

TI Designs

Shunt-Based, 200-A Peak Current Measurement Reference Design Using Reinforced Isolation Amplifier



Description

This TI Design provides a complete reference solution for isolated current measurement using external shunts, reinforced isolation amplifiers, and an isolated power supply. The shunt voltage is limited to 25 mV maximum. This limit reduces power dissipation in the shunt to enable a high current measurement range up to 200 A. The shunt voltage is amplified by an instrumentation amplifier configuration with a gain of 10 to match the input range of the isolation amplifier for a better signal-to-noise ratio (SNR). The output of the isolation amplifier is level shifted and scaled to fit the complete input range of 3.3-V analog-to-digital converters (ADCs). This design uses a free-running transformer driver that operates at 410 kHz to generate an isolated supply voltage in a small form factor to power the high voltage side of the circuit.

Resources

TIDA-00912	Design Folder
AMC1301	Product Folder
OPA2376	Product Folder
OPA376	Product Folder
REF2033	Product Folder
SN6501	Product Folder
LM4040-N	Product Folder

Design Features

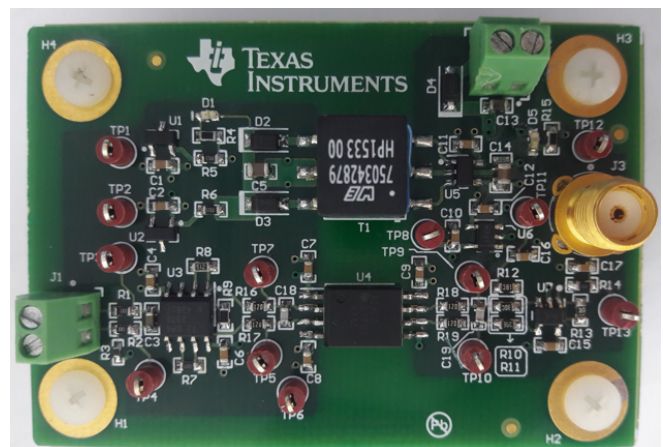
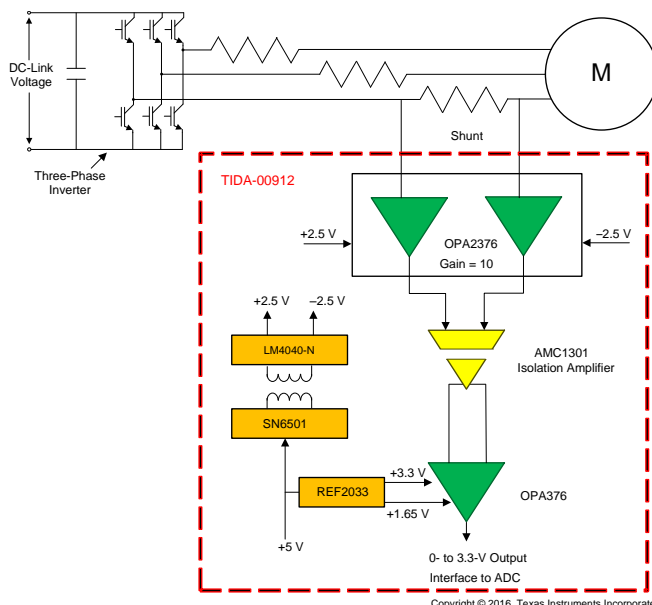
- Shunt-Based, 200-A Peak Current Measurement Solution With Reinforced Isolation
- Limiting Shunt Voltage to 25 mV Reduces Power Dissipation
- High-Side Current Sense Circuit With High Common-Mode Voltage of 1500-V_{PEAK}; Supports up to 690-V AC Mains-Powered Drives
- Calibrated AC Accuracy of < 1% Across Temperatures of -25°C to 85°C
- Interfaces Directly With Differential or Single-Ended ADC
- Small-Form-Factor, Push Pull-Based Isolated Power Supply to Power High-Side Circuit
- Built-in 1.65-V_{REF} to Level Shift Output

Featured Applications

- Active Front-End Converters
- Uninterruptable Power Supply (UPS)
- Variable Speed Drives



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1 System Overview

1.1 System Description

Current measurement is an inherent part of any inverter-driven application such as motor control, uninterruptible power supplies (UPSs), active front-end converters, and so forth. Motor control algorithms like vector control and direct torque control require current sensing for control purposes. Active front-end converters also measure grid current to ensure that the current is in phase with the voltage. Current measurement in UPS is used to control the battery charging current as well as the inverter operation and overload protection.

Active front-end converters are often used in high-performance adjustable speed drives where frequent acceleration and de-acceleration is required. Active front-end converters have many advantages like constant DC voltage, fast dynamic response, unity power factor, low harmonic distortion, and bidirectional power flow. Generally, two control methods have been proposed for pulse-width modulation (PWM) rectifiers: voltage-oriented control and direct power control. The main goal of these control techniques is to reduce the current harmonics and to regulate the DC bus voltage.

An Inverter for motor control requires four kinds of sensors to detect motor phase voltages, motor currents, DC-bus current, and DC-link bus voltages. The motor line currents are measured for torque control and field oriented control algorithms. The DC bus currents are optional and are measured for safety, diagnostic purposes, and power monitoring purposes. [Figure 1](#) shows the current sensor locations in the inverter.

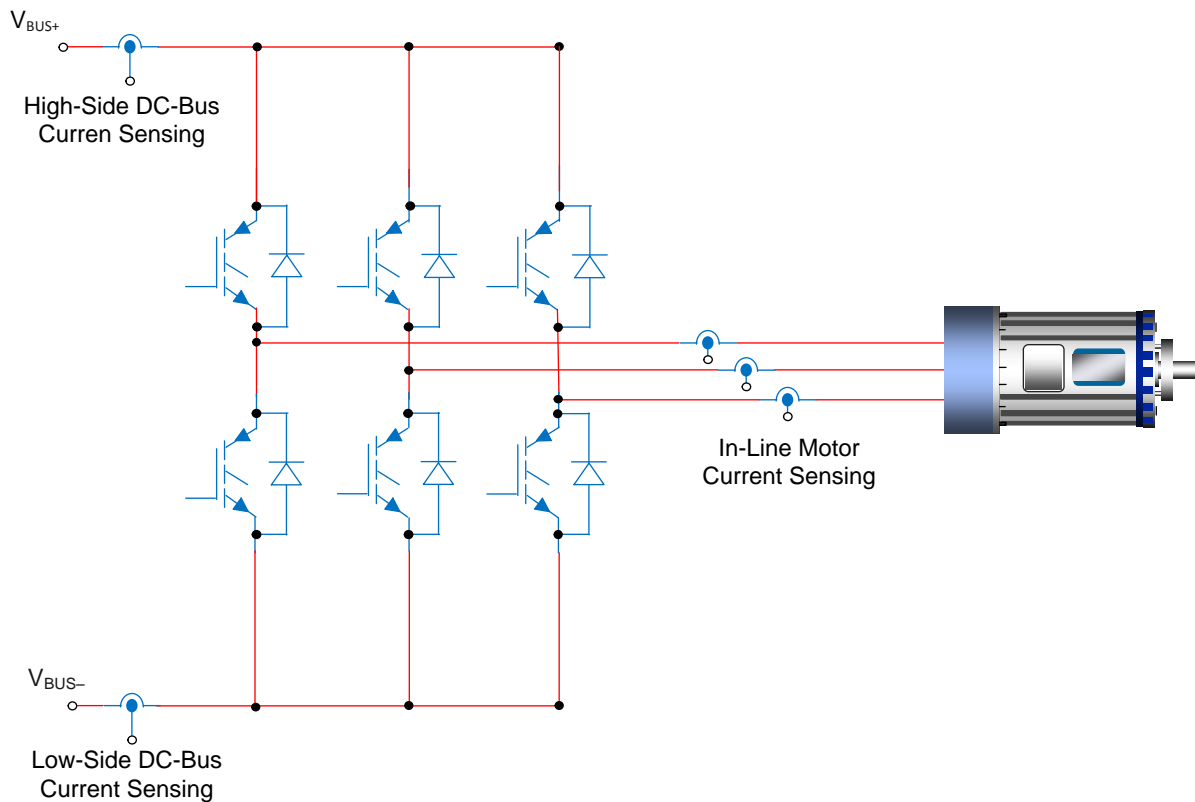


Figure 1. Current Sensor Locations in Inverter

Multiple solutions exist today to measure current like Hall effect sensors, flux gate sensors, current transformers, and shunts. Magnetic-based solutions inherently offer isolation benefits and have the capability to measure higher currents; however,, magnetic-based solutions can be expensive. The shunts are usually limited to measure currents less than 50 A because of power dissipation in the shunt. This TI Design provides a low-cost solution to enhance the current measurement range using a 125- $\mu\Omega$ shunt up to 200 A_{PK} with isolation amplifier and signal conditioning circuit. The voltage across the shunt is limited to 25 mV, which is subsequently amplified to 250 mV by a gain stage before fed to the isolation amplifier. The complete circuit design with simulation and test results are covered in this design guide. The current measurement range can be further enhanced by reducing the value of the shunt.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Maximum current	200 A _{PK}
Current type	AC and DC
Common-mode voltage	1500 V _{PK}
Calibrated accuracy	< 1%
Common-mode transient immunity	15 kV/ μ s
Output	112 mV to 3.19 V
Operating ambient temperature	-25°C to 85°C
Features	Isolated current sense outputs designed to be interfaced to 3.3-V built-in ADCs of MCUs

1.3 Block Diagram

Figure 2 shows the block diagram for current measurement using a shunt. The main parts of this design consists of a gain-stage succeeding shunt using a precision op amp (OPA2376), a reinforced isolation amplifier (AMC1301), and a differential to single-ended conversion using the OPA376.

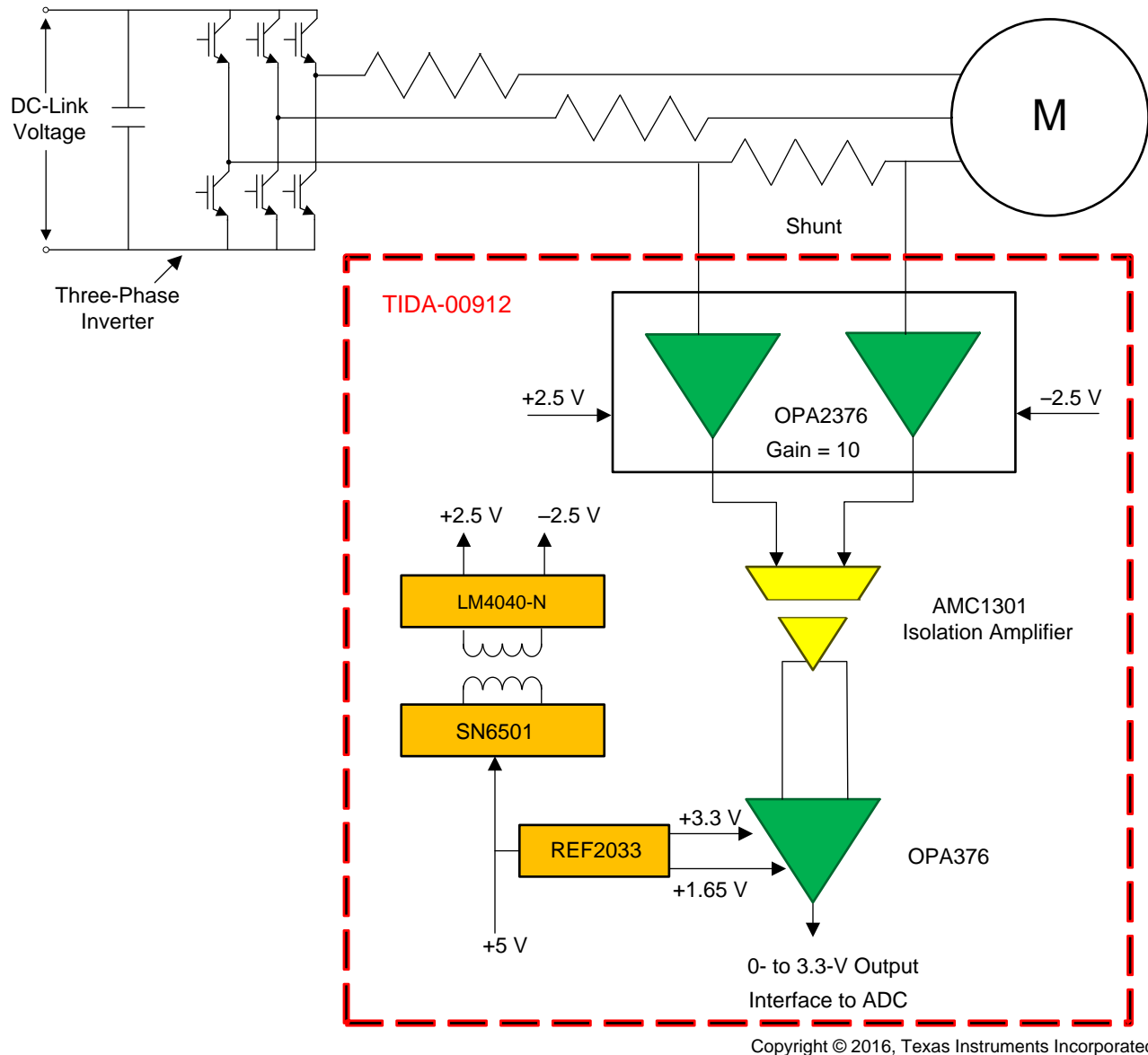


Figure 2. Block Diagram for Current Measurement Using Shunt

The front-end gain stage is designed using the OPA2376 in an instrumentation amplifier topology, which enables it to accept differential input and have differential output. The overall gain of this stage is set to 10 for amplifying the ± 25 mV across the shunt to ± 250 mV to fit the input range of the isolation amplifier. The OPA2376 is supplied with ± 2.5 V.

The next stage involves the AMC1301, which provides galvanic isolation of up to $7000 V_{PEAK}$ between the high-voltage and low-voltage circuit. The AMC1301 has a fixed internal gain of 8.2 and accepts a maximum input of ± 250 mV to operate in a linear region. The AMC1301 is biased by ± 2.5 V on the high-voltage side and by 3.3V on the low voltage side. The output of AMC1301 can be given directly to a differential ADC. However, in this design, the output of the AMC1301 device is level shifted and attenuated by the OPA376 device. This process converts the output to a voltage signal between 0 V and

3.3 V for interfacing to single-ended ADCs. The output of the isolation amplifier is fed to the level shifter circuit. This circuit converts the differential output from the AMC1301 device to a single-ended signal along with the level shift to match the input range of the single-ended ADC. This task is achieved by using the precision op amp OPA376 and the final output is mapped on to 0 V to 3.3 V. This op amp is powered using 3.3 V with a reference voltage of 1.65 V for level shifting.

The power supply circuit consists of the REF2033 and the SN6501.

The REF2033 reference derives 3.3 V and 1.65 V from the 5-V supply. The 3.3 V is used to power the OPA376 op amp and the low-voltage side of the AMC1301 device. The 1.65 V is used as a reference voltage for the OPA376 to map the output of the isolation amplifier to 0 V to 3.3 V.

The SN6501 device drives the transformer to generate an isolated power supply for powering the high-voltage side of the circuit, which consists of the front-end gain stage and the high side of the AMC1301 device. The SN6501 is powered from the 5-V input supply.

1.4 Highlighted Products

This TIDA-00912 reference design features the following devices, which were selected based on their specifications. The key features of the highlighted products are mentioned as follows. For more information on each of these devices, see their respective product folders at www.ti.com or click on the links for the product folders on the first page of this reference design.

1.4.1 OPA376 and OPA2376

The OPA376 family represent a new generation of low-noise operational amplifiers with the eTrim™ System Reference Voltage Trim, which offers outstanding AC precision and AC performance. Rail-to-rail input and output, low offset (25 μ V max), low noise (7.5 nV/ $\sqrt{\text{Hz}}$), quiescent current (950 μ A max), and a 5.5-MHz bandwidth make this part very attractive for a variety of precision and portable applications.

In this design, the OPA2376 works as an instrumentation amplifier for the front-end gain stage and in the level shifter circuit.

This op amp has been chosen for this design for its extremely low voltage offset, low temperature drift, rail-to rail output, low noise, and low cost.

1.4.2 AMC1301

The AMC1301 is a precision isolation amplifier with an output separated from the input circuitry by a silicon dioxide (SiO₂) barrier that is highly resistant to magnetic interference. This barrier has been certified to provide galvanic isolation of up to 7000 V_{PEAK} according to VDE-V 0884-10 and UL1577. When using in conjunction with isolated power supplies, this device prevents noise currents on a high common-mode voltage line from entering the local ground and interfering with or damaging sensitive circuitry.

The excellent performance of this device supports accurate current control, which results in system-level power savings and lower torque ripple, especially in motor control applications.

The function of the AMC1301 device in this design is to provide galvanic isolation between the high and low voltage sides. This amplifier has been selected mainly because of its very-high-transient immunity (15 kV/ μ s min), very low non-linearity (0.075 % max), and very low offset error.

1.4.3 REF2033

Applications with only a positive supply voltage often require an additional stable voltage in the middle of the ADC input range to bias input bipolar signals. The REF2033 provides a reference voltage for the ADC and a second highly-accurate voltage that can be used to bias the input bipolar signals.

The REF2033 offers excellent temperature drift (8 ppm/°C, max) and initial accuracy (0.05%) on both the V_{REF} and V_{BIAS} outputs while operating at a quiescent current less than 430 μ A. In addition, the V_{REF} and V_{BIAS} outputs track each other with a precision of 6 ppm/°C (max) across the temperature range of -40°C to 85°C . All these features increase the precision of the signal chain and decrease board space, while reducing the cost of the system as compared to a discrete solution. Both the V_{REF} and V_{BIAS} have the same excellent specifications and can sink and source current equally well. Very long-term stability and low-noise levels make these devices ideally suited for high-precision industrial applications.

The REF2033 is used for its dual outputs in a very small package, for its very low drift in output with temperature, and for its V_{REF} and V_{BIAS} tracking for higher accuracy.

1.4.4 SN6501

The SN6501 is a monolithic oscillator and power-driver, specifically designed for small form factor, isolated power supplies in isolated interface applications. The device drives a low-profile, center-tapped transformer primary from a 3.3- or 5-V DC power supply. The secondary can be wound to provide any isolated voltage based on the transformer turns ratio.

This device includes an oscillator that feeds a gate-drive circuit. The gate-drive, comprising a frequency divider and a break-before-make logic, provides two complementary output signals that alternately turn the two output transistors ON and OFF with a duty cycle of 50%.

The function of the SN6501 device in this design is to provide its isolated power supply to power the AMC1301 high-voltage side and first gain stage.

2 System Design Theory

This section details the design procedure for each circuit selection.

2.1 Selection of Shunt Resistor

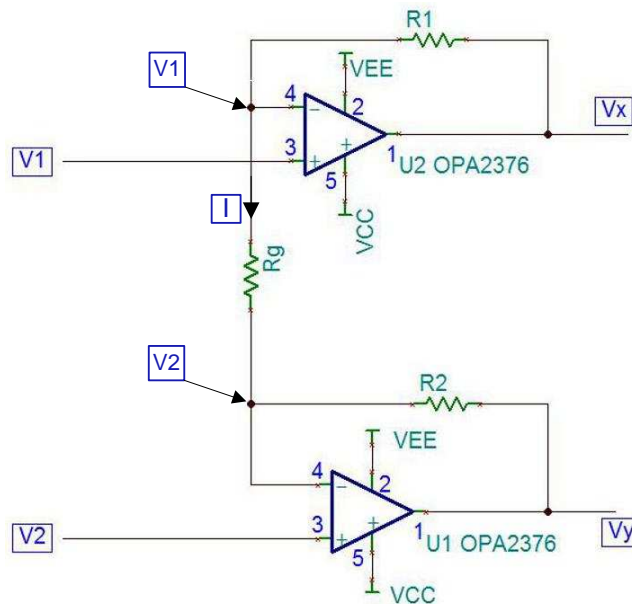
The shunt should drop a voltage of 25 mV across it when carrying 200 A. A shunt value of 125- $\mu\Omega$ is required. The minimum power-handling capability of the shunt must be 5 W. For the purposes of testing, two 250- $\mu\Omega$ resistors (part number CSS2725FTL250CT, from Stackpole Electronics) were connected in parallel, with each having a 125-A current capability and 4-W dissipation. Other important parameters include the resistance tolerance, temperature coefficient of resistance, low-thermal electromotive force and low inductance.

2.2 Front-End Gain Stage With Isolation Amplifier

2.2.1 Gain Stage Using OPA2376

This design has been set up to measure current as high as 200-A DC or 200-A peak-to-peak AC with a maximum drop of 25 mV across the shunt. The major requirement of this particular stage is to provide an amplified differential output to match the input (± 250 mV) of the isolation amplifier.

Figure 3 shows the gain stage configuration, which resembles an instrumentation amplifier configuration. The individual op amp gains are set to 5; however, the outputs are differential and each op amp provides an output of ± 125 mV out of phase with each other by 180°. This effectively leads to a total gain of 10.



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Figure 3. Configuration to Obtain Differential Output

The voltage drop across the shunt is connected to the positive terminals of both op amps shown in Figure 3. Applying KVL to the loop $V_x - R_1 - R_G - R_2 - V_y$ results in Equation 1:

$$V_x - V_y = I \times (R_1 + R_G + R_2) \tag{1}$$

$$I = \frac{V_1 - V_2}{R_G}$$

Here, I is given as:

Equation 1 now simplifies to Equation 2:

$$V_x - V_y = \frac{V1 - V2}{R_G} \times (R1 + R_G + R2);$$

$$V_x - V_y = (V1 - V2) \times \left(1 + \frac{R1 + R2}{R_G} \right); \quad (2)$$

In this design, V2 is grounded to the high-voltage side ground on the board. Thus, considering V2 to be at the ground potential with respect to V1, to obtain Equation 3:

$$V_x - V_y = V1 \times \left(1 + \frac{R1 + R2}{R_G} \right) \quad (3)$$

Because the design requires a differential output that can directly be given to the isolation amplifier, V_x and V_y must be equal and opposite of each other (see Equation 4).

$$V_x = -V_y \quad (4)$$

Again, referring to the preceding Figure 3, if considering V2 is at the ground potential, V_x and V_y now become Equation 5 and Equation 6:

$$V_x = I \times (R1 + R_G) \quad (5)$$

$$V_y = -I \times R2 \quad (6)$$

Equation 7 results from substituting Equation 5 and Equation 6 in Equation 4:

$$I \times (R1 + R_G) = -(-I \times R2);$$

$$R1 + R_G = R2 \quad (7)$$

Equation 7 shows one of the constraints for choosing the values of the resistors. To provide an overall gain of 10, each individual op amp has to provide a gain of 5 so that both the inputs to the isolation amplifier are equal and opposite.

Again looking at Figure 3, considering V2 to be at the ground potential, U2 functions like a non-inverting

$$V_x = V1 \times \left(1 + \frac{R1}{R_G} \right)$$

amplifier having transfer function:

To obtain a gain of 5, calculate the following Equation 8:

$$\frac{R1}{R_G} = 4 \geq R1 = 4R_G \quad (8)$$

Equation 9 is obtained from Equation 7 and Equation 8:

$$R2 = 5R_G \quad (9)$$

To limit the gain error, 0.1% accurate resistors have been chosen. The choices of feedback resistors are restricted to less than 10 kΩ to reduce the impact of noise voltages. Based on the availability and accuracy required, the values chosen for this design are $R_G = 1.27 \text{ k}\Omega$, $R1 = 5.1 \text{ k}\Omega$, and $R2 = 6.34 \text{ k}\Omega$.

Figure 4 shows the simulation results using the TINA-TI™ simulation software. All TINA-TI models can be found on the respective device product folders.

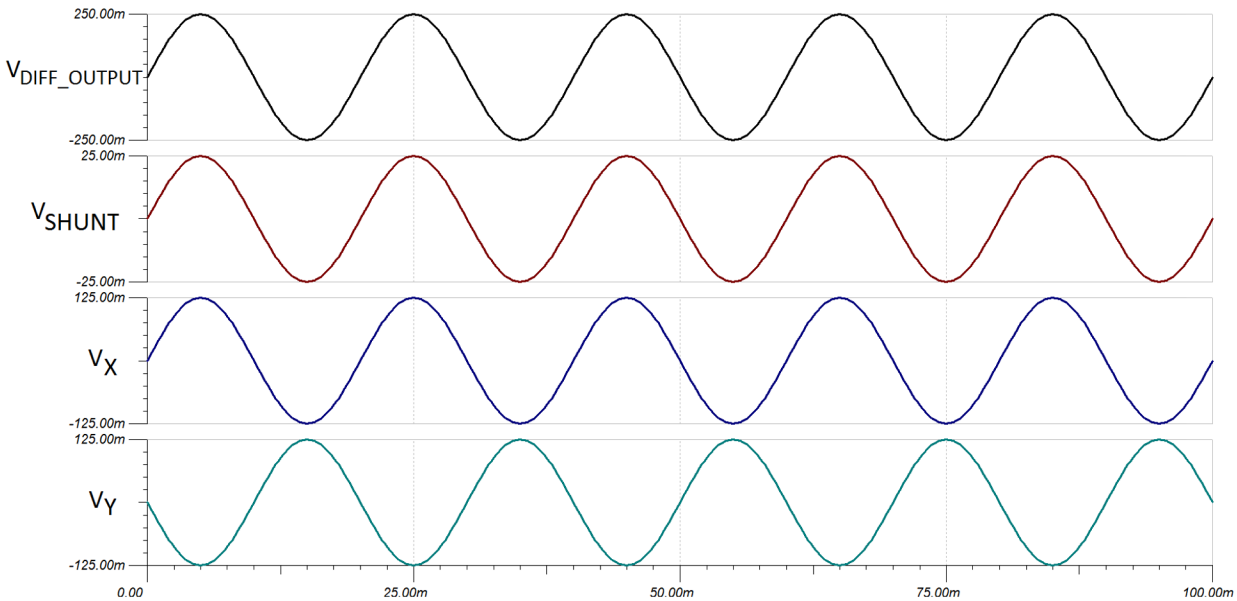


Figure 4. Simulation Result of Gain Stage

The variables as defined in the preceding Figure 4 are as follows:

- V_{SHUNT} is the voltage across the shunt
- V_x is the output of the upper op amp in the schematic
- V_y is the output of the lower op amp in the schematic
- V_{DIFF_OUTPUT} is the output of this gain stage

An RC filter with a 200-kHz cut-off frequency is added before the gain stage to avoid the entry of any high-frequency noise into the circuit. This filter can be changed according to the requirements of bandwidth versus noise immunity. Figure 5 shows the schematic for this stage.

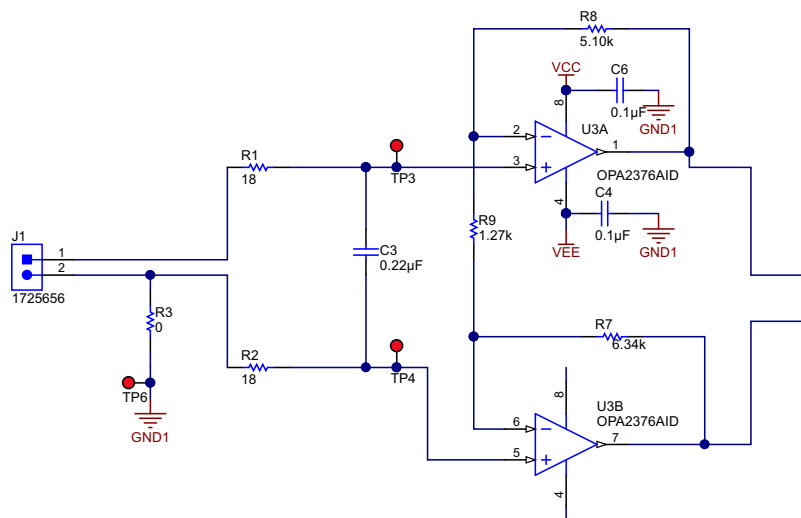


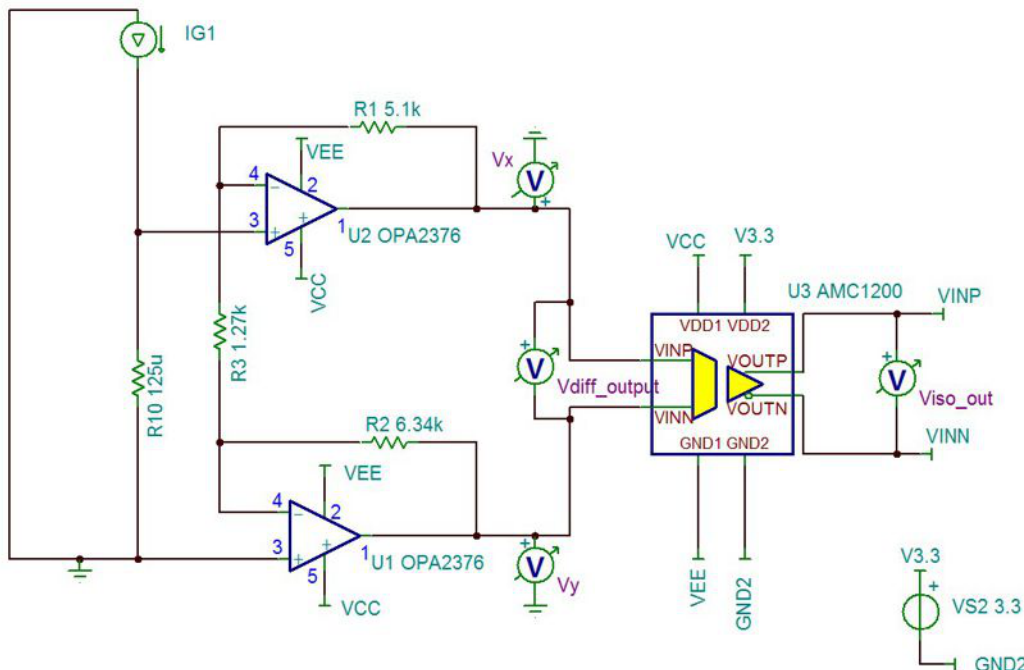
Figure 5. First Gain Stage

Connector J1 is used to connect the front-end stage with the shunt. The output of this gain stage is fed to the isolation amplifier through the RC filter.

2.2.2 Isolation Amplifier

This design uses the AMC1301 to provide galvanic isolation between the high- and low-voltage sides. The AMC1301 provides a fixed gain of 8.2. In this design a 5-V bias has been selected to power the high-voltage side, while the low-voltage side can be powered by either 5 V or 3.3 V depending on the voltage swing of the required output.

This design uses ± 2.5 V to power the high-voltage side, which effectively provides the 5 V and 3.3 V to power the low-voltage side. Figure 6 shows a TINA-TI simulation model for the isolation amplifier along with the gain stage. In this simulation, the $V_{DIFF_OUTPUT} = \pm 250$ mV, where V_{DIFF_OUTPUT} is the output of the gain stage, which is given to the isolation amplifier, and $V_{ISO_OUT} = \pm 250$ mV \times 8.2 = ± 2.05 V, where V_{ISO_OUT} is the output of the isolation amplifier.



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Figure 6. TINA-TI™ Model of Isolation Amplifier and First Gain Stage

In the preceding Figure 6, a current of 200 A passes through a resistor of 125 μΩ, resulting in a voltage drop of 25 mV, which is amplified and given to the isolation amplifier. Figure 7 shows the output of both stages as simulation results.

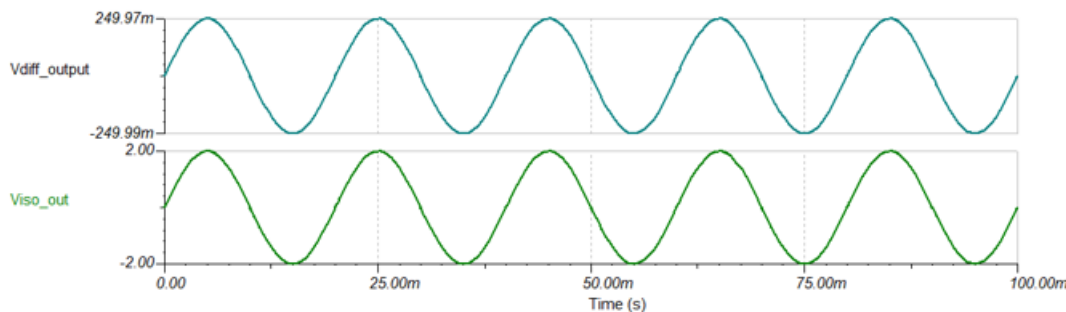
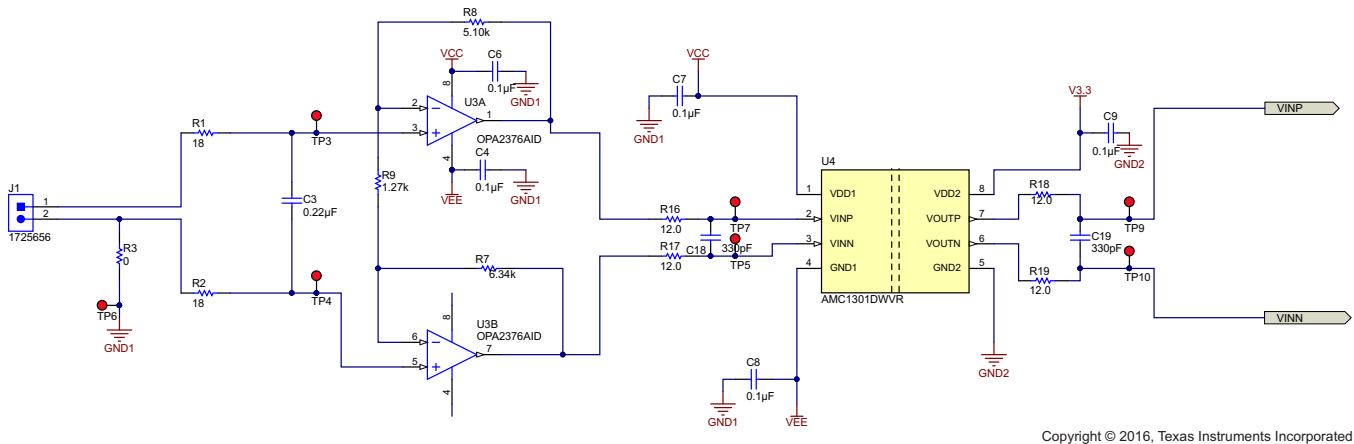


Figure 7. Simulation Result of Isolation Amplifier

Figure 8 shows the schematic for this circuit.

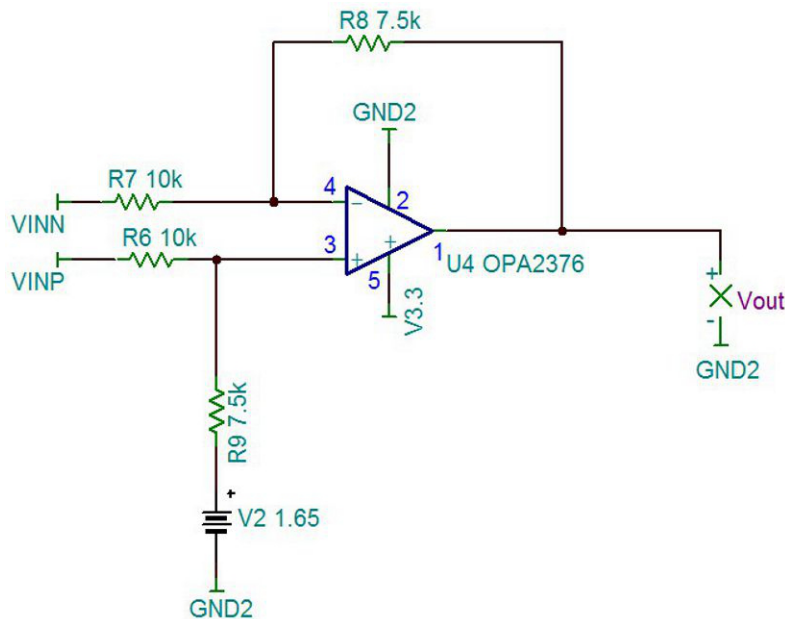


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Figure 8. Isolation Amplifier Along With Front-End Amplifier

2.3 Differential to Single-Ended Conversion

To use the complete dynamic input range of a 3.3-V ADC, the $\pm 2.05\text{-V}$ output swing is mapped to approximately 0 V to 3.3 V. This mapping is accomplished by the differential amplifier stage that Figure 9 shows. The OPA376 op amp was chosen for this stage mainly because of its low offset and high CMRR.



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Figure 9. TINA-TI™ Model for Differential to Single-Ended Conversion

The transfer function for this circuit can be derived easily considering $R13 = R12$ and $R11 = R10$ (see [Figure 11](#)) and using only two variables for them. [Equation 10](#) show that the transfer function for this circuit is:

$$V_{OUT} = (VINP - VINN) \times \left(\frac{R13}{R11} \right) + V_{REF} \tag{10}$$

In this equation, V_{REF} is 1.65 V.

The OPA376 output voltage swing is limited up to 10 mV from the rails typically and 20 mV over temperature. Considering the mismatch in resistor values, the output voltage has been designed to be limited to a little over 100 mV from the rails.

The ± 2.05 -V input to the differential amplifier is to be mapped to 0 V to 3.3 V and the input of 0 V is mapped to 1.65 V (V_{REF}). Providing a window of 150 mV from the rails, the maximum swing of output becomes 0.15 V to 3.15 V. As a result, the positive and negative swing that is allowed is $3.15 \text{ V} - 1.65 \text{ V} = 1.5 \text{ V}$ riding over the V_{REF} of 1.65 V.

Thus, the ratio of resistors required to achieve this shift is calculated as the following [Equation 11](#):

$$1.5 \text{ V} = \left(\frac{R13}{R11} \right) \times (2.05 \text{ V});$$

$$\frac{R13}{R11} = 0.7317 \tag{11}$$

To obtain a margin of 150 mV from the rails, the values to choose are $R13 = 15 \text{ k}\Omega$ and $R11 = 20 \text{ k}\Omega$. [Figure 10](#) shows the simulation result with the output of this differential amplifier.

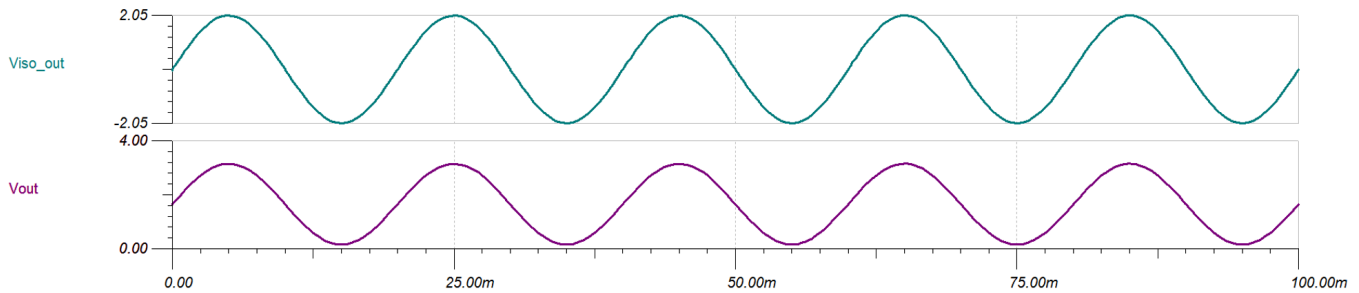
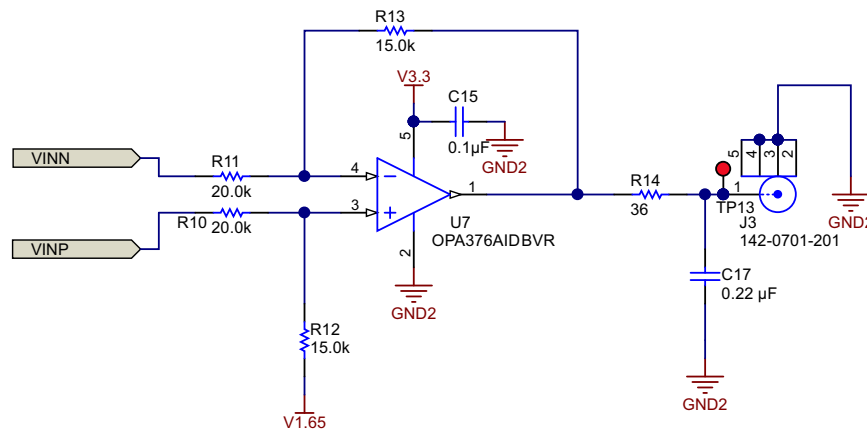


Figure 10. Simulation Result for Differential to Single-Ended Converter

In this scenario, V_{ISO_OUT} is the output of the AMC1301 device, as the preceding [Figure 10](#) shows, and V_{OUT} is the final output of the level shifter. [Figure 11](#) shows the schematic of the level shifter.



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Figure 11. Differential Amplifier Stage

To compare the overall performance and linearity of the circuit, the transfer function is plotted for input current versus output and separately for every stage, as Figure 12 shows.

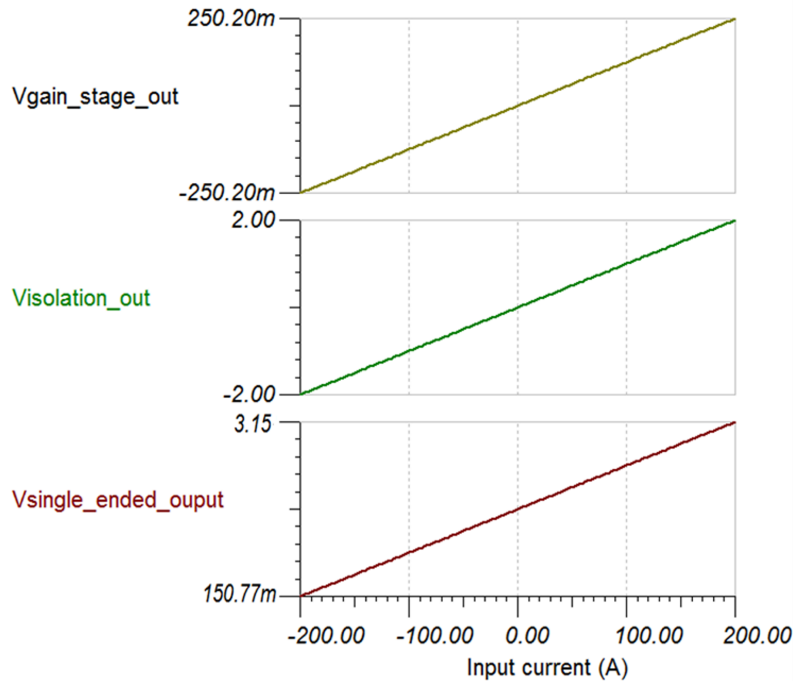


Figure 12. Transfer Function Plotted Using TINA-TI™

2.4 Power Supply and Reference Solution

2.4.1 Isolated Power Supply

The AMC1301 requires an isolated power supply for powering its input section. The SN6501 is used as a switching device to generate a 5-V isolated output and drives the transformer.

The SN6501 is a monolithic oscillator and power-driver, specifically designed for isolated power supplies in isolated interface applications with a small form factor. The device drives a low-profile, center-tapped transformer primary from a 3.3- or 5-V DC power supply. The SN6501 consists of an oscillator followed by a gate drive circuit that provides the complementary output signals to drive the ground referenced N-channel power switches. The internal logic ensures break-before-make action between the two switches.

The SN6501 features a push-pull driver for small transformers and a single 3.3- or 5-V supply.

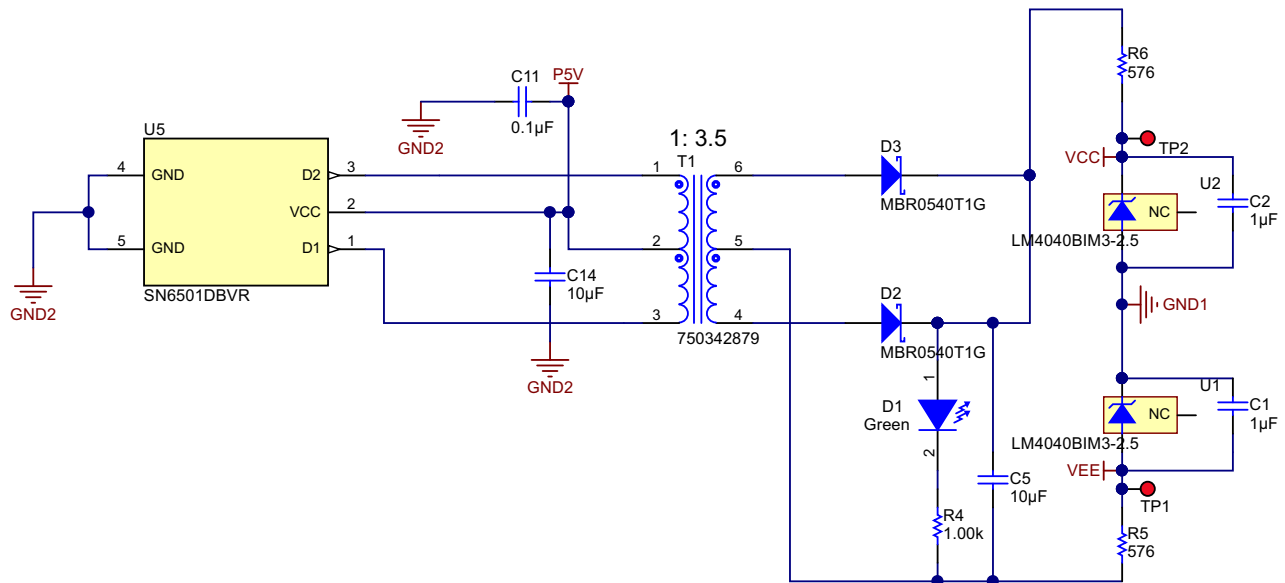
While selecting the transformer, preventing the transformer from saturation is important. To achieve this protection, the $V \times t$ product of the transformer must be greater than the maximum $V \times t$ product applied by the SN6501 device. The maximum voltage delivered by the SN6501 device is the nominal converter input plus 10%. The maximum time this voltage is applied to the primary is half the period of the lowest frequency at the specified input voltage. Therefore, the minimum $V \times t$ product of the transformer is determined through the following Equation 12:

$$V \times t_{\text{MIN}} \geq V_{\text{IN_MAX}} \times \frac{T_{\text{MAX}}}{2} = \frac{V_{\text{IN_MAX}}}{2 \times f_{\text{MIN}}};$$

$$V \times t_{\text{MIN}} \geq \frac{5.5 \text{ V}}{2 \times 300 \text{ kHz}} = 9.1 \text{ V}\mu\text{s} \quad (12)$$

Common $V \times t$ values for low-power center-tapped transformers range from 22 V μs to 150 V μs with typical footprints of 10 mm \times 12 mm.

This design must have the capability to sense bipolar signal using a unipolar power supply. The front-end amplifier is designed to be biased from a dual supply. The purpose of this design function is to process the negative inputs as well as positive inputs. After rectifying the output of the transformer, the design splits the power rail to obtain ± 2.5 V. Splitting is achieved by using Zener diodes, as Figure 13 shows.



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Figure 13. Isolated Power Supply

The V_{CC} and V_{EE} that the preceding Figure 13 show are used to power the first gain stage as well as the high-voltage side of the isolation amplifier. The turns ratio of the selected transformer is 1:3.5. Thus, for a 5-V primary input voltage, the secondary voltage is 17.5 V. After accounting for the forward voltage drop of the diodes, the voltage available after rectification is approximately 16.5 V.

The maximum output current required from this supply is less than 10 mA and the minimum current required by the Zener diode to stay in regulation is only 45 μ A. The voltage across the resistor in series with the Zener diode is calculated in the following Equation 13:

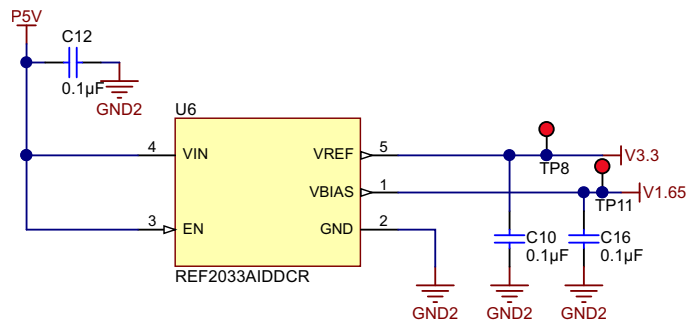
$$V_{RES} = \frac{16.5}{2} \times -2.5 = 5.75 \text{ V} \tag{13}$$

$$R = \left(\frac{5.75 \text{ V}}{10 \text{ mA}} \right) = 575 \ \Omega$$

For a current of 10 mA, the required resistor value is:

2.4.2 Reference Solution

In this application, a unipolar power supply must be used to sense a bipolar signal. This sensing requires level shifting of the signal to the midpoint of the power supply rail. A voltage reference is used to bias the signal-conditioning stage output to the middle of the ADC dynamic range. The REF2033 integrated circuit (IC) provides both the 3.3-V supply to the OPA317 op amp as well as the 1.65-V reference voltage for biasing the signal to the middle of the ADC range. Both the outputs of the REF2033 IC can sink or source 20 mA. Also, there is excellent tracking between the 3.3-V and 1.65-V supplies, and both the supplies are available in a single, extremely small SOT23-5 package, which reduces the bill of materials (BOM) count and board size. Figure 14 shows this power supply section.



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Figure 14. Power Supply and Reference Circuit

The IC is supplied with a 5-V power supply. The outputs are 3.3 V and 1.65 V. Place 0.1-µF noise decoupling capacitors close to the IC pins for a clean power input and output rails.

3 Testing and Results

The tests were conducted with DC input voltage, AC input voltage, and current input. The frequency of AC input used for conducting the tests was 50 Hz. The values of voltages were measured after every stage using a 6½ digital multimeter (DMM) from Agilent with the aid of averaging functionality. Figure 15 shows the test setup for the DC test.

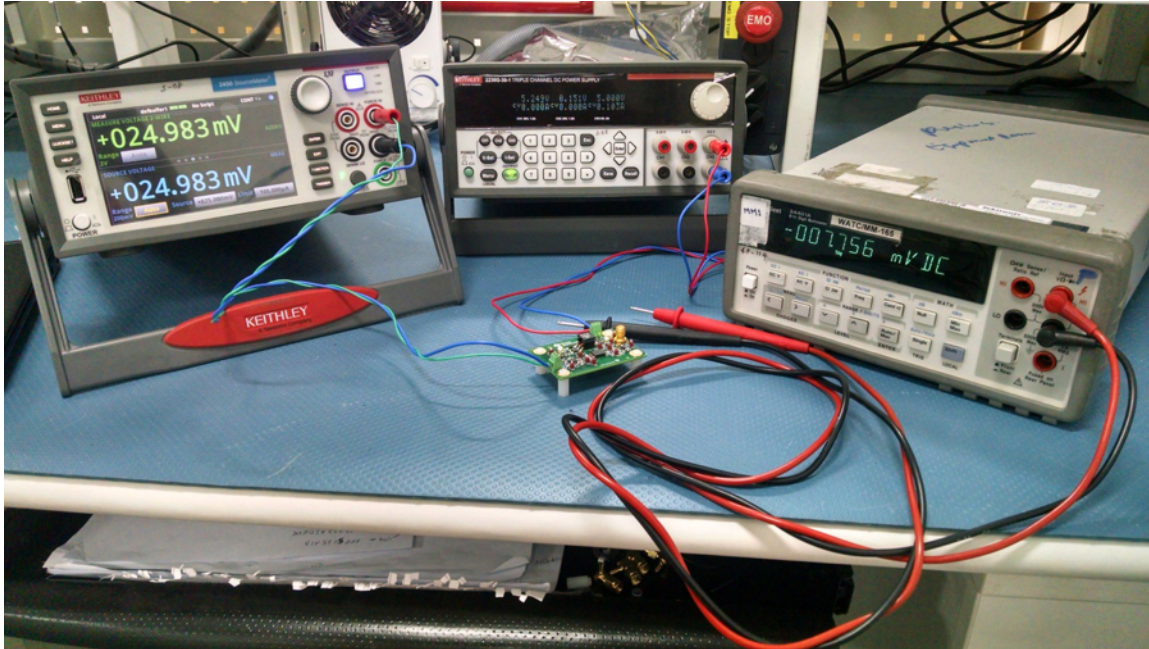


Figure 15. Test Setup for DC Input

The DC input voltage was supplied by a Keithley 2450 source meter. The accuracy of the design was calculated for every 1 mV in the input voltage over a range of -25 mV to 25 mV .

A similar test was conducted with AC input voltage and current wherein the design was tested for an input ranging from 1 mV_{RMS} to $17\text{ mV}_{\text{RMS}}$ with 1-mV steps.

For testing the design over the temperature range of $-25\text{ }^{\circ}\text{C}$ to $85\text{ }^{\circ}\text{C}$, the board was kept inside the temperature chamber and similar tests were conducted. Figure 16 shows the setup for testing across the temperature range of $-25\text{ }^{\circ}\text{C}$ to $85\text{ }^{\circ}\text{C}$.



Figure 16. Test Setup for Testing Over Temperature Range

3.1 Test Data

3.1.1 Power Supply

Figure 17 and Figure 18 show the ± 2.5 -V isolated power supplies generated onboard to bias the front-end gain stage and high-voltage side of the AMC1301 device.

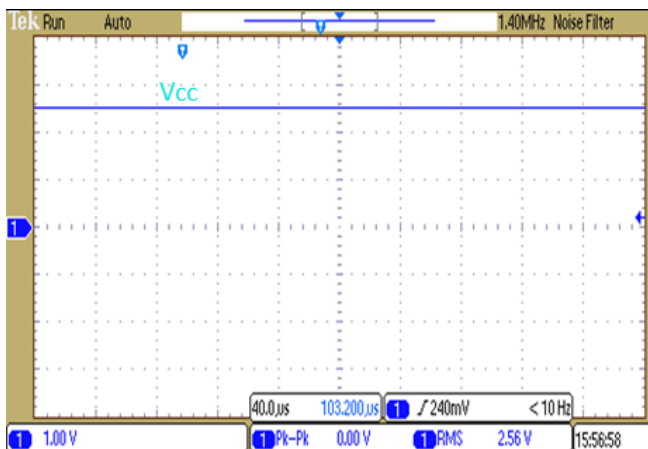


Figure 17. ± 2.5 -V Supply—Waveform 1

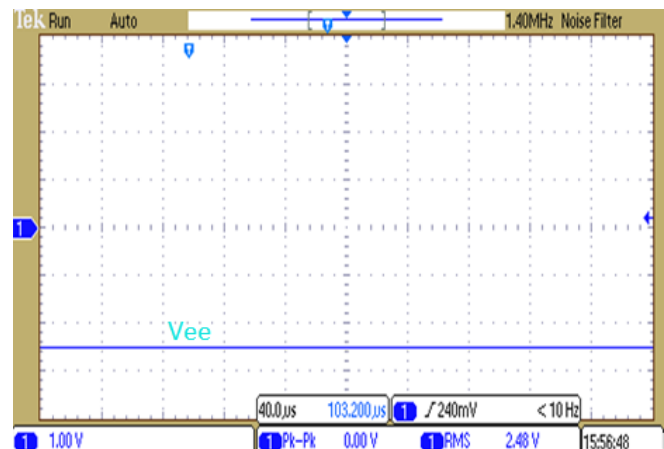


Figure 18. ± 2.5 -V Supply—Waveform 2

Figure 19 and Figure 20 show the 3.3-V supply powering the low-voltage side of the AMC1301 device and level shifter and the 1.65-V built-in reference to level shift the output.

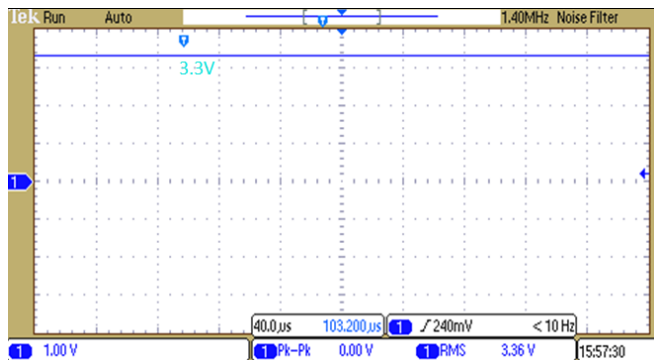


Figure 19. 3.3-V Supply Waveform

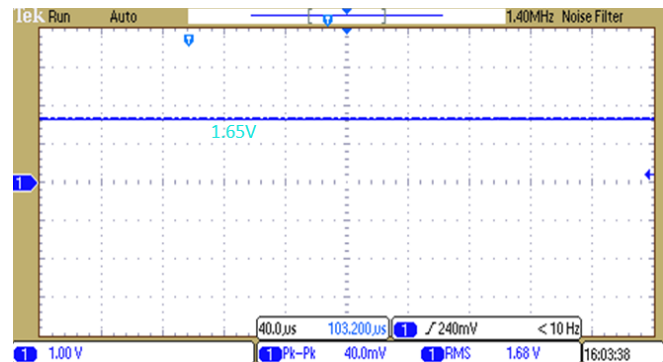


Figure 20. 1.65-V Supply Waveform

3.2 Accuracy Results

Figure 21 shows the accuracy for measuring a DC voltage given at the shunt terminal on the board (simulating shunt voltage) over the temperature range. The 25-mV input corresponds to the 200-A DC current.

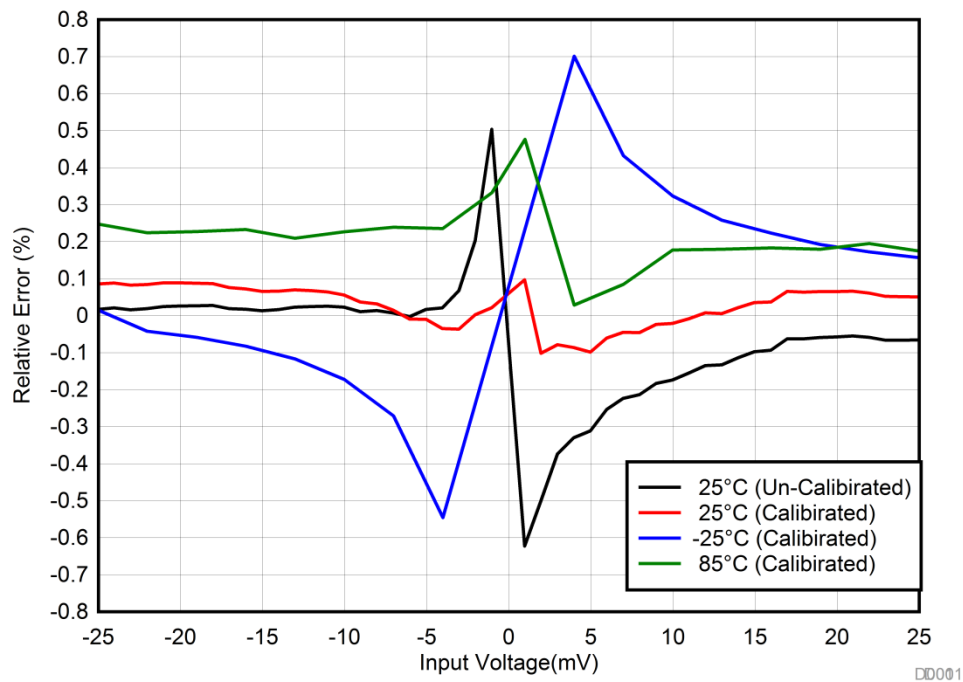


Figure 21. DC Accuracy Over Temperature

Figure 22 shows the accuracy for measuring an AC input voltage to the board over the temperature range, where the frequency for the input is 50 Hz. The 17-mV input corresponds to the 136-A RMS current.

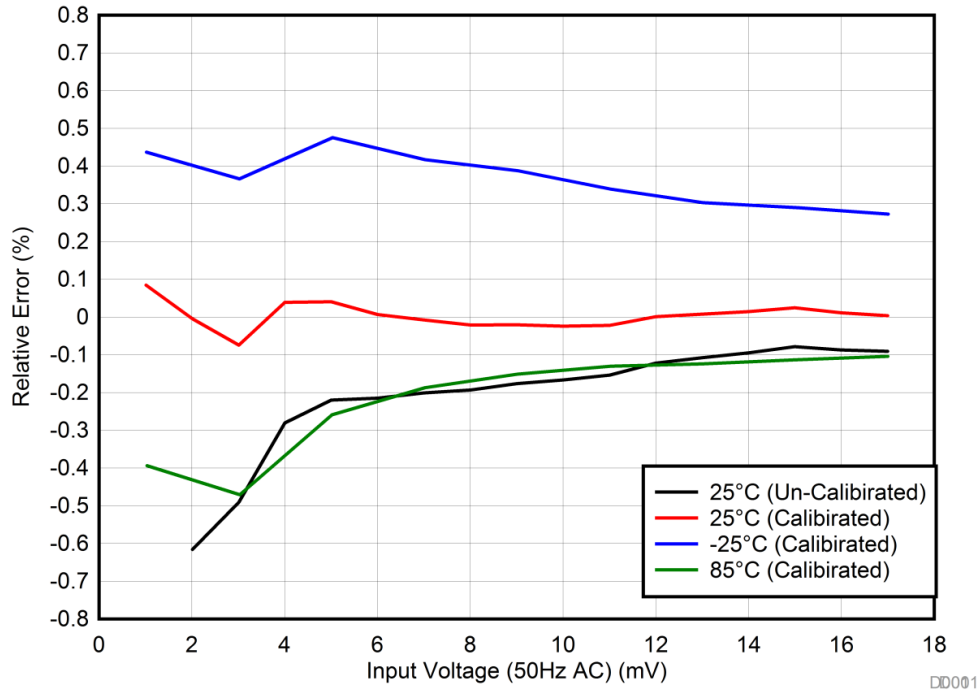


Figure 22. Accuracy for AC Input Voltage Over Temperature

Figure 23 shows the accuracy for AC current input wherein the current was passed through the shunt resistor of 125 μΩ and the voltage drop across the shunt was fed to the board as an input voltage.

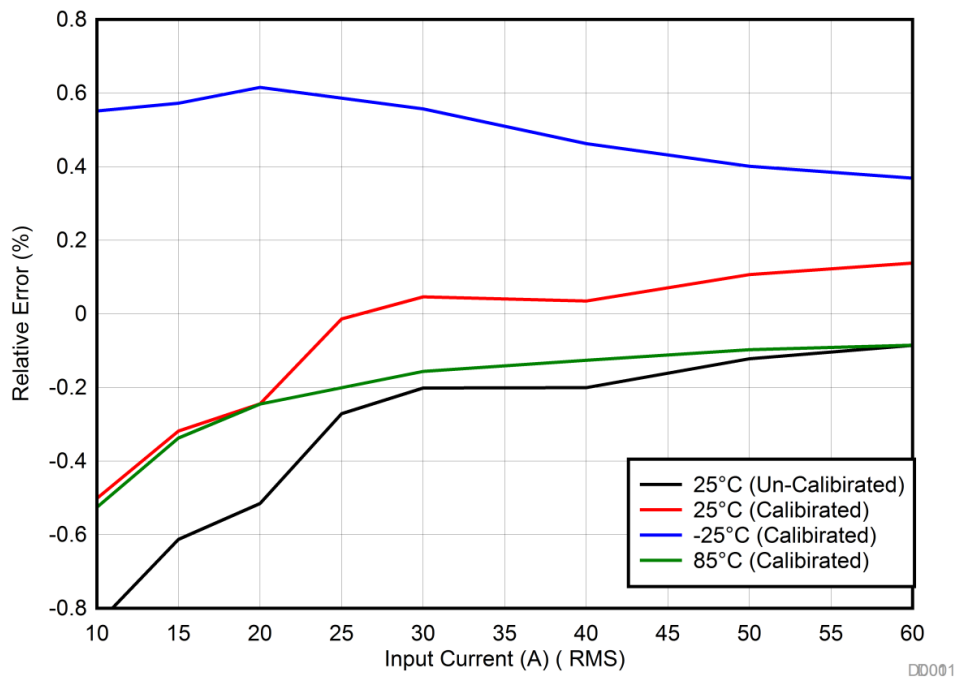


Figure 23. Accuracy for AC Current Input Over Temperature

The following figures provide a deeper analysis wherein the behavior of all the stages is shown separately for various tests conducted at 25°C. Figure 24 shows the behavior of the individual stages for the DC input voltage.

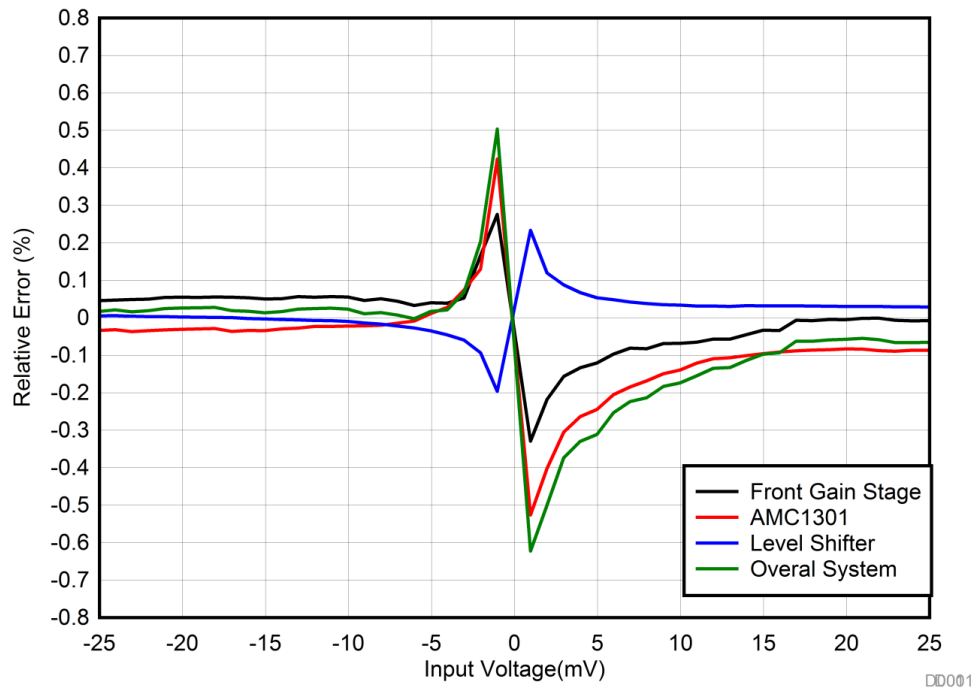


Figure 24. Accuracy for AC Current Input Over Temperature

Figure 25 and Figure 26 show the behavior for the AC voltage input and AC current input to shunt, respectively.

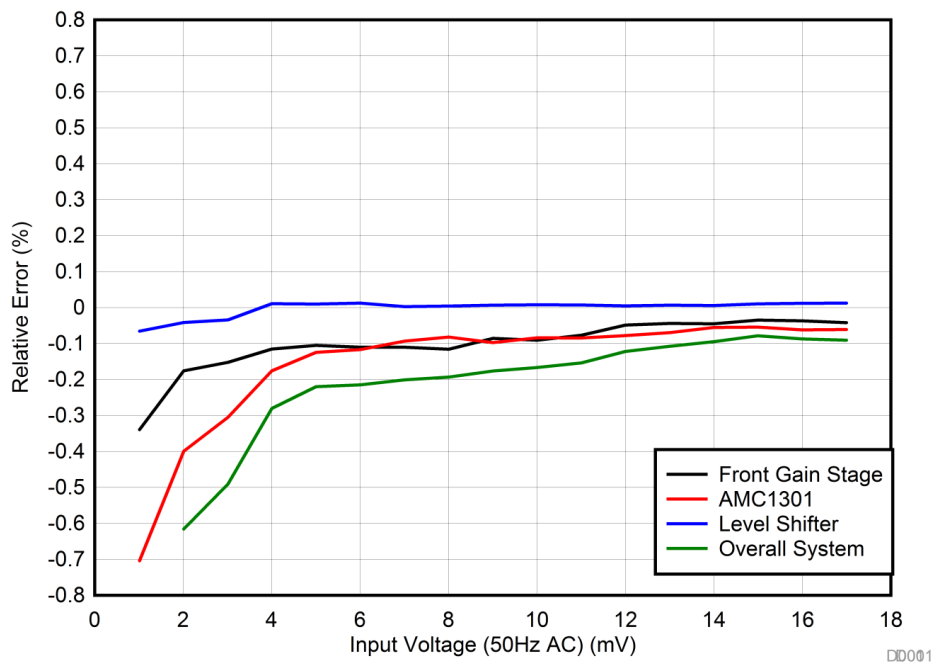


Figure 25. Accuracy of All Stages for AC Input Voltage at 25°C

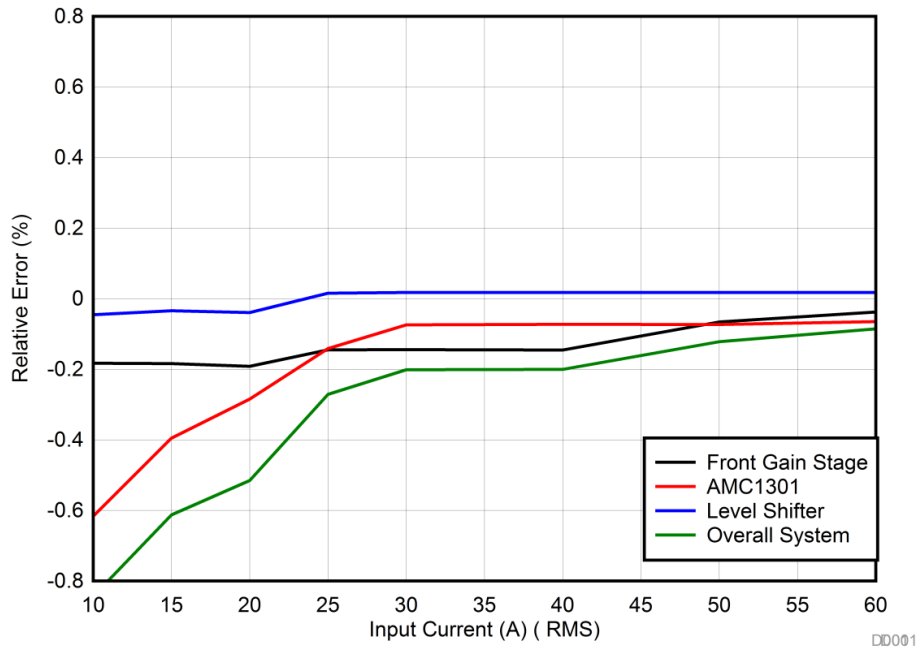


Figure 26. Accuracy of All Stages for AC Current Input to Shunt at 25°C

3.3 Time Response

This subsection shows the response of the design to a step input of 25 mV. Figure 27 shows the total rise time of the input and corresponding rise time of the output.

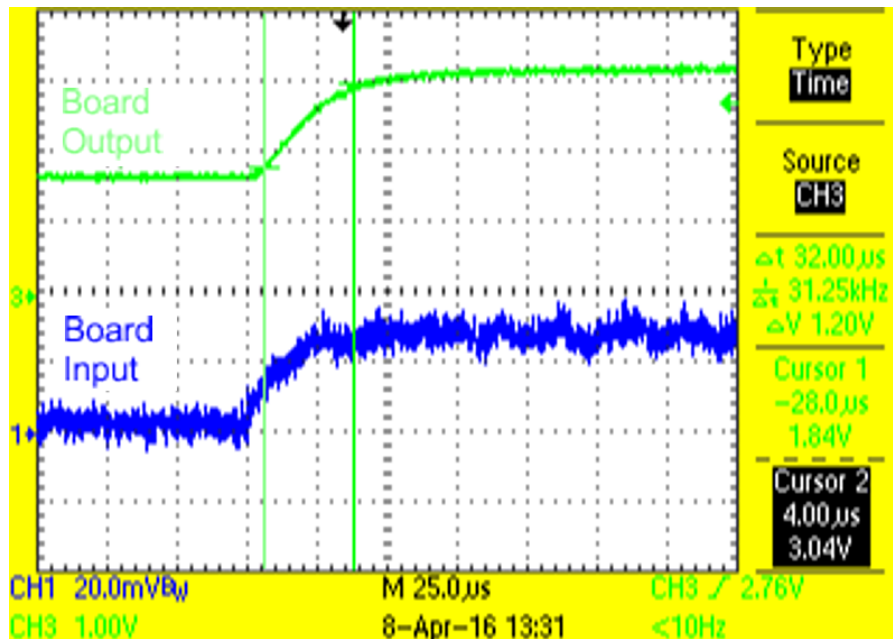


Figure 27. Rise Time of Input (CH1) and Output (CH2)

The measured rise time of the step input is 16.76 μ s and the corresponding rise time of the output is 32 μ s.

Figure 28 shows the rise time of the AMC1301 device for a step input of 250 mV.

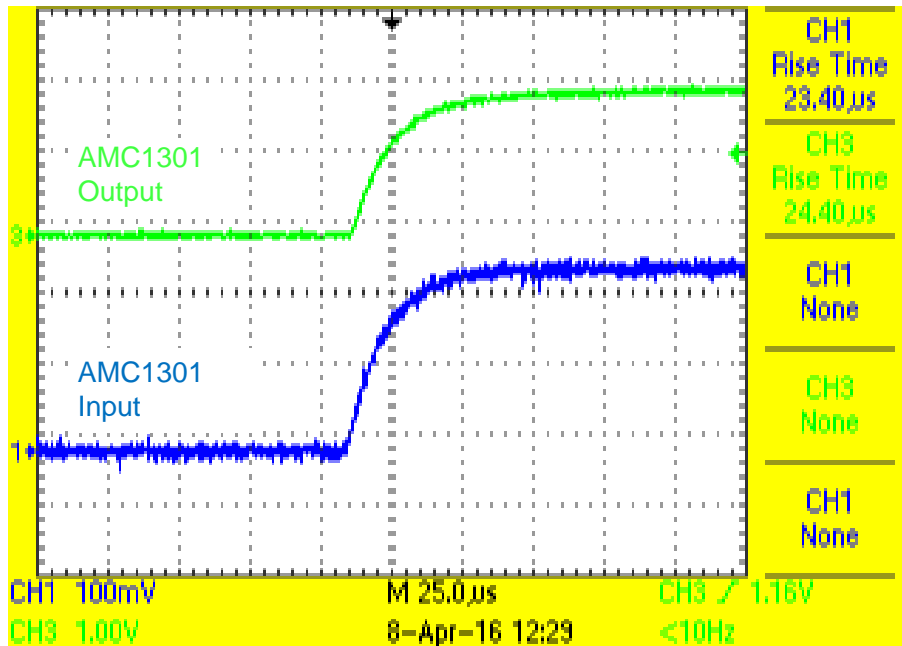


Figure 28. Rise Time of AMC1301

The rise time of the input to the AMC1301 device is 23.4 μs and the corresponding rise time of the AMC1301 device is 24.4 μs.

Figure 29 and Figure 30 show the propagation delay of the AMC1301 and the entire board, respectively.

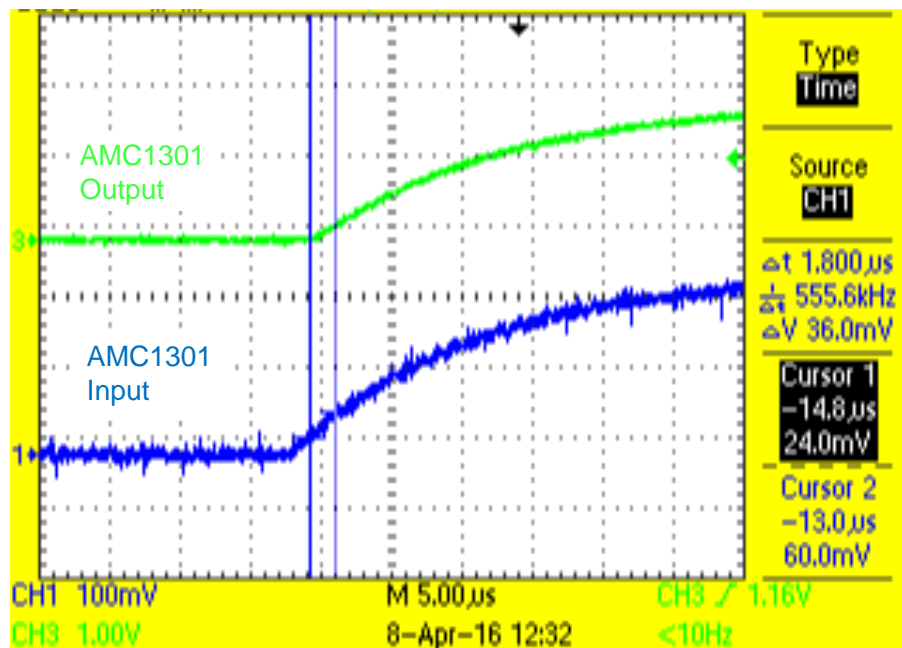


Figure 29. Propagation Delay of AMC1301

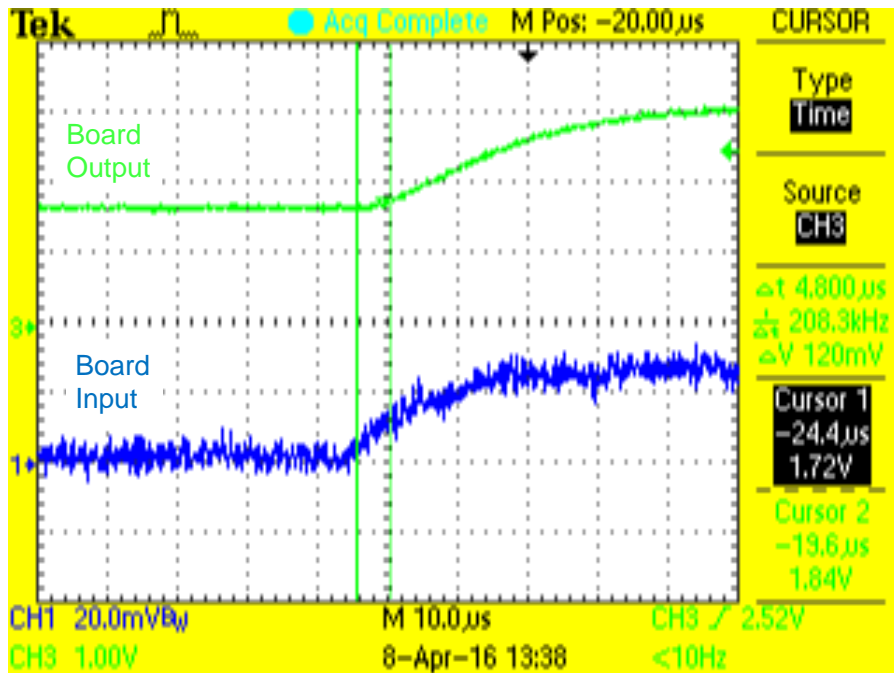


Figure 30. Propagation Delay of Board

As these waveforms show, the measured propagation delay of the AMC1301 device is 1.8 μs and the board is 4.8 μs.

4 Design Files

4.1 Schematics

To download the schematics, see the design files at [TIDA-00912](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-00912](#).

4.3 PCB Layout Recommendations

The following steps outline the proper PCB layout recommendations:

1. Do not allow any copper between the isolation with a minimum width of 9 mm (see [Figure 31](#)).

No copper between isolation with a minimum width of 9 mm

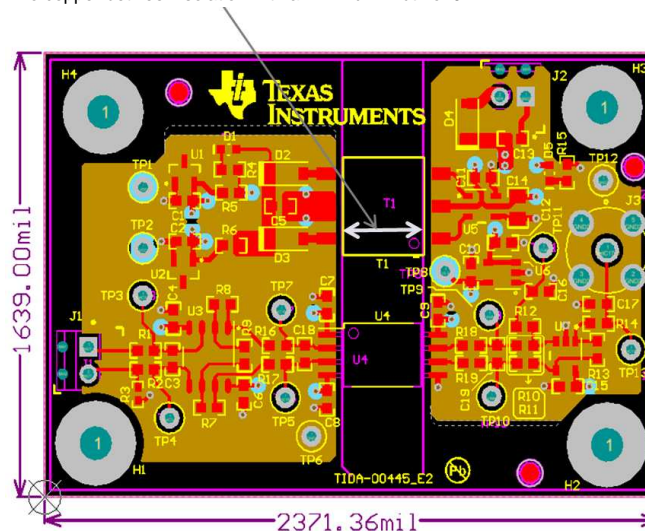
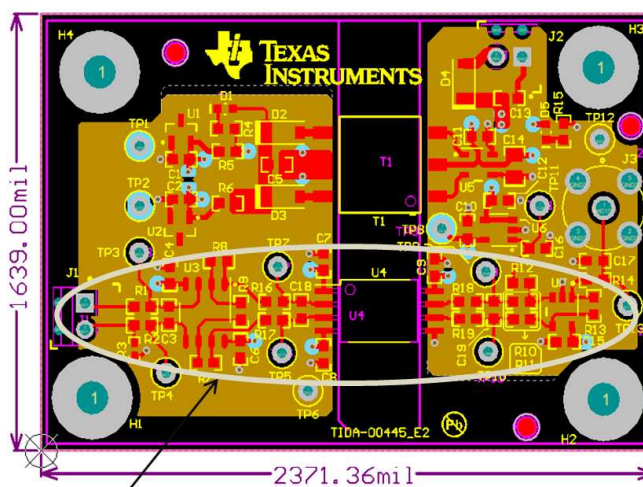


Figure 31. PCB Layout Showing Isolation Between High- and Low-Voltage Side of AMC1301

2. Do not place any test points near the transformer to avoid noise pick up.
3. Place decoupling capacitors very close to their corresponding pins with a low impedance path to the device GND (see [Figure 32](#)).



Minimum track lengths

Figure 32. PCB Layout Representing Signal Chain

4. Keep the trace length from the input-to-signal chain equal and make sure the entire signal chain is in one straight line.
5. Place the input resistors very close to their corresponding pins. Traces for output resistors can be a little longer if required.
6. Make sure to have non-plated mounting holes if any holes are to be placed in the regions with no copper pour kept for isolation.

4.3.1 Layout Prints

To download the layer plots, see the design files at [TIDA-00912](#).

4.4 Altium Project

To download the Altium project files, see the design files at [TIDA-00912](#).

4.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-00912](#).

4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-00912](#).

5 Software Files

To download the software files, see the design files at [TIDA-00912](#).

6 References

1. Texas Instrument, *Shunt-Based 200-A Peak Current Measurement Reference Design Using Isolation Amplifier*, TIDA-00445 User's Guide ([TIDUB91](#))

7 About the Author

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (July 2016) to A Revision	Page
• Changed design to Active from Preview	1

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