Electronic Design

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Improve EV Battery System Performance with Integrated Resistor Dividers

Sponsored by Texas Instruments: Precision management of battery systems requires solutions such as resistor dividers, which offer remarkable specs to meet design demands.

The vision of electric vehicles (EVs) as a primary transportation platform is slowly coming of age. EVs are moving away from being seen as eclectic to having a presence next to their fueled counterparts.

With an EV battery assembly costing upwards of $30,000, tending to these systems to maximize life expectancy, reliability, and safety is a critical directive.

Rising to the challenge of modern battery assembly management is the battery-management system (BMS). These are essentially the epitome of battery tending. By employing such advanced BMS, EVs can extract every coulomb of electricity, optimize performance, and extend battery life as long as possible.

Furthermore, tapping a 400-V, 1000-A+ battery system for other components that require a few milliwatts requires edge of the envelope technology. This is where the integrated resistor-divider chip comes to the rescue.

The Advantages of Resistor Dividers

Resistors, in general, are notoriously loose in tolerance, even precision varieties. But the real issue is that getting discrete resistors with the same exact parameters (resistance, temperature excursion, load and shelf life, and aging) is time-consuming and expensive—and sometimes even impossible.

One might ask why a few tenths of milliohms, or similar minuscule differences in resistors, would make a difference.

It circles back to precision. When chaining (series or parallel) such devices, any deviations in tolerances get compounded along the circuit chain. When working with voltages and amps in the hundreds, component proximity also becomes an issue.

All of this means that long-chain discrete resistor circuits aren't ideal for EV BMS due to the system's critical performance requirements.

The Solution to Resistor Management

One solution to managing resistor parameters comes in the form of integrated components, i.e., semiconductor wafers. In this case, thin-film silicon chromium (SiCr).

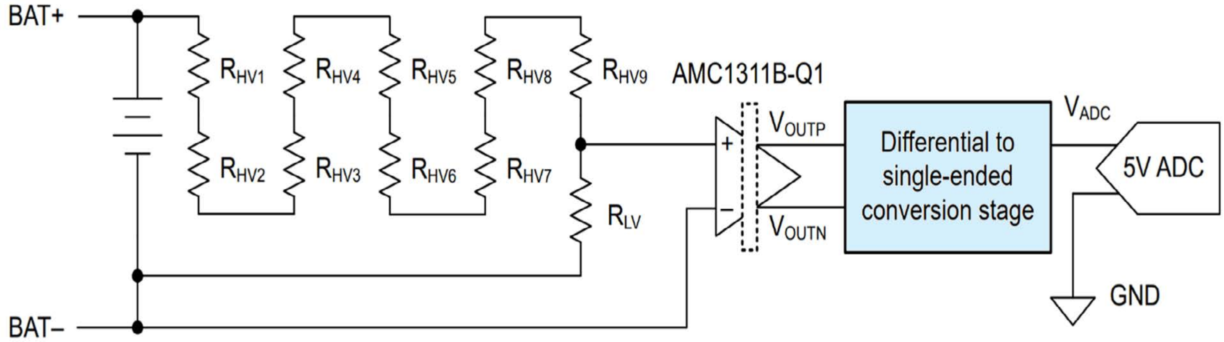
As it turns out, integrating the resistor into the substrate has several advantages. While the chip parameters on a layer of material don't necessarily display tighter specification than their discrete brethren, they do present a remarkably identical matching property. That means if a resistor layer is created, even if the error factor is high, it's the same for all devices within that layer.

Therefore, once the right specifications are dialed in for that part of the design, it becomes a non-variable. That's because all of the resistors on that chip will have the same properties.

This eliminates the time and costs associated with repeating the parameter matching process of individual long-chain discretes. It also manages other variables of discretes, such as temperature drift, stability, load life, creepage, and the need for high voltage and current isolation. And they offer a much smaller footprint.

The Application

Other than precision management of the battery system's parameters, there's the need to tap off voltages from the bat-



1. The resistor ladder reduces voltages to the desired output to drive the op amp.

teries to power the rest of the vehicle electronics. A large majority of EV peripheral devices (such as analog-to-digital converters, or ADCs) are controlled by and use low voltage—typically 5 and 12 V DC. Obviously, the only place to find power for them is from the battery system.

With a precision integrated long-chain resistance string, all resistors will be identical in parameters. Therefore, when creating a voltage-divider circuit, the designer can be confident that the output of the various take-off points will be the same for all resistors on the wafer.

In addition, integrated resistor dividers reduce collateral effects such as leakage or parasitics. Plus, there are fewer solder and other connection points. That matters because a number of low-voltage circuits populate EVs. They must be protected from both direct and incidental high voltages and currents provided by the battery system.

A long-standing solution for that has been the voltage divider. Advances in substrates and components have developed long-chain chip resistors that can handle extremely high voltages, up to 1,400 V DC for sustained operation and 4,000 V DC over a 60-second HiPOT test. This is accomplished by using a SiO_2 insulative layer to encapsulate the resistors.

For digital device drive voltages, they can be picked off at any point of the divider chain, as required by the device *(Fig. 1)*.

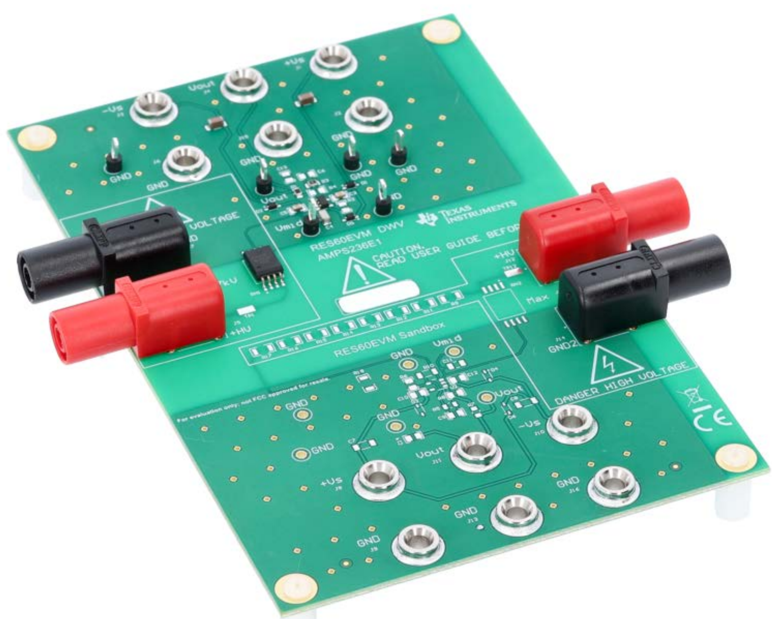
Resistor-Divider Performance

These precision resistor dividers have remarkable specifications. They're AEC-Q200, grade-1 qualified for automotive use. This means they meet a temperature specification of −40 to +125°C for under-the-hood applications. They also offer much better precision, lower thermal noise, and low drift over their life when compared to discrete resistors, as the following specifications:

- Initial ratio matching precision: ±0.1% (max)
- Low drift: ±1 ppm/°C (typ)
- Accurate ±0.2% across aging and temperature
- Low thermal noise (1 kHz) thin-film resistors:
  - 30 nV/√Hz (210:1 ratio)
  - 25 nV/√Hz (310:1 ratio)
  - 22 nV/√Hz (410:1 ratio)
  - 20 nV/√Hz (500:1 ratio)
  - 18 nV/√Hz (610:1 ratio)
  - 14 nV/√Hz (1000:1 ratio)

Other specifications, of course, play a part. All need to be designed with respect to the harshness of their physical environment.

In many EV applications, heat is a primary design constrict. There are two heat metrics in under-the-hood applications: thermal generated by the device, and environmen-



2. Operation of the RES60 resistor divider can be tested using the RES60A-Q1 evaluation module.

tal. This is discussed in IEC 61010 standard for safety, which is important here because of the high voltages and current in the working environment.

Normalizing Specifications

Electric vehicles have unique considerations that put a lot of pressure on the power platform. From safety to multiple voltages.

to economics, EV battery and power systems need to meet a diverse set of demands.

With EVs, specifications can be normalized for each chip created on the same wafer. This not only simplifies the design, but also shortens the production cycle, thus saving costs. And to ensure best design practices, the RES60A-Q1 evaluation module *(Fig. 2)* is available to help users easily evaluate and test the functionality of the RES60 device.