Current Sensing Solutions for Hybrid Electric Vehicles

With so much engineering design effort now being invested by so many of the Automotive world's R&D organisations in various forms of electric and hybrid-electric vehicle development, perhaps now is a good time to review a few of the basic needs of the design engineer when dealing with current measurement.

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Good current measurement techniques have long been identified as a basic requirement in the automotive industry. Now, with the advent of EVs (Electric Vehicles), HEVs (Hybrid-Electric Vehicles) and FCEVs (Fuel Cell Electric Vehicles) the idea of 'good current measurement' just isn't good enough any longer – now we need 'excellent current measurement!'

In a previous article [1] we looked at some of the more widely used methods of current measurement and then went on to discuss their various merits, and shortfalls. When we now consider the prospect of accurately measuring current, in some cases from many 100's of Amps through to perhaps a few milliamps, all via the same device, and then couple that with a pretty hostile environment, subject to electrical noise, vibration, mechanical shock, extremes of temperature, ingress of contaminants, etc…whilst also demanding a robust, reliable, galvanic isolation, high speed, yet low-cost device with extreme ease of integration allied with incredibly low power consumption – the open-loop Hall effect current transducer showed itself to be a truly formidable candidate.

Building upon the experience in the development of the current sensing technologies used on the New Zealand entrant for the 2007 Panasonic World Solar Challenge, Raztec engineers have cooperated with automotive industry leaders to develop sensors precisely targeted at some of the more demanding roles HEVs offer. When the design engineer is faced with selecting the correct solution for use in the various areas of electric vehicle design – accurate current measurement really is 'mission critical (see Figure 1).

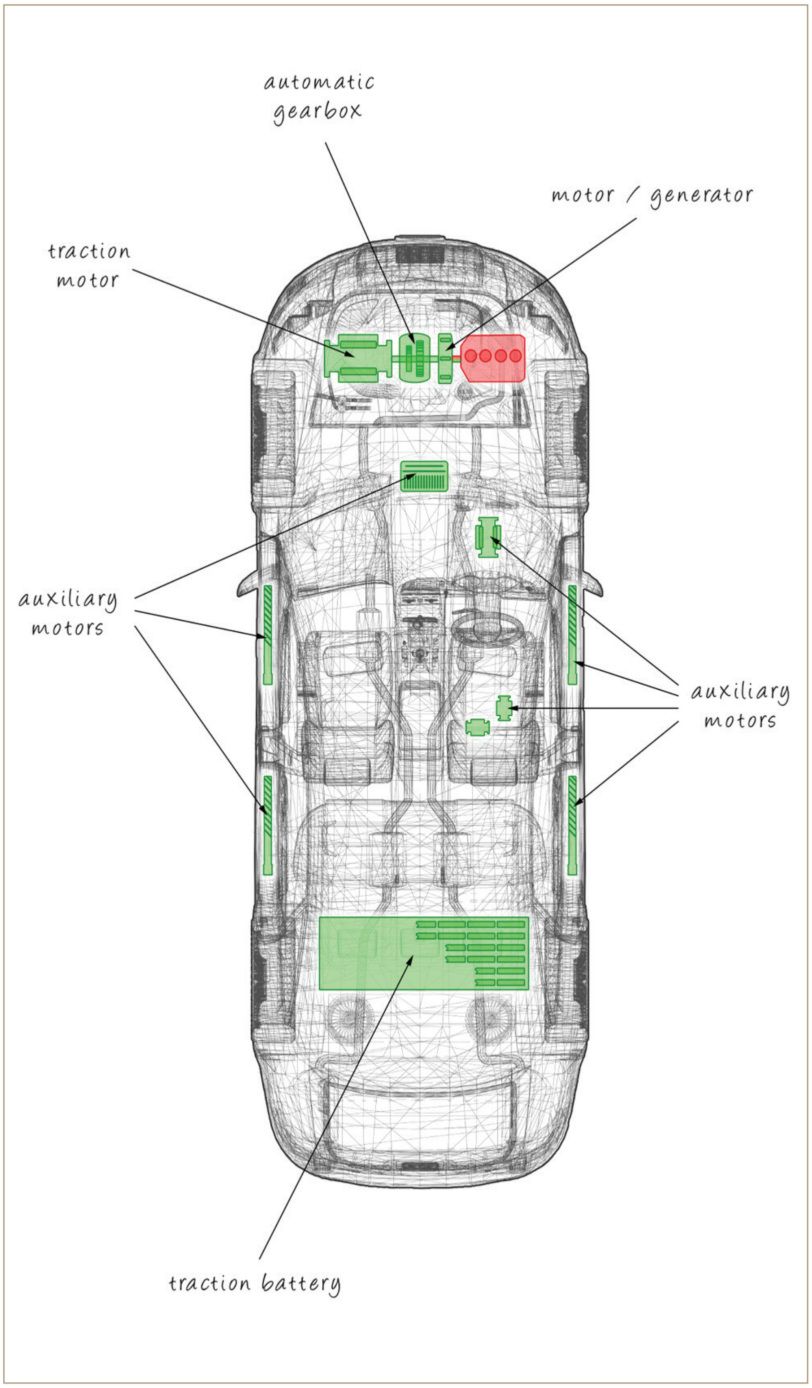

Figure 1: Typical HEV showing major areas requiring accurate current measurement

Traction motor current sensor

The function of the traction motor current sensor is to provide phase

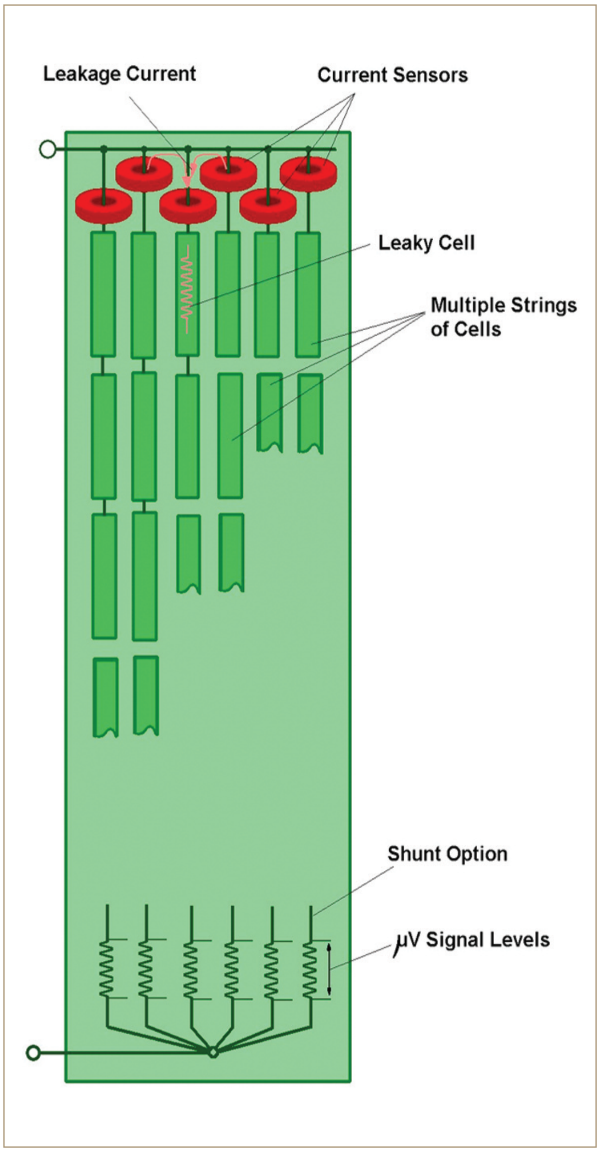

Figure 2: Traction battery string detail with alternative current measurement options

current measurement for the current loop within the traction controller itself. This essential parameter is critical for the stability and dynamic performance of the speed/torque controller. Key requirements are high frequency response (>100kHz), galvanic isolation to avoid issues related to HF common mode voltages, compact size, 5V operation, stable performance over the automotive temperature range, immunity to stray magnetic fields, low quiescent current, and modest price.

High performance open-loop current sensors that meet all of the above criteria, and additionally can be shaped to fit any tight physical requirements that the controller configuration may demand, will provide hybrid vehicle engineers the freedom to be more creative in their designs.

The drive to optimise efficiency leads to six or more speed gearboxes with electric actuators managing all gear shifts. To assure correct function, it is useful to monitor not only deflection but also the actuation forces or current flow in the actuators. This is a reasonably straightforward task, but again wide temperature range stability is important along with low installed cost, robust trouble-free design and small size.

Traction battery management

One of the most important requirements in hybrid vehicles is also one of the most demanding applications for current sensing; this is the measurement of battery current to determine its state of charge (SOC) and state of health (SOH). Absolutely critical for battery performance and longevity is the strict management of charge and discharge currents. Thorough management involves the measurement of current in each string of cells. With the trend to very small cell sizes, there will almost certainly be a multitude of series/parallel cell combinations which must be kept in equal state of charge. A weak string must be detected

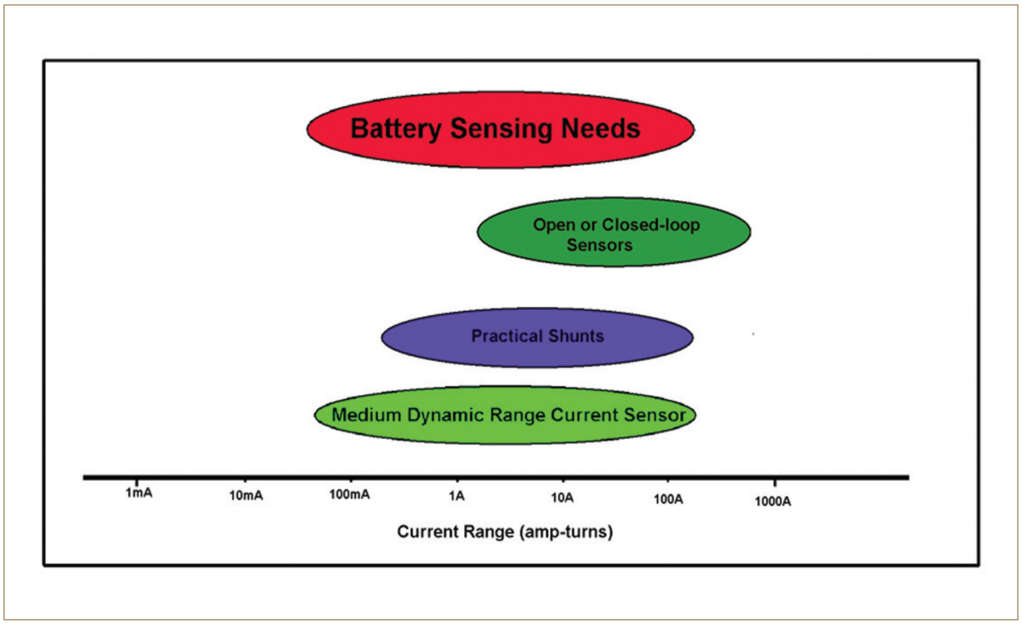

Figure 3: Current sensor types for battery sensing needs

immediately and corrected, before it causes the rest of the battery to be damaged (see Figure 2). This is particularly relevant for Lithium chemistry.

Ideally, we need a sensor that is able to detect a weak cell in a string. This weak cell would cause just a very small increase of float current of some 10's of mA, and at the same time the sensor must be capable of measuring discharge currents of 100's of Amps. No normal sensor based on Hall sensor technology is, at present, capable of doing this. However, this need is currently the matter of intense engineering development that should result in a suitable solution being generally available imminently.

A possible option for sensing string current could be to use shunts in the battery negative line, but their application is not straightforward. There will be common mode voltage differences that the interface amplifiers must cope with. The current waveforms will be noisy with noise levels far exceeding signal levels, and the dynamic range requirements are demanding.

For example, if the current range is 25mA to 150A and we choose a 0.5mΩ shunt, peak power dissipation is 11.25W, signal at 150A = 75mV, and signal at 25mA = 12.5µV. It is quite common to experience thermoelectric voltages of this magnitude resulting in signal corruption, thus a high quality amplifier would definitely be required, there may be volts of noise, and biasing resistors must be very stable as current flow will be both negative and positive.

Typical battery current sensor requirements would be galvanic isolation, easy/flexible application, current range from ~50mA to 150A, excellent performance stability throughout automotive temperature range, compact size, modest price, 5V operation, high immunity to stray fields, and very low quiescent current (Figure 3).

Monitoring of cranking currents

If the cranking currents are monitored, a great deal of diagnostic information becomes available such as the condition of the battery, the condition of the motor/generator, the condition and compression of the engine, and the condition of the starter circuit.

For this application, the sensor must be able to operate reliably and accurately over a wide temperature range. Galvanic isolation makes the monitoring of small signals that are superimposed on PWM voltages much less problematic. Key requirements include high frequency operation, galvanic isolation, compact size, 5V operation, very low quiescent current, stable over a wide range of temperatures, and modest price level.

Auxiliary motor current control includes power steering motors, cooling fans and water pump motors. The needs are very similar as those for traction control, but price and small size is more important.

Overload protection is applicable to protect seat adjust motors, window motors, power locks etc. Some intelligence could be included with current monitoring to help protect against trapping in power windows.

Conclusion

Whilst this article attempts to throw some light on the demands placed upon the design engineer when it comes to the best selection of a particular current sensing technology for HEV applications, it is far from being a comprehensive guide to all options. The intention of the author is to offer 'food for thought' regarding both the sensing needs of successful control design relating to HEVs, and to suggest alternatives to the type of current sensor historically used in the automotive industry. HEVs are going to require a complete re-think regarding those attributes of a current sensor deemed essential for 'excellent' performance. It's obvious that the immense interest now being shown in the development of these type of vehicle is going to continue driving product design and innovation. We already see the absolute need for a current sensor operating in the ~50mA through 150A range, you can be sure that any current sensor manufacturer worth his salt is going to be working on the early release of a device that extends this range – at both ends!

Literature

[1] Selecting the Most Effective Current Sensing Technology, Power Electronics Europe issue 8/2007, pages 27-31