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.

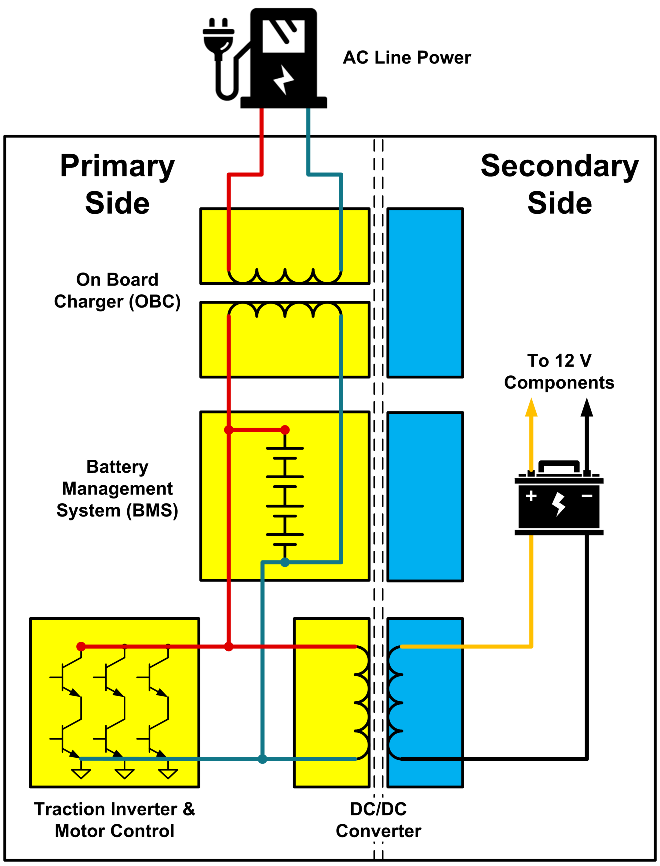

Figure 1. HEV/EV Powertrain Block Diagram

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.

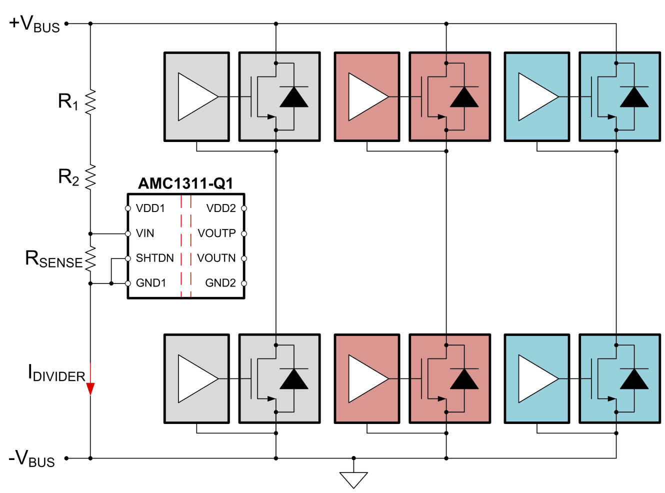

Figure 2. Traction Inverter Block Diagram

This bus voltage is commonly measured using a resistor divider network (R_1, R_2 and R_{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_{SENSE} can be calculated from the following parameters:

- Amplifier's maximum input voltage (V_{IN})
- Maximum resistor divider current ($I_{DIVIDER}$)
- Bus voltage (V_{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_{BUS}	800 V	EV bus voltage
V_{IN} (max)	2 V	Maximize amplifier's allowable input voltage for best dynamic range
$I_{DIVIDER}$ (max)	100 µA	Tradeoff between size of R_{SENSE} and reducing heat dissipation across R_{SENSE}

The required value of R_{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:

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

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

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

The 20 kΩ sense resistor in parallel with the AMC1311-Q1's 1 GΩ 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°C to +125°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)	±1	±0.3
Gain Error Drift (ppm/°C) (max)	±30 (typ)	±45
Initial Input Offset (mV) (max)	±9.9	±1.5
Offset Drift (µV/°C) (max)	±20 (typ)	±15
High-Side Supply Voltage (max)	4.5 V to 5.5 V	3 V to 5.5 V
CMTI (kV/µs) (min / typ)	15 / 30	75 / 140
Price (1kU, $USD)	Click here	

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/µs (min) and 45 kV/µs (typ). Also, the AMC1211A-Q1's working voltage is 1 kV_{RMS}, compared to 1.5 kV_{RMS} 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
AMC1304-Q1	Isolated delta-sigma modulator
ADS1118-Q1 + ISO7741-Q1	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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