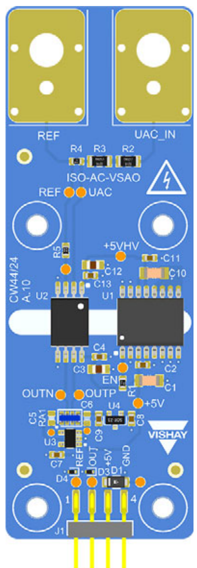
Reference Design
Isolated AC Voltage Sensing Using the VIA0250DD



LINKS TO ADDITIONAL RESOURCES

- ISO-AC-VSAO

FEATURES

- AC voltage measurements up to 400 V_{RMS}
- Maximum working isolation voltage of 1200 V_{RMS}
- Isolated single-ended analog output
- Low temperature offset and gain drift
- Large bandwidth of 300 kHz

KEY COMPONENTS

- VIA0250DD
- TNPV E3 2M
- ACAS

APPLICATIONS

- Motor control applications
- Power supplies
- Charging stations
- EV powertrains

DESCRIPTION

This reference design focuses on the voltage sensing solutions used in high AC voltage applications, in which an isolated high voltage sensing circuit is a must.

This application is based on the VIA0250DD isolation amplifier and a voltage divider comprising a set of TNPV resistors. The high voltage input (UAC_{IN} to REF) is scaled down to UAC to REF using a set of TNPV resistors. This reduced voltage is then fed into the VIA0250DD isolation amplifier, which produces an isolated, amplified analog signal at its output (OUT_P to OUT_N). The differential output signal, with a common-mode voltage of 1.44 V, is accessible via pin headers labeled OUT_P and OUT_N, allowing users to connect a differential ADC or use it for other prototyping needs. This differential output is converted to a single-ended output, providing an output in the range from 0 V to 2.5 V (OUT to GND), which is ready to be interfaced by a single-ended ADC or multimeter.

To allow for the lowest possible thermal drift, the differential to single-ended conversion stage is based on the ACAS resistor network, providing well-matched resistance values over a wide range of temperatures.

OVERALL SYSTEM BLOCK DIAGRAM

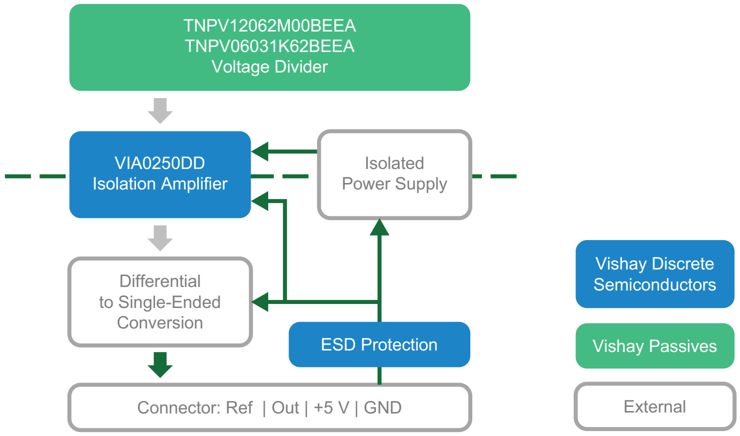


Fig. 1 - Overall System Block Diagram

APPLICATION DESCRIPTION

This application comprises a few stages that work together to provide an accurate isolated current measurement. In the following subsections, these stages are briefly explained.

Voltage Sensing Stage

In this design, a set of TNVP resistors is used to build a voltage divider circuit in order to scale down the input voltage to a voltage level that matches the input voltage range of the isolation amplifier.

The TNVP-e3 resistor offers a high operating voltage of up to 1000 V, an exceptionally low voltage coefficient of less than 1 ppm/V, and excellent stability across various environmental conditions, with less than 0.05 % variation over 1000 h at 70 °C. It also provides superior moisture resistance (tested at 85 °C and 85 % relative humidity) and is AEC-Q200 qualified for automotive applications.

Isolation Amplifier and Single-Ended Conversion

The voltage across the voltage divider from the voltage sensing stage is fed to the isolation amplifier (VIA0250DD). The VIA0250DD is a high performance isolated amplifier with differential output, ideally suited for shunt-based current sensing. Built on proprietary capacitive isolation technology, it features a linear differential input signal range of ± 50 mV (linear, ± 64 mV full scale). With a typical offset drift of 0.15 µV/°C and GAIN drift of 15 ppm/°C, it maintains high accuracy across the entire temperature range. Its exceptional common-mode transient immunity (CMTI) of 100 kV/µs enables precise measurements even in noisy environments.

In this application, the gain of the VIA0250DD is $GAIN_{VIA}$ = 8.2. The output of the VIA0250DD is then fed to a simple “differential to a single-ended” conversion circuit with a fixed gain of $GAIN_{DSC}$ = 0.5.

GAIN Calculation

This section details the GAIN calculation required to confirm that the voltage output from the voltage divider matches the maximum input voltage range of an isolation amplifier. Proper GAIN adjustment is essential to ensure that the voltage signal is within the amplifier’s linear input range. If the input signal exceeds this range, the output voltage of the isolation amplifier will enter a non-linear or a clipping range.

The following calculation applies to the available reference designs and can be adapted to specific customer needs. By following the outlined procedures, you can achieve accurate and reliable current sensing, which is crucial for the effective operation of your electronic applications.

The overall GAIN can be calculated using the following equation:

$$GAIN = GAIN_{VD} \times GAIN_{VIA} \times GAIN_{DSC}$$

Where:

$GAIN_{VD}$: is the voltage divider $GAIN \cong \frac{1\ V}{2460\ V}$ (-67.8 dB)

$GAIN_{VIA}$: is the isolation amplifier $GAIN = 8.2$ (18.3 dB)

$GAIN_{DSC}$: is the differential to single-ended $GAIN = 0.5$ (-6.0 dB)

GAIN of Voltage Divider

$$GAIN_{VD} = \frac{R_4 \times R_{IND}}{R_4 \times R_{IND} + R_{23} \times (R_{IND} + 2 \times R_4)}$$

with $R_{23} = R_2 + R_3$,

R_{IND} = differential input resistance

$R_5 = R_4 \parallel R_{23} \approx R_4$

$$GAIN_{VD} = \frac{1}{1 + \frac{R_{23} \times (R_{IND} + 2 \times R_4)}{R_4 \times R_{IND}}}$$

Reduction with $\frac{R_{23} \times (R_{IND} + 2 \times R_4)}{R_4 \times R_{IND}} \gg 1$

$$GAIN_{VD} = \frac{R_4 \times R_{IND}}{R_{23} \times (R_{IND} + 2 \times R_4)}$$

$$GAIN_{VD} = \frac{1.8\ k\Omega \times 22\ k\Omega}{3.8\ M\Omega \times (22\ k\Omega + 2 \times 1.8\ k\Omega)}$$

$$GAIN_{VD} = 0.00040707$$

$$GAIN_{VD} \cong \frac{1\ V}{2460\ V}$$

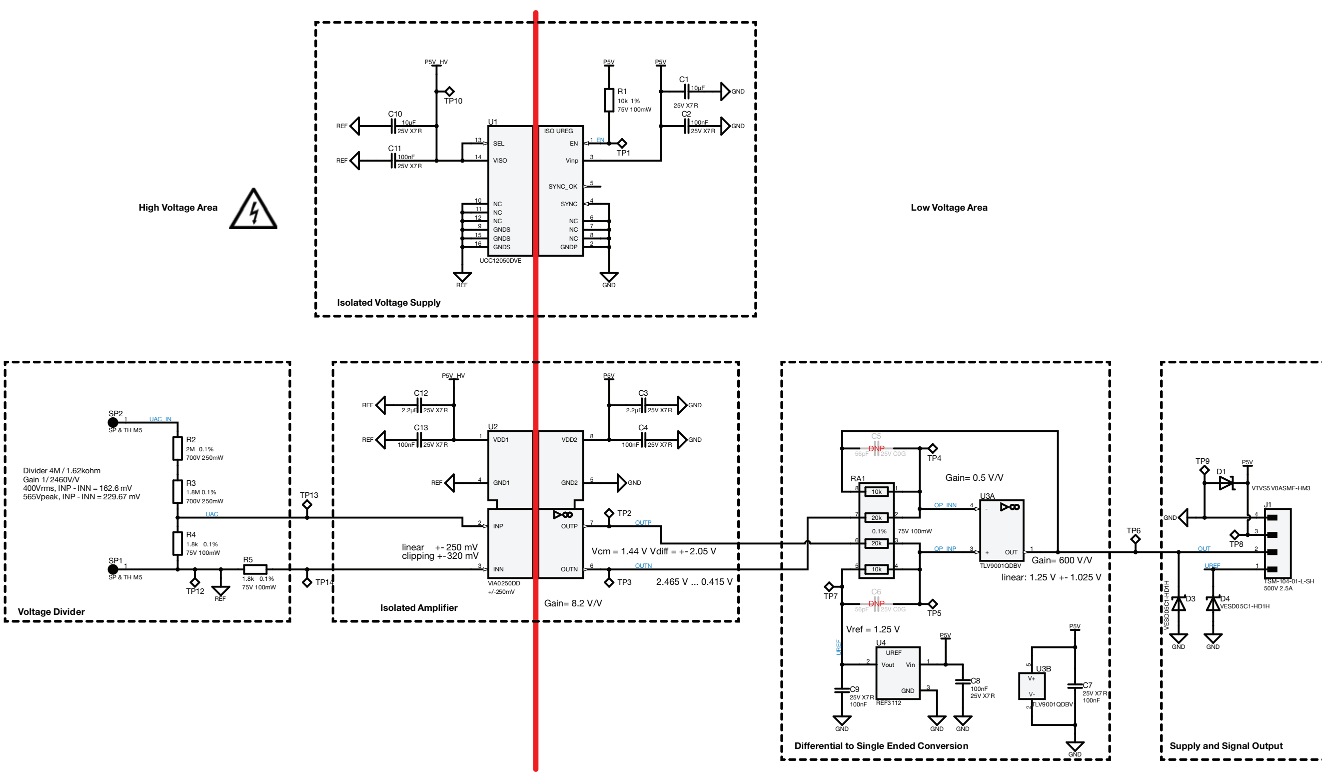


Fig. 2 - Schematic

Total GAIN

$$GAIN = GAIN_{VD} \times GAIN_{VIA} \times GAIN_{DSC}$$

$$GAIN_{VD} = \frac{1\ V}{2460\ V} \times 8.2 \times 0.5$$

$$GAIN_{VD} = 0.0016667 = \frac{1\ V}{600\ V}$$

In addition to the linear calculation, the total GAIN of the amplifier can be calculated by adding the individual GAINs in dB. The following table gives an overview and helps when the voltage divider is modified to specific requirements.

STAGE	GAIN (LINEAR)	GAIN (dB)
Voltage divider	$\frac{1}{2460}$	-67.8
Isolated amplifier	8.2	18.3
Differential to single-ended conversion	0.5	-6.0
Total	$\frac{1}{600}$	-55.5

The following figure shows the measured OUT and REF output voltages. By correcting the offset OUT - REF, the output signal is centered to zero and the output signal includes the sign represented in the output.

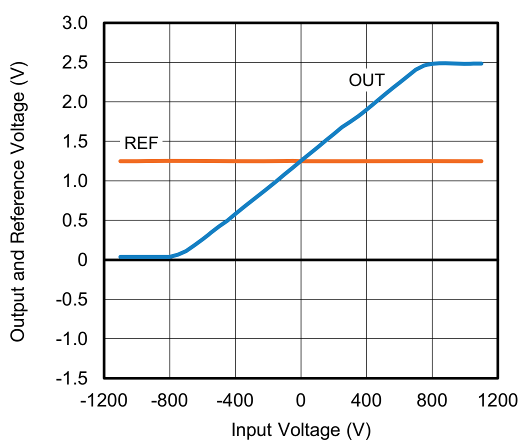


Fig. 3 - Output Voltage vs. Input Voltage

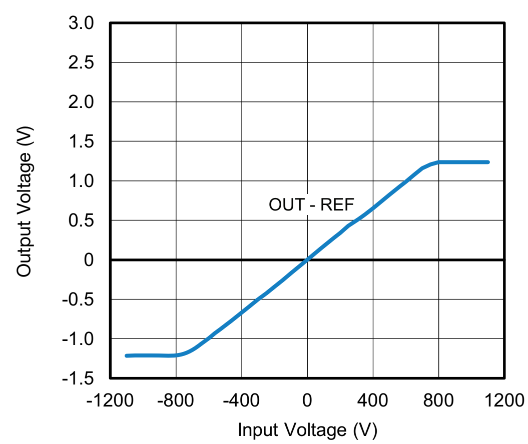


Fig. 4 - Output and Reference Voltage vs. Input Voltage

The following figure shows the measured GAIN of the isolated amplifier together with the differential to single-ended conversion (without voltage divider) versus frequency. For total GAIN, the GAIN of the voltage divider must be added.

The GAIN sum without the voltage divider GAIN is shown in Fig. 3. Total gain can be calculated by adding the voltage divider gain $GAIN_{VD}$, which in the current reference design is -67.8 dB. The GAIN of the new voltage divider needs to be added according to the following equation:

$$GAIN = GAIN_{VD} + 12.3\ dB$$

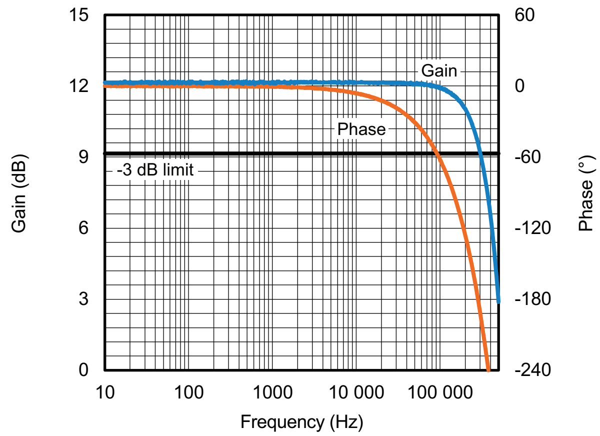


Fig. 5 - GAIN of Isolated Amplifier and Differential to Single-Ended Conversion vs. Frequency

PIN CONFIGURATION

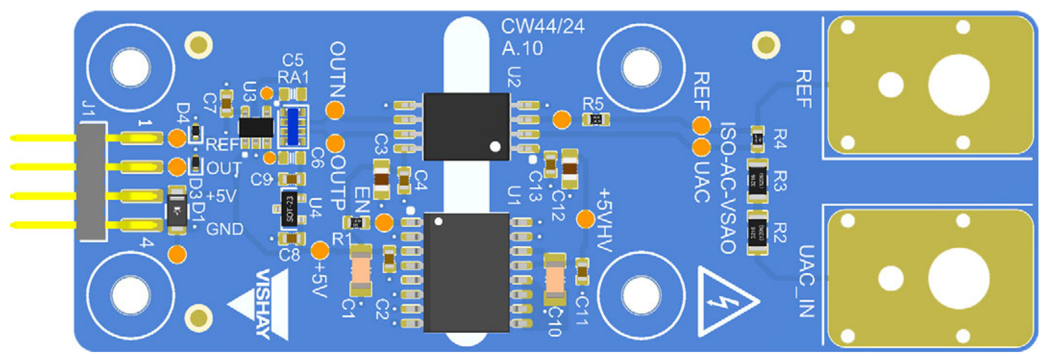


Fig. 6 - Pin Configuration

PIN DESCRIPTION		
PIN NUMBER	**SYMBOL**	**DESCRIPTION**
HV1	UAC_IN	HV AC voltage input
HV2	REF	Reference point AC input
1	REF	Reference output: 1.25 V typ.
2	OUT	Single-ended output: 0 V to 2.5 V
3	+5 V	DC supply input / V_{DD2} (+5 V)
4	GND	Ground level / GND_2

DIMENSIONS in millimeters

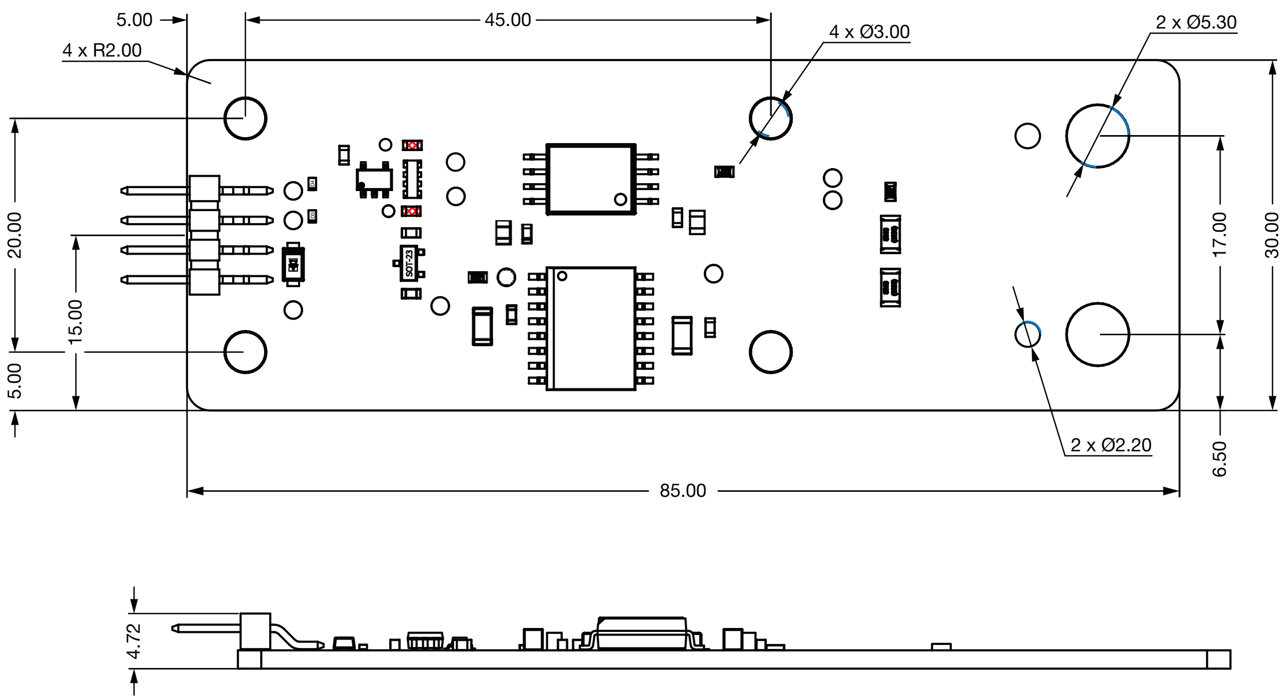


Fig. 7

ABSOLUTE MAXIMUM RATINGS

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)		
ELECTRICAL PARAMETER	**LIMITS**	**UNIT**
HV U_{AC} to ref.	1280	V
V_{CC} to GND	-0.3 to +6.0	V
OUT to GND	0 to 2.56	V
Ambient temperature	-40 to +125	°C
Storage temperature	-55 to +125	°C
Current consumption	600	mA

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)					
PARAMETER		**MIN.**	**TYP.**	**MAX.**	**UNIT**
DC supply		4.0	5.0	5.5	V
HV UAC_IN to REF	linear range	-615	-	+615	V
	before clipping	-785	-	+785	V
Reference output		-	1.25	-	V
Single-ended output		0	-	2.5	V
Output bandwidth		-	300	-	kHz
Current consumption		-	65	300	mA
Power consumption		-	300	1500	mW

SAFETY AND INSULATION RATINGS				
PARAMETER	**TEST CONDITION**	**SYMBOL**	**VALUE**	**UNIT**
Maximum rated withstanding isolation voltage		V_{ISO}	5000	V_{RMS}
Maximum transient isolation voltage		V_{IOTM}	7071	V_{peak}
Maximum repetitive isolation voltage		V_{IORM}	1697	V_{peak}
Maximum working isolation voltage	AC voltage	V_{IOWM}	1200	V_{RMS}
	DC voltage		1697	V_{DC}

Note

- Isolation from component datasheets, not measured in system.

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