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The Evolution of Integrated Current Sensors Takes a Digital Path with First Sigma Delta Bitstream Output ICS

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The evolution of integrated current sensors (ICSs) has been slow and gradual. Current measurement technology has been developed increasingly over the years to focus on miniaturization of high-density components that can also deliver high levels of performance. Bulky sensors are inevitably losing their market share as more streamlined competitors enter the market.

The question is how to get ahead of the market and work out what users require. Finding out this information and then developing products to meet those needs demands a top-down and bottom-up approach, in which forecasting market trends sits alongside customer-based surveys. Having a genuinely close relationship with customers can pay significant dividends when operating in the semiconductors market. Customers usually know what they want from their ICSs and their feedback has proved to be essential in driving this evolutionary process.

Customer input has identified four key elements that they look for in current sensors:
Performance Over Temperature: This relates to drift and sensitivity offset and is the single most important feature.

Current Handling Capability: A small current sensor with an integrated primary has a limit on how much current it can support – 30 amps or 50 amps continuous – and technological breakthroughs come about by pushing these limits

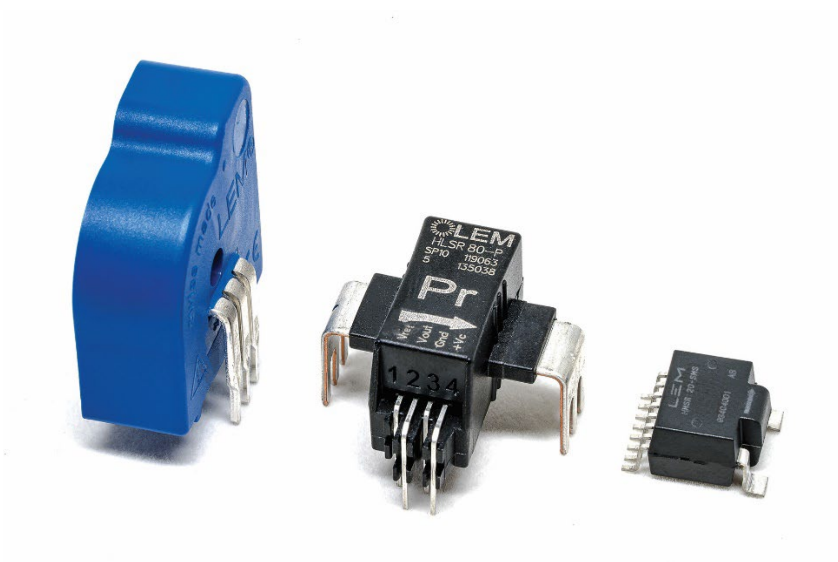
Over-Current Detection: A threshold for protection with over-current continually being monitored.

Insulation: Basic or reinforced insulation based on the system voltage can be a key factor in choice of sensor.

Closed Loop and Open loop

In recent years, users have benefited from closed loop Hall effect technology – LEM designed a special closed loop Application-Specific Integrated Circuit (ASIC) – and then open loop technology which represented a much lower cost solution. This technology led to the development of the HLSR Series of current transducers, a compact, low-cost PCB-mounted solution which took miniaturization to new levels.

Next on the evolutionary path came the HMSR, a high insulated ICS designed to satisfy the continuous market requirements of cost reduction, performance improvements and miniaturization. This new series saw the expansion of miniature current sensors for AC and DC isolated current measurement in highly demanding, switching power applications for commercial and industrial markets. Microcore-based open loop sensors with reinforced insulation and over-current detection, the HMSR units featured a low-resistance primary conductor (to minimize power losses), a miniature ferrite and a proprietary ASIC to allow direct current measurement and consistent insulation performance. All of these features made the HMSR ideal for high voltage applications that demand high precision and significant immunity against external fields. The micro magnetic core meant the device was particularly useful in power electronic applications that tend to experience high levels of disturbance.

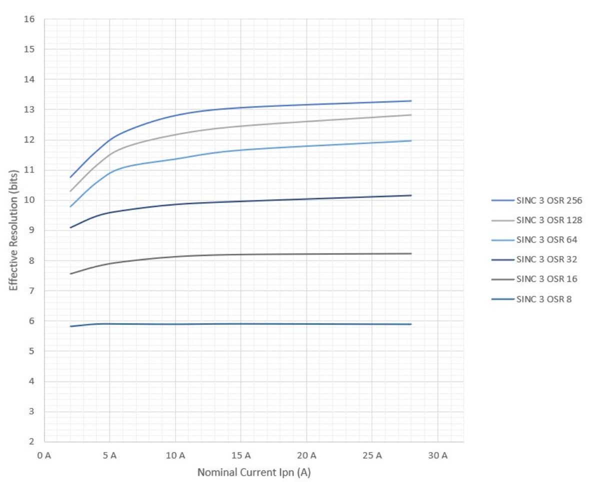


For these reasons, power electronics engineers have been using analogue HMSR sensors successfully for many years to measure DC and AC currents. They have enjoyed the benefits of a compact current sensor that has strong immunity to stray fields, reinforced isolation and a 300kHz bandwidth.

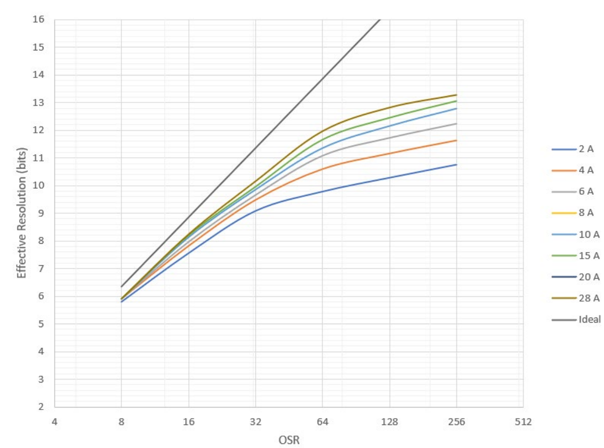
The latest solution in this continuing evolution of integrated current sensors is the HMSR DA, the first ICS on the market to offer Sigma Delta bitstream output while measuring low current and still delivering high resolution. Using a digital signal means a fixed delay is introduced on to the sensor's output (also known as response time) while quantization noise from the analogue-to-digital converter (ADC) is reduced significantly and the digital filter ensures an even better resolution of a Sigma Delta modulator (SDM) through noise shaping. Creating an ADC is simple by combining the modulator with a digital filter. Advantages of this include a reduced number of connections, each user being able to define their own system performance levels, and users being able to make two or more converters with different performances. This kind of architecture is particularly well suited to inexpensive CMOS processes.

Another of the characteristics of a digital current sensor is the settling time, also known as response time or delay. With a 10MHz clock and 128 oversampling ratio (OSR), the settling time of an SDM would be around 38.4us. Yet another benefit of using a Sigma Delta output bitstream is the flexibility offered, meaning that different digital low pass filters can be applied on the customer side, depending on the specific needs of the application. The user has a choice of using a high order slower filter if a high-resolution result is required or a smaller order faster signal for more rapid results but in lower resolution. These are some of the features that make the HMSR DA sensor superior to other digital output ICSs, including even a digital version of the HLSR units and the HO series of open loop current transducers.

HMSR DA effective resolution vs I_{PN}



HMSR DA resolution vs OSR (sinc3)



OSR can go down to 64 and still have above 11 bits of ER on most cases

Typical Applications

The market is receptive to an ICS delivering digital output because it can offer superior signal shape and lower noise levels at the same time with a reduced cost and smaller mechanical footprint. Typical applications for this kind of ICS include robotics, servo drives, sewing machines, CNC machine tools, welding equipment and automated guided vehicles (AGVs).

In recent times, the automotive sector has begun to show an interest in these sensors. R&D organizations and expert makers who feed into this market are excited by the fact that a digital solution is immune to external noise – including electric and magnetic noise – which is notorious for causing major difficulties when using analogue signaling.

On the Digital ICS Roadmap

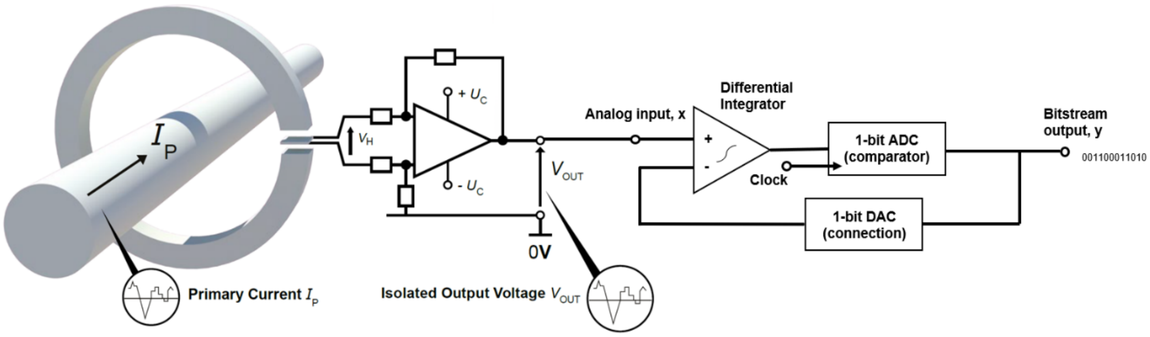
The HMSR DA sensor – seen as the first step along LEM's digital ICS roadmap – is the first of its kind on the market, offering users resolution of between 11 and 13 bits and a 10MHz clock.

The goal is to approach the current levels of traditional sensors using an integrated current sensor. The HMSR DA can support 30 to 36 amps of continuous current or 35 amps peak but subsequent generations would look to support 100 amps continuous while still being extremely compact and PCB mounted. Future versions will also aim to eliminate the need for a magnetic microcore, which will improve frequency response and do away with potentially problematic magnetic disturbances.

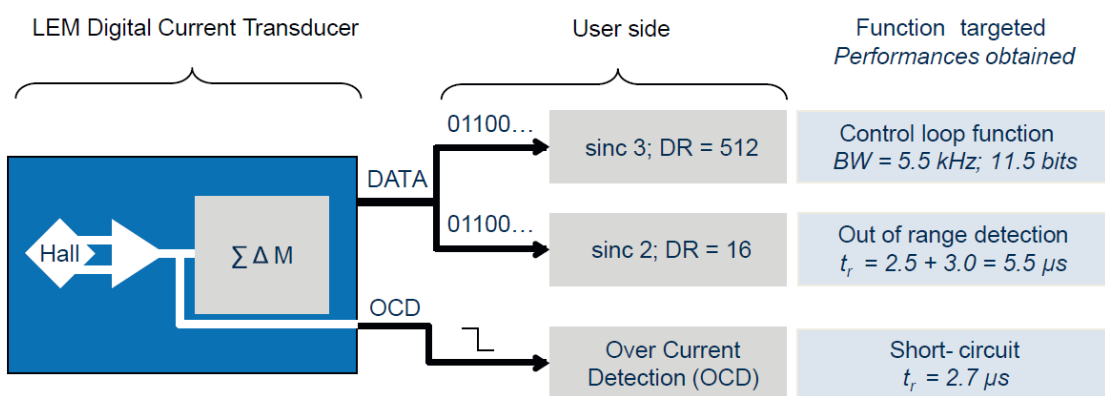
Ideal for applications that are prone to noise, distortion and interference, the HMSR DA achieves genuine cost savings by enabling customers to economize on their bill of materials (BoM). It does this by replacing in a single unit a much more complex and costly alternative system that would traditionally include a shunt resistor, a digital isolator, and low/high power supply circuitry with diodes and capacitors. The shunt is by no means the best solution because of thermal noise when dealing with high currents. Another problem is the space required to contain these separate pieces of equipment, whereas with the HMSR DA there is just one chip that does the same job of those three elements and directly delivers the output for customers. The new sensor also provides customers with features that are not available with those separate units, such as an ASIC and over-current detection that the shunt does not offer.

Different Ways of Formulating System Design

In addition, different output modes are available – single with the bitstream and the clock but also differential, eliminating the need to purchase output drivers to convert from single mode to differential. A solution based around RS-422 data and an LVDS (low-voltage differential signaling) receiver will deliver output and inverted output as well as clock and inverted clock, which is important when handling differential signals because it becomes possible to remove all noises while operating at low power and high speeds. With the new digital sensor, all these features are incorporated into a single unit.



It is expected that the HMSR DA sensor will enable engineers to look at new ways of formulating their system design. Customers will also be able to use filters to adapt the sensor to meet their specific requirements when working in any industry that has a need for clean signals but is traditionally subjected to electric noise, vibrations and magneto-electronic noise. Distortion and interference are significant problems in such highly demanding applications and only by pushing the boundaries in terms of digital output can truly ground-breaking developments that address the issues of noisy systems reach the market.



Digital output is still in its infancy and, even today, some customers may still be hesitant to go down this route. However, it is a powerful future trend that will become far more widespread in the coming years. That’s why it is essential to be on the ground floor with this technology and to encourage credible feedback from users on the viability of applying digital output solutions in their sector.