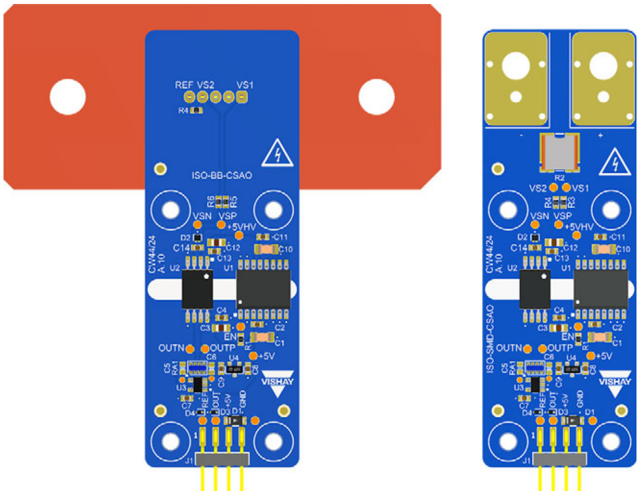
Reference Design
Isolated Current Sensing Using the VIA0050DD



LINKS TO ADDITIONAL RESOURCES

- ISO-BB-CSAO, ISO-SMD-CSAO

FEATURES

- AC current measurement up to 1415 A
- Maximum working isolation voltage of 1200 V_{RMS}
- Isolated single-ended analog output
- Low temperature offset and GAIN drift
- Bandwidth of approx. 280 kHz

KEY COMPONENTS

- VIA0050DD
- WSBE series for high current
- WSL2726 series for lower current
- ACAS 10 kΩ, 20 kΩ

APPLICATIONS

- Motor control applications
- Power supplies
- Battery monitoring systems
- Charging stations
- EV powertrains

DESCRIPTION

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

The measured current goes through a low TCR shunt resistance - the WSBE and WSL are explored in this application. The voltage drop across the shunt resistance is fed to a high performance differential output isolated amplifier, which in this case is the VIA0050DD. The VIA0050DD has a linear differential range of ± 50 mV. The differential output voltage between OUT_P and OUT_N is ± 2.05 V. This differential output is converted to a single-ended output, providing an output in the range of 0 V to 2.5 V (OUT to GND), which is ready to be interfaced by a single-ended ADC or multimeter.

OVERALL SYSTEM BLOCK DIAGRAM

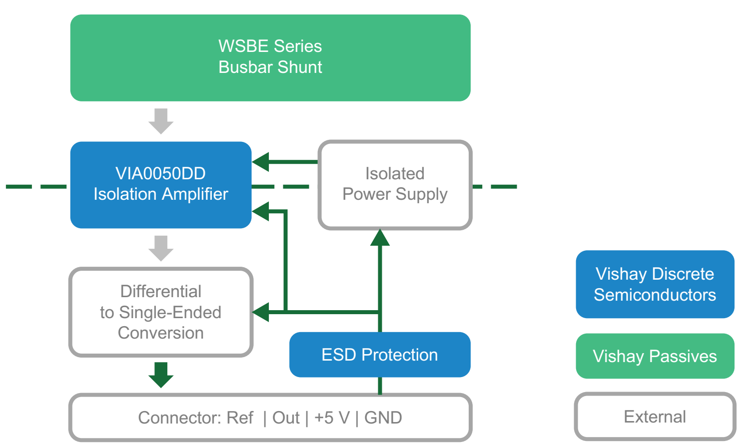


Fig. 1 - Overall System Block Diagram

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.

Current Sensing Stage

In this design, WSBE and WSL shunt resistors are selected. The WSBE features high power capability for current sensing up to 1825 A, ultra low resistance, an all-welded construction, a nickel-chrome alloy resistive element with low TCR (down to ± 10 ppm/°C), very low inductance (< 5 nH), low thermal EMF (< 1.25 μV/°C), and is AEC-Q200 qualified. On the other hand, WSL resistors feature an all-welded construction with extremely low resistance (down to 0.0005 Ω), sulfur resistance, very low inductance (0.5 nH to 5 nH), low thermal EMF (< 3 μV/°C), and AEC-Q200 qualification.

Isolation Amplifier, Current Filter Stage, and Single-Ended Conversion

The voltage drop across the shunt resistance is filtered through a low pass RC filter before it goes to the Isolation amplifier.

The cut-off frequency is chosen to be less than the ΕΔ modulator's sampling (20 MHz); the cut-off frequency is chosen to be f_c = 800 kHz.

To select the R and C values, C must be kept higher than1 nF. Selecting R = 10 Ω + 10 Ω, the C value will be 10 nF.

The R values have been selected to be low enough to avoid significant voltage drop caused by input bias. Also, the resistance has been split between the positive and negative inputs of the isolation amplifier ensuring a balanced impedance to minimize the common mode noise and symmetrical signal paths.

The VBUS05M2-HT5 is a two-line ESD protection device with a bidirectional and symmetrical (BiSy) breakdown and clamping performance, and is used to protect the isolated amplifier from transient voltages.

With a fixed GAIN of "$GAIN_{VIA}$ = 41", the VIA0050DD can output voltages up to ± 2.05 V.

The output of the VIA0050DD is then fed to a simple "differential to a single-ended" conversion circuit with a fixed GAIN of $GAIN_{DSC}$ = 0.5.

6.3 GAIN Calculation for Shunt-Based Current Measurements

This section details the GAIN calculation required to match the voltage output from a shunt-based current measurement to the maximum input voltage range of an isolation amplifier. Proper GAIN adjustment is essential to ensure that the current signal is accurately represented within the amplifier's input range. If the input signal exceeds this range, the output voltage of the isolation amplifier will enter a clipping state.

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, crucial for the effective operation of your electronic applications.

The overall GAIN can be calculated using the following equation:

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

Where:

$GAIN_{SH}$: is the shunt resistor GAIN, which is a resistor value dependent= R_{shunt}

$GAIN_{VIA}$: is the voltage isolator GAIN = 41 (32.2 dB)

$GAIN_{DSC}$: is the differential to single-ended GAIN = 0.5 (-6 dB)

The $GAIN_{SH}$ values can be seen in the following table:

R (Ω)	$GAIN_{SH}$ (V/A)	$GAIN_{SH}$ (V/A)	$GAIN_{SH}$ (DB)	$I_{max.}$ (A)
25µ	0.000025	$\frac{1}{40\,000}$	-92.0	1415
50µ	0.00005	$\frac{1}{20\,000}$	-86.0	1000
100µ	0.0001	$\frac{1}{10\,000}$	-80.0	600
1m	0.001	$\frac{1}{1000}$	-60.0	50

Sometimes it is more convenient to calculate the GAIN in dB, in this case:

$$GAIN(dB) = (GAIN_{SH}(dB) + GAIN_{VIA}(dB) + GAIN_{DSC}(dB))$$

In this design, a 1 mΩ resistor is used and the overall GAIN versus frequency is shown in Fig. 3. If the user wants to calculate the GAIN for a different resistor, the equation will be as below;

$$GAIN(dB) = GAIN_{SH}(dB) + 32.2\ dB - 6\ dB$$

The overall GAIN can be summarized as below:

R (Ω)	GAIN (V/A)	GAIN (V/A)	GAIN (DB)
25µ	0.0005125	$\frac{1}{1951.2}$	-65.8
50µ	0.001025	$\frac{1}{975.6}$	-59.8
100µ	0.00205	$\frac{1}{487.8}$	-53.8
1m	0.0205	$\frac{1}{48.78}$	-33.8

The measured GAIN of this reference design with R_{shunt} (1 mΩ) is shown below. In this graph, the input current is swept from -30 A to +30 A and the "Ref" and "OUT" signals are measured. OUT is the measured voltage at the "OUT-pin" J1-2, REF is the measured voltage at "Ref-pin" J1-1, and OUT-Ref is the calculated voltage, which represents the input current with a GAIN of $\frac{1}{48.78}$ 148.78 V/A.

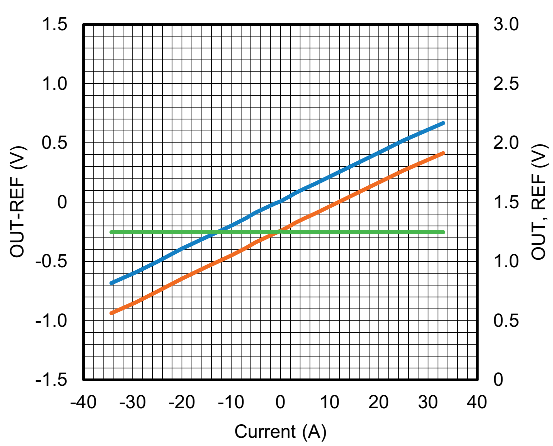


Fig. 2 - Measured GAIN

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

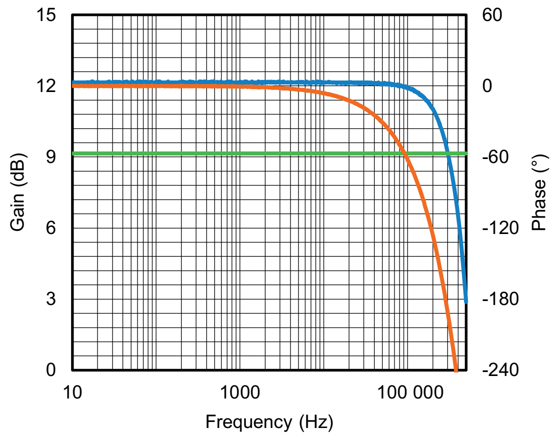


Fig. 3 - GAIN of Isolated Amplifier and Differential to Single-Ended Conversion vs. Frequency (without R_{SH})

PIN CONFIGURATION

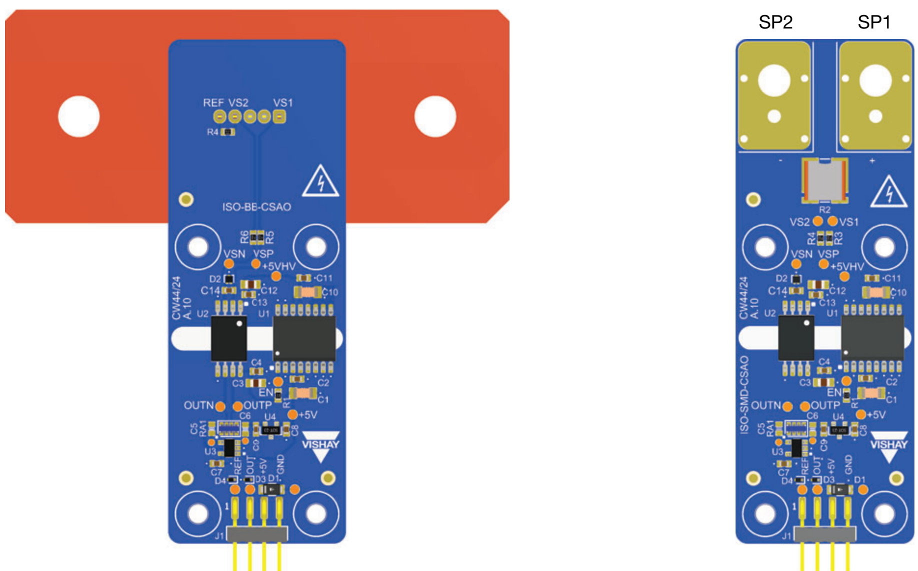


Fig. 4 - ISO-BB-CSAO and ISO-SMD-CSAO

PIN DESCRIPTION		
PIN NUMBER	**SYMBOL**	**DESCRIPTION**
HV1	VS1	Positive load terminal
HV2	VS2	Negative load terminal
1	Ref	Reference output (1.25 V typ.)
2	OUT	Single ended output (0 V to 2.5 V)
3	+5V	DC supply input / V_{DD2} (+5 V)
4	GND	Ground level / GND_2

ABSOLUTE MAXIMUM RATINGS

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)

PRODUCT NAME	ISOLATED AMPLIFIER	SENSING ELEMENT	CURRENT RANGE
ISO-BB-CSAO	VIA0050DD	WSBE 25 μΩ	± 1415 A (continues) ± 2560 A (for less than 5 s)
		WSBE 50 μΩ	± 1000 A (continues) ± 1280 A (for less than 5 s)
		WSBE 100 μΩ	± 600 A (continues) ± 640 A (for less than 5 s)
ISO-SMD-CSAO	VIA0050DD	WSL 1 mΩ	± 54 A (continues) ± 64 A (for less than 5 s)

ELECTRICAL PARAMETER

PARAMETER	LIMITS	UNITS
Ambient temperature	-40 to +125	°C
Storage temperature	-55 to +125	°C

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	MIN.	TYP.	MAX.	UNIT
DC supply	4.0	5.0	5.5	V
CURRENT FROM SP1 TO SP2				
(WSBE 1 μΩ) resistance linear	-50	-	50	A
(WSBE 1 μΩ) resistance before clipping	-64	-	64	A
(WSBE 25 μΩ) resistance linear	-2000	-	2000	A
(WSBE 25 μΩ) resistance before clipping	-2560	-	2560	A
(WSBE 50 μΩ) resistance linear	-1000	-	1000	A
(WSBE 50 μΩ) resistance before clipping	-1280	-	1280	A
(WSBE 100 μΩ) resistance linear	-500	-	500	A
(WSBE 100 μΩ) resistance before clipping	-640	-	640	A
Reference output	-	1.25	-	V
Single ended output	0	-	2.5	V
Output bandwidth	-	280	-	kHz
Current consumption	-	65	300	mA
Power consumption	-	300	1500	mW

SAFETY AND INSULATION RATINGS

PARAMETER	TEST CONDITIONS	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 datasheet, not measured in system

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