

# High-Accuracy Isolated Voltage Measurements in HEV/EV Subsystems Using AMC1311-Q1 and AMC1211-Q1



## Introduction

Most electric vehicles (EV) and hybrid electric vehicles (HEV) have multiple high-voltage (HV) powertrain subsystems, including:

- **Traction inverter & motor control** – drives 3-phase traction motor by converting HV DC battery to multi-phase AC
- **On-board charger (OBC)** – charges HV DC battery by converting AC line voltage to DC
- **DC/DC converters** – converts HV DC battery voltage to low voltage auxiliary power supplies for various electric loads such as infotainment systems, headlights, etc.
- **Battery management systems (BMS)** – monitors, controls and protects the charging and discharging of HV DC battery

Figure 1 shows the relationship between these subsystems in a typical HEV/EV system.

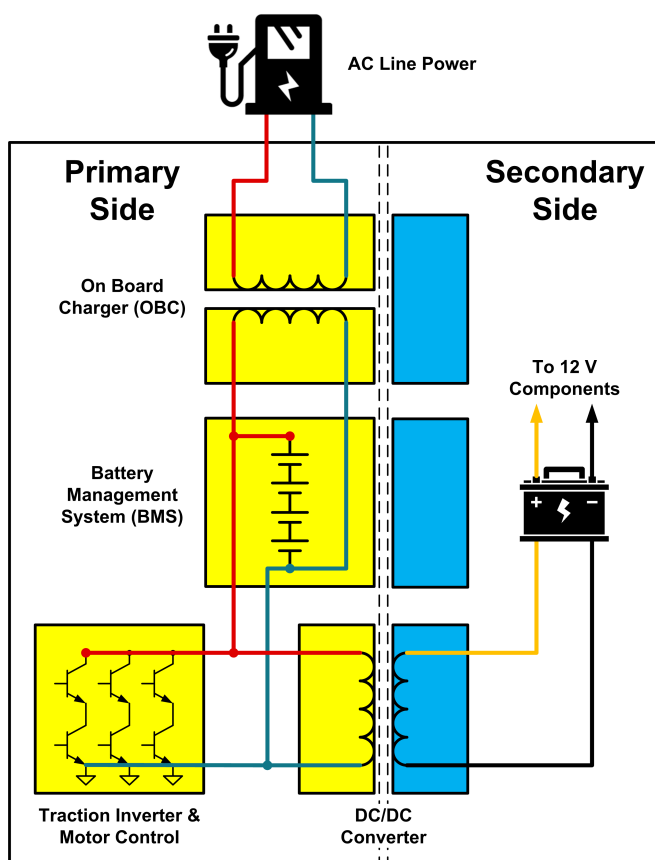


Figure 1. HEV/EV Powertrain Block Diagram

Since HEV/EVs operate at high voltages in very harsh environments, high-performance isolated voltage and current measurement solutions are critical for maintaining powertrain efficiency and long-term reliability. To meet these performance and isolation requirements, Texas Instruments has released the **AMC1311-Q1**, an AEC-Q100 qualified, high-accuracy, reinforced isolation amplifier.

## AMC1311-Q1 for Isolated Voltage Measurements

While Texas Instruments offers a wide variety of **isolated amplifiers** and **modulators** for voltage and current measurements, the AMC1311-Q1 has several features that make this device particularly well-suited for isolated voltage sensing. The AMC1311-Q1 offers high input impedance (1 GΩ typical), a wide input full-scale range (0–2 V) and excellent DC accuracy and drift performance, enabling high performance resistor-divider-based voltage measurements over a wide temperature range.

Additionally, the AMC1311-Q1 offers high common-mode transient immunity (CMTI) and several fail-safe output modes to ensure reliable and accurate operation, even in noisy automotive environments.

## AMC1311-Q1 in an HEV/EV Subsystem

In any typical HEV/EV subsystem, some isolated voltage measurements are required to ensure proper operation. For example, a traction inverter requires an isolated voltage measurement between the positive and negative bus voltages ( $\pm V_{BUS}$ ), as shown in Figure 2.

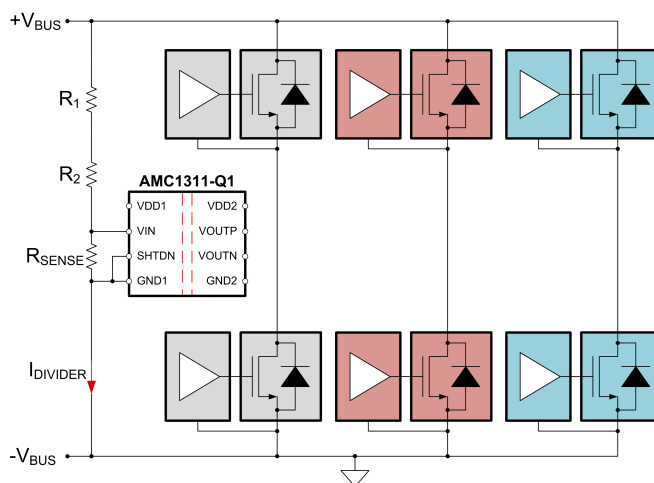


Figure 2. Traction Inverter Block Diagram

This bus voltage is commonly measured using a resistor divider network ( $R_1$ ,  $R_2$  and  $R_{\text{SENSE}}$  in [Figure 2](#)). This network divides the bus voltage down to a level that is within the isolated amplifier's linear input range. The values of these resistors can be calculated from the subsystem parameters and the isolation amplifier's specifications.

### Resistor Divider Calculations

The values of  $R_1$ ,  $R_2$  and  $R_{\text{SENSE}}$  can be calculated from the following parameters:

- Amplifier's maximum input voltage ( $V_{\text{IN}}$ )
- Maximum resistor divider current ( $I_{\text{DIVIDER}}$ )
- Bus voltage ( $V_{\text{BUS}}$ )

[Table 1](#) summarizes these system parameters and how each are determined, as well as provides some typical values.

**Table 1. Typical Inverter System Parameters**

Parameter	Value	Choosing a Value
$V_{\text{BUS}}$	800 V	EV bus voltage
$V_{\text{IN}}$ (max)	2 V	Maximize amplifier's allowable input voltage for best dynamic range
$I_{\text{DIVIDER}}$ (max)	100 $\mu\text{A}$	Tradeoff between size of $R_{\text{SENSE}}$ and reducing heat dissipation across $R_{\text{SENSE}}$

The required value of  $R_{\text{SENSE}}$  is calculated using Ohm's law. Assuming  $R_1 = R_2$ , the values of  $R_1$  and  $R_2$  can be calculated as shown below:

$$R_{\text{SENSE}} = V_{\text{IN}} / I_{\text{DIVIDER}} = 2 \text{ V} / 100 \mu\text{A} = 20 \text{ k}\Omega \quad (1)$$

$$R_1, R_2 = (V_{\text{BUS}} - V_{\text{IN}}) / 2 \cdot I_{\text{DIVIDER}} \quad (2)$$

$$R_1, R_2 = (800 \text{ V} - 2 \text{ V}) / 2 \cdot 100 \mu\text{A} = 3.99 \text{ M}\Omega \quad (3)$$

The 20 k $\Omega$  sense resistor in parallel with the AMC1311-Q1's 1 G $\Omega$  input impedance results in a negligible 0.002% error contribution.

### AMC1311-Q1 vs AMC1311B-Q1

Texas Instruments offers two versions of the AMC1311-Q1. These devices have different performance levels depending on the needs of the system:

- Standard grade (AMC1311-Q1)
- High grade (AMC1311B-Q1)

[Table 2](#) summarizes the differences between the two devices. Please note that the minimum and maximum specifications of the AMC1311-Q1 in [Table 2](#) apply from  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .

**Table 2. AMC1311-Q1 vs AMC1311B-Q1**

Parameter	AMC1311-Q1	AMC1311B-Q1
Bandwidth (kHz) (min / typ)	100 / 220	220 / 275
Initial Gain Error (%) (max)	$\pm 1$	$\pm 0.3$
Gain Error Drift (ppm/ $^\circ\text{C}$ ) (max)	$\pm 30$ (typ)	$\pm 45$
Initial Input Offset (mV) (max)	$\pm 9.9$	$\pm 1.5$
Offset Drift ( $\mu\text{V}/^\circ\text{C}$ ) (max)	$\pm 20$ (typ)	$\pm 15$
High-Side Supply Voltage (max)	4.5 V to 5.5 V	3 V to 5.5 V
CMTI (kV/ $\mu\text{s}$ ) (min / typ)	15 / 30	75 / 140
Price (1kU, \$USD)	<a href="#">Click here</a>	

Additionally, Texas Instruments offers the [AMC1211A-Q1](#), a basic isolated amplifier that is pin-compatible to the AMC1311x-Q1 devices. The AMC1211A-Q1 offers the same performance as the AMC1311B-Q1 in [Table 2](#), except for a lower CMTI of 30 kV/ $\mu\text{s}$  (min) and 45 kV/ $\mu\text{s}$  (typ). Also, the AMC1211A-Q1's working voltage is 1 kV<sub>RMS</sub>, compared to 1.5 kV<sub>RMS</sub> for the AMC1311x-Q1 devices.

### Alternative Measurement Methods

While the AMC1311-Q1 isolation amplifier offers excellent performance and high input impedance for isolated voltage measurements, alternative measurement methods exist.

One such method uses an isolated delta-sigma modulator that sends a digital bitstream across the isolation barrier to be filtered by a microcontroller (MCU) or field-programmable gate array (FPGA). Another method uses a [precision SAR or delta-Sigma ADC](#) and a digital isolator. [Table 3](#) highlights some devices recommendations for these alternative methods.

**Table 3. Device Recommendations for Alternative Isolated Voltage Measurement Methods**

Device	Description
<a href="#">AMC1304-Q1</a>	Isolated delta-sigma modulator
<a href="#">ADS1118-Q1</a> + <a href="#">ISO7741-Q1</a>	16-bit delta-sigma ADC + high speed, 3/1 digital isolator

### Conclusion

As the HEV and EV market continues to grow, so too will the need for high-performance isolated voltage measurements. Texas Instruments' AMC1311-Q1 is a high-input impedance, AEC-Q100 qualified, reinforced isolation amplifier specifically designed to provide accurate isolated voltage measurements that help maintain reliable vehicle operation.

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