

Weighing Current-Sensing Options in EV Applications

Due to the myriad technology alternatives out there, selecting the best EV current-sensing method becomes a challenge.

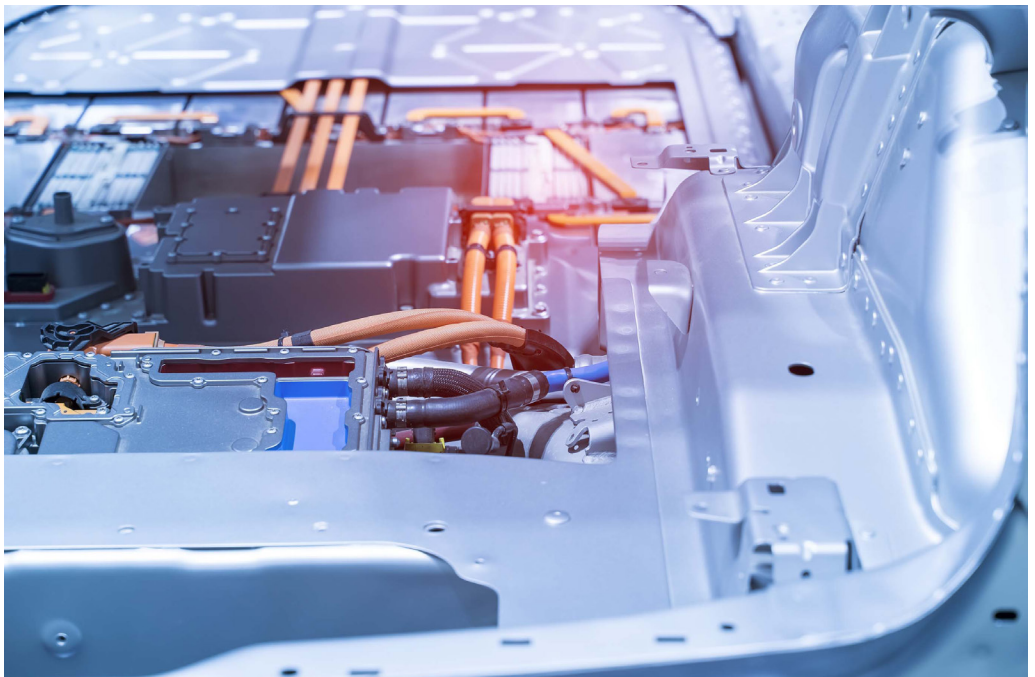
Multiple points within an electric vehicle (EV) or hybrid EV (HEV) require accurate and frequent current measurement, and a wide range of current-measuring options exist to address this need. When making a selection, the whole complex design environment of the vehicle should be considered, starting with a clear understanding of what must be measured, why, and how often, as well as the level of accuracy.

In addition, it's important to have a clear grasp of operating environment factors such as temperature range and vi-

bration. And, of course, the dimensional, weight, and cost budgets are equally critical in creating a practical solution.

While many EV components and systems handling relatively high-current DC and AC bear some resemblance to those deployed in industrial applications, the wide variation in operating conditions are much more demanding. For example, external operating conditions can easily range from 10 to 120°F, from sea level to 10,000 feet, and from nearly zero humidity to 100% humidity. Within a vehicle, the range of temperatures is even greater, and the potential for water immersion or exposure to hydrocarbons can't be ignored.

This image of a Tesla chassis and battery pack provides some idea of the space limitations in many EV applications as well as the large scale of battery packs—dual realities that shape current monitoring.



Fundamental Sensor Types

Four sensor types comprise a “short list” of choices in EV applications, though other options can also be relevant. They are the shunt resistor, Hall-effect sensor, fluxgate sensor, and current-sensing transformer. Each of the four has strengths and weaknesses, and some overlap in terms of the best choices for a given challenge. The strengths and weaknesses described here are broad generalities. Specific situations and circuits would likely bring additional ‘data sheet’ factors to the fore.

Shunt resistor

The shunt resistor works for both AC and DC currents. The resistor is installed parallel with the current path. Its great virtues are that it's generally simple, inexpensive, and available in many different form factors, including surface-mount devices for PCBs. All of these factors mean that shunt resistors are often widely used, with variants created for different types of current.

The problem with using a shunt resistor is that it is a resistor, with a power penalty proportional to the square of the current passing through. Thus, it's less suitable for high-current measurements.

And, of course, it does produce a voltage drop. As might be expected, that resistance can result in heating, sometimes to the point where heat dissipation needs to be considered in design. A further corollary for shunt resistors is that they're temperature sensitive and, in fact, their tendency to heat up can produce flawed measurements.

Hall-effect sensors

Hall-effect current sensors work well for AC and DC and high or low currents, but performance is limited with higher frequencies. By nature, they're smaller and well isolated, let alone accurate within certain current ranges. Importantly, they can be located anywhere on the current path, simplifying design, installation, and maintenance. Typically based on a semiconductor material, they're placed perpendicular to the magnetic field produced by a current. The voltage they generate is proportional to the current.

Unlike shunt resistors, they have no meaningful impact on the current being measured. But they also can be comparatively slow to respond, so they might miss transient behaviors. Furthermore, Hall-effect devices have a susceptibility to external or residual magnetic fields that can impact measurement accuracy. Its impact will depend on physical and electrical factors, which themselves may be transient.

There's also risk of temperature drift—for example, when ferrite core material changes behavior due to changing temperature. Time drift is a risk, too, as sensors age. Another significant consideration is that Hall-effect devices require their own power source.

Fluxgate sensors

Fluxgate current sensors can generally work with both AC

and DC, offering good isolation, good low-current performance, slightly greater size and complexity, and often better accuracy than Hall-effect devices. Fluxgate sensors, built around nonlinear magnetic materials, depend on changes in magnetization related to the magnetic field created by the current. This produces precise as well as highly linear results.

Current transformers

Current transformers convert a high primary current into a smaller secondary current, which makes them useful particularly when it comes to AC current measurement. Current transformers can measure high current while consuming very little power. Among the potential problems are magnetization of the core, which can affect accuracy, and inaccuracy at low frequencies.

Additional Sensor Considerations

A challenge with electric vehicles is that relatively high current (hundreds of amps) is often involved, though subsystems may use lower current. But systems, for the most part, must be both robust and precise, since EV efficiency, performance, and range depend on optimal energy management. And current management is central to that optimization.

Most battery packs deliver a voltage range of 300 to 450 V DC, and that current is delivered to one or more electric motors. Those higher voltages combined with higher current mean designers of EV systems are constantly balancing the need to provide current capacity with insulation and safety requirements, space limitations, weight, and costs. Those concerns necessarily extend to sensors.

Batteries are composed of scores or hundreds of individual lithium-ion or, sometimes, nickel-metal hydride cells. The crucial battery-management system (BMS) that looks after the health of individual cells as well as the efficient functioning of the whole pack must measure current and voltage to monitor and assess state of charge (SOC) and other factors that keep operations safe. This includes potentially monitoring series circuits between cells and parallel circuits between groups of cells.

Current monitoring in the BMS, including both delivery to the cells and current delivered by the cells, is vital. That's because cells vary and need to be kept functioning in balance as much as possible to avoid damage to any individual cell as well as deliver the best overall range and performance.

Those selecting technologies and specific devices must weigh a long list of factors that are both system-wide and task specific. Additional reading and product review is recommended.