RTKA788000DE0000BU

Opposite Sensor Board

The RTKA788000DE0000BU evaluation board allows for the measurement of power line currents up to 40A.

The board includes two RAA788000 current sensor ICs in an opposite sensor topology and a 1ft section of AWG-8 cable, for easy connection to a high-current source.

The output amplifiers of the two sensors are configured to a single differential amplifier to allow for differential current measurements with minimum noise.

Specifications

- V_S = 3.3V
- Trendline Error Calculations use linear best fit for three Decades of Current
  - 1A - 40A: Trendline Error < 0.25%

Features

- Two current sensor ICs
- Gain setting of 1400V/V
- Opposite sensor topology
- Differential current measurement up to 40A
- Wide 2.7V to 3.6V supply voltage range

Board Contents

- Evaluation board
- 1' AWG-8 cable
- Evaluation board manual

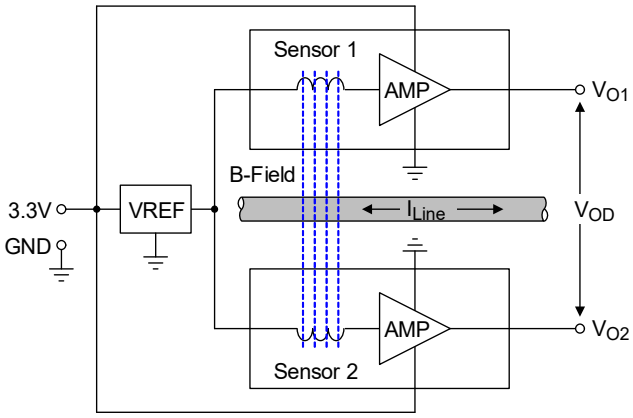

Figure 1. Block Diagram

Contents

1. Functional Description

The RAA788000 evaluation board allows for quick powerline current measurements by affixing the board to a powerline cable with zip ties. The current within the cable produces a magnetic field, which is picked up by the on-chip coil. The coil generates a voltage in the form of an electromotive force, EMF. The coil outputs are amplified and then made available as differential output voltage (V_{OD}) between V_{O1} and V_{O2}. The main connection points on the board are the supply (VS, GND1, GND2) and the outputs (V_{O1}, V_{O2}).

Figure 2. RTKA788000DE0000BU Evaluation Board

1.1 Operational Characteristics

The supply voltage and passband gain may be adjusted as necessary.

1.1.1 Supply Voltage

The operating range for the RAA788000 is between 2.7V and 3.6V.

1.1.2 Passband Gain

When measuring line currents larger than 40A, the passband gain can be lowered to avoid op-amp saturation. The gain can adjusted through the R_G resistor within the differential amplifier. Equation 1 is the differential passband gain equation.

(EQ. 1) $$G_{PB(DIF)} = 1 + \frac{2R_F}{R_G}$$

Changing R_G has a ramification on the high-pass cut-off frequency created by the gain resistor and the DC blocking capacitor. If the gain needs to be changed, see the Band-Pass Filtering section in the datasheet.

1.2 Quick Setup

1. Connect an external +3.3V DC supply voltage to VS and GND terminals.
2. An alternating current is to be applied through the wire strapped to the board.
3. Differential output voltage (V_{OD}) between V_{O1} and V_{O2} are recorded
4. Voltage measurements are converted from V_{OD} to current using a linear equation.

1.2.1 Wire Size

Included with the evaluation board is an optimal AWG-8 cable (Figure 3), however other sizes may be strapped in its place. The wire gauge size affects the sensitivity of the opposite board topology in two ways. First, if a large cable such as AWG-2 is used, the center of the cable is further from the coil causing a reduction in sensitivity (Figure 4). Second, if a small cable such as AWG-18 is used, the distance between the cable and the coil is increased causing a reduction in sensitivity (Figure 5).

Figure 3. Optimal Cable

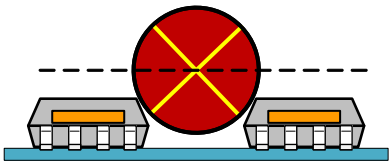

Figure 4. Larger Cable

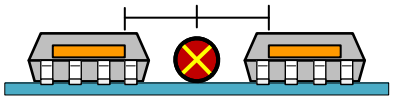

Figure 5. Smaller Cable

1.2.2 Measurement Process

On the evaluation board, there are two outputs V_{O1} and V_{O2} that make up the differential output voltage (V_{OD}). These (V_{OD}) measurements can be recorded using a multimeter on the AC voltage setting (Figure 6).

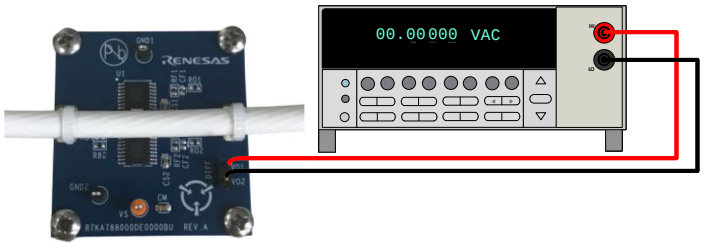

Figure 6. Example VOD Measurement with Multimeter

1.2.3 Best Fit Trendline

Small variations such as wire distance have a large effect on coil sensitivity, therefore Renesas recommends that each user develops a setup-specific trendline for best accuracy. To create this trendline, perform a load current sweep using at least three data points for the range in which measurements will be taken. For the entire 1A-40A range, these data points may be taken at 1A, 20A, and 40A. When the V_{OD} measurements have been recorded, a best fit trend (Figure 15) is developed using a linear best fit equation.

(EQ. 2) $y = mx + b$

With the load current on the x-axis and the V_{OD} on the y-axis, Equation 2. can be represented as:

(EQ. 3) $V_{OD} = m \times I_{L(Estimated)} + b$

Solving for $I_{L(Estimated)}$, Equation 3 becomes Equation 4:

(EQ. 4) $$I_{L(Estimated)} = \frac{V_{OD} - b}{m}$$

For each measured V_{OD}, an estimated load current is determined using Equation 4. The estimated load current is compared with the actual load current to determine its error percentage (Figure 16).

(EQ. 5) $$\%Error = \frac{I_{L(Actual)} - I_{L(Estimated)}}{I_{L(Actual)}} \times 100$$

2. Board Design

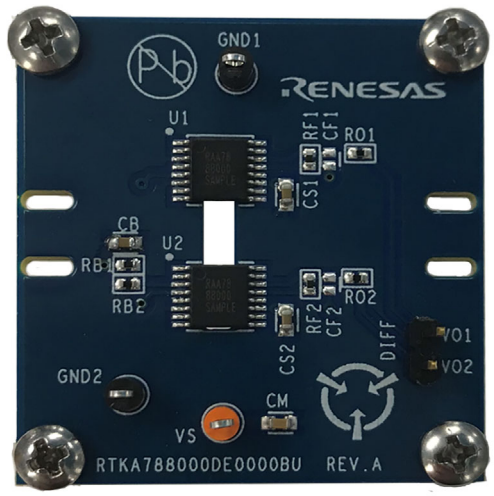

Figure 7. Evaluation Board (Top)

Figure 8. Evaluation Board (Bottom)

2.1 Layout Guidelines

Place bypass capacitors (C_B) as close as possible to the IC supplies to suppress high frequency noise (Figure 9).

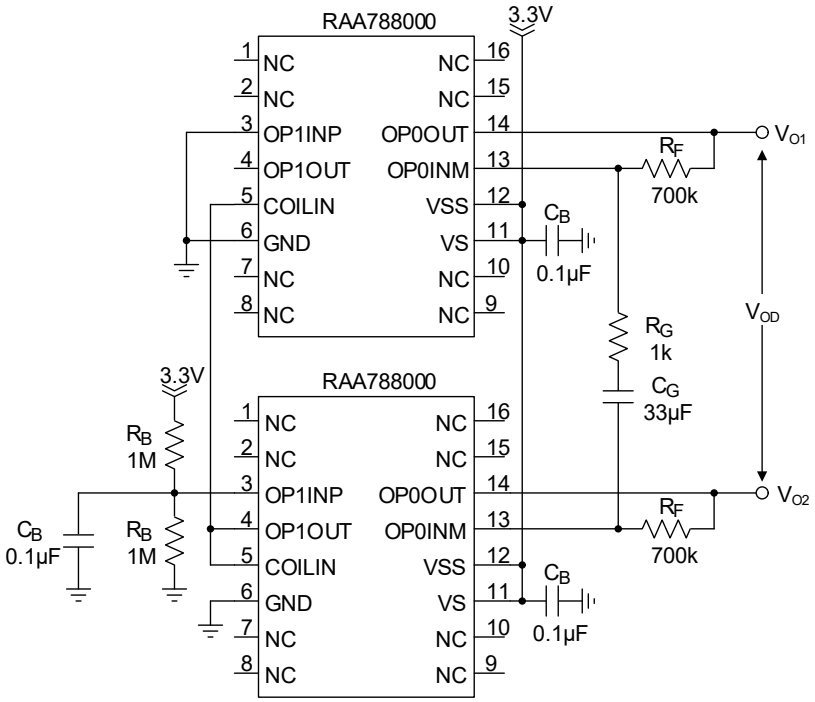

Figure 9. Decoupling and DC Blocking Capacitor Placement

Place a DC blocking cap in series with R_G (Figure 9) to prevent the internal op-amps input offset from being amplified. Without this capacitor, in high gain applications such as the evaluation board, the high input offset of the internal op-amp ±2mV (maximum) would drive the output into saturation.

For opposite topology designs, such as this evaluation board, it is important to cut-out the PCB underneath the chips (Figure 8) to create an unobstructed magnetic field path. As well, it is important to distance the two chips based on the diameter of the powerline cable for optimal sensitivity (Figure 3).

2.2 Schematic Diagrams

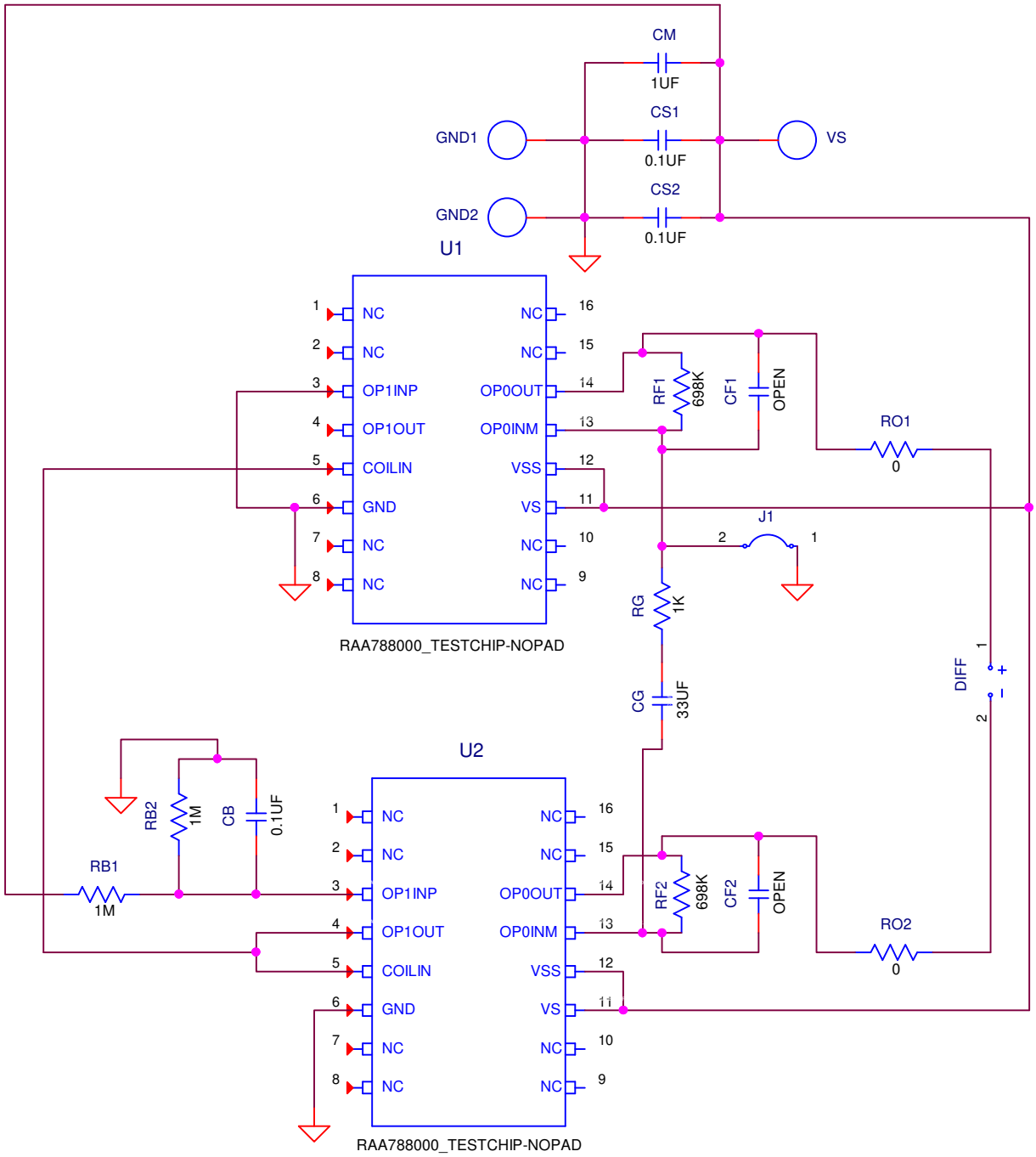

Figure 10. RTKA788000DE0000BU Schematic

2.3 Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	-	PWB-PCB, RTKA788000DE0000BU, REVA, ROHS	MTL (Multilayer PCB International (HK) CO.LTD)	RTKA788000DE0000BURVAPCB
1	CG	CAP, SMD, 1812, 33µF, 16V,20%, X7R, ROHS	TDK	C4532X7R1C336M250KC
1	CM	CAP-AEC-Q200, SMD, 0603, 1µF, 25V, 10%, X7R, ROHS	Murata	GCM188R71E105KA64D
0	CF1, CF2	CAP, SMD, 0402, DNP-PLACE HOLDER, ROHS	-	-
3	CB, CS1, CS2	CAP, SMD, 0603, 0.1µF, 50V, 10%, X7R, ROHS	AVX	06035C104KAT2A
2	GND1, GND2	CONN-MINI TEST PT, VERTICAL, BLK, ROHS	Keystone	5001
1	VS	CONN-MINI TEST POINT, VERTICAL, ORG, ROHS	Keystone	5003
1	DIFF	CONN-HEADER, 1x2, RETENTIVE, 2.54mm, 0.230x0.120, ROHS	BERG/FCI	69190-202HLF
2	U1, U2	IC-CURRENT SENSE, 16P, TSSOP, ROHS	Renesas Electronics	RAA788000GSP#HA0
2	RO1, RO2	RES, SMD, 0402, 0Ω, 1/16W, 5%, TF,ROHS	Venkel	CR0402-16W-00T
2	RB1, RB2	RES, SMD, 0402,1M, 1/16W, 1%, TF, ROHS	Various	Generic
2	RF1, RF2	RES, SMD, 0402, 698K, 1/16W, 1%, TF, ROHS	Vishay/Dale	CRCW0402698KFKED
1	RG	RES, SMD, 0805, 1k, 1/8W, 1%, TF, ROHS	Venkel	CR0805-8W-1001FT
4	Four corners	SCREW, 4-40x1/4in, PHILLIPS, PANHEAD, STAINLESS, ROHS	Building Fasteners	PMSSS 440 0025 PH
4	Four corners	STANDOFF, 4-40x3/4in, F/F, HEX, ALUMINUM, 0.25OD, ROHS	Keystone	2204
1	Place assy in bag	BAG,STATIC, 4x6, ZIPLOC, ROHS	Uline	S-2261
0	J1	DO NOT POPULATE OR PURCHASE	-	-
1	AFFIX TO BACK OF PCB	LABEL-DATE CODE_LINE 1: YRWK/REV#, LINE 2: BOM NAME	Renesas Electronics America	LABEL-DATE CODE

2.4 Board Layout

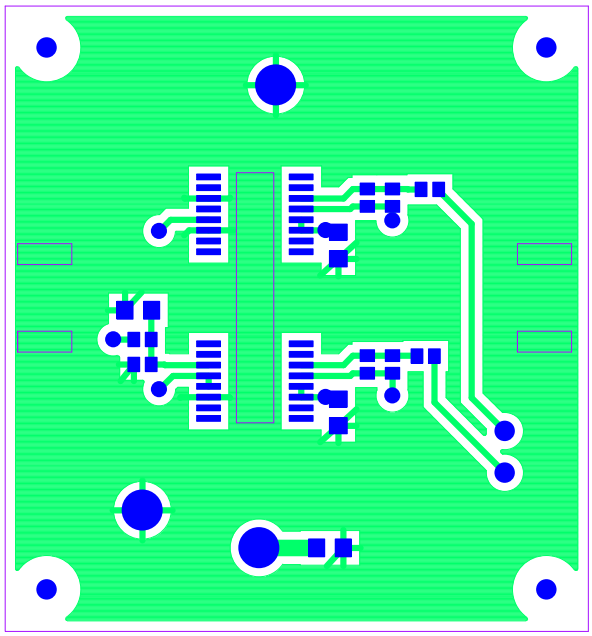

Figure 11. Top Layer

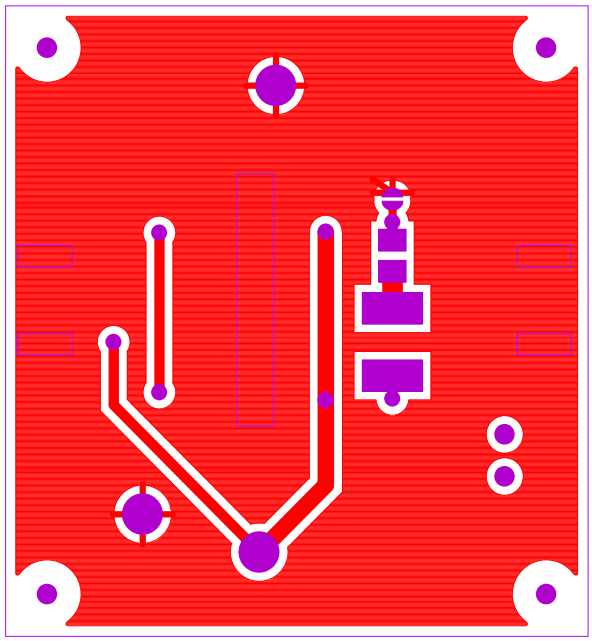

Figure 12. Bottom Layer

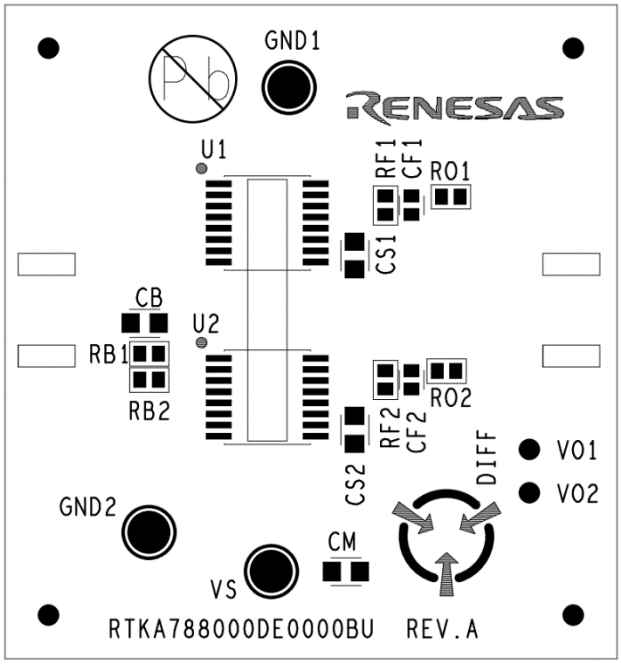

Figure 13. Top Silk Screen

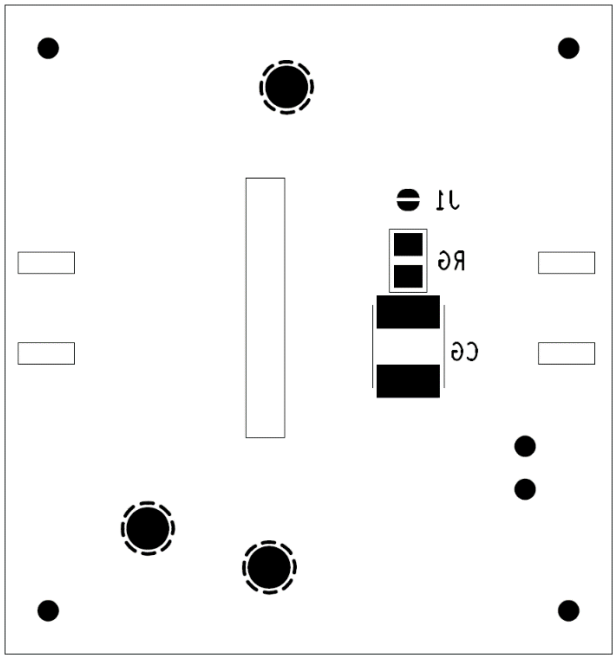

Figure 14. Bottom Silk Screen

3. Typical Performance Graphs

Figure 15 and Figure 16 depict the linearity and trendline error for the current measurement range 1A - 40A. All trendlines represent the linear best fit. The applied operating conditions were, T_A = 25°C, V_S = 3.3V, AWG = 8, and G_{DIFF} = 2001.

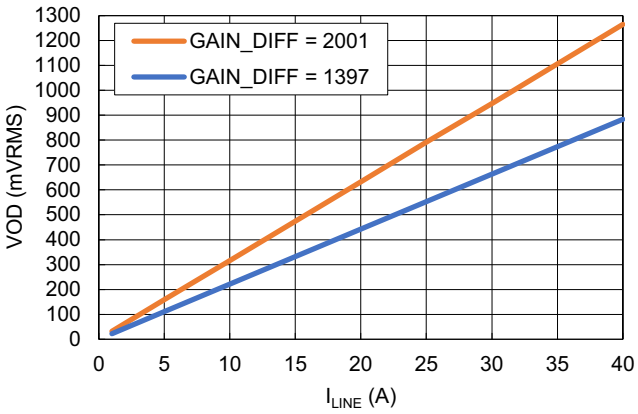

Figure 15. Output Voltage vs Line Current, I_{LOAD} = 0A

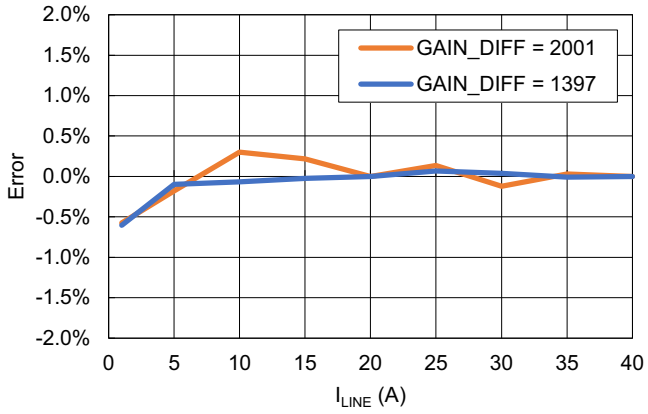

Figure 16. Trendline Error vs Line Current, I_{LOAD} = 0A

Figure 17 shows supply current performance with test condition: V_S = 3.3V, V_{IN} = VS/2.

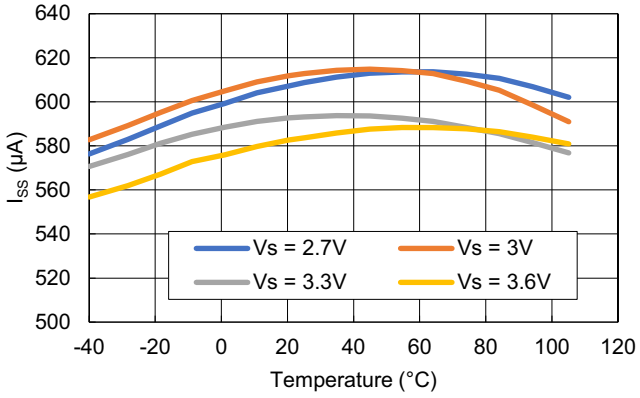

Figure 17. Supply Current vs Ambient Temperature

4. Ordering Information

Part Number	Description
RTKA788000DE0000BU	Opposite Sensor Topology Evaluation Board

5. Revision History

Revision	Date	Description
2.04	Apr 30, 2024	Updated gain setting from 2000V/V to 1400V/V. Removed Figures 7 and 8. Updated Figure 15 and 16. Added Figure 17.
2.03	Jun 20, 2023	Updated BOM.
2.02	May 30, 2023	Updated Figure 11 and 12. Updated BOM for RB1 and RB2.
2.01	Jul 19, 2022	Updated Schematic and BOM.
2.00	Aug 4, 2021	Updated Figures 1, 7, 8, 11, 17, and 18 Updated Supply Voltage information throughout. Removed Figures 19 through 22 Removed multiple measurement decades. Consolidated to one range 1-40A.
1.00	Jun 3, 2021	Initial release

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