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.

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 (±VBUS), as shown in Figure 2.
This bus voltage is commonly measured using a resistor divider network \( (R_1, R_2, \text{ and } R_{\text{SENSE}} \text{ in Figure } 2) \). 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

<table>
<thead>
<tr>
<th>Parameter ( V_{\text{BUS}} )</th>
<th>Value ( 800 \text{ V} )</th>
<th>Choosing a Value</th>
<th>EV bus voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{\text{IN}} ) (max)</td>
<td>2 V</td>
<td>Maximize amplifier’s allowable input voltage for best dynamic range</td>
<td></td>
</tr>
<tr>
<td>( I_{\text{DIVIDER}} ) (max)</td>
<td>100 ( \mu \text{A} )</td>
<td>Tradeoff between size of ( R_{\text{SENSE}} ) and reducing heat dissipation across ( R_{\text{SENSE}} )</td>
<td></td>
</tr>
</tbody>
</table>

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:

\[
R_{\text{SENSE}} = \frac{V_{\text{IN}}}{I_{\text{DIVIDER}}} = \frac{2 \text{ V}}{100 \mu \text{A}} = 20 \text{ kΩ} \quad (1)
\]

\[
R_1, R_2 = \frac{(V_{\text{BUS}} - V_{\text{IN}}) / 2 \cdot I_{\text{DIVIDER}}}{2 \cdot 100 \mu \text{A}} \quad (2)
\]

\[
R_1, R_2 = \frac{(800 \text{ V} - 2 \text{ V}) / 2 \cdot 100 \mu \text{A}}{2 \cdot 100 \mu \text{A}} = 3.99 \text{ MΩ} \quad (3)
\]

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>
<thead>
<tr>
<th>Parameter</th>
<th>AMC1311-Q1</th>
<th>AMC1311B-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (kHz) (min / typ)</td>
<td>100 / 220</td>
<td>220 / 275</td>
</tr>
<tr>
<td>Initial Gain Error (%) (max)</td>
<td>±1</td>
<td>±0.3</td>
</tr>
<tr>
<td>Gain Error Drift (ppm/°C) (max)</td>
<td>±30 (typ)</td>
<td>±45</td>
</tr>
<tr>
<td>Initial Input Offset (mV) (max)</td>
<td>±9.9</td>
<td>±1.5</td>
</tr>
<tr>
<td>Offset Drift (µV/°C) (max)</td>
<td>±20 (typ)</td>
<td>±15</td>
</tr>
<tr>
<td>High-Side Supply Voltage (max)</td>
<td>4.5 V to 5.5 V</td>
<td>3 V to 5.5 V</td>
</tr>
<tr>
<td>CMTI (kV/µs) (min / typ)</td>
<td>15 / 30</td>
<td>75 / 140</td>
</tr>
<tr>
<td>Price (1kU, $USD)</td>
<td>Click here</td>
<td></td>
</tr>
</tbody>
</table>

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\( \text{RMS} \), compared to 1.5 kV\( \text{RMS} \) 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>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
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<tbody>
<tr>
<td>AMC1304-Q1</td>
<td>Isolated delta-sigma modulator</td>
</tr>
<tr>
<td>ADS1118-Q1 + ISO7741-Q1</td>
<td>16-bit delta-sigma ADC + high speed, 3/1 digital isolator</td>
</tr>
</tbody>
</table>

**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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