

ISL81401EVAL1Z

User's Manual: Evaluation Board

Industrial Analog and Power

ISL81401EVAL1Z

Evaluation Board

UG188
Rev. 0.00
Oct 25, 2018

1. Overview

The ISL81401EVAL1Z evaluation board (shown in [Figure 5 on page 8](#)) features the [ISL81401](#), a 40V high voltage synchronous buck-boost controller that offers external soft-start, independent enable functions and integrates UV/OV/OC/OT protection. A programmable switching frequency ranging from 100kHz to 600kHz helps to optimize inductor size while the strong gate driver delivers up to 20A for the buck-boost output.

1.1 Key Features

- Wide input range: 6V to 40V
- Bi-directional operation
- High light-load efficiency in pulse skipping DEM operation
- Programmable soft-start
- Optional DEM/PWM operation
- Optional CC/HICCUP OCP protection
- Supports prebias output with soft-start
- PGOOD indicator
- OVP, OTP, and UVP protection
- Back biased from output to improve efficiency

1.2 Specifications

The ISL81401EVAL1Z evaluation board is designed for high current applications. The current rating of the ISL81401EVAL1Z is limited by the FETs and inductor selected. The ISL81401EVAL1Z electrical ratings are shown in [Table 1](#).

Table 1. Electrical Rating

| Parameter | Rating |
|---------------------|---|
| Input Voltage | 6V to 40V |
| Switching Frequency | 200kHz |
| Output Voltage | 12V |
| Output Current | 8A |
| OCP Set Point | Minimum 10A at ambient room temperature |

1.3 Ordering Information

| Part Number | Description |
|----------------|---|
| ISL81401EVAL1Z | High Voltage BUCK-BOOST Controller Evaluation Board |

1.4 Related Literature

For a full list of related documents, visit our website

- [ISL81401](#) product page

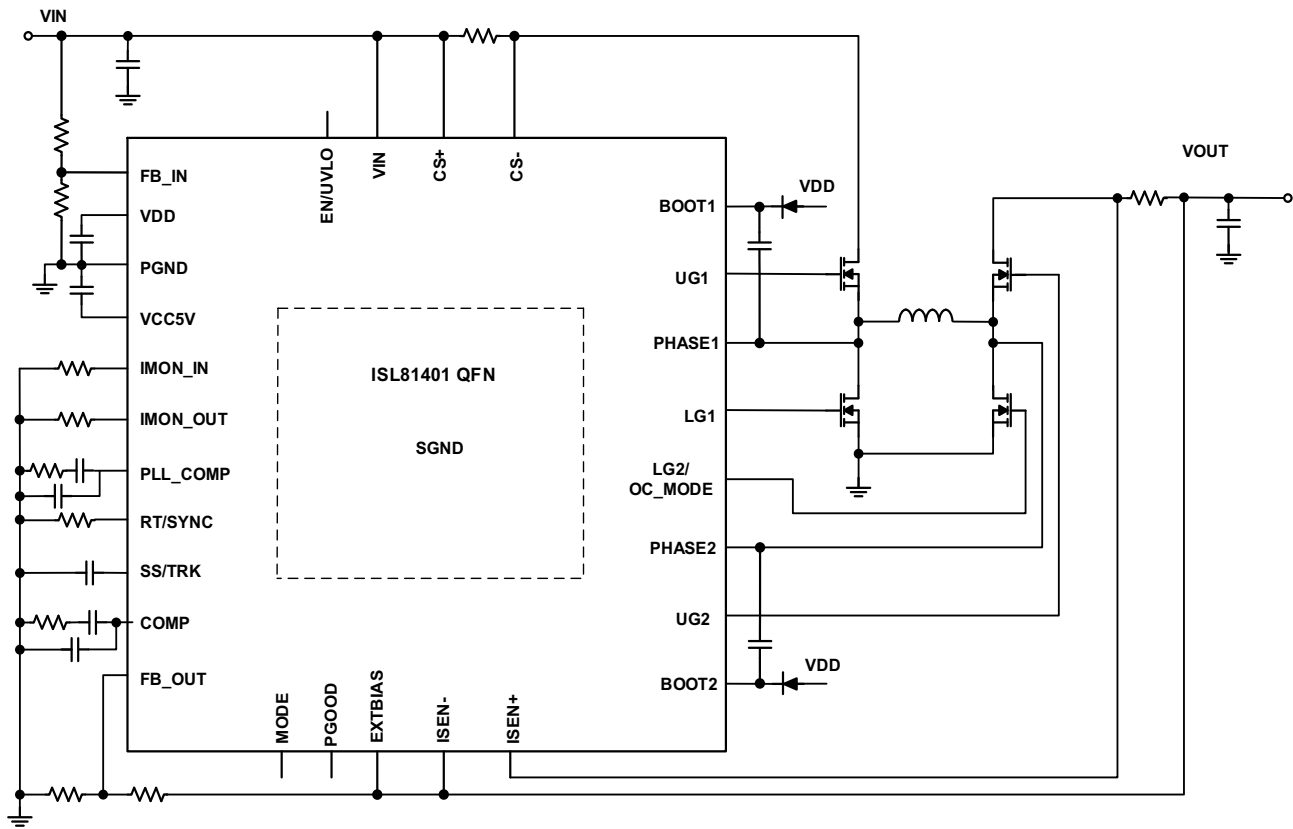


Figure 1. ISL81401EVAL1Z Block Diagram

2. Functional Description

The ISL81401EVAL1Z is the same test board used by Renesas application engineers and IC designers to evaluate the performance of the ISL81401 QFN IC. The board provides an easy and complete evaluation of all the IC and board functions.

As shown in [Figure 4 on page 6](#), 6V to 40V VIN is supplied to J1 (+) and J2 (-). The regulated 12V output on J4 (+) and J5 (-) can supply up to 8A to the load. Due to the high power efficiency, the evaluation board can run at 8A continuously without airflow at room temperature ambient conditions.

Test points TP1 through TP28 provide easy access to the IC pin and external signal injection terminals.

As shown in [Table 2 on page 5](#), connector J8 provides selection of either Forced PWM mode (shorting Pin 1 and Pin 2) or DEM mode (shorting Pin 2 and Pin 3). Connector J9 provides selection of either constant current limit (shorting Pin 1 and Pin 2) or HICCUP OCP (shorting Pin 2 and Pin 3). Connector J3 provides an option to disable the converter by shorting its Pin 1 and Pin 2.

2.1 Recommended Testing Equipment

The following materials are recommended for testing:

- 0V to 40V power supply with at least 30A source current capability
- Electronic loads capable of sinking current up to 20A
- Digital Multimeters (DMMs)
- 100MHz quad-trace oscilloscope

2.2 Operating Range

The input voltage range is from 6V to 40V for an output voltage of 12V. If the output voltage is set to a lower value, the minimum V_{IN} can be reset to a lower value by changing the ratio of R_2 and R_3 . The minimum EN threshold that V_{IN} can be set to is 4.5V.

The rated load current is 8A with the OCP point set at minimum 10A at ambient room temperature conditions. The operating temperature range of this board is -40°C to $+85^{\circ}\text{C}$. Note that airflow is needed for higher temperature ambient conditions.

2.3 Bi-Directional Operation

Refer to [Figure 2](#) for proper setup. Float the FBI pin (J7) and set the mode to CCM before powering on the board. The rated voltage of the super capacitor must be higher than 12V.

- (1) Adjust the input voltage higher than 6V. Switch on the input power source.
- (2) Switch off the input power source after the super capacitor is fully charged.

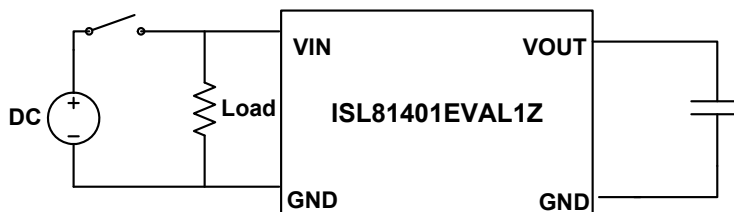


Figure 2. Proper Setup for Bi-Directional Operation

2.4 Quick Test Guide

- (1) Jumper J8 provides the option to select PWM or DEM. Jumper J9 provides the option to select constant current limit or HICCUP. Refer to [Table 2](#) for the operating options. Ensure that the circuit is correctly connected to the supply and electronic loads before applying any power. Refer to [Figure 4 on page 6](#) for proper setup.
- (2) Turn on the power supply.
- (3) Adjust input voltage V_{IN} within the specified range and observe the output voltage. The output voltage variation should be within 3%.
- (4) Adjust the load current within the specified range and observe the output voltage. The output voltage variation should be within 3%.
- (5) Use an oscilloscope to observe output voltage ripple and phase node ringing. For accurate measurement, refer to [Figure 3](#) for proper test setup.

Table 2. Operating Options

| Jumper | Position | Function |
|--------|-------------------|-----------------------------|
| 3 | EN-GND | Disable output |
| | EN Floating | Enable output |
| 6 | I_{IN} Floating | Enable input current limit |
| | I_{IN} -VCC5 | Disable input current limit |
| 7 | FBI-GND | Disable V_{IN} limit |
| | FBI Floating | Enable V_{IN} limit |
| 8 | Pin 1-2 | PWM |
| | Pin 2-3 | DEM |
| 9 | Pin 1-2 | Constant current limit |
| | Pin 2-3 | HICCUP |

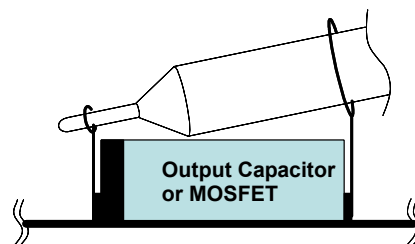


Figure 3. Proper Probe Setup to Measure Output Ripple and Phase Node Ringing

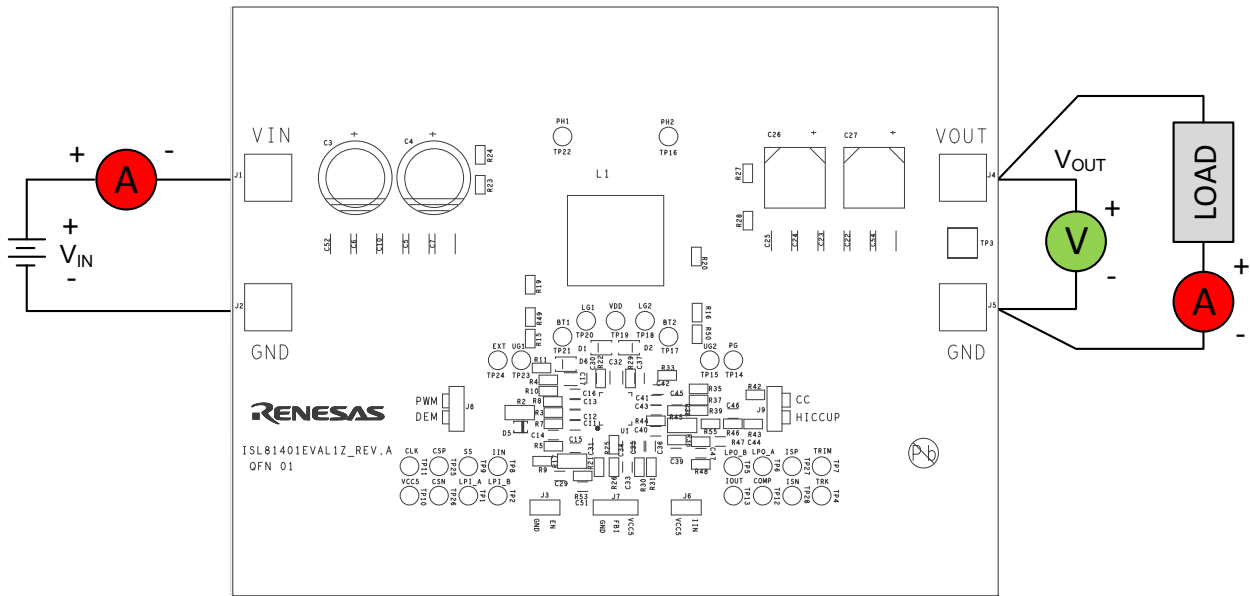


Figure 4. Proper Test Setup

3. PCB Layout Guidelines

Careful attention to Printed Circuit Board (PCB) layout requirements is necessary for successful implementation of an ISL81401 based DC/DC converter. The ISL81401 switches at a very high frequency, so the switching times are very short. At these switching frequencies, even the shortest trace has significant impedance and the peak gate drive current rises significantly in an extremely short time. The transition speed of the current from one device to another causes voltage spikes across the interconnecting impedances and parasitic circuit elements. These voltage spikes can degrade efficiency, generate EMI, and increase device voltage stress and ringing. Careful component selection and proper PCB layout minimizes the magnitude of these voltage spikes.

Three sets of components are critical when using the ISL81401 DC/DC converter:

- Controller
- Switching power components
- Small signal components

The switching power components are the most critical to the layout, because they switch a large amount of energy, which tends to generate a large amount of noise. The critical small signal components are those connected to sensitive nodes or those supplying critical bias currents. A multilayer PCB is recommended.

Complete the following steps to optimize the PCB layout.

- (1) First, place the input capacitors, buck FETs, inductor, boost FETs, and output capacitor. Isolate these power components on dedicated areas of the board with their ground terminals adjacent to one another. Place the input and output high frequency decoupling ceramic capacitors very close to the MOSFETs.
- (2) If signal components and the IC are placed separately from the power train, it is recommended to use full ground planes in the internal layers with shared SGND and PGND to simplify the layout design. Otherwise, use separate ground planes for the power ground and the small signal ground. Connect the SGND and PGND together close to the IC. DO NOT connect them together anywhere else.
- (3) The loop formed by the input capacitor, the buck top FET, and the buck bottom FET must be kept as small as possible. The loop formed by the output capacitor, the boost top FET, and the boost bottom FET must also be kept as small as possible.
- (4) Ensure the current paths from the input capacitor to the buck FETs, the power inductor, the boost FETs, and the output capacitor are as short as possible with maximum allowable trace widths.
- (5) Place the PWM controller IC close to the lower FETs. The low side FETs gate drive connections should be short and wide. The IC should be placed over a quiet ground area. Avoid switching ground loop currents in this area.
- (6) Place the VDD bypass capacitor very close to the VDD pin of the IC and connect its ground end to the PGND pin. Connect the PGND pin to the ground plane by a via. Do not connect the PGND pin directly to the SGND EPAD.
- (7) Place the gate drive components (BOOT diodes and BOOT capacitors) together near the controller IC.
- (8) Place the output capacitors as close to the load as possible. Use short, wide copper regions to connect output capacitors to load to avoid inductance and resistances.
- (9) Use copper filled polygons or wide, short traces to connect the junction of the buck or boost upper FET, buck or boost lower FET, and output inductor. Keep the buck and boost PHASE nodes connection to the IC short. DO NOT unnecessarily oversize the copper islands for the PHASE nodes. Because the phase nodes are subjected to very high dv/dt voltages, the stray capacitor formed between these islands and the surrounding circuitry will tend to couple switching noise.
- (10) Route all high speed switching nodes away from the control circuitry.
- (11) Create a separate small analog ground plane near the IC. Connect the SGND pin to this plane. All small signal grounding paths including feedback resistors, current monitoring resistors and capacitors, soft-starting capacitors, loop compensation capacitors and resistors, and EN pull-down resistors should be connected to this SGND plane.
- (12) Use a pair of traces with minimum loop for the input or output current sensing connection.
- (13) Ensure the feedback connection to the output capacitor is short and direct.

3.1 ISL81401EVAL1Z Evaluation Board

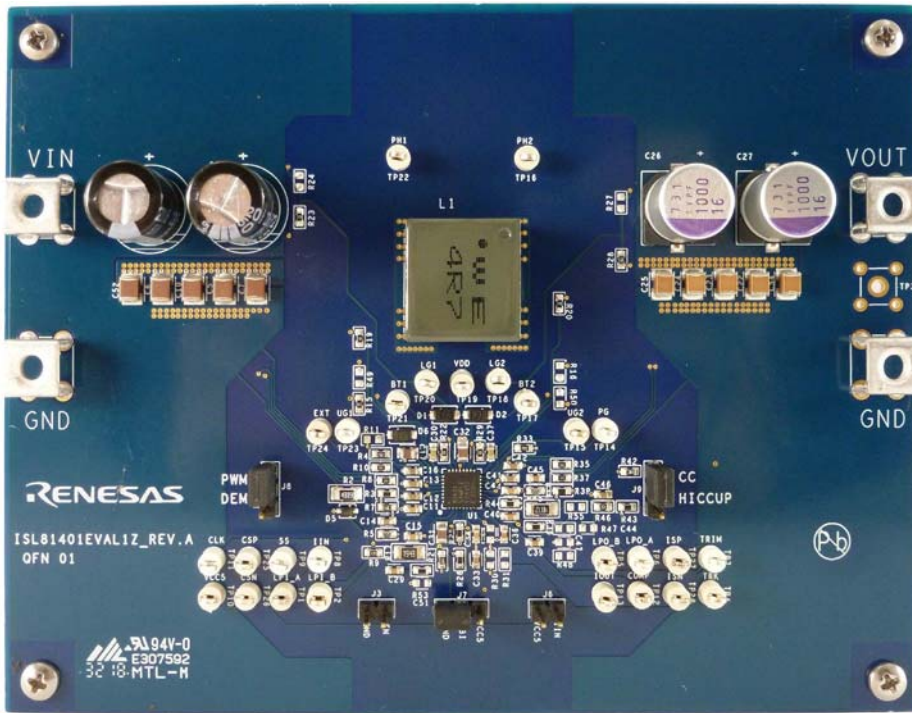


Figure 5. ISL81401EVAL1Z Evaluation Board, Top View

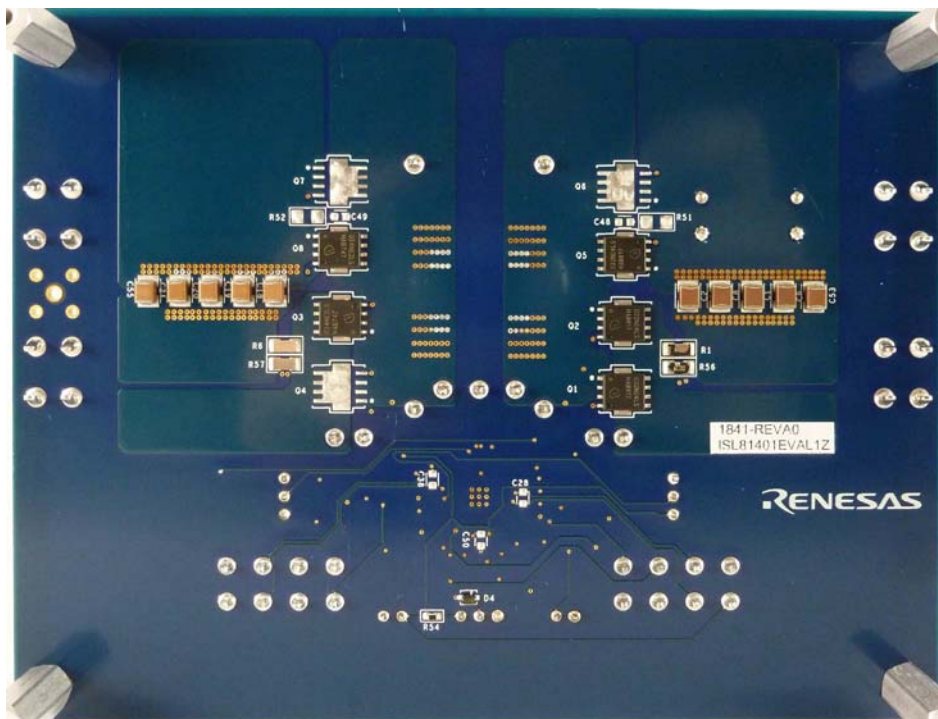


Figure 6. ISL81401EVAL1Z Evaluation Board, Bottom View

3.2 ISL81401EVAL1Z Circuit Schematic

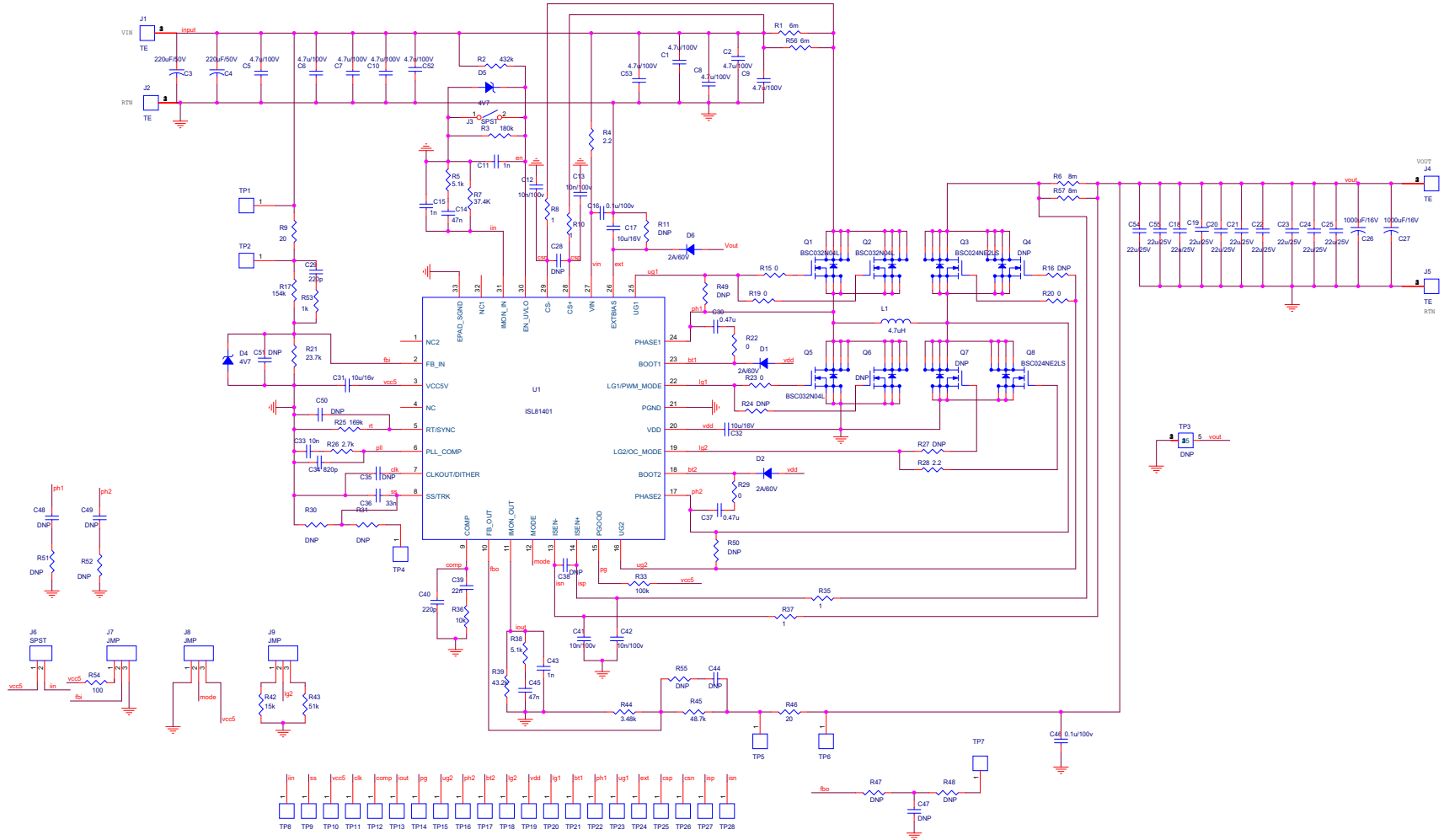


Figure 7. Schematic

3.3 Bill of Materials

| Qty | Reference Designator | Description | Manufacturer | Manufacturer Part |
|-----|---|--|----------------------------------|-----------------------|
| 1 | | PWB-PCB, ISL81401EVAL1Z, REVA, ROHS | Multilayer Pcb (Hi Tech Circuit) | ISL81401EVAL1ZREVAPCB |
| 1 | C33 | CAP-AEC-Q200, SMD, 0603, 0.01uF, 50V, 10%, X7R, ROHS | TDK | CGA3E2X7R1H103K080AE |
| 10 | C1, C2, C5, C6, C7, C8, C9, C10, C52, C53 | CAP-AEC-Q200, SMD, 1210, 4.7uF, 100V, 10%, X7S, ROHS | TDK | CGA6M3X7S2A475K200AE |
| 1 | C39 | CAP-AEC-Q200, SMD, 0603, 0.022uF, 25V, 10%, X7R, ROHS | TDK | CGJ3E2X7R1E223K080AA |
| 1 | C36 | CAP-AEC-Q200, SMD, 0603, 0.033uF, 25V, 10%, X7R, ROHS | TDK | CGJ3E2X7R1E333K080AA |
| 2 | C14, C45 | CAP-AEC-Q200, SMD, 0603, 0.047uF, 25V, 10%, X7R, ROHS | TDK | CGJ3E2X7R1E473K080AA |
| 2 | C16, C46 | CAP-BOARDFLEX, SMD, 0603, 0.1uF, 100V, 10%, X7R, ROHS | Murata | GRJ188R72A104KE11D |
| 3 | C17, C31, C32 | CAP, SMD, 0805, 10uF, 16V, 10%, X7S, ROHS | Murata | GRM21BC71C106KE11L |
| 10 | C18-C25, C54, C55 | CAP, SMD, 1210, 22uF, 25V, 10%, X7R, ROHS | Murata | GRM32ER71E226KE15L |
| 3 | C11, C15, C43 | CAP, SMD, 0603, 1000pF, 50V, 10%, X7R, ROHS | Avx | 06035C102KAT2A |
| 4 | C12, C13, C41, C42 | CAP, SMD, 0603, 0.01uF, 100V, 10%, X7R, ROHS | Kemet | C0603C103K1RECAUTO |
| 1 | C29 | CAP, SMD, 0603, 220pF, 100V, 10%, X7R, ROHS | Panasonic | ECJ-1VB2A221K |
| 1 | C40 | CAP, SMD, 0603, 220pF, 50V, 10%, X7R, ROHS | Murata | GRM188R71H221KA01D |
| 2 | C30, C37 | CAP, SMD, 0603, 0.47uF, 25V, 10%, X7R, ROHS | Murata | GRM188R71E474KA12D |
| 1 | C34 | CAP, SMD, 0603, 820pF, 50V, 10%, X7R, ROHS | Kemet | C0603C821K5RACTU |
| 0 | C28, C35, C38, C44, C47-C51 | CAP, SMD, 0603, DNP-PLACE HOLDER, ROHS | | |
| 2 | C26, C27 | CAP-OSCON, SMD, 10mm, 1000uF, 16V, 20%, 12mohm, ROHS | Sanyo | 16SVPF1000M |
| 1 | L1 | COIL-PWR INDUCTOR, SMD, 16.4X15.4, 4.7uH, 20%, 17A, ROHS | Würth Electronics | 74439370047 |
| 27 | TP1, TP2, TP4-TP28 | CONN-COMPACT TEST PT, VERTICAL, WHT, ROHS | Keystone | 5007 |
| 3 | J7, J8, J9 | CONN-HEADER, 1x3, BREAKAWY 1X36, 2.54mm, ROHS | BERG/FCI | 68000-236HLF |
| 2 | J3, J6 | CONN-HEADER, 1X2, RETENTIVE, 2.54mm, 0.230X 0.120, ROHS" | BERG/FCI | 69190-202HLF |
| 3 | J7-Pins FBI-GND, J8-Pins PWM, J9-Pins CC | CONN-JUMPER, SHORTING, 2PIN, BLACK, GOLD, ROHS | Sullins | SPC02SYAN |
| 2 | D4, D5 | DIODE-ZENER, SMD, SOD-323, 4.7V, 6%, 300mW, ROHS | Diodes, Inc. | MM3Z4V7T1G |
| 3 | D1, D2, D6 | DIODE-SCHOTTKY, SMD, SOD-123FL, 60V, 2A, ROHS | Rohm | RBR2MM60CTR |

| Qty | Reference Designator | Description | Manufacturer | Manufacturer Part |
|-----|---|---|-----------------------------|----------------------------|
| 1 | U1 | IC-40V PWM CONTROLLER, 32P, QFN, 5X5, ROHS | Renesas Electronics America | ISL81401FRZ |
| 2 | Q3, Q8 | TRANSIST-MOS, N-CHANNEL, 8P, PG-TDSON, 25V, 25A, ROHS | Infineon Technology | BSC024NE2LSATMA1 |
| 3 | Q1, Q2, Q5 | TRANSISTOR-MOS, N-CHANNEL, SMD, 8P, TDSON, 40V, 98A, ROHS | Infineon Technology | BSC032N04LS |
| 4 | R8, R10, R35, R37 | RES, SMD, 0603, 1ohm, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3RQF1R0V |
| 2 | R9, R46 | RES, SMD, 0603, 20ohm, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3EKF20R0V |
| 2 | R4, R28 | RES, SMD, 0603, 2.2ohm, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3RQF2R2V |
| 6 | R15, R19, R20, R22, R23, R29 | RES, SMD, 0603, 0ohm, 1/10W, TF, ROHS | Venkel | CR0603-10W-000T |
| 1 | R54 | RES, SMD, 0603, 100ohm, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-1000FT |
| 1 | R53 | RES, SMD, 0603, 1K, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3EKF1001V |
| 1 | R36 | RES, SMD, 0603, 10K, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-1002FT |
| 1 | R33 | RES, SMD, 0603, 100K, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-1003FT |
| 1 | R42 | RES, SMD, 0603, 15K, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3EKF1502V |
| 1 | R25 | RES, SMD, 0603, 169K, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-1693FT |
| 1 | R3 | RES, SMD, 0603, 180K, 1/10W, 1%, TF, ROHS | Yageo | RC0603FR-07180KL |
| 1 | R21 | RES, SMD, 0603, 23.7K, 1/10W, 1%, TF, ROHS | Yageo | RC0603FR-0723K7L |
| 1 | R26 | RES, SMD, 0603, 2.7K, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-2701FT |
| 1 | R44 | RES, SMD, 0603, 3.48K, 1/10W, 1%, TF, ROHS | Panasonic | ERJ-3EKF3481V |
| 1 | R7 | RES, SMD, 0603, 37.4K, 1/10W, 1%, TF, ROHS | Yageo | RC0603FR-0737K4L |
| 1 | R39 | RES, SMD, 0603, 43.2K, 1/10W, 1%, TF, ROHS | Yageo | RC0603FR-0743K2L (Pb FREE) |
| 2 | R5, R38 | RES, SMD, 0603, 5.1K, 1/10W, 1%, TF, ROHS | Venkel | CR0603-10W-5101FT |
| 1 | R43 | RES, SMD, 0603, 51K, 1/10W, 1%, TF, ROHS | Yageo | RC0603FR-0751KL |
| 0 | R11, R16, R24, R27, R30, R31, R47, R48, R49, R50, R55 | RES, SMD, 0603, DNP-PLACE HOLDER, ROHS | | |
| 1 | R17 | RES, SMD, 1206, 154K, 1/4W, 1%, TF, ROHS | Yageo | RC1206FR-07154KL |
| 1 | R2 | RES, SMD, 1206, 432K, 1/4W, 1%, TF, ROHS | Panasonic | ERJ-8ENF4323V |

| Qty | Reference Designator | Description | Manufacturer | Manufacturer Part |
|-----|----------------------|---|--------------------|-------------------|
| 1 | R45 | RES, SMD, 1206, 48.7K, 1/4W, 1%, TF, ROHS | Yageo | RC1206FR-0748K7L |
| 0 | R51, R52 | RES, SMD, 1206, DNP, DNP, DNP, TF, ROHS | | |
| 2 | R1, R56 | RES, SMD, 1206, 0.006ohm, 1W, 1%, TF, ROHS | Rohm | PMR18EZPFU6L00 |
| 2 | R6, R57 | RES, SMD, 1206, 0.008ohm, 1W, 1%, TF, ROHS | Rohm | PMR18EZPFU8L00 |
| 2 | C3, C4 | CAP, RADIAL, 10x17.5mm, 220uF, 50V, 20%, ALUM.ELEC., ROHS | Panasonic | EEU-FR1H221B |
| 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, 0.25 OD, ROHS | Keystone | 2204 |
| 4 | J1, J2, J4, J5 | HDWARE, TERMINAL, M4 METRIC SCREW, TH, 4P, SNAP-FIT, ROHS | Keystone | 7795 |
| 1 | Place assy in bag | BAG, STATIC, 6X8, ZIPLOC, ROHS | Uline | S-2262 |
| 0 | Q4, Q6, Q7 | DO NOT POPULATE OR PURCHASE | | |
| 0 | TP3 | DO NOT POPULATE OR PURCHASE | | |

3.4 Board Layout

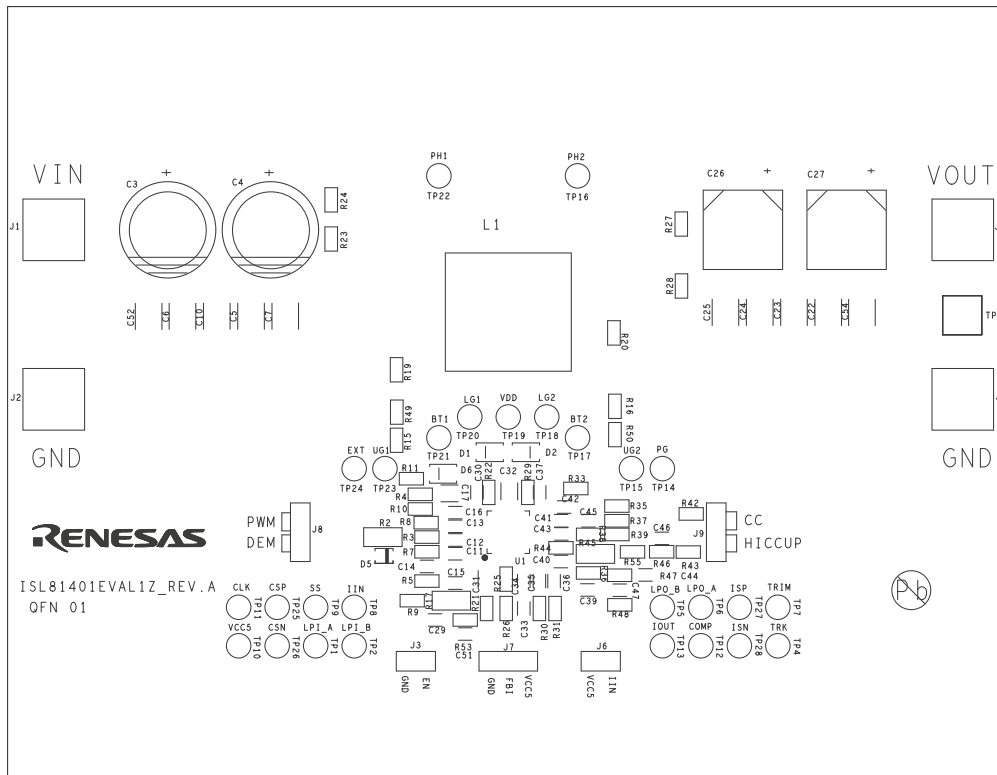


Figure 8. Silkscreen Top

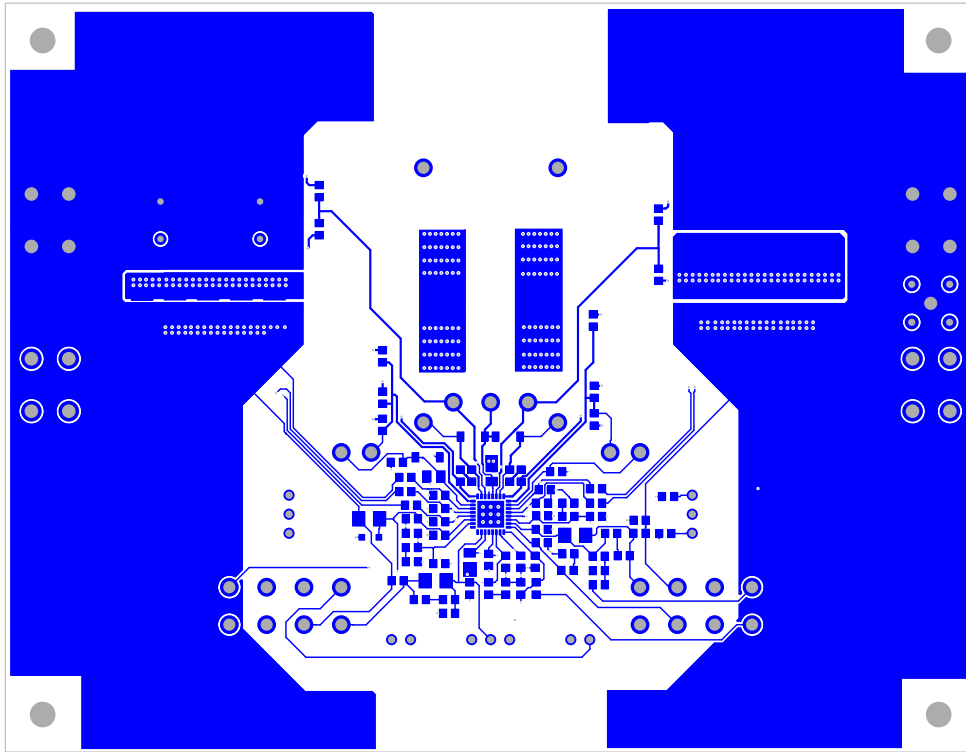


Figure 9. Top Layer

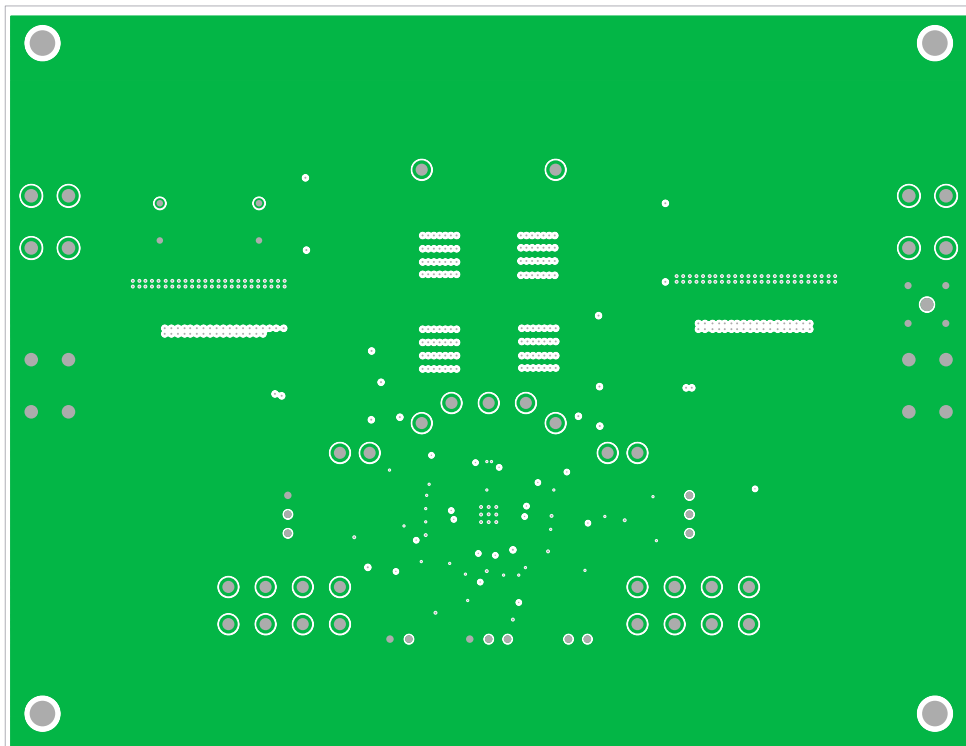


Figure 10. Second Layer (Solid Ground)

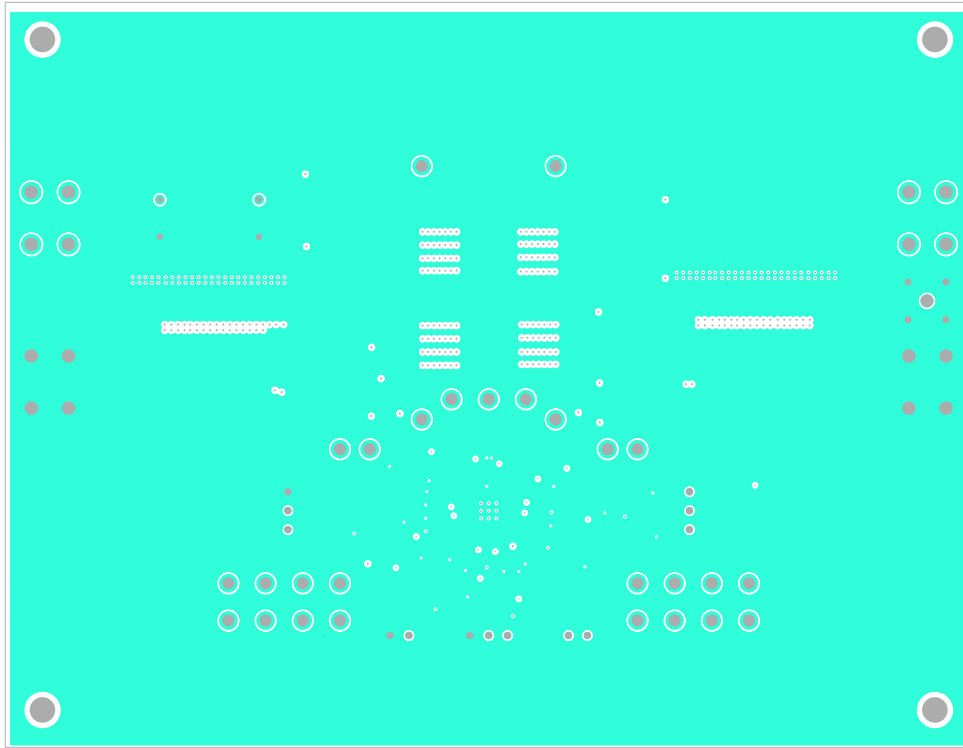


Figure 11. Third Layer

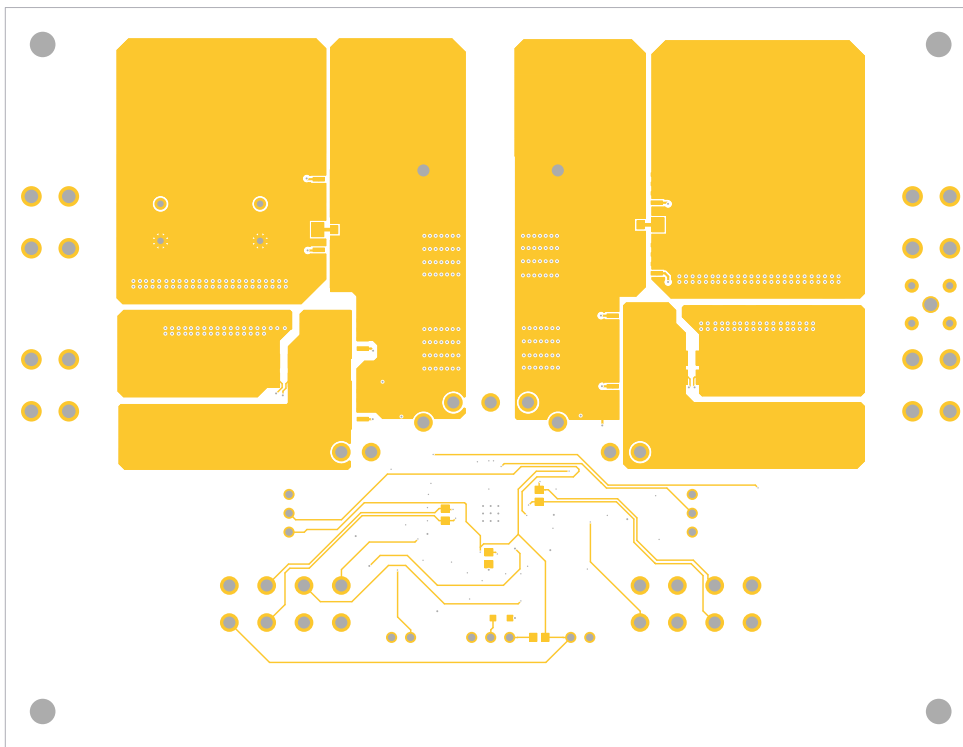


Figure 12. Bottom Layer

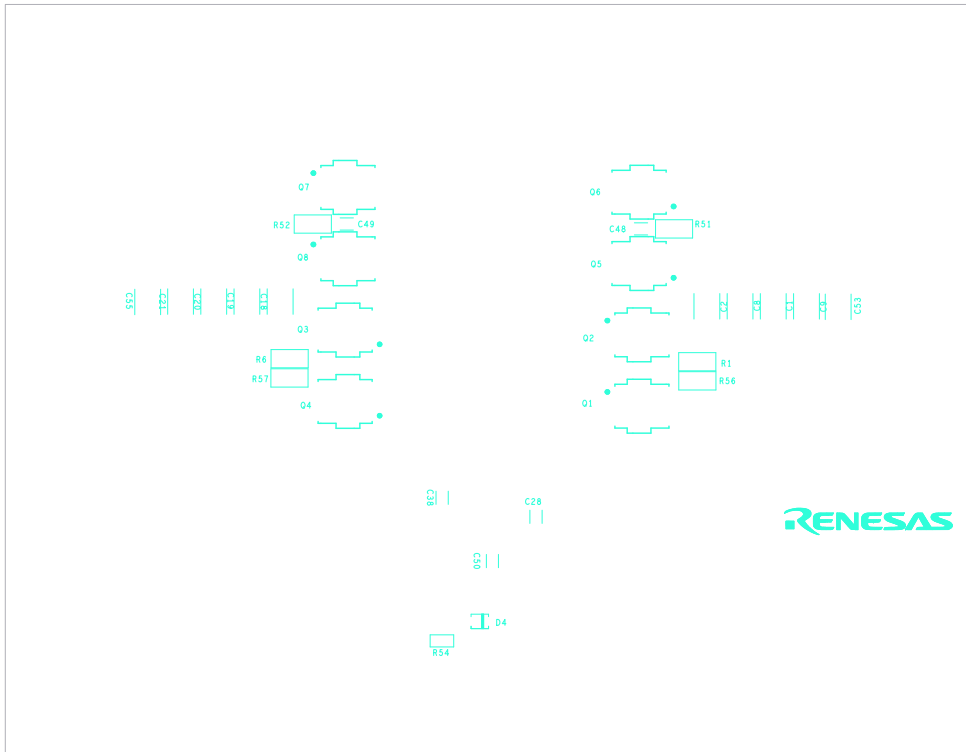


Figure 13. Silkscreen Bottom

4. Typical Performance Curves

$V_{IN} = 12V$, unless otherwise noted.

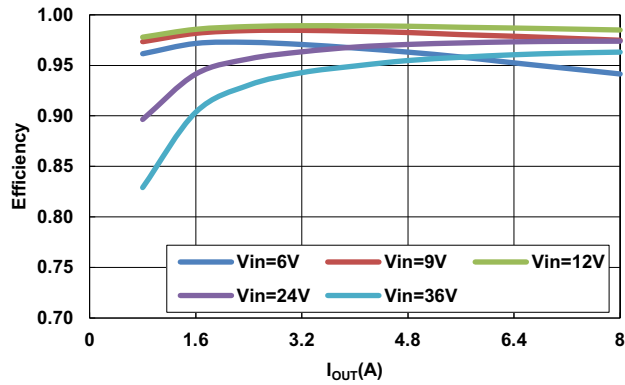


Figure 14. Efficiency, CCM

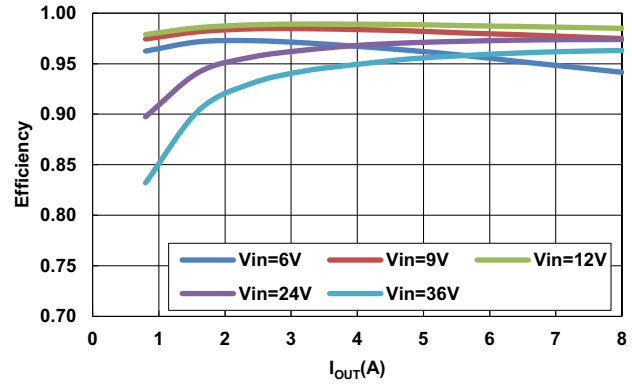


Figure 15. Efficiency, DEM

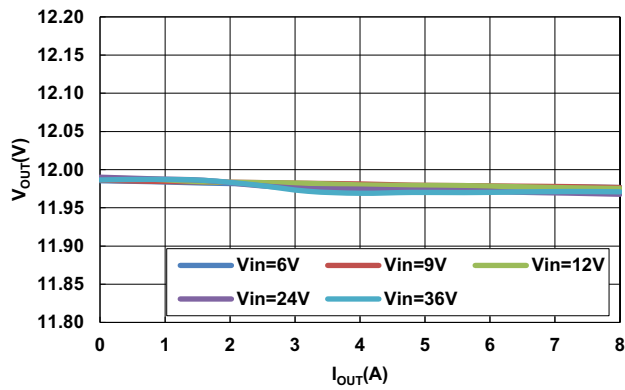


Figure 16. Load Regulation, CCM

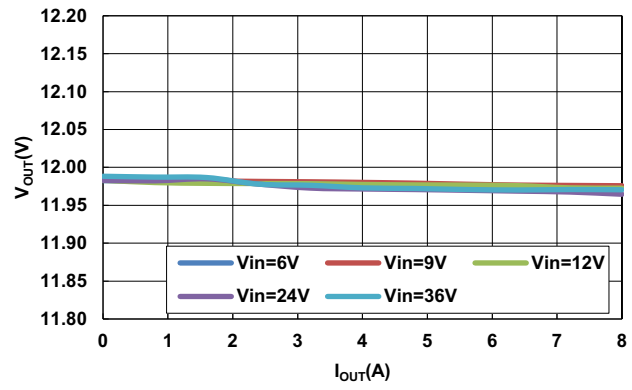


Figure 17. Load Regulation, DEM

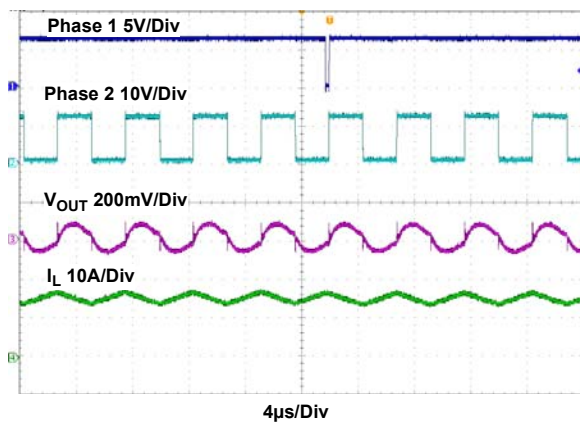


Figure 18. Phase 1, Phase 2, V_{OUT} and Inductor Current, $V_{IN} = 6V$, $I_{OUT} = 8A$

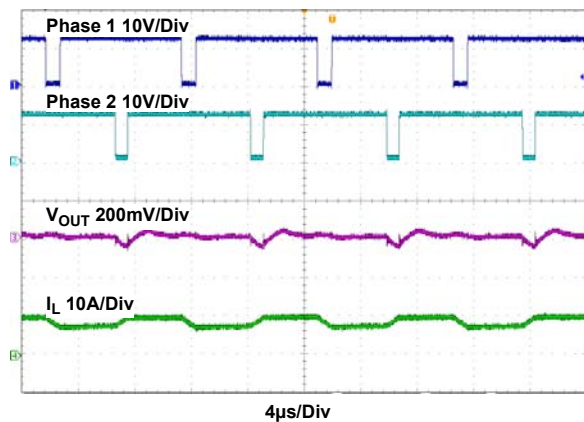


Figure 19. Phase 1, Phase 2, V_{OUT} and Inductor Current, $V_{IN} = 12V$, $I_{OUT} = 8A$

$V_{IN} = 12V$, unless otherwise noted. (Continued)

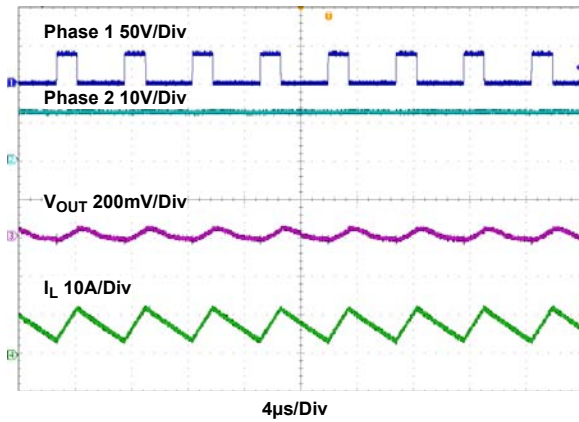


Figure 20. Phase 1, Phase 2, V_{OUT} and Inductor Current, $V_{IN} = 40V$, $I_{OUT} = 8A$

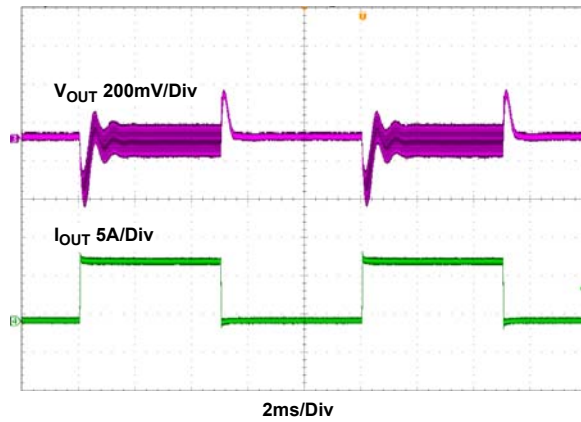


Figure 21. Load Transient, $V_{IN} = 6V$, $I_{OUT} = 0A$ to $8A$, $2.5A/\mu s$, CCM

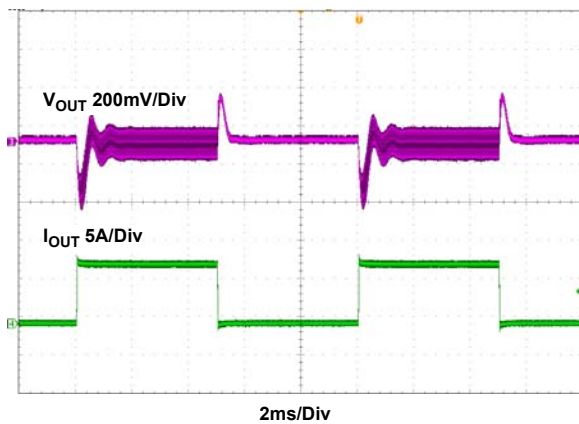


Figure 22. Load Transient, $V_{IN} = 12V$, $I_{OUT} = 0A$ to $8A$, $2.5A/\mu s$, CCM

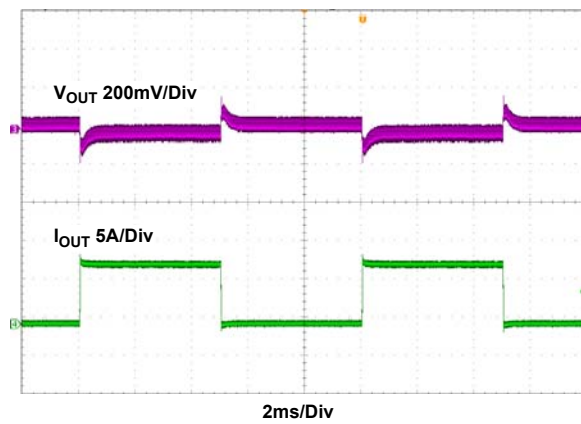


Figure 23. Load Transient, $V_{IN} = 40V$, $I_{OUT} = 0A$ to $8A$, $2.5A/\mu s$, CCM

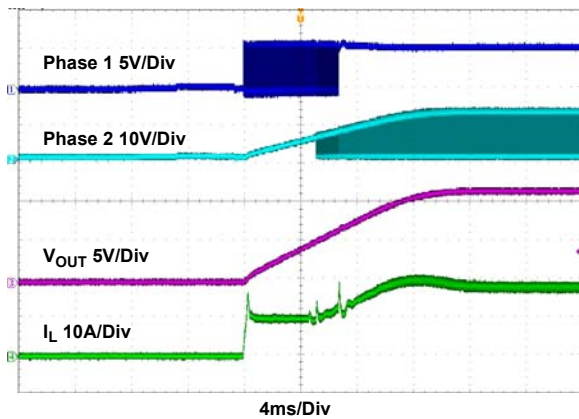


Figure 24. Start-Up Waveform, $V_{IN} = 6V$, $I_{OUT} = 8A$, CCM

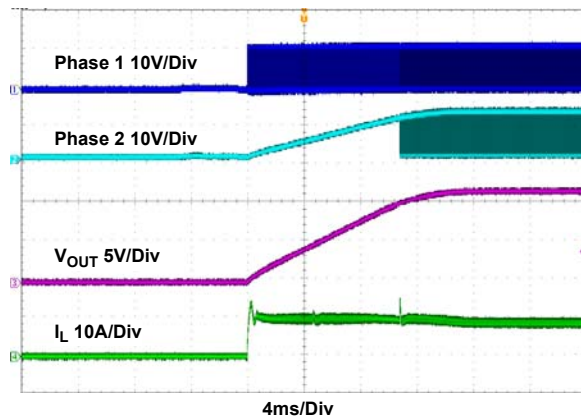


Figure 25. Start-Up Waveform, $V_{IN} = 12V$, $I_{OUT} = 8A$, CCM

$V_{IN} = 12V$, unless otherwise noted. (Continued)

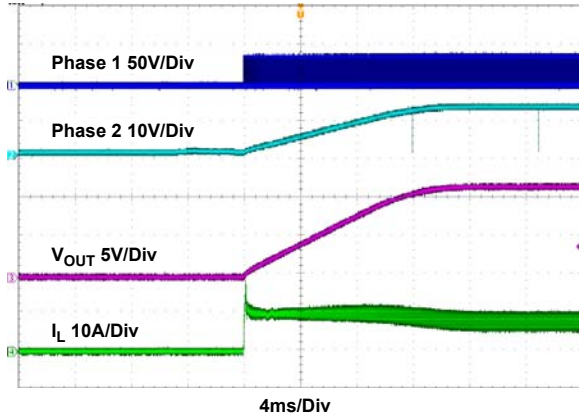


Figure 26. Start-Up Waveform, $V_{IN} = 40V$, $I_{OUT} = 8A$, CCM

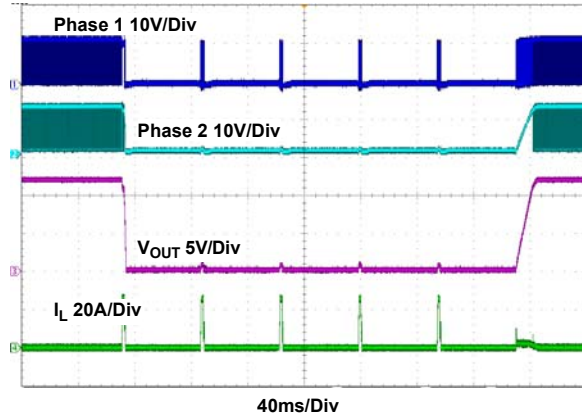


Figure 27. Short-Circuit Waveform

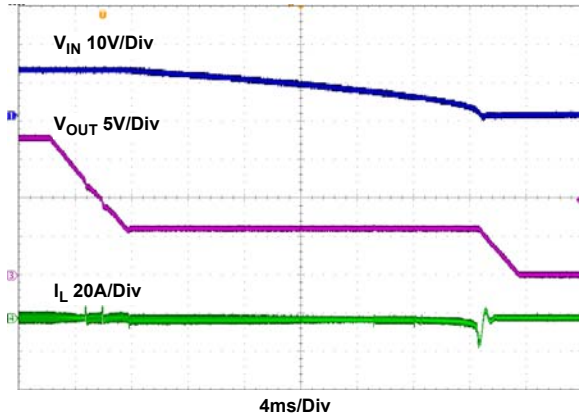


Figure 28. Bi-Directional Operation, $V_{IN} = 18V$, $V_{in_limit} = 6V$, $I_{IN} = 1A$

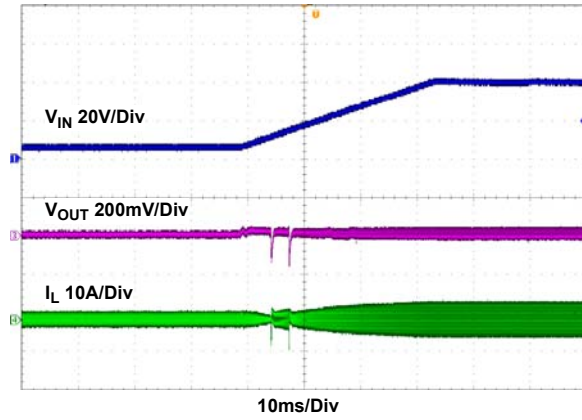


Figure 29. Line Transient, $V_{IN} = 6V$ to $40V$, $1V/ms$, $I_{OUT} = 0A$

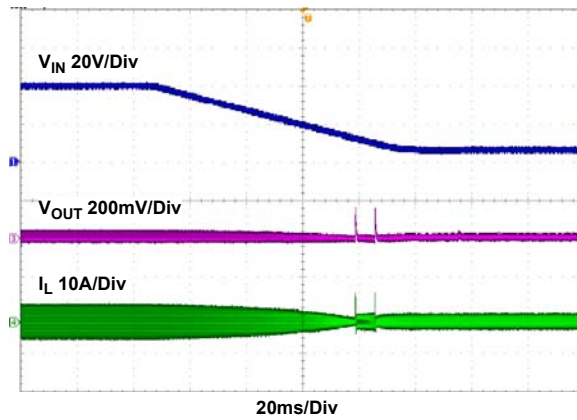


Figure 30. Line Transient, $V_{IN} = 40V$ to $6V$, $1V/ms$, $I_{OUT} = 0A$

5. Revision History

| Rev. | Date | Description |
|------|--------------|-----------------|
| 0.00 | Oct 25, 2018 | Initial release |

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(Rev.4.0-1 November 2017)



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