Reference Design Material for Current Sensing

Reference Board for Low-side Current Sensing Circuit

REFSENS002-EVK -001

The reference design for low-side current sensing circuits is achieved by using shunt resistors, an op-amp, and external components to configure a low-side current sensing circuit to be used for functions including current (voltage) control, over current limiting, and remaining battery level detection in the areas of automotive and industrial equipment. The low-side current sensing circuits can be incorporated most simply at a lower cost compared with other methods.

Reference board REFSENS002-EVK-001 is configured with an op-amp and shunt resistors for industrial equipment, enabling current detection up to 100 A.

Features

- The current detection circuit is configured with the simplest circuit using shunt resistors and an op-amp
- The circuit uses PSR series shunt resistors (PSR400, 2mΩ, 4 in parallel), which are ideal for current detection in large current circuits
- The circuit uses a low noise LMR1802G CMOS op-amp, which is ideal for high precision sensing
- Current detection range: max. 100 A
- Proper thermal design enables operations with a detection current of 100 A and the ambient temperature at 85°C

Electrical characteristics

The electrical characteristics of REFSENS002-EVK-001 are shown below.

Table 1. Electrical characteristics of REFSENS002-EVK-001

Item	Min	Typ	Max	Unit	Conditions
Detection current range	–		100	A	R11/12=2kΩ, R21/22=120kΩ
Sense voltage			50	mV	RS = 0.5mΩ
Sensing precision			7	%	Iin=50A
Operating voltage range	2.5		5.5	V	
Operating temperature range	-40		85	ºC	
Output voltage		3.0		V	Iin=100A, V_{DD}=5.0V
DC Gain		60		V/V	R11/12=2kΩ, R21/22=120kΩ

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Appearance of evaluation board

The appearance of the REFSENS002-EVK-001 board is shown below.

Board name	REFSENS002-EVK-001
Board size	90mm × 80mm × 1.6mmt
Board structure	FR-4 4-layer board, copper foil thickness per layer: 3 oz, thermal via: ø0.3 mm

Figure 1. Appearance of REFSENS002-EVK-001 board

Example of operating procedure

Necessary devices

- DC power supply: Vo=2.5V～5.5V, Io=100mA
- Voltmeter
- Device under test (DUT): circuit with a maximum current of 100 A

The evaluation of the DC items is performed with REFSENS002-EVK-001 according to the procedure below. Other measurements are described in “Measurement circuit diagrams” on page 12.

1. Preset the DC power supply to 5 V and disable the power supply output.
2. Set the DUT to 100 A or less and disable the DUT.
3. Connect the positive and negative terminals of the DC power supply to the VDD and GND terminals, respectively.
4. Connect the positive and negative terminals of the DUT to the +VIN and -VIN, respectively.
5. Connect the positive and negative terminals of the voltmeter to the OUT1 and GND terminals, respectively.
6. Enable the DC power supply.
7. Enable the DUT.
8. Confirm that the reading of the voltmeter is 3.0 V (under a 100 A load).

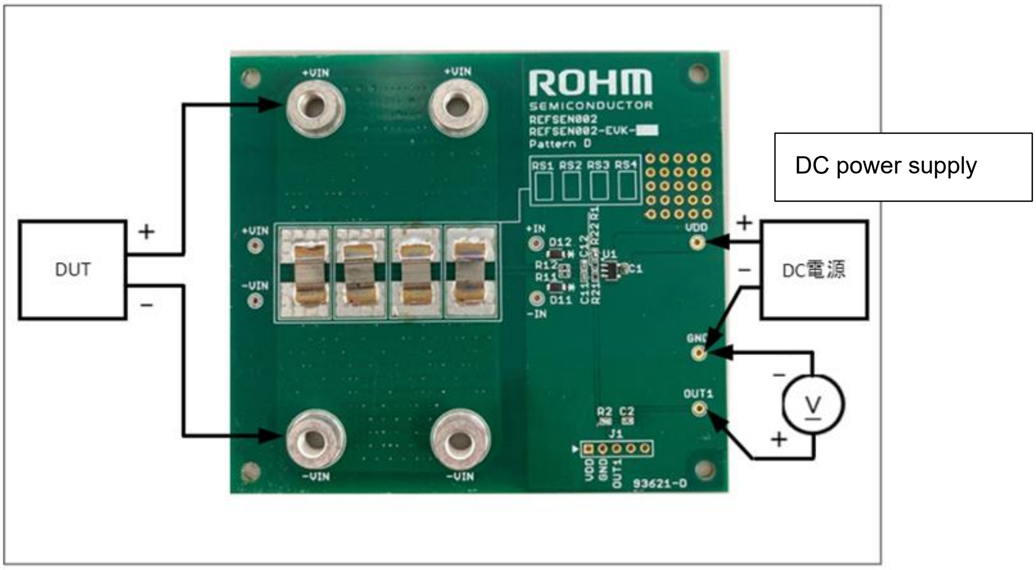


Figure 2. Connection diagram

Design procedure

In this reference design, the selection of components, design of circuit constants, and setting of sensing precision refer to the application note “Design of Low-Side Current Sensing Circuit”, which is available from the following link.

Design of Low-Side Current Sensing Circuit

Circuit diagram

The circuit diagram of REFSENS002-EVK-001 is shown below. The circuit diagram is available from ROHM's website.

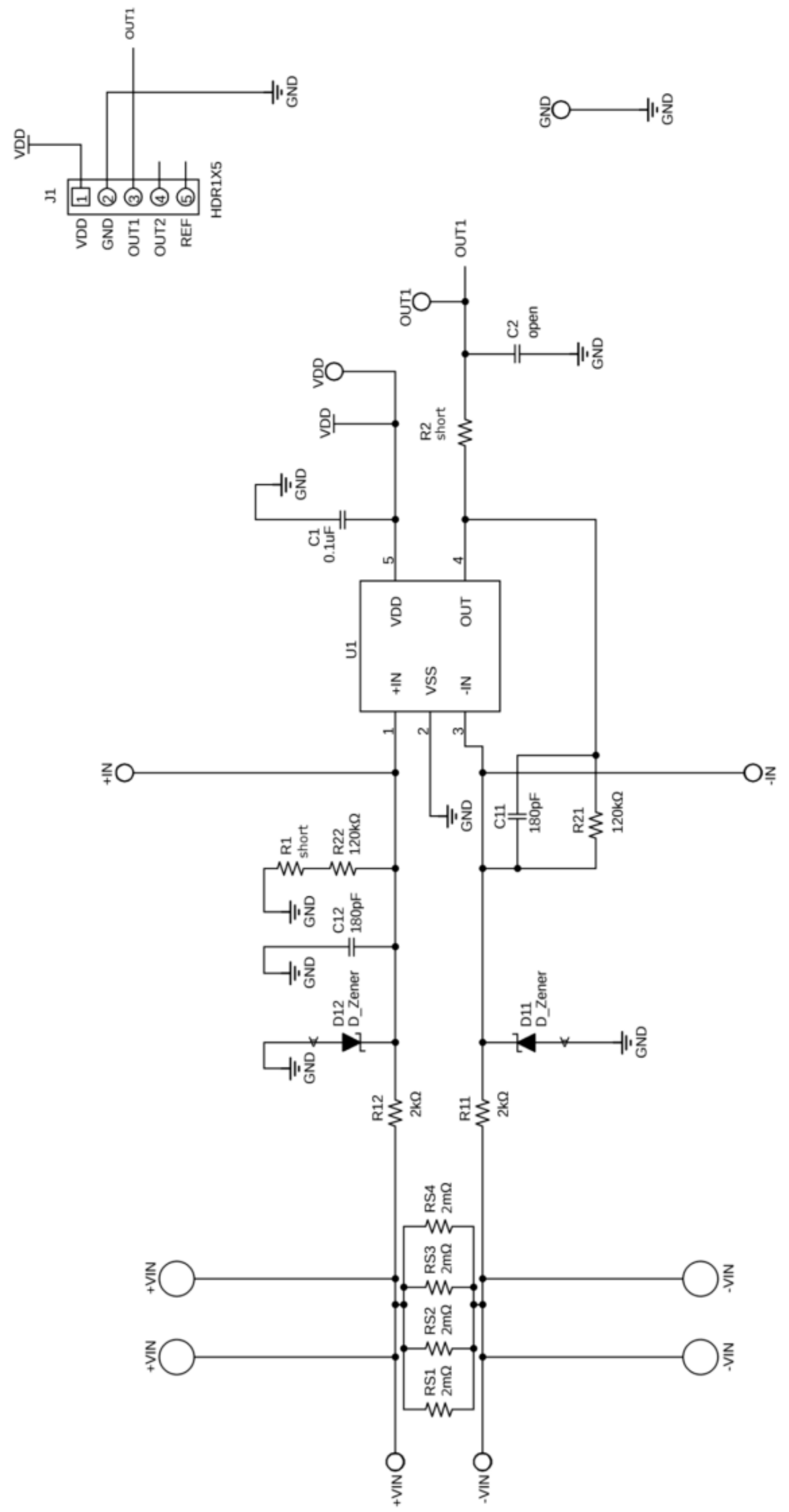


Figure 3. Circuit diagram of REFSENS002-EVK-001

Parts list

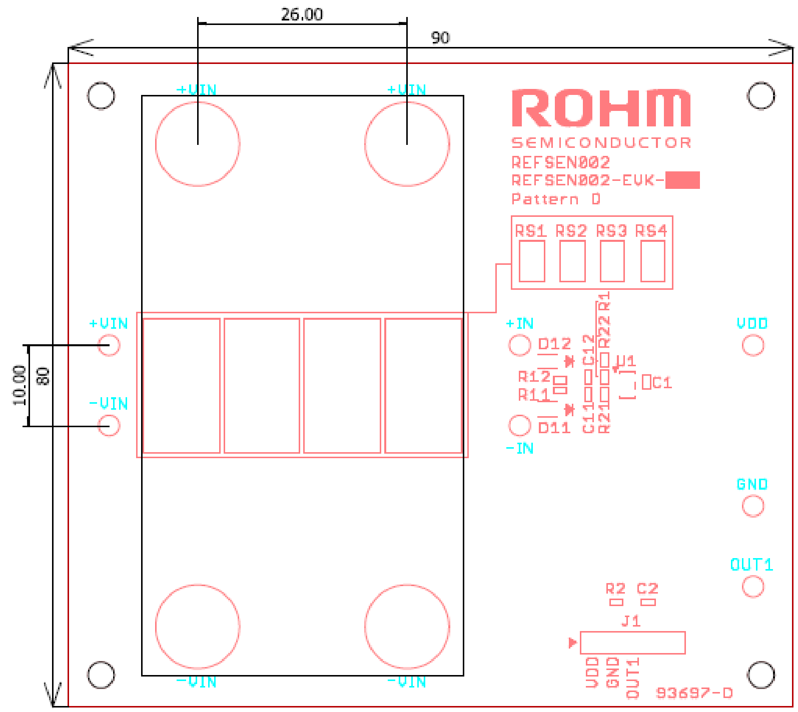
The parts list of REFSENS002-EVK-001 is shown below. The parts list is available from ROHM's website.

Table 2. Parts list of REFSENS002-EVK-001

List of Materials					
Part	**Product name**	**Value**	**Footprint**	**Description**	**Quantity**
C1	GCM155R71H104KE02J	0.1uF	C_1005_0402	Capacitor, Surface Mount	1
C2	-	open	C_1005_0402	Capacitor, Surface Mount	1
C11, C12	GCM1552C1H181JA01	180pF	C_1005_0402	Capacitor, Surface Mount	2
D11, D12	TDZV5.1	5.1V	TUMD2M-SOD_323HE	Zener Diode, Surface Mount	2
J1	-	-	61300511121	Connector Header1x5,pitch 2.54	1
R1	MCR01SMQPF	short	R_1005_0402	Resistor, Surface Mount	1
R2	MCR01SMQPF	short	R_1005_0402	Resistor, Surface Mount	1
R11, R12	MCR01SMQPF	2kΩ	R_1005_0402	Resistor, Surface Mount	2
R21, R22	MCR01SMQPF	120kΩ	R_1005_0402	Resistor, Surface Mount	2
RS1~4	PSR400ITQFJ2L00	2mΩ	10mm x 5.2mm	Resistor, Surface Mount	4
+VIN	-	-	TP_10P0/7P20	Test Pin, Through Hole	2
+VIN	-	-	TP_2P0/1P05	Through Hole	1
-VIN	-	-	TP_10P0/7P20	Test Pin, Through Hole	2
-VIN	-	-	TP_2P0/1P05	Through Hole	1
VDD	-	-	TP_2P0/1P05	Through Hole	1
OUT1	-	-	TP_2P0/1P05	Through Hole	1
GND	-	-	TP_2P0/1P05	Through Hole	1
+IN	-	-	TP_2P0/1P05	Through Hole	1
-IN	-	-	TP_2P0/1P05	Through Hole	1
U1	LMR1802G-LB	-	SSOP5	CMOS OP-AMP	1

Layout

The PCB layout of REFSENS002-EVK-001 is shown below. This PCB is configured with four layers. The layout data is also available from ROHM's website.



Unit:mm

Figure 4. Top silkscreen (top view)

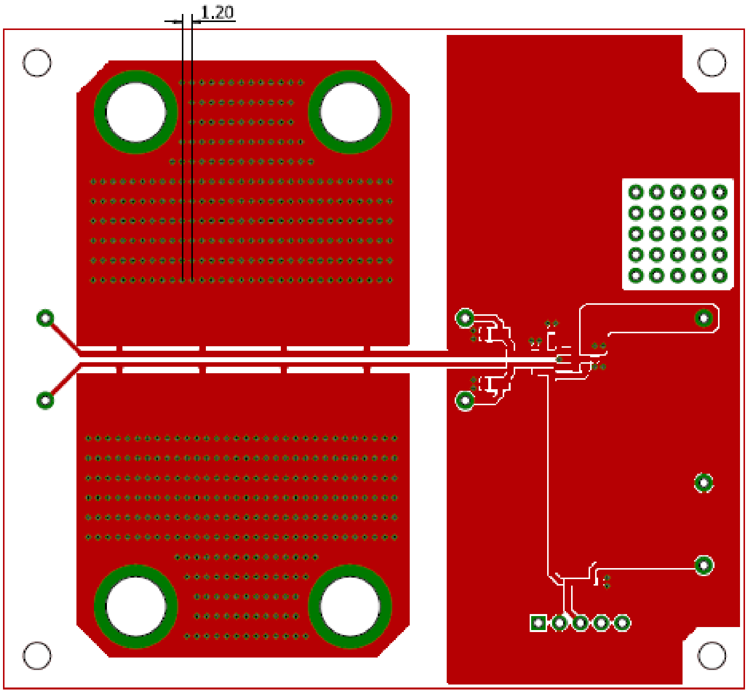


Figure 5. Top layout (top view)

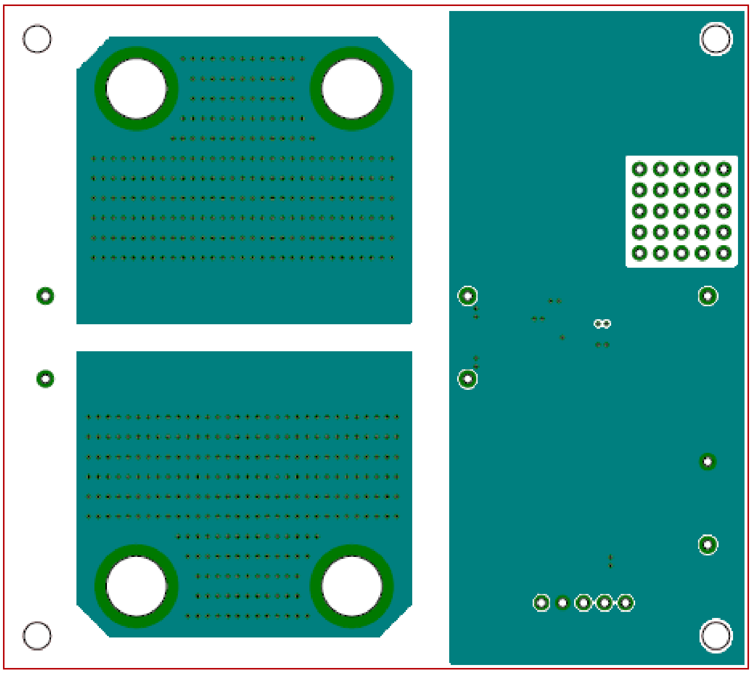


Figure 6. Second layer layout (top view)

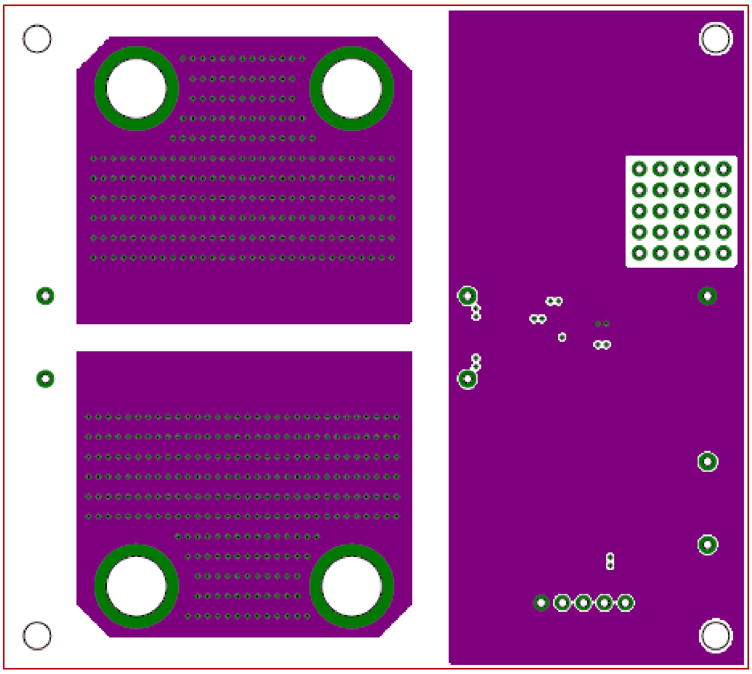


Figure 7. Third layer layout (top view)

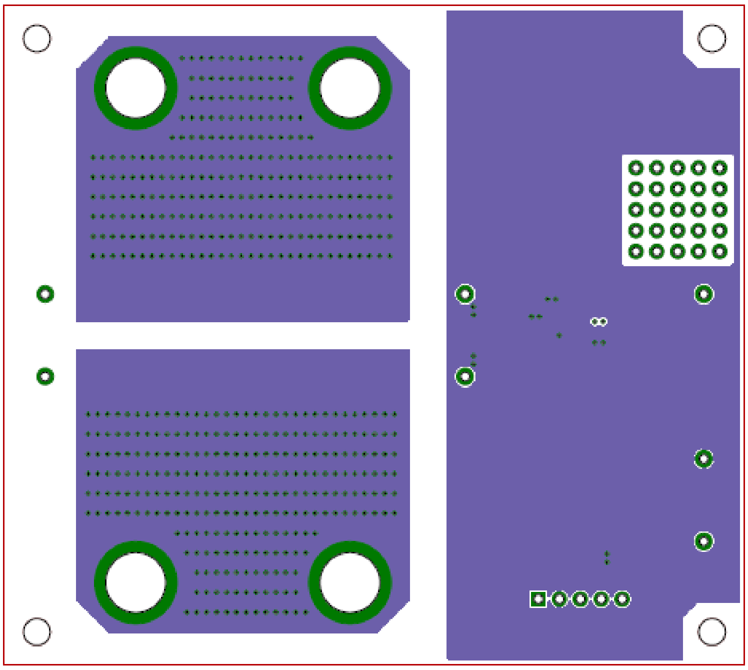


Figure 8. Bottom layout (top view)

Reference application characteristics

The reference application characteristics are shown below. Unless otherwise noted, T_A = 25°C and V_{DD} = 5.0 V

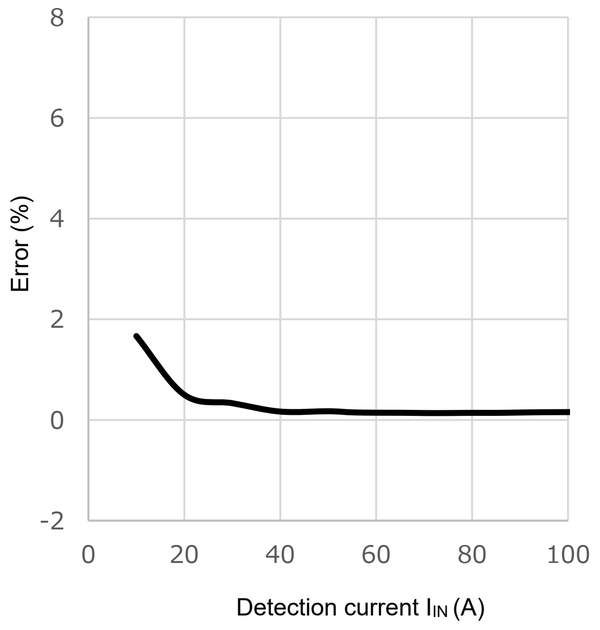


Figure 9. Error rate of current sensing precision vs. detection current

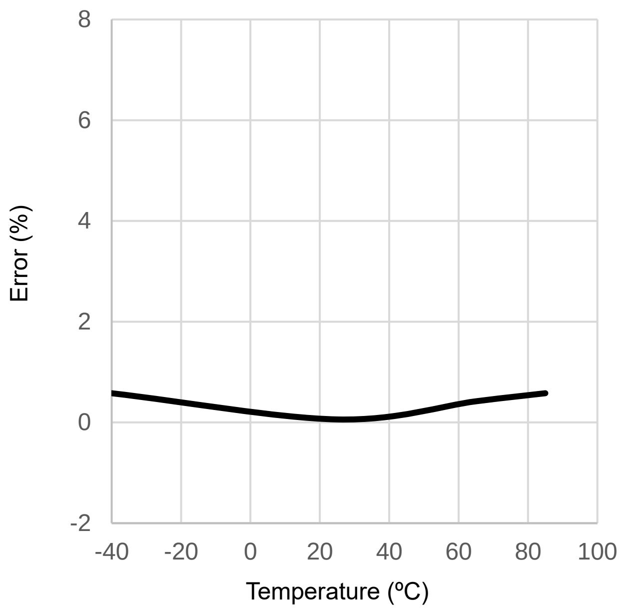


Figure 10. Error rate of current sensing precision vs. ambient temperature

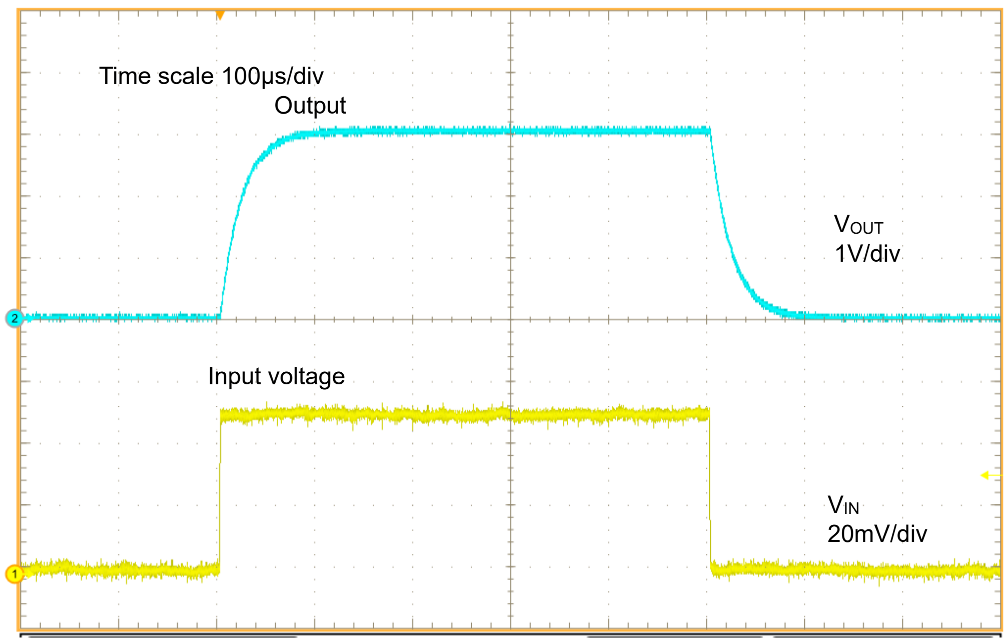


Figure 11. Step Response

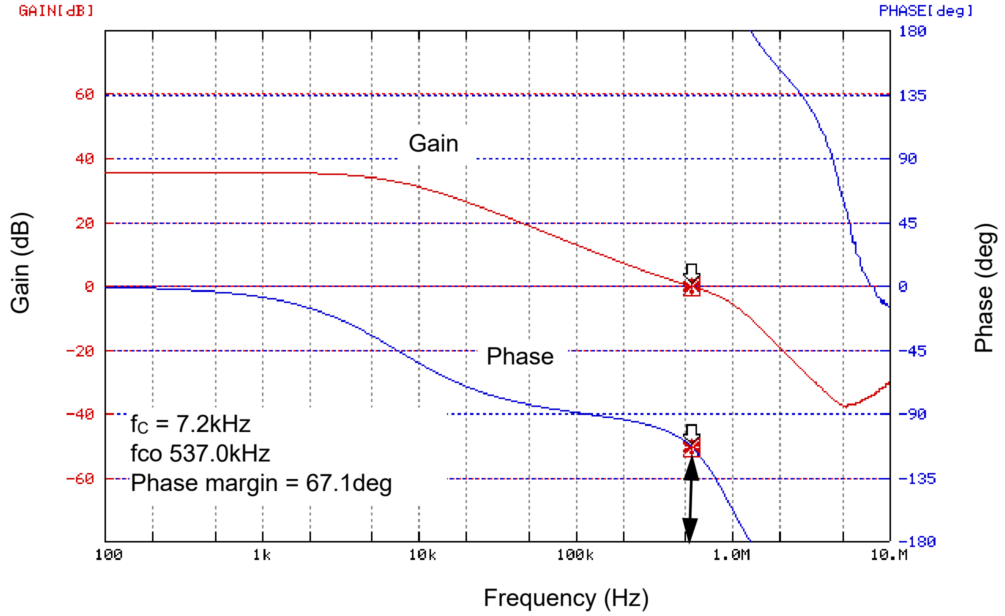


Figure 12. Voltage gain and phase vs. frequency characteristics (-40°C)

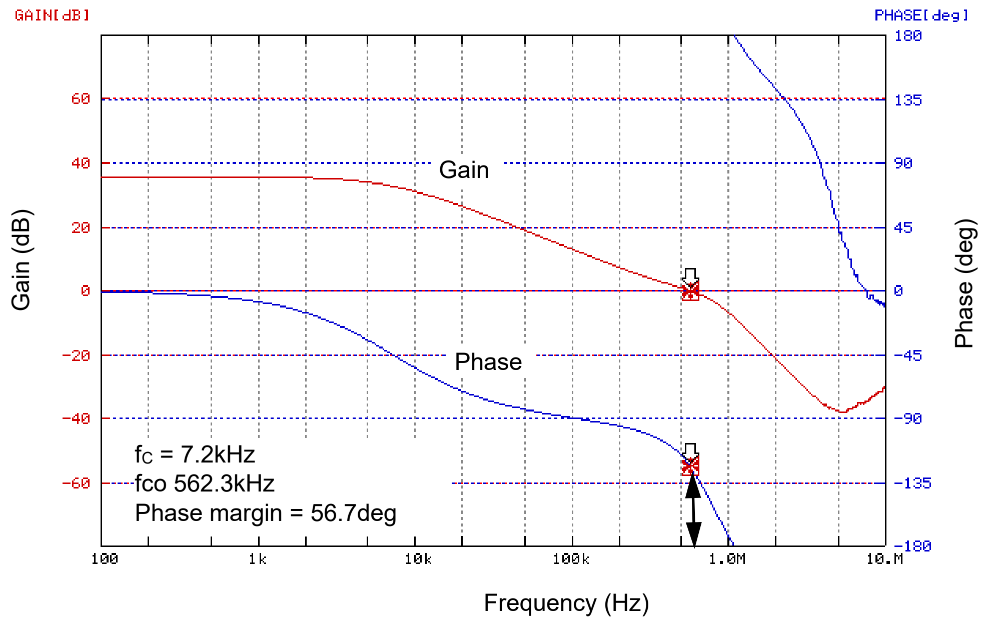


Figure 13. Voltage gain and phase vs. frequency characteristics (25°C)

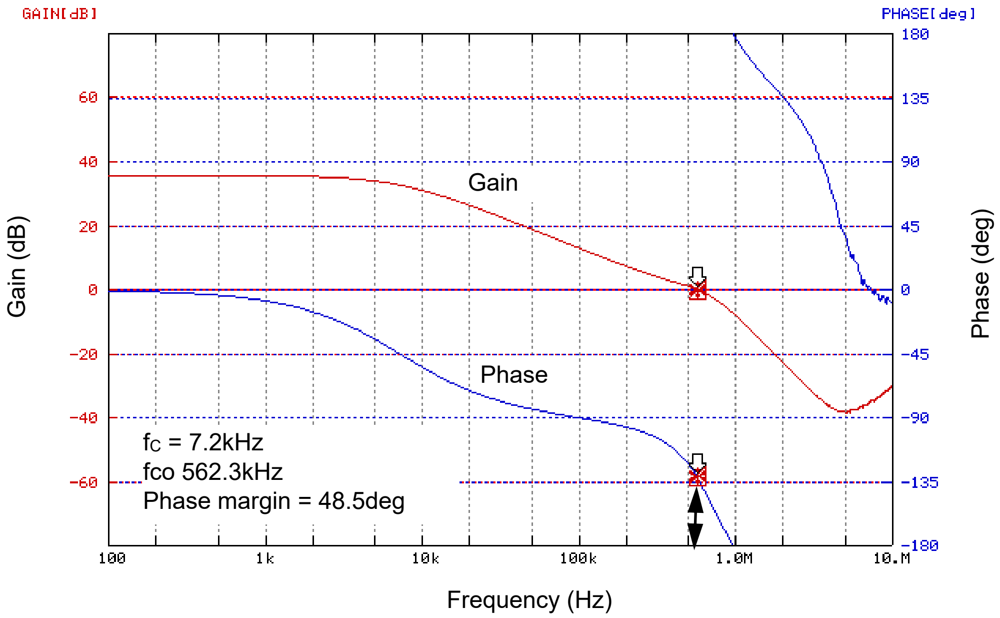


Figure 14. Voltage gain and phase vs. frequency characteristics (65°C)

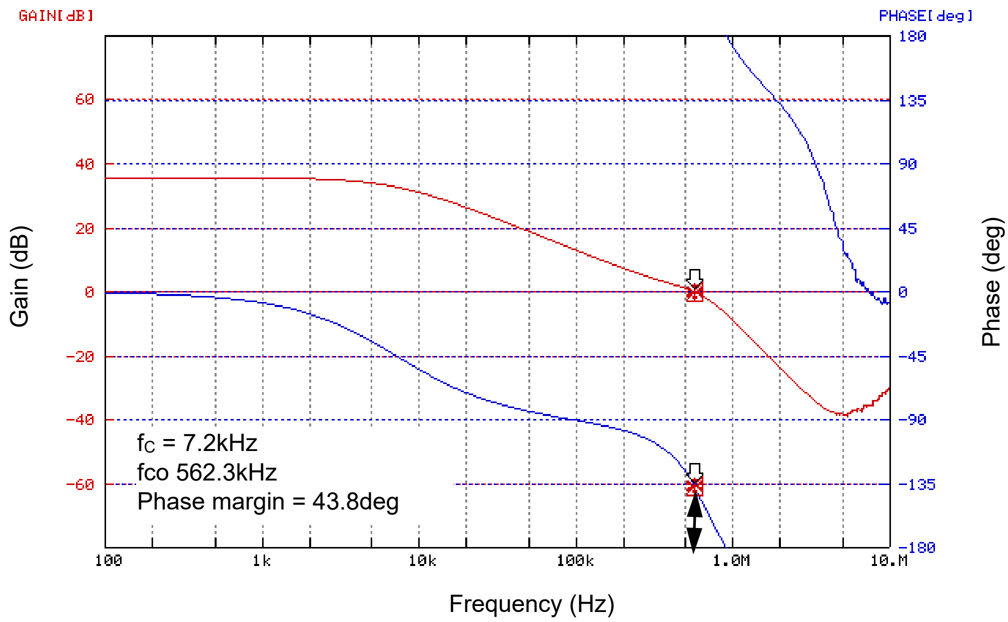


Figure 15. Voltage gain and phase vs. frequency characteristics (85°C)

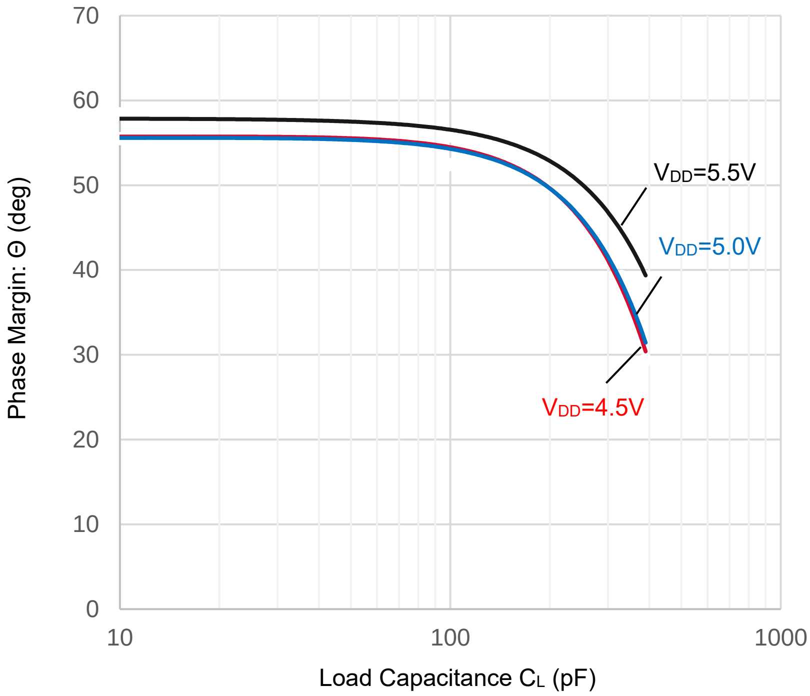


Figure 16. Phase margin vs. load capacitance characteristics

Measurement circuit diagrams

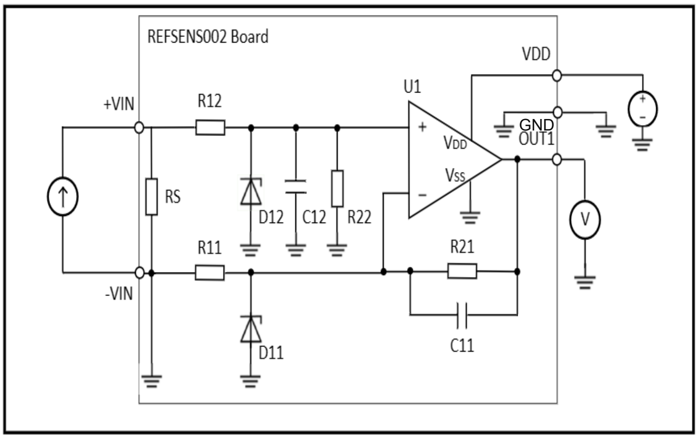


Figure 17. Measurement circuit diagram for DC Sweep

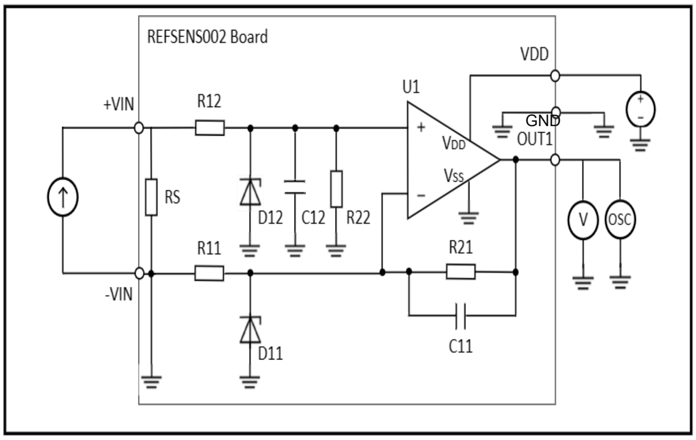


Figure 18. Measurement circuit diagram for transient analysis (pulse application)

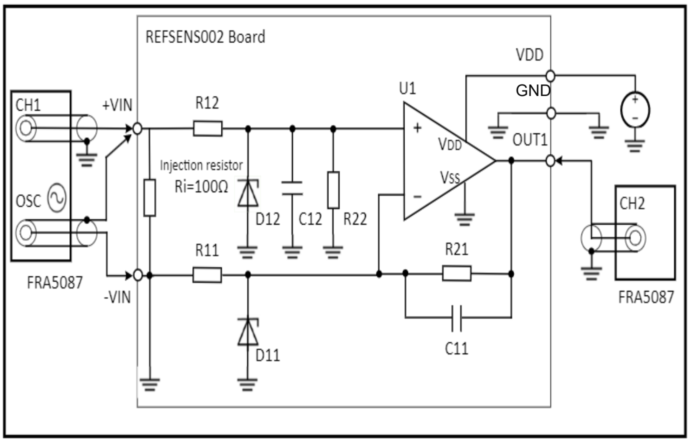


Figure 19. Measurement circuit diagram for AC analysis

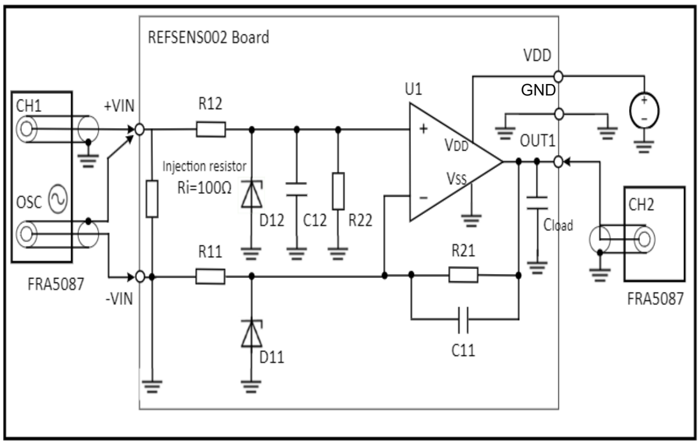


Figure 20. Measurement circuit diagram for AC analysis (load capacitance characteristics)

Thermal Design

The following is the result of temperature measurement on the shunt resistors when a detection current of 100 A is applied (at ambient temperature T_A = 25°C).

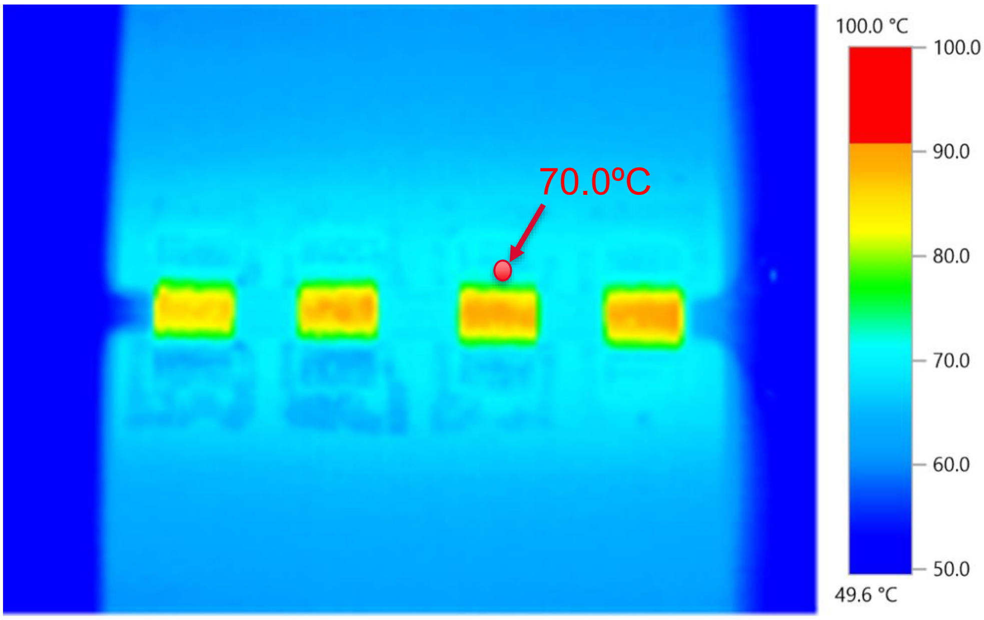


Figure 21. Temperature distribution of shunt resistors

To apply a large current to the current detection part, it is necessary to maintain the temperature of each component within the specified operating temperature range. The specified operating temperature range for each component is described in the data sheet. The specified operating temperature range is between -65°C and +175°C for PSR400, which is the type of shunt resistor used in this reference design. Reduce the power along the power reduction curve so that the temperature will not exceed the specified operating temperature range.

For ROHM's shunt resistors, the rated power guarantee is specified with the terminal temperature of the product when power is applied, instead of the ambient temperature.

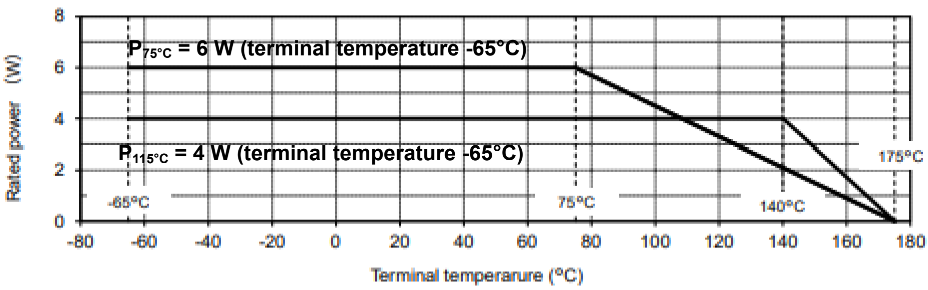


Figure 22. Power reduction curves for PSR400 2.0mΩ (taken from the data sheet)

In Figure 21, the highest terminal temperature is T_k = 70.0°C (at ambient temperature T_A = 25°C). If the ambient temperature during actual operations is assumed (T_A = 85°C), the terminal temperature is T_k = 130°C (at T_A = 85°C). According to the power reduction curves in Figure 22, the power reduction curve for $P_{115°C}$ is applicable if T_k = 115°C or more. Therefore, it is necessary to reduce the power consumption to 3 W or less.

The power consumption of each shunt resistor is calculated to be 1.25 W as shown in the equation below. Therefore, it can be confirmed that the power consumption remains lower than the rated power even at the ambient temperature during actual operations.

$P_C = V_{shunt} \times I_{IN}$ = 50 mV × 100 A = 5 W (1.25 W per resistor)

T_k: Temperature at center of the shunt resistor terminal
T_A: Ambient temperature
P_C: Power consumption
V_{shunt}: Voltage produced across the shunt resistor
I_{IN}: Detection current

Reference: High Power Guarantee Using Terminal Temperature Derating

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Precautions for use

• In this reference design, the temperature is maintained within the specified operating temperature range by placing four shunt resistors in parallel in order to disperse heat generation.
Determine the number of parallel shunt resistors according to the detection current, so that the temperature will not exceed the specified operating temperature range.

• Check the absolute maximum rating and the precautions for use described in the data sheets of the op-amp and other components.

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