = Vref – in other words, the reference voltage is setting the quiescent output voltage (zero current mode).

LEM has developed two families of ICS, the HMSR series and GO series. LEM HMSR and GO-SMS ICSs feature internal and external OCDs for maximal system protection and are also available with ratiometric and fixed voltage outputs on demand, depending on the system characteristics. While the LEM HMSR series provides extra immunity with its integrated core, the LEM GO series takes full advantage of differential measurements to offer all the performance of a Hall current sensor in a compact, surface mounted small outline integrated circuit (SOIC) – SOIC8 or 16. For example, the LEM GO-SMS can guarantee a basic isolation up to 2088V and a reinforced isolation of 1041V (DC or peak working voltage) according to IEC 62368-1.

Plug-and-play by design

In summary, integrated current sensors allow designers to realise the current sensing function with a plug-and-play approach and with virtually all their challenges solved using a single component. Complete mechanical integration and very low power losses make an ICS's footprint as small as possible with zero thermal challenges.

By design, contactless measurement with galvanic isolation and standard creepage and clearance distances make ICSs suitable for high-voltage applications and can support a reinforced isolation design strategy. Smaller packages with less isolation and un-populated features can bring the cost down to be cost-competitive where isolation is not needed (< 60Vdc). This flexibility in the product definition allows LEM ICSs to be suitable for various products, whether in cost-optimised applications or high-end isolated designs.

The performance of the ICSs is not compromised because all the signal treatment is done in the package with semiconductor elements. This enables the integration of ad hoc, specific system protection mechanisms such as fast overcurrent detection. Depending on the system architecture and design choices, the current-proportional voltage output can be referenced to the supply voltage Vcc or an external Vref.

It's clear, then, that integrated current sensors are ideal in a wide range of applications where accurate control, efficiency and protection are needed. In particular, LEM's latest ICSs are especially suited to applications where space is at a premium and high power density is required.

Looking forward on this front, LEM has an ambitious roadmap to develop even more ICS products that cater for the specific needs of its customers. The next stage on this roadmap will be the launch of the HMSR DA, the first ICS with sigma delta bitstream digital output.

About the Author

Charles is LEM Global Product Manager for e-mobility. He joined LEM in 2022 after 8 years in the automotive industry at TOLV (ex Phoenix Mobility), BorgWarner and Nissan. He holds a Master of Science at EDHEC Business School as well as a Bachelor of Science in electrical and electronics engineering from Université Grenoble Alpes. Charles is building on his experience in strategy and operations for e-mobility electronics and semiconductors to develop LEM's footprint and solutions in the e-mobility segment, especially focusing on the Integrated Current Sensors.

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