RTKA489301DE0000BU

3-Level Buck Voltage Controller Board and GUI

Use the RTKA489301DE0000BU to evaluate the RAA489301, a 3-level buck voltage controller that provides seamless transitions among $V_{OUT} < V_{IN}/2$, $V_{OUT} = V_{IN}/2$, and $V_{OUT} > V_{IN}/2$. The RTKA489301DE0000BU evaluation board includes system operation functions such as the isolation MOSFET control, adjustable output voltage, programmable switching frequency, and a power-good indicator. The protection functionalities include OCP, OVP, UVP, and OTP. The RTKA489301DE0000BU has serial communication through SMBus/I^{2}C that allows the programming of many critical parameters to deliver a customized solution. These programming parameters include but are not limited to, minimum input voltage, maximum output voltage, maximum input current limit, and maximum output current limit setting.

Specifications

The RTKA489301DE0000BU is configured and optimized for the following operating conditions:

- V_{IN} = 4.5V to 24V
- V_{OUT} = 3V to 6.3V
- f_{SW} = 367kHz maximum

Note: The RTKA489301DE0000BU uses two dual MOSFETs.

Features

- Single inductor 3-level buck controller
- Proprietary modulator for flying capacitor balancing and smooth mode transition
- Wide input voltage range: 4.5V to 24V
- Wide output voltage range: 3V to 24V
- Programmable switching frequency (f_{SW}): up to 367kHz (734kHz at switching node effectively)
- EXT5V pin to generate 5V or 10V gate drive voltage through the internal charge pump
- Low shutdown current: 25µA
- Pass-through mode (PTM) in both directions
- Support pre-biased output with soft-start
- Input and output current monitor
- MOSFET drivers with adaptive shoot-through protection
- Complete protection: OCP, OVP, UVP, and OTP
- SMBus and I^{2}C compatible

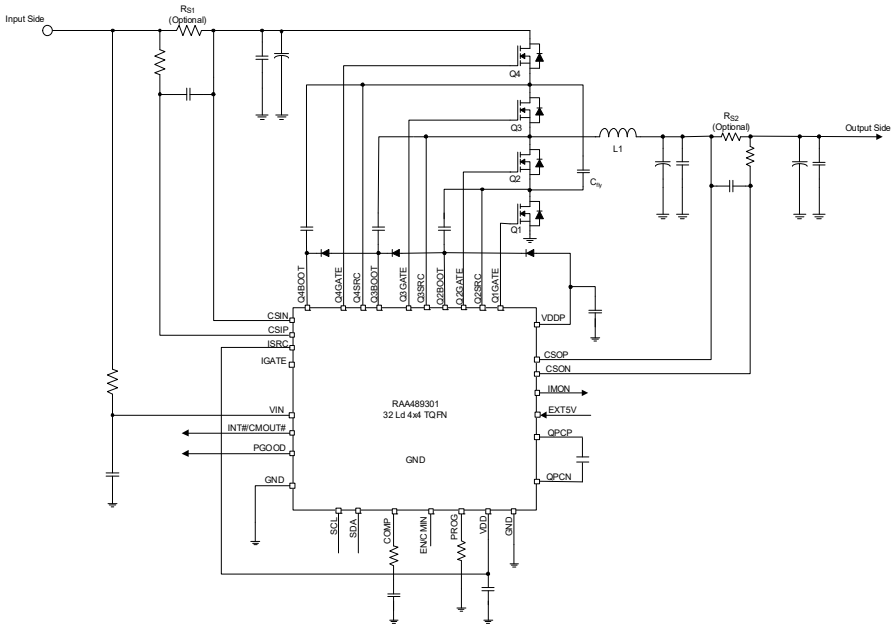

Figure 1. Typical Application Circuit

Contents

1. Software Installation Guide

The RAA489301 HID I2C Control Tool communicates with the RAA489301 controller through the HID USB-I2C interface board (ISLUSBADAPT-EVZ). The Graphical User Interface (GUI) facilitates access to RAA489301 registers.

1.1 Getting Started

This section describes how to install, start, and use the GUI software.

1.2 Required Hardware

- RAA489301 Evaluation Board
- HID USB-I2C interface board (ISLUSBADAPT-EVZ)
- USB 2.0 A/B cable

1.3 Required Software

The software Installation Wizard package includes two components, RAA489301 HID I2C Control Tool and National Instruments Runtime VISA Engine.

1.4 GUI Installation

Both the RAA489301 Control Software and the National Instruments Runtime Engine are installed automatically from the installation wizard.

Note: Renesas recommends to close all other applications before this installation and to reboot the computer when the installation is complete.

1. Extract the zip file to local drive and not the network drive. The network's security may prohibit the .inf file to be copied on the network.
2. Run **AutoRun.exe**. An installation menu appears (see Figure 2).

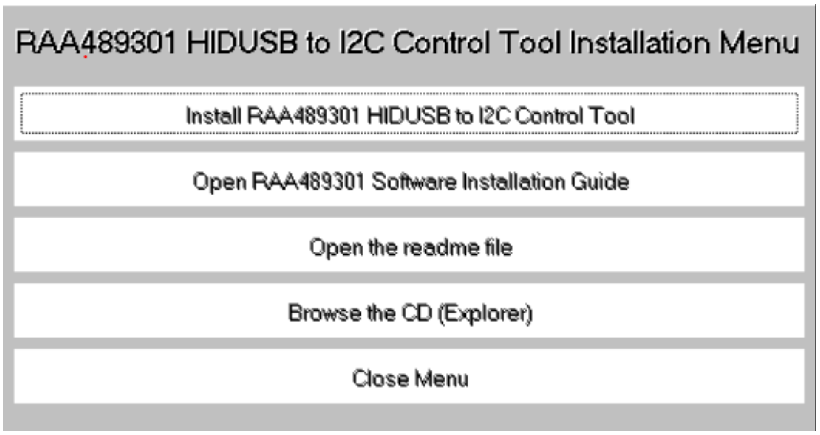

Figure 2. Installation Menu

3. Click **Install RAA489301 USBHID Control Tool** and the **Destination Directory** dialog box appears (see Figure 3).

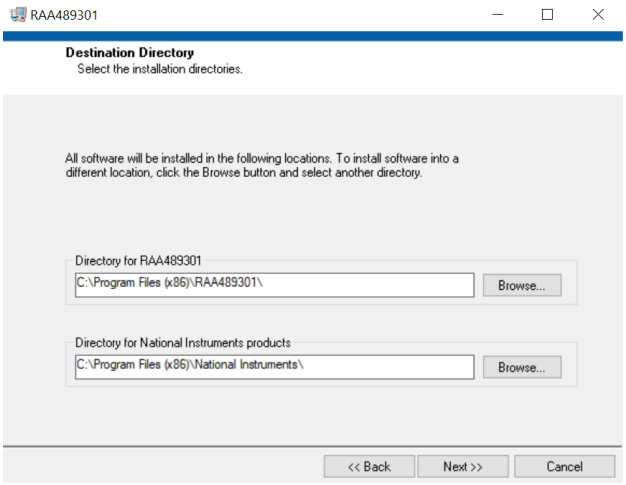

Figure 3. Destination Directory

4. Click **Next** to continue with the selected directory.
5. To complete the software installation, follow the instructions to accept two End User License Agreements.
6. Click **Close Menu** from the installation wizard after the installation is complete.

2. Using the GUI

To use the evaluation system, the *RAA489301 USBHID to I2C Control Tool Software* must first be installed.

- Do not connect the evaluation board to the USB port until installation is completed.
- The RAA489301 evaluation board must be set up before using the GUI.

2.1 Setting a USB Connection with the Hardware

This section describes how to setup RAA489301 EVB with HID USB-I2C Interface board to communicate with GUI.

1. Connect HID USB-I2C interface board to USB port on computer using USB A/B cable.
2. Connect SCL, SDA, GND of interface board to the evaluation board, respectively.
3. Provide 5V to 5V_EXT on the EVB.

2.2 Getting Started

1. Select **Microsoft Start** > **All Programs** > **Renesas** > **RAA489301 HID USB-I2C Control Tool**. The GUI appears (see Figure 4).

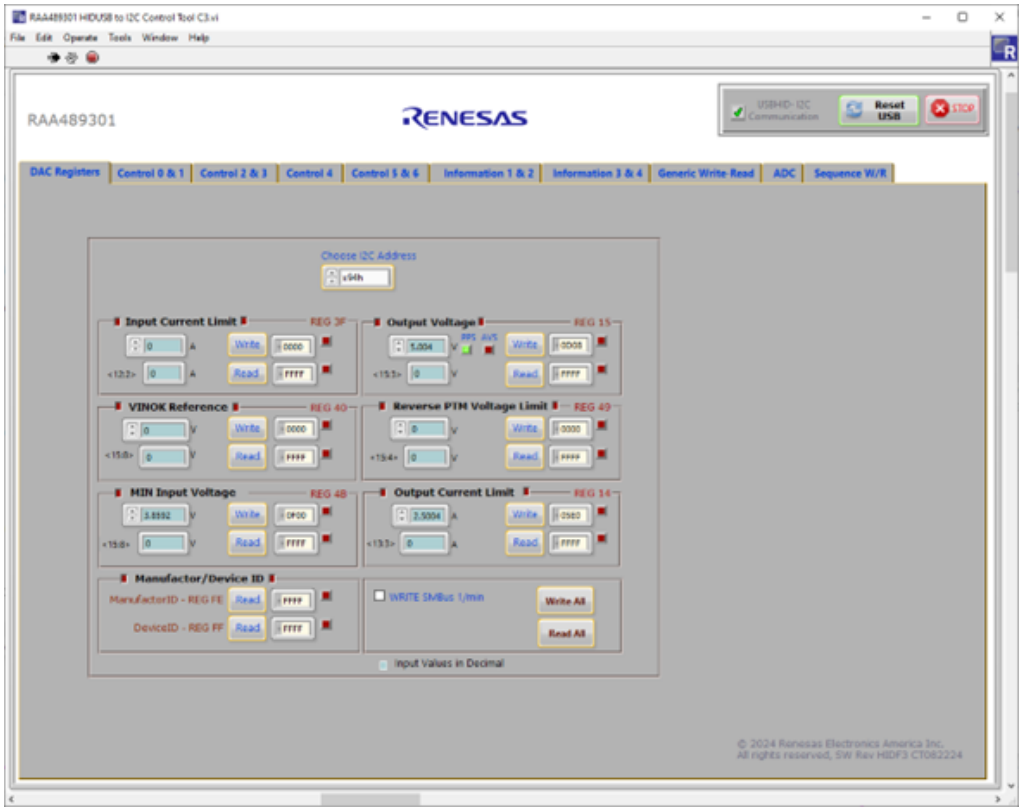

Figure 4. RAA489301 Graphical User Interface

2. Check the status of the HID USB-I2C Communication at the top-right of the GUI. If the communication is OK, the HID USB-I2C Communication status shows a green checkmark (see Figure 4).
   - A green LED turns ON in the HID USB-I2C interface board when the communication between the computer and the HID USB-I2C interface board is established (see Figure 5):

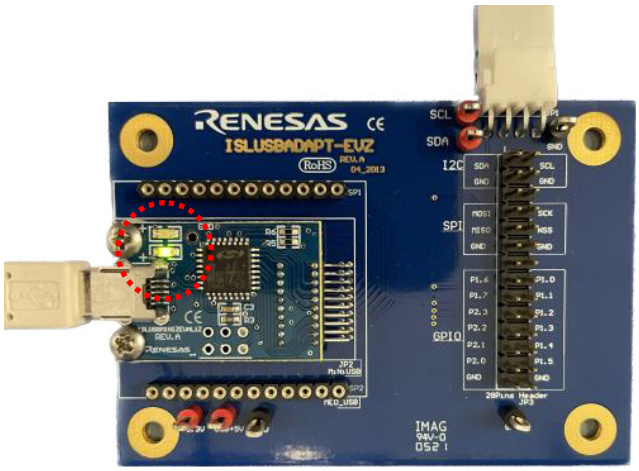

Figure 5. HID USB-I2C Interface Board

If the status in the GUI shows a red crossing mark, it indicates that the computer cannot establish the connection. The following describes two communication issues:

- (**Issue 1**) Computer to HID USB-I2C Interface Board Communication

When there is communication issue between computer and HID USB-I2C interface board, the following message appears, and a green LED turns off in the HID USB-I2C interface board.

Figure 6. Failed to Establish Message

Please follow these steps to troubleshoot:

1. When the message above appears, reconnect the USB connection.
2. Click the **OK** button.
3. The green LED is on when the interface board is connected to the computer.
4. Read any register to check the communication.

- (**Issue 2**) HID USB-I2C Interface Board to EVB Communication

When there is a communication issue between the HID USB-I2C interface board and the EVB, the following message appears.

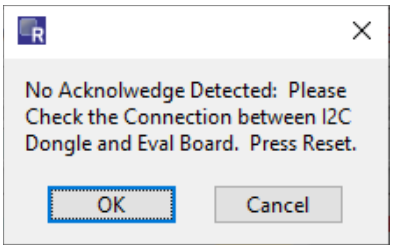

Figure 7. No Acknowledge Message

Note: A green LED in the interface board can remain on if the communication between the computer and the HID USB-I2C interface board is OK.

Please follow these steps to troubleshoot:

1. When the message above appears, reconnect SDA, SCL, and GND to the EVB.
2. Click the **OK** button.
3. Read any register to check communication.

Note: If the problem continues, power off and on the evaluation board and reconnect the USB for the interface board.

3. Quick Startup Guide

3.1 Board Configuration and I²C/SMBus Connection

The RAA489301 can be powered by an internal LDO or an external 5V input. The RTKA489301DE0000BU board has three jumpers, so users can select whether to use the internal LDO or an external 5V power supply. Figure 8 shows the locations of the jumpers related to the selection of driving power for the RAA489301 on the RTKA489301DE0000BU board.

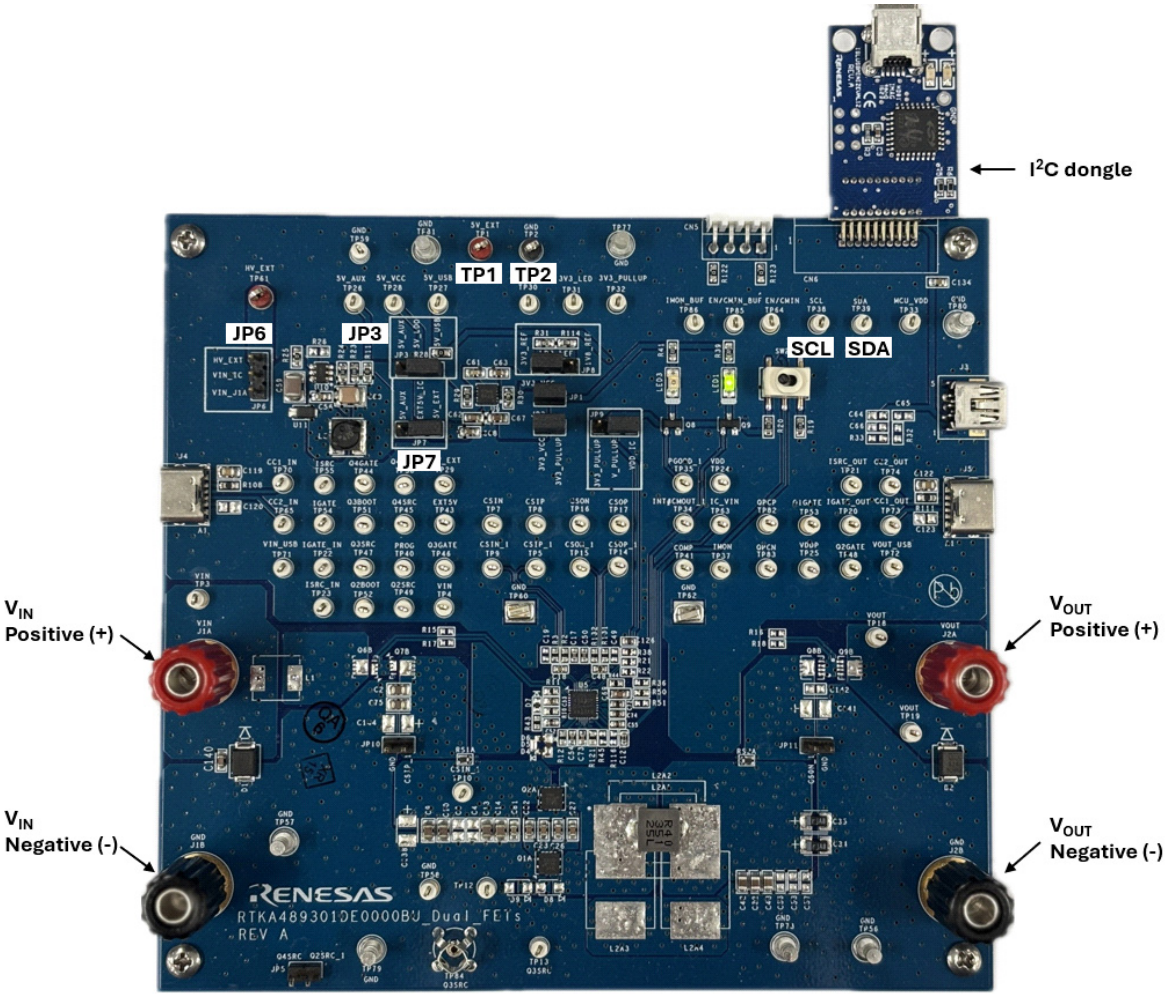

Figure 8. RTKA489301DE0000BU Board Connection Guideline

The RTKA489301DE0000BU board has a buck converter to generate external 5V (EXT5V). JP6 is a jumper that selects whether to receive the input of the buck converter to generate EXT5V from J1A (VIN) or from TP61. JP6 is not used by default because the EXT5V can be supplied through TP1 and TP2. Jumper JP3 sets whether to use the 5V from the buck converter or the USB to input the on-board external 3.3V LDO. JP7 is a jumper that can select whether to directly receive 5V from TP1 or use 5V generated from the buck converter. The following are two examples of using EXT5V:

- When receiving 5V driving power of RAA489301 from an external power source through the EXT5V pin, Pin 2 and Pin 3 (5V_EXT) of JP7 must be connected.
- When using the internal LDO of RAA489301 without using EXT5V, leave all the pins of JP6 unconnected or 5V power is not supplied from the external power supply while Pin 2 and Pin 3 (5V_EXT) of JP7 are connected.

Note: Verify that all the jumpers are covered.

See Figure 9 for descriptions of the driving power of the RAA489301 according to each jumper connection.

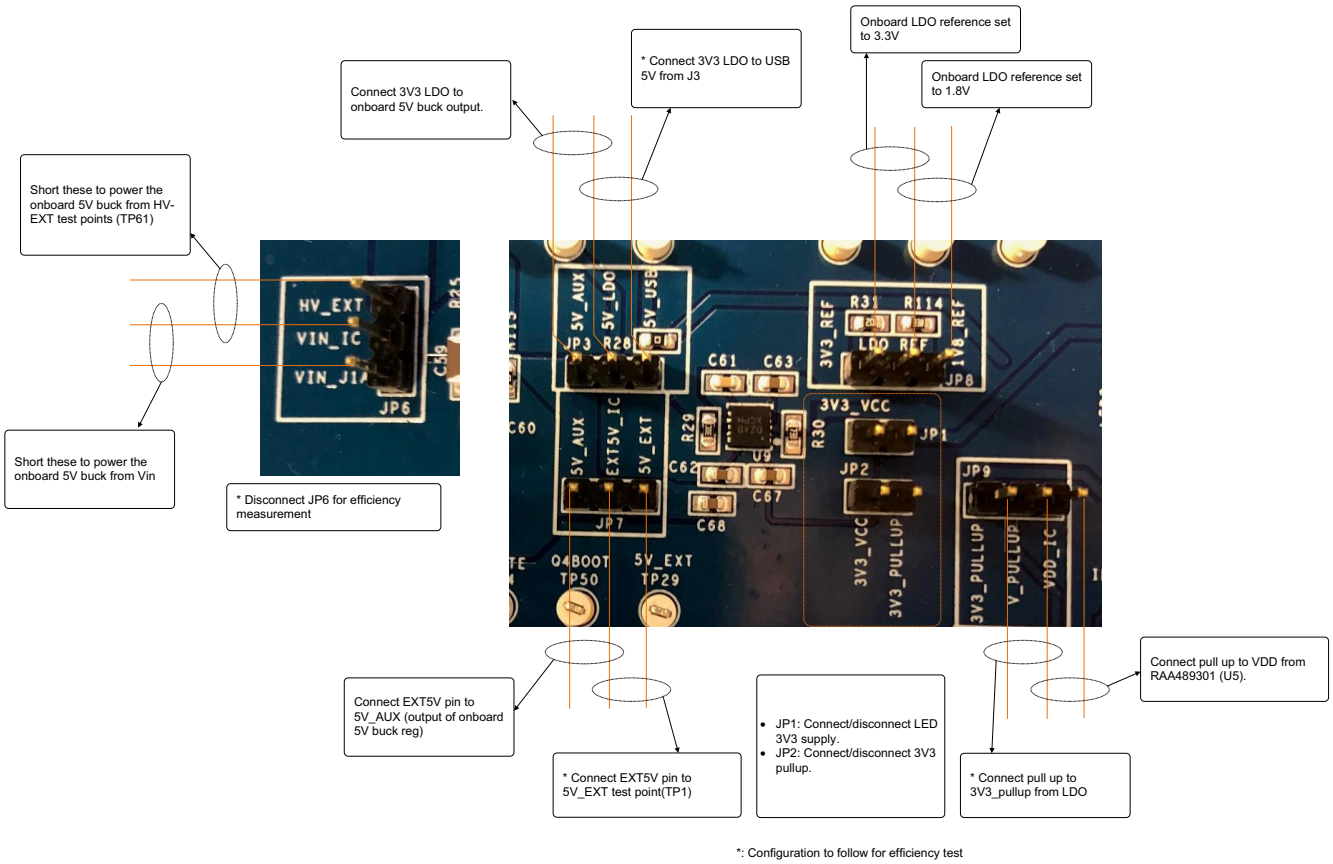

Figure 9. Jumper Configuration Guide for the Evaluation Board

3.2 Apply Input Voltage and Startup

Complete the following the steps for startup. The register settings of the RAA489301 can be changed using the RAA489301 GUI software. For a description of the RAA489301 GUI software, see Software Installation Guide.

1. If driving the RAA489301 using 5V of an external power supply, supply 5V of the external power supply through TP1 and TP2 with the main power of the 3-level buck converter. Set the current limit of the external 5V power supply to 300mA.
2. Before enabling switching, the control registers must be set as follows:

Defaults	Recommended Register Setting
Control1 (0x3C) = 0x0000 Control2 (0x3D) = 0x0302 Control3 (0x4C) = 0x0000	Control4 (0x4E) = 0x0100

- Control1 (0x3C) = 0x0000 → V_{OUT} Absolute OV Threshold = 7.2V (default)
- Control2 (0x3D) = 0x0302 → VDDP Charge Pump Ratio = 1:1, PGOOD Window = 20% (default)
- Control3 (0x4C) = 0x0000 → Switching Frequency = 275kHz (default)
- Control4 (0x4E) = 0x0100 → Set the Low-Side ZCD Blanking Time to 80ns

3. To improve the light-load efficiency in DCM, utilize auto Vgs function, and set for faster startup, control registers must be set as follows:

Defaults	Recommended Register Setting
Control1 (0x3C) = 0x0000 Control3 (0x4C) = 0x0000	Control0 (0x39) = 0x6000 Control2 (0x3D) = 0x0306 Control4 (0x4E) = 0x0520

   - Control0 (0x39) = 0x6000 → Pre-charge wait time = 50ms
   - Control1 (0x3C) = 0x0000 → V_{OUT} Absolute OV Threshold = 7.2V (default)
   - Control2 (0x3D) = 0x0306 → Auto Vgs enabled
   - Control3 (0x4C) = 0x0000 → Switching Frequency = 275kHz (default)
   - Control4 (0x4E) = 0x0520 → Disable CSOP short-circuit check, Low-side ZCD blanking time = 80ns, Disable Boot QP in modulator OFF state
4. After confirming that the current limit of the power supply that provides main power is sufficient, turn on the main power through J1A (VIN) and J1B (GND) with no load. Ensure the main input voltage does not exceed 24V. Renesas recommends starting the RTKA489301DE0000BU by setting the main input voltage to 20V.
5. Verify that the CFLY voltage is close to half the input voltage.
6. Set the output voltage using the output voltage register (0x15). Renesas recommends starting up initially with the main input voltage at 20V and the output voltage at 4.2V.
7. Set the Enable Bit (Control0 (0x39) bit [0]) to 1 (Enable Switching) and verify if switching is enabled.
8. Renesas recommends that the input voltage change slew rate is lower than 1mV/µs and changing the input voltage with a small load, (for example, 20mA load).

3.3 ADC register

RAA489301 provides four ADC registers. Table 1 shows the ADC register information provided by RAA489301 silicon. In RAA489301, when 3mΩ sense resistor is used, the ADC output current measurements value is clamped at 18.89A. RAA489301 can reduce the current feedback gain by half through Control1 (0x3C) bit [7]. If Control1 (0x3C) bit [7] = b1, the maximum ADC current measurement range can be doubled.

Table 1. RAA489301 ADC Channel Overview

Channel	Register Address	LSB	Sensing Resistor	Valid Bits	Maximum Value
Input Current	0x83	74mA (0.5x gain case = 148mA)	3mΩ	[7:0]	18.89A (0.5x gain case = 37.78A)
Output Current	0x85	74mA (0.5x gain case = 148mA)	3mΩ	[7:0]	18.89A (0.5x gain case = 37.78A)
Output Voltage	0x86	192mV	N/A	[7:0]	48.96V[1]
Input Voltage	0x87	192mV	N/A	[7:0]	48.96V[1]

1. Limited by Overvoltage.

4. Board Design

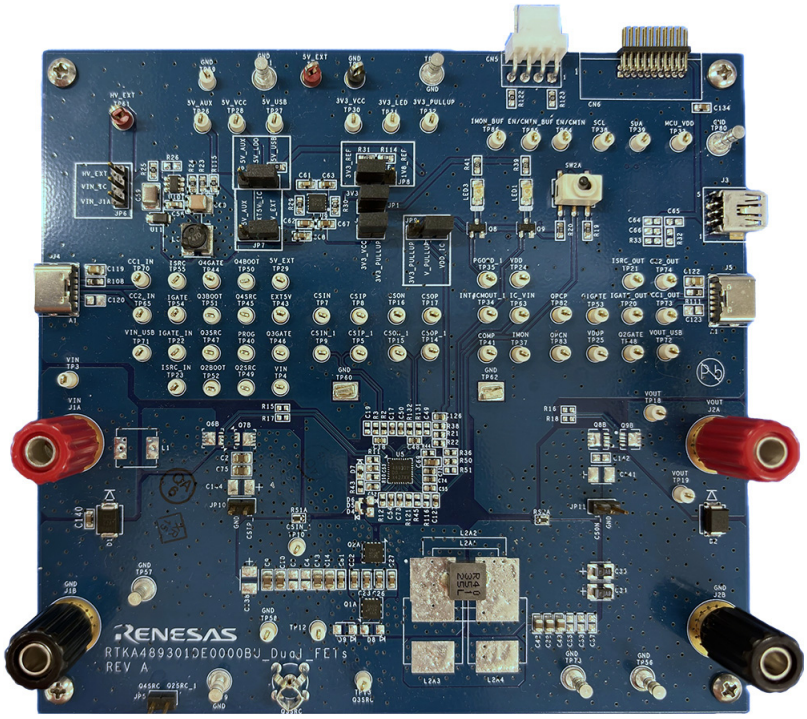

Figure 10. RTKA489301DE0000BU Evaluation Board (Top)

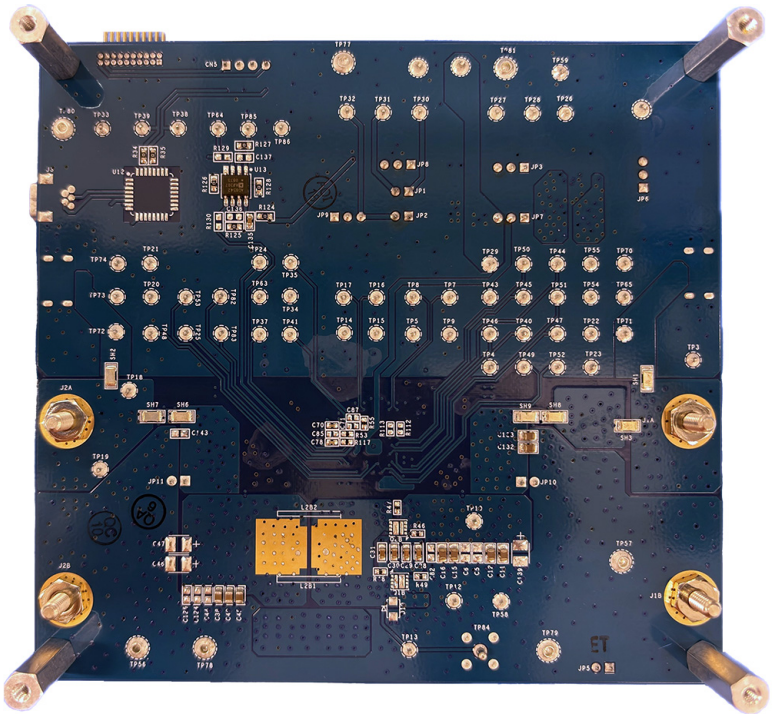

Figure 11. RTKA489301DE0000BU Evaluation Board (Bottom)

4.1 Schematic Diagrams

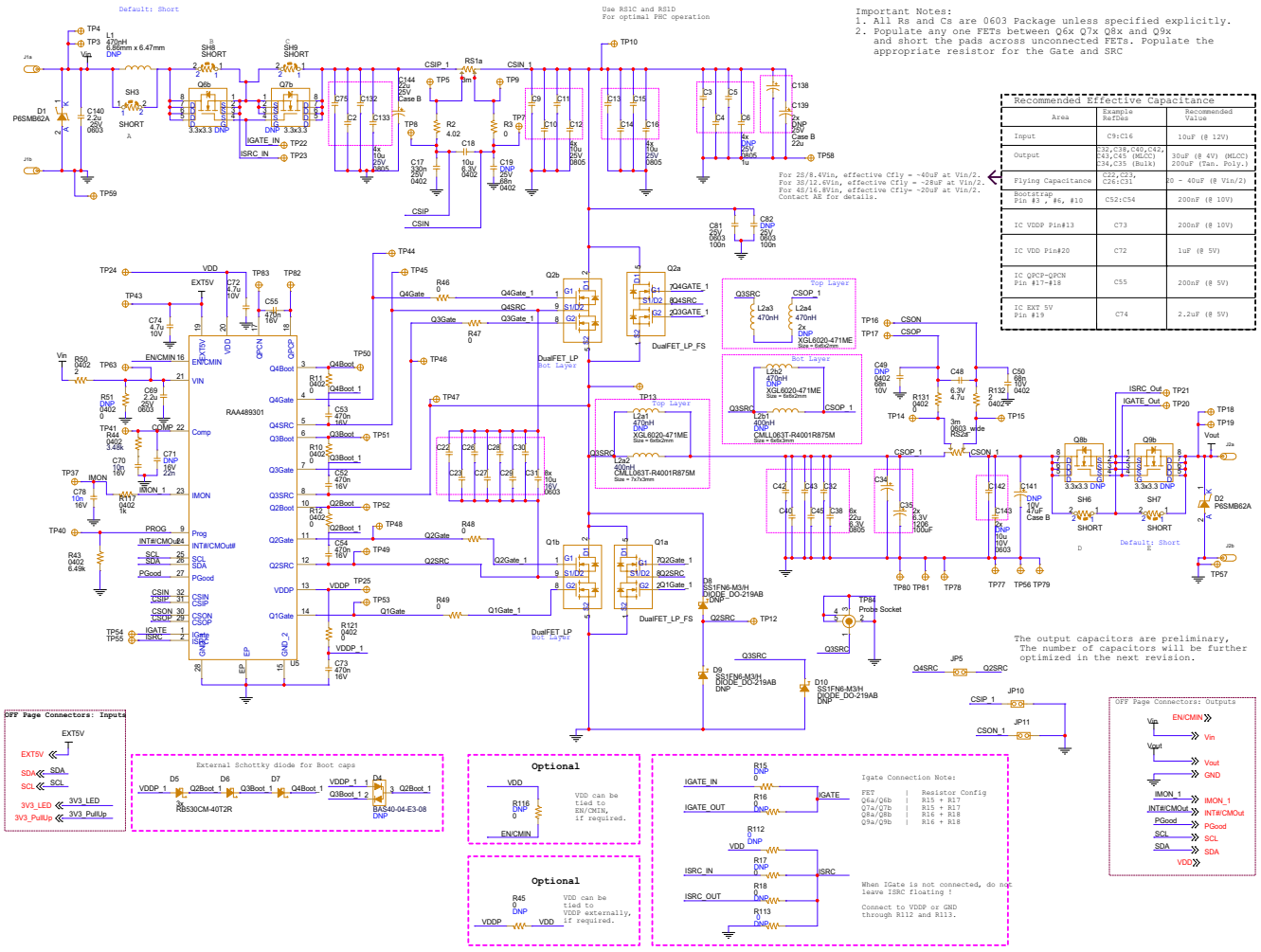

Figure 12. Schematic Diagram (1 of 3)

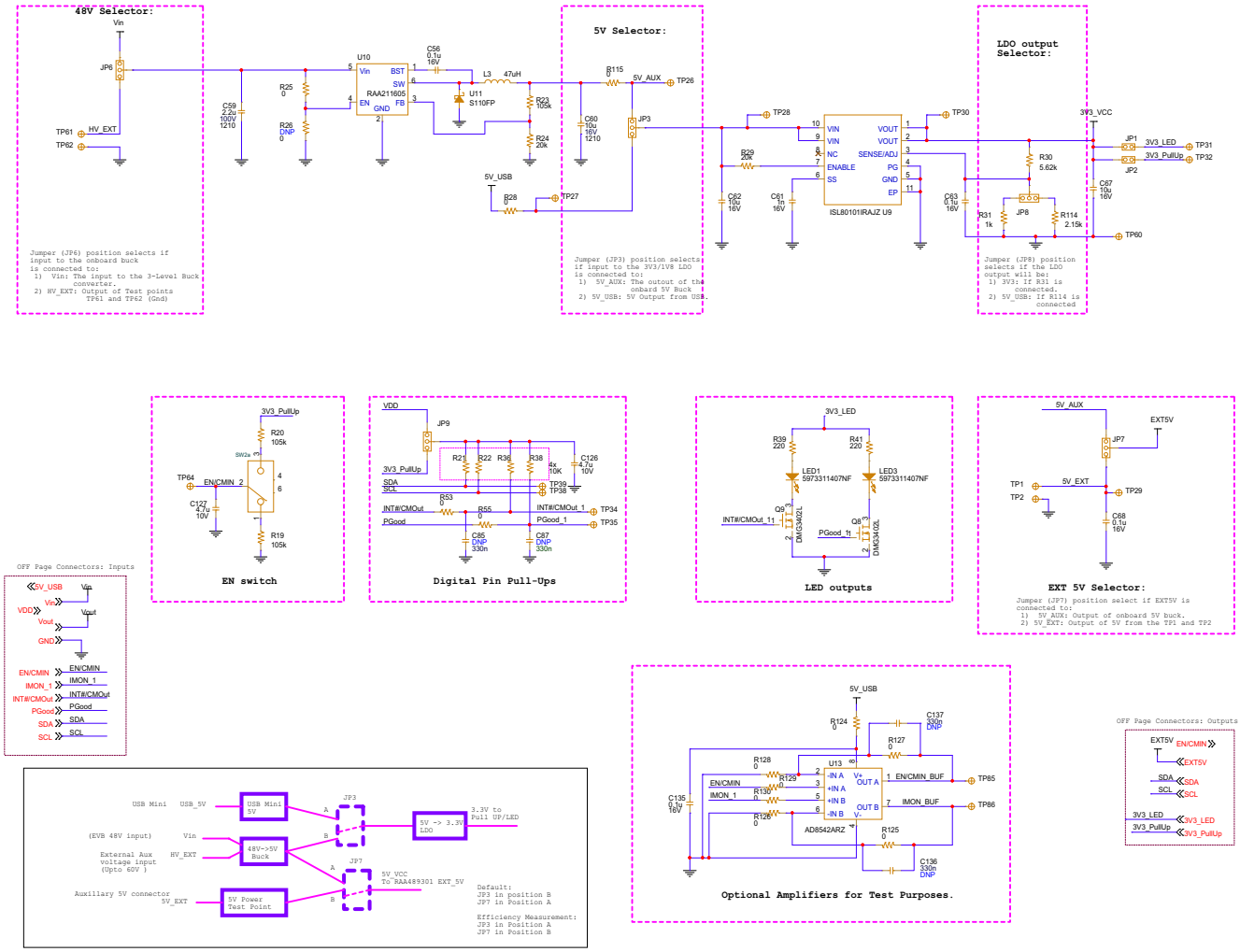

Figure 13. Schematic Diagram (2 of 3)

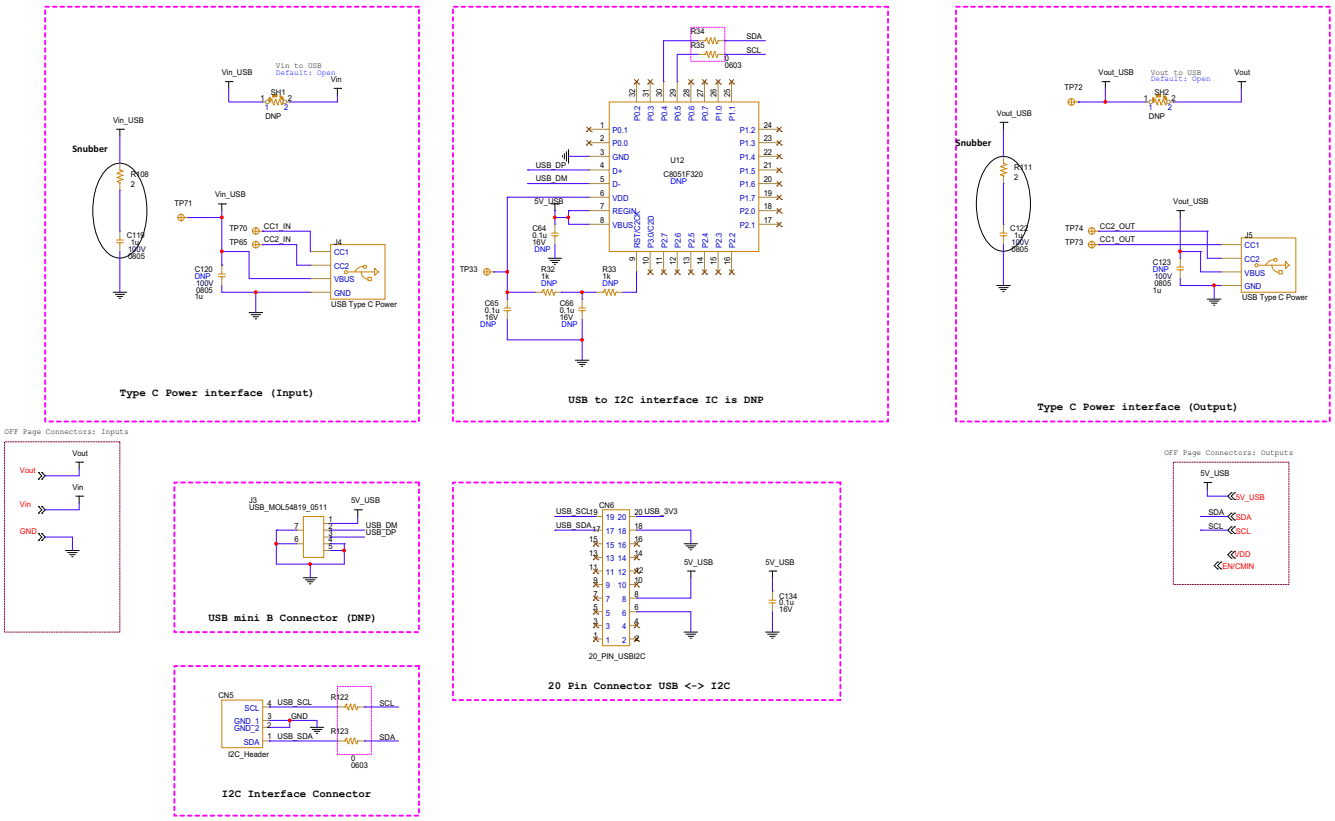

Figure 14. Schematic Diagram (3 of 3)

4.2 Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	CN5	CONN Header R/A 4POS 2.54MM	Molex	22053041
1	CN6	CONN Header R/A 20POS 1.27MM	Harwin Inc.	M50-3901042
12	C2, C9, C10, C11, C12, C13, C14, C15, C16, C75, C132, C133	CAP CER 10µF 25V X7R 0805	Murata Electronics	GRM21BZ71E106KE15L
1	C17	CAP CER 0.33µF 25V X5R 0402	TDK Corporation	C1005X5R1E334K050BB
1	C18	CAP CER 10µF 6.3V X5R 0402	Murata Electronics	GRM155R60J106ME47D
10	C22, C23, C26, C27, C28, C29, C30, C31, C62, C67	CAP CER 10µF 16V X6S 0603	Murata Electronics	GRM188C81C106MA73D
6	C32, C38, C40, C42, C43, C45	CAP CER 22µF 6.3V X7S 0805	TDK Corporation	C2012X7S0J226M125AC
2	C34, C35	CAP TANT POLY 100µF 6.3V 1206	KEMET	T520A107M006ATE025
5	C48, C72, C74, C126, C127	CAP CER 4.7µF 10V X6T 0402	Murata Electronics	GRM155D81A475ME15D
1	C50	CAP CER 0.068µF 10V X5R 0402	Murata Electronics	GRM155R61A683KA01D
5	C52, C53, C54, C55, C73	CAP CER 0.47µF 16V X7S 0402	TDK Corporation	CGA2B1X7S1C474K050BC
6	C56, C63, C68, C81, C134, C135	CAP CER 0.1µF 25V X7R 0603	Murata Electronics	GCJ188R71E104KA12D
1	C59	CAP CER 2.2µF 100V X7R 1210	TDK Corporation	C3225X7R2A225M230AB
1	C60	CAP CER 10µF 16V X8R 1210	TDK Corporation	C3225X8R1C106K250AB
1	C61	CAP CER 1000PF 16V X7R 0603	KEMET	C0603C102K4RACTU
2	C69, C140	CAP CER 2.2µF 25V X7R 0603	Murata Electronics	GRM188Z71E225ME43D
1	C70	CAP CER 10000pF 16V X7R 0402	Murata Electronics	GRM155R71C103KA01D
1	C78	CAP CER 10000pF 16V X7R 0402	YAGEO	CC0402MRX7R7BB103
2	C119, C122	CAP CER 1µF 100V X7S 0805	Murata Electronics	GRM21BC72A105KE01L
2	D1, D2	TVS DIODE 53VWM 85VC DO214AA	Littelfuse Inc.	P6SMB62A
3	D5, D6, D7	Diode Schottky 40V 100MA VMN2	Rohm Semiconductor	RB530CM-40T2R
5	JP1, JP2, JP5, JP10, JP11	CONN Header VERT 2POS 2.54MM	Samtec Inc.	MTLW-102-07-L-S-250
5	JP3, JP6, JP7, JP8, JP9	CONN Header VERT 3POS 2.54MM	Amphenol ICC (FCI)	68000-103HLF
2	J1a, J2a	CONN BIND Post Knurled Red	Cinch Connectivity Solutions Johnson	111-0702-001
2	J1b, J2b	CONN BIND Post Knurled Black	Cinch Connectivity Solutions Johnson	111-0703-001

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	J3	CONN RCPT USB2.0 MINI B 5P R/A	Molex	54819-0519
2	J4, J5	CONN RCPT TYPE C 24POS SMD RA	Same Sky	UJC-HP-3-SMT-TR
2	LED1, LED3	LED Green Clear 1206 SMD	Dialight	599-0460-127F
1	L3	FIXED IND 47UH 800MA 351MΩ SMD	Würth Elektronik	74408943470
1	Q1a	MOSFET 2N-CH 30V 35A PWRPAIR	Vishay Siliconix	SIZF5300DT-T1-GE3
1	Q2a	MOSFET 2N-CH 30V 28.1A PWRPAIR	Vishay Siliconix	SIZF5302DT-T1-RE3
2	Q8, Q9	MOSFET N-CH 30V 4A SOT23	Diodes Incorporated	DMG3402L-7
2	RS1a, RS2a	RES 0.003Ω 1% 1/2W Wide 0603	Delta Electronics/Cyntec	RLM0816T4F-4-R003-FNH
1	R2	RES 4.02Ω 1% 1/16W 0402	YAGEO	RC0402FR-074R02L
13	R3, R10, R11, R12, R46, R47, R48, R49, R53, R55, R112, R121, R131	RES SMD 0Ω Jumper 1/10W 0402	Panasonic Electronic Components	ERJ-2GE0R00X
3	R19, R20, R23	RES SMD 105kΩ 0.1% 1/10W 0603	YAGEO	RT0603BRE07105KL
4	R21, R22, R36, R38	RES SMD 10kΩ 1% 1/16W 0402	Bourns Inc.	CR0402-FX-1002GLF
2	R24, R29	RES SMD 20kΩ 1% 1/10W 0603	YAGEO	RT0603FRE1320KL
12	R25, R28, R34, R35, R115, R122, R123, R124, R125, R126, R127, R128	RES 0Ω Jumper 1/10W 0603	YAGEO	RC0603FR-070RL
1	R30	RES 5.62kΩ 1% 1/10W 0603	YAGEO	RC0603FR-075K62L
1	R31	RES 1kΩ 5% 1/5W 0603	YAGEO	RC0603JR-7W1KL
2	R39, R41	RES 220Ω 5% 1/10W 0603	YAGEO	RC0603JR-07220RL
1	R43	RES 6.49kΩ 1% 1/16W 0402	YAGEO	RC0402FR-076K49L
1	R44	RES 3.48kΩ 1% 1/16W 0402	YAGEO	RC0402FR-073K48L
2	R50, R132	RES 2Ω 5% 1/16W 0402	YAGEO	RC0402JR-072RL
2	R108, R111	RES SMD 2Ω 1% 1/3W 0603	Vishay Dale	CRCW06032R00FKEAHP
1	R114	RES 2.15kΩ 1% 1/10W 0603	YAGEO	RC0603FR-072K15L
1	R117	RES 1kΩ 5% 1/16W 0402	YAGEO	RC0402JR-071KL
7	SH1, SH2, SH3, SH6, SH7, SH8, SH9	RES SMD 0Ω Jumper 1/2W 1206	Keystone Electronics	5108
1	SW2a	Switch Toggle SPDT 0.4VA 20V	C&K	GT11MSCBE
2	TP1, TP61	PC Test Point Multipurpose Red	Keystone Electronics	5010
1	TP2	PC Test Point Multipurpose Black	Keystone Electronics	5011

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
63	TP3, TP4, TP5, TP7, TP8, TP9, TP10, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP37, TP38, TP39, TP40, TP41, TP43, TP44, TP45, TP46, TP47, TP48, TP49, TP50, TP51, TP52, TP53, TP54, TP55, TP58, TP59, TP63, TP64, TP65, TP70, TP71, TP72, TP73, TP74, TP82, TP83, TP85, TP86	PC Test Point Miniature White	Keystone Electronics	5002
7	TP56, TP57, TP77, TP78, TP79, TP80, TP81	Term Turret Single L = 7.65MM Tin	Keystone Electronics	1598-2
1	TP84	Test Connectors PK 25 EA 136-0962-00 AND 131-4209-00	Tektronix	131-5031-00
1	U9	IC Reg Linear Pos Adj 1A 10DFN	Renesas Electronics Corporation	ISL80101IRAJZ
1	U10	IC Reg Buck Adj 500MA TSOT23-6	Renesas Electronics Corporation	RAA2116054GP3#JA0
1	U11	Diode Schottky 100V 1A SOD123HE	onsemi	S110FP
1	U13	IC OPAMP GP 2 Circuit 8SOIC	Analog Devices Inc.	AD8542ARZ
2	TP60, TP62	PC Test Point Compact	Keystone Electronics	5016
1	L2a1	Inductor, 400nH	Delta Electronics/Cyntec	CMLL063T-R40ME1R875-87
4	Four Corners	MACHINE SCREW PAN PHILLIPS 4-40	B&F Fastener Supply	PMSSS 440 0025 PH
4	Four Corners	HEX STANDOFF #4-40 ALUMINUM 3/4"	Keystone Electronics	2204

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
6	JP3 2 to 3, JP7 2 to 3, JP8 1 to 2, JP1, JP2, JP9 1 to 2	CONN Jumper Shorting Gold Flash	Sullins Connector Solutions	SPC02SYAN
1	U5	IC, 3-Level Buck Controller, 32P, QFN, 4×4	Renesas Electronics Corporation	RAA489301

4.3 Board Layout

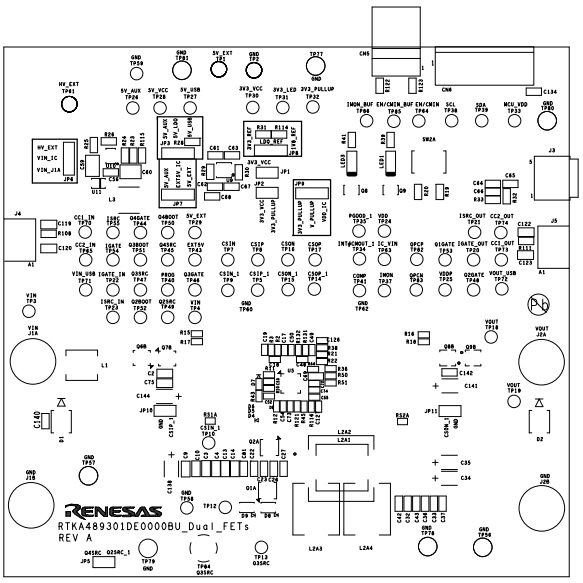

Figure 15. Silk Top Layer

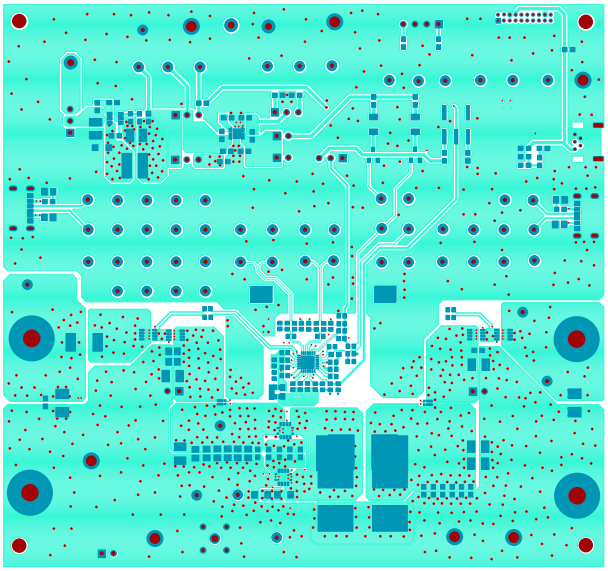

Figure 16. Layer 1

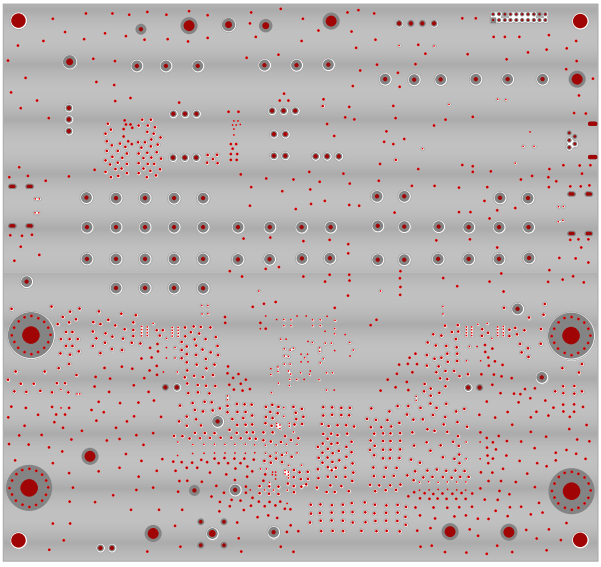

Figure 17. Layer 2

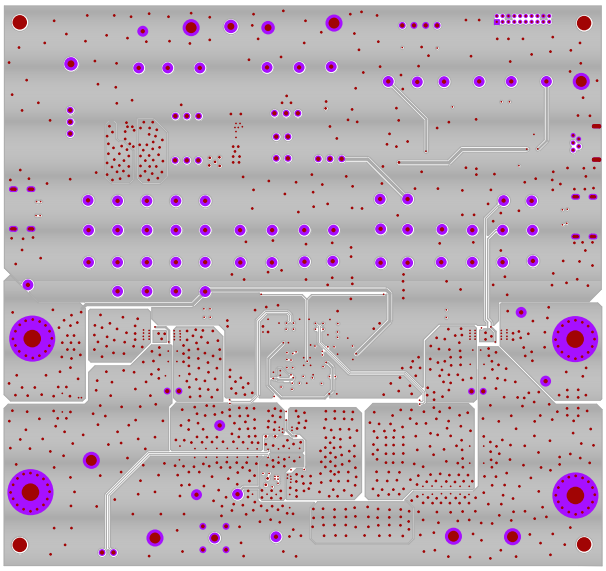

Figure 18. Layer 3

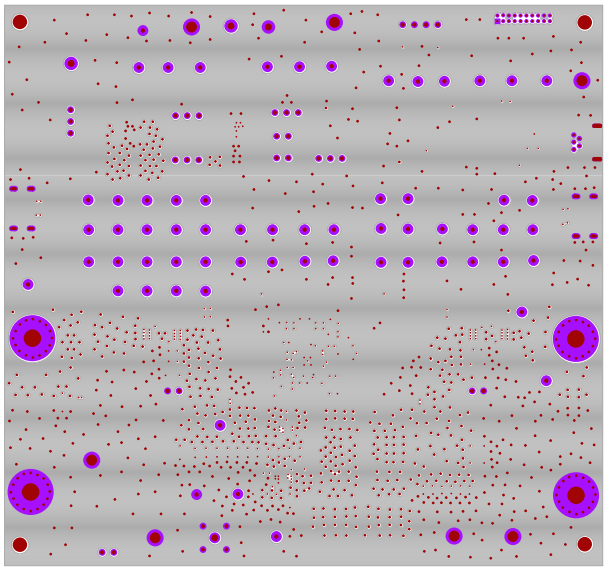

Figure 19. Layer 4

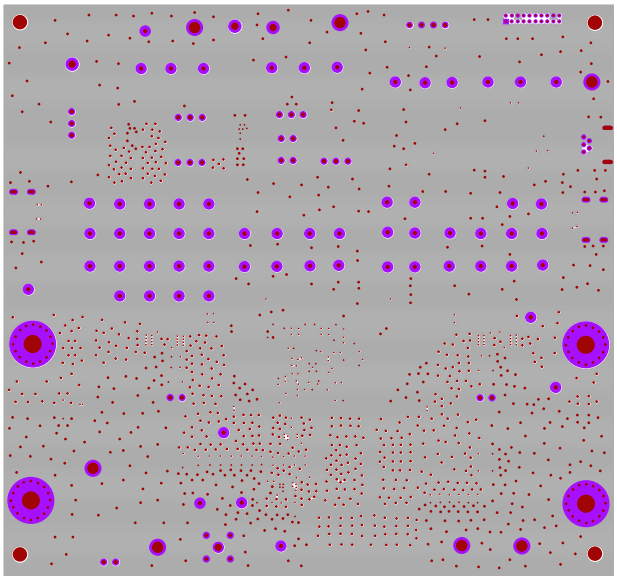

Figure 20. Layer 5

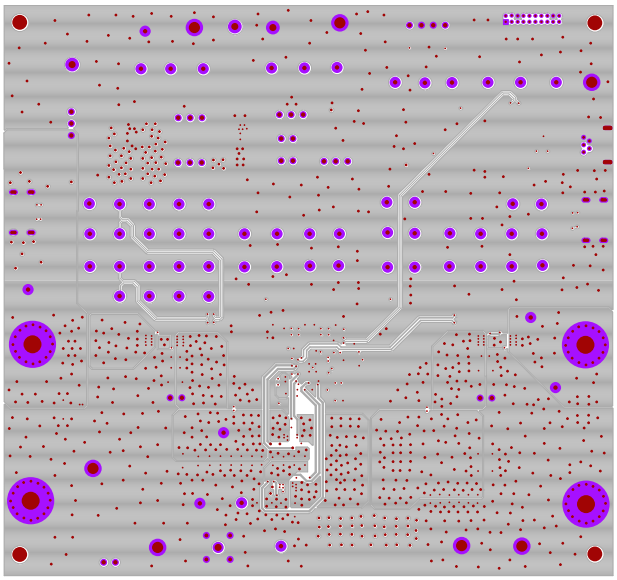

Figure 21. Layer 6

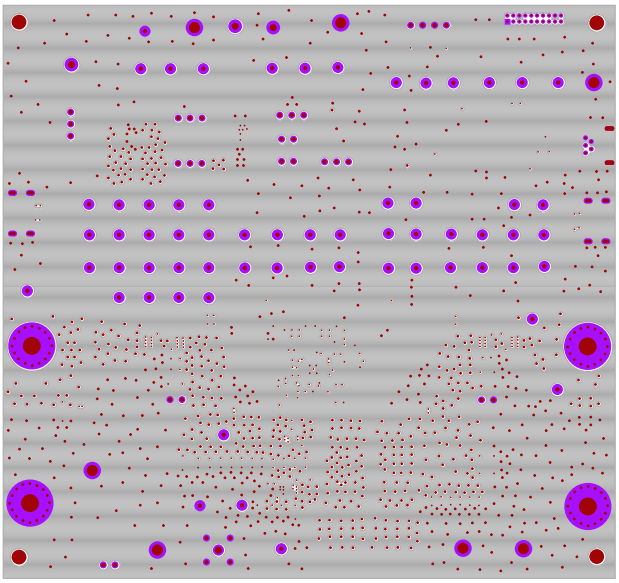

Figure 22. Layer 7

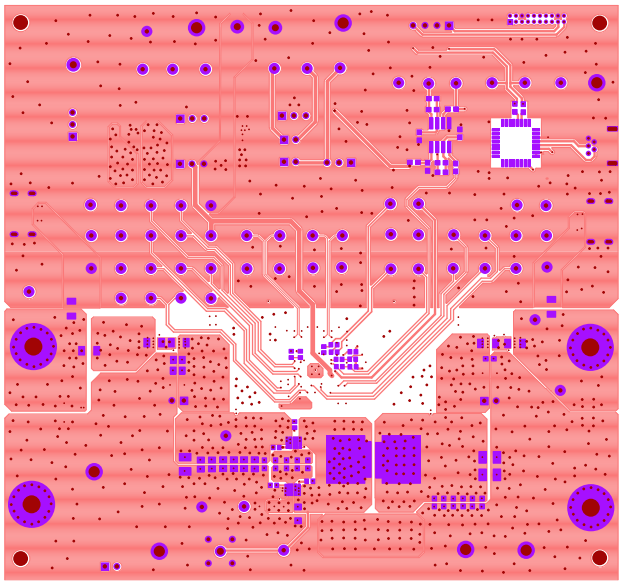

Figure 23. Layer 8

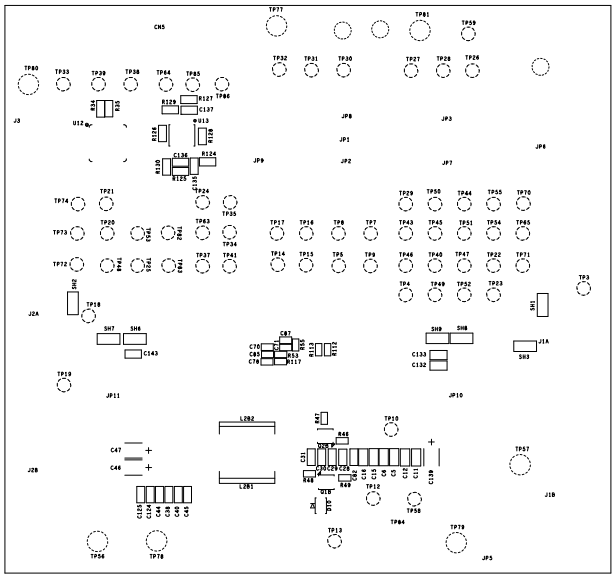

Figure 24. Silk Bottom Layer

5. Ordering Information

Part Number	Description
RTKA489301DE0000BU	RAA489301 Evaluation Board

6. Revision History

Revision	Date	Description
1.00	Oct 14, 2024	Initial release.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD-PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers who are designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only to develop an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third-party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising from your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Disclaimer Rev.1.01 Jan 2024)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit www.renesas.com/contact-us/.

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.