

# ISL81601EVAL2Z

User's Manual: Evaluation Board

Industrial Analog and Power

## ISL81601EVAL2Z

Evaluation Board

UG160  
Rev.0.00  
Mar 23, 2018

## 1. Overview

The ISL81601EVAL2Z evaluation board (shown in [Figure 5 on page 8](#)) features the [ISL81601](#), a 60V high voltage synchronous buck-boost controller that offers external soft-start, independent enable functions, and integrates UV/OV/OC/OT protection. 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: 32V to 60V
- 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

### 1.2 Specifications

The ISL81601EVAL2Z evaluation board is designed for high current applications. The current rating of the ISL81601EVAL2Z is limited by the FETs and inductor selected. The ISL81601EVAL2Z electrical ratings of are shown in [Table 1](#).

**Table 1. Electrical Rating**

Parameter	Rating
Input Voltage	32V to 60V
Switching Frequency	200kHz
Output Voltage	48V
Output Current	5A
OCP Set Point	Minimum 5.5A at ambient room temperature

### 1.3 Ordering Information

Part Number	Description
ISL81601EVAL2Z	High Voltage BUCK-BOOST Controller Evaluation Board

### 1.4 Related Literature

- For a full list of related documents, visit our website
  - [ISL81601](#) product page

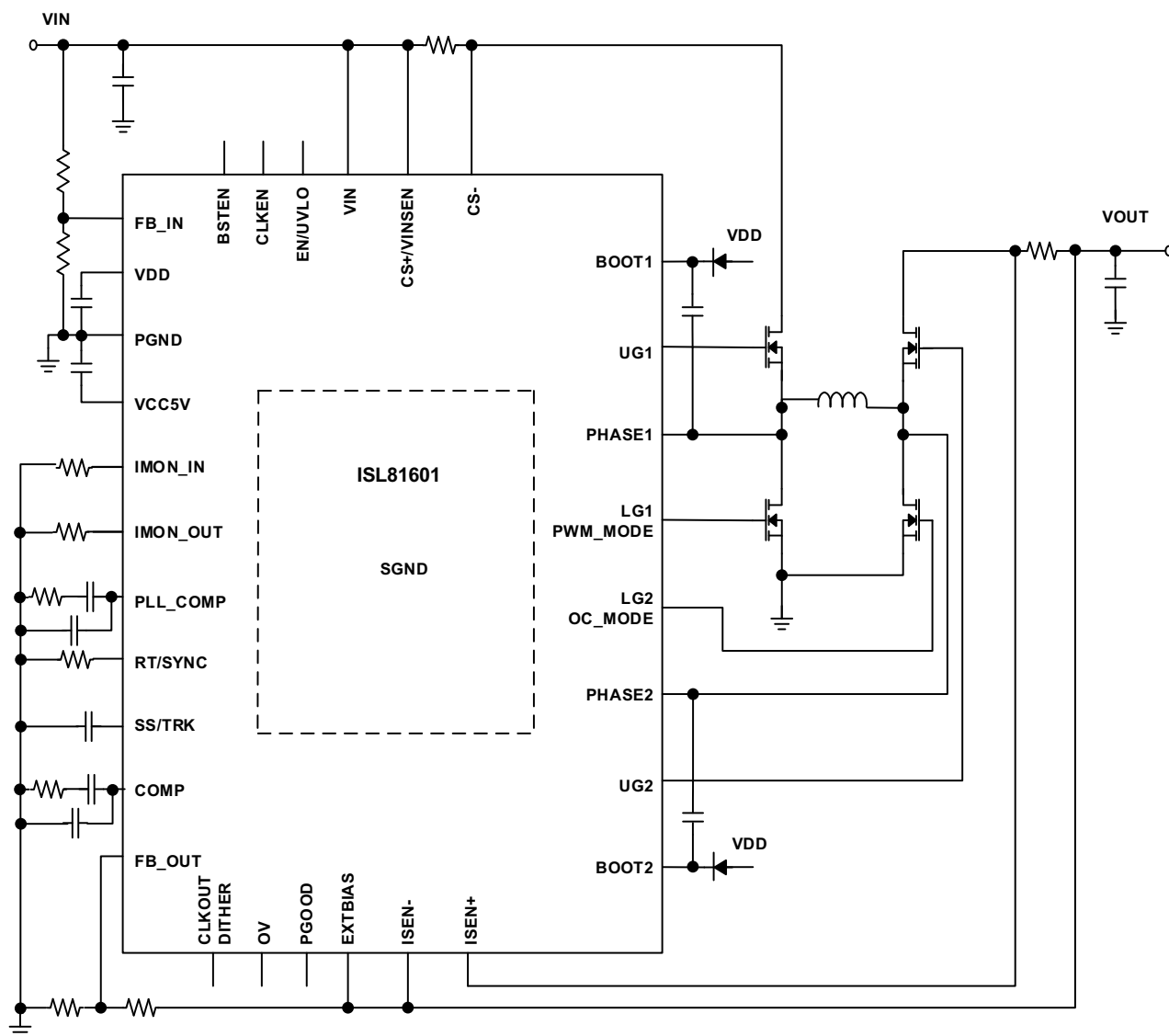


Figure 1. ISL81601EVAL2Z Block Diagram

## 2. Functional Description

The ISL81601VAL2Z is the same test board used by Renesas application engineers and IC designers to evaluate the performance of the ISL81601 HTSSOP IC. The board provides an easy and complete evaluation of all the IC and board functions.

As shown in [Figure 4 on page 6](#), 32V to 60V  $V_{IN}$  is supplied to J1 (+) and J2 (-). The regulated 48V output on J4 (+) and J5 (-) can supply up to 5A to the load. Due to the high power efficiency, the evaluation board can run at 5A 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 60V power supply with at least 10A source current capability
- Electronic loads capable of sinking current up to 10A
- Digital Multimeters (DMMs)
- 100MHz quad-trace oscilloscope

### 2.2 Operating Range

The input voltage range is from 32V to 60V for an output voltage of 48V. 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 5A with the OCP point set at minimum 5.5A at ambient room temperature conditions. The operating temperature range of this board is from -40°C to +85°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 PWM before powering on the board. The rated voltage of the super capacitor must be higher than 48V.

- (1) Adjust the input voltage higher than 36V. Switch on the input power source.
- (2) Switch off the input power source after the super capacitor is fully charged.

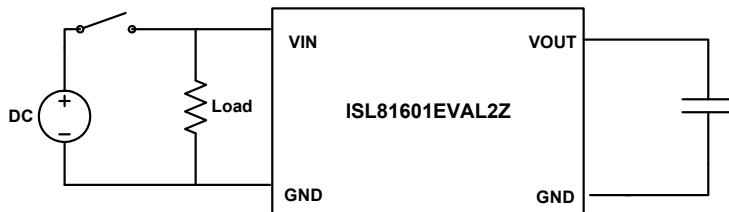


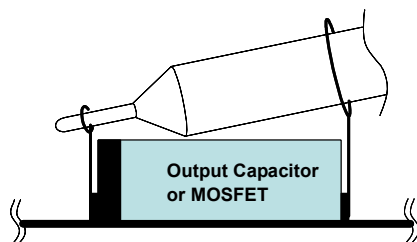
Figure 2. Proper Set-Up for Bi-Directional Operation

## 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 prior to 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 Set-Up to Measure Output Ripple and Phase Node Ringing**



### 3. PCB Layout Guidelines

Careful attention to layout requirements is necessary for successful implementation of an ISL81601 based DC/DC converter. The ISL81601 switches at a very high frequency; therefore the switching times are very short. At these switching frequencies, even the shortest trace has significant impedance. The peak gate drive current also rises significantly in an extremely short time. 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 PC board layout minimizes the magnitude of these voltage spikes.

Three sets of components are critical when using the ISL81601 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 printed circuit board is recommended.

Complete the following steps to optimize the PCB layout.

- (1) The input capacitors, buck FETs, inductor, boost FETs, and output capacitor should be placed first. 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. Also, 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 the load to avoid inductance and resistance.
- (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 ISL81601VAL2Z Evaluation Board

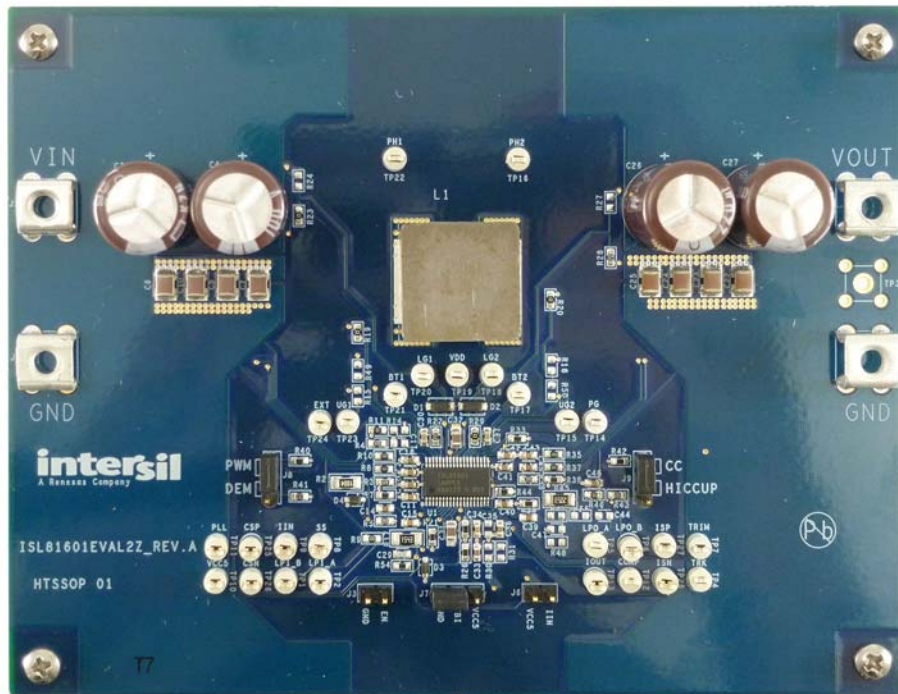


Figure 5. ISL81601VAL2Z Evaluation Board (Top)

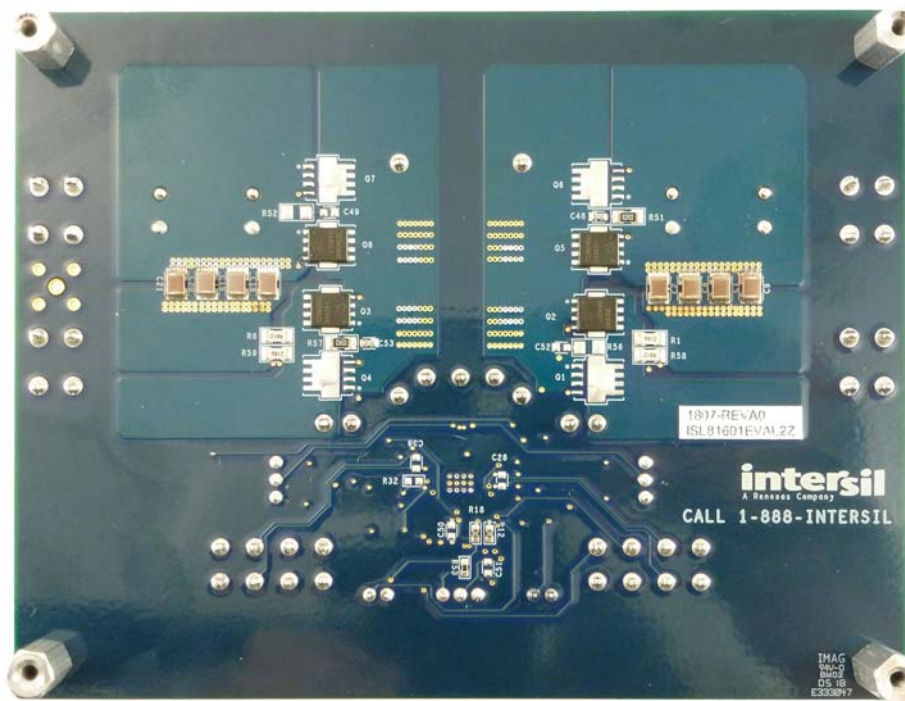


Figure 6. ISL81601VAL2Z Evaluation Board (Bottom)



## 3.2 ISL81601VAL2Z Circuit Schematic

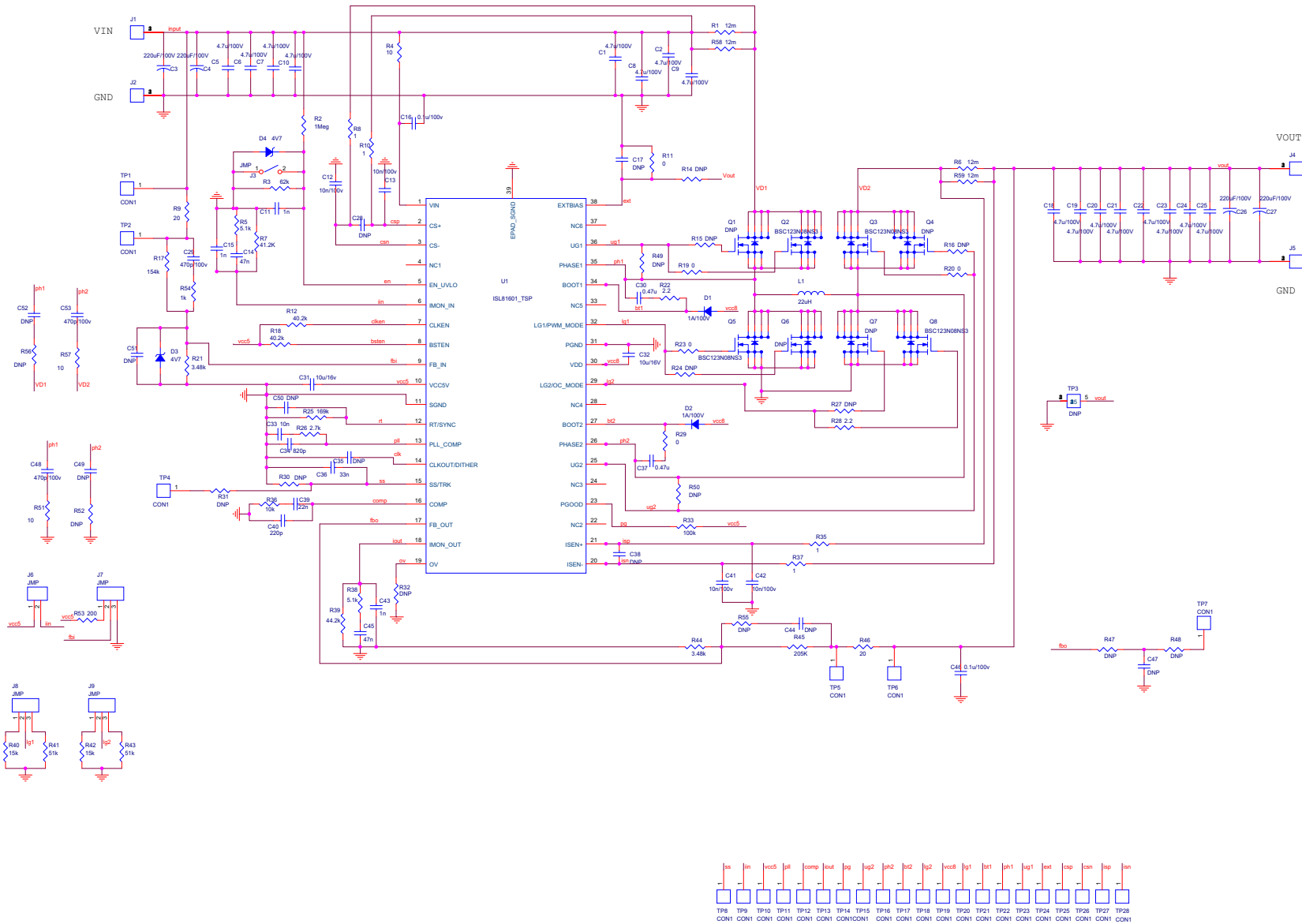


Figure 7. Schematic

### 3.3 Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part
1		PWB-PCB, ISL81601EVAL2Z, REVA, ROHS	IMAGINEERING INC	ISL81601EVAL2ZREVAPCB
1	C33	CAP-AEC-Q200, SMD, 0603, 0.01μF, 50V, 10%, X7R, ROHS	TDK	CGA3E2X7R1H103K080AE
16	C1, C2, C5, C6, C7, C8, C9, C10, C18, C19, C20, C21, C22, C23, C24, C25	CAP-AEC-Q200, SMD, 1210, 4.7μF, 100V, 10%, X7S, ROHS	TDK	CGA6M3X7S2A475K200AE
1	C39	CAP-AEC-Q200, SMD, 0603, 0.022μF, 25V, 10%, X7R, ROHS	TDK	CGJ3E2X7R1E223K080AA
1	C36	CAP-AEC-Q200, SMD, 0603, 0.033μF, 25V, 10%, X7R, ROHS	TDK	CGJ3E2X7R1E333K080AA
2	C14, C45	CAP-AEC-Q200, SMD, 0603, 0.047μF, 25V, 10%, X7R, ROHS	TDK	CGJ3E2X7R1E473K080AA
4	C12, C13, C41, C42	CAP-AEC-Q200, SMD, 0603, 0.01μF, 100V, 10%, X7R, ROHS	MURATA	GCM188R72A103KA37D
2	C16, C46	CAP-BOARDFLEX, SMD, 0603, 0.1μF, 100V, 10%, X7R, ROHS	MURATA	GRJ188R72A104KE11D
2	C31, C32	CAP, SMD, 0805, 10μF, 16V, 10%, X7S, ROHS	MURATA	GRM21BC71C106KE11L
3	C11, C15, C43	CAP, SMD, 0603, 1000pF, 50V, 10%, X7R, ROHS	AVX	06035C102KAT2A
1	C40	CAP, SMD, 0603, 220pF, 50V, 10%, X7R, ROHS	MURATA	GRM188R71H221KA01D
3	C29, C48, C53	CAP, SMD, 0603, 470pF, 100V, 5%, C0G, ROHS	TDK	C1608C0G2A471J
2	C30, C37	CAP, SMD, 0603, 0.47μF, 25V, 10%, X7R, ROHS	MURATA	GRM188R71E474KA12D
1	C34	CAP, SMD, 0603, 820pF, 50V, 10%, X7R, ROHS	KEMET	C0603C821K5RACTU
0	C17, C28, C35, C38, C44, C47, C49, C50, C51, C52	CAP, SMD, 0603, DNP-PLACE HOLDER, ROHS		
4	C3, C4, C26, C27	CAP, RADIAL, 12.5x26.5, 220μF, 100V, 20%, ALUM.ELEC., 5mm, ROHS	UNITED CHEMI-CON	EKZN101ELL221MK25S
1	L1	COIL-PWR INDUCTOR, SMD, 17.15mm, 22μH, 20%, 12A, 21mΩ, ROHS	VISHAY	IHLP6767GZER220M11
27	TP1, TP2, TP4-TP28	CONN-COMPACT TEST PT, VERTICAL, WHT, ROHS	KEYSTONE	5007
2	J3, J6	CONN-HEADER, 1x2, BRKAWY 1x36, 2.54mm, ROHS	BERG/FCI	68000-236HLF

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part
3	J7, J8, J9	CONN-HEADER, 1x3, BREAKAWY 1x36, 2.54mm, ROHS	BERG/FCI	68000-236HLF
3	J7-Pins FBI-GND, J8-Pins PWM, J9-Pins CC	CONN-JUMPER, SHORTING, 2PIN, BLACK, GOLD, ROHS	SULLINS	SPC02SYAN
2	D1, D2	DIODE-RECTIFIER, SMD, 2P, S0D-123FL, 100V, 1A, ROHS	ON SEMICONDUCTOR	MBR1H100SFT3G
2	D3, D4	DIODE-ZENER, SMD, SOD-323, 4.7V, 6%, 300mW, ROHS	DIODES, INC.	MM3Z4V7T1G
1	U1	IC-60V 4-SWITCH PWM CONTROLLER, 38P, TSSOP, ROHS	RENESAS ELECTRONICS AMERICA	ISL81601FVEZ
4	Q2, Q3, Q5, Q8	TRANSIST-MOS, N-CHANNEL, SMD, 8P, PG-TDSON, 80V, 55A, ROHS	INFINEON TECHNOLOGY	BSC123N08NS3GATMA1
4	R8, R10, R35, R37	RES, SMD, 0603, 1Ω, 1/10W, 1%, TF, ROHS	PANASONIC	ERJ-3RQF1R0V
1	R4	RES, SMD, 0603, 10Ω, 1/10W, 1%, TF, ROHS	KOA	RK73H1JT10R0F
2	R9, R46	RES, SMD, 0603, 20Ω, 1/10W, 1%, TF, ROHS	PANASONIC	ERJ-3EKF20R0V
2	R22, R28	RES, SMD, 0603, 2.2Ω, 1/10W, 1%, TF, ROHS	PANASONIC	ERJ-3RQF2R2V
5	R11, R19, R20, R23, R29	RES, SMD, 0603, 0Ω, 1/10W, TF, ROHS	VENKEL	CR0603-10W-000T
1	R54	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
2	R40, 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	R53	RES, SMD, 0603, 200Ω, 1/10W, 1%, TF, ROHS	VENKEL	CR0603-10W-2000FT
1	R26	RES, SMD, 0603, 2.7k, 1/10W, 1%, TF, ROHS	VENKEL	CR0603-10W-2701FT
2	R21, R44	RES, SMD, 0603, 3.48k, 1/10W, 1%, TF, ROHS	PANASONIC	ERJ-3EKF3481V
2	R12, R18	RES, SMD, 0603, 40.2k, 1/10W, 1%, TF, ROHS	YAGEO	RC0603FR-0740K2L
1	R7	RES, SMD, 0603, 41.2k, 1/10W, 1%, TF, ROHS	VENKEL	CR0603-10W-4122FT
1	R39	RES, SMD, 0603, 44.2k, 1/10W, 1%, TF, ROHS	VENKEL	CR0603-10W-4422FT
2	R5, R38	RES, SMD, 0603, 5.1k, 1/10W, 1%, TF, ROHS	VENKEL	CR0603-10W-5101FT

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part
2	R41, R43	RES, SMD, 0603, 51k, 1/10W, 1%, TF, ROHS	YAGEO	RC0603FR-0751KL
1	R3	RES, SMD, 0603, 62k, 1/10W, 1%, TF, ROHS	YAGEO	RC0603FR-0762KL
0	R14, R15, R16, R24, R27, R30, R31, R32, R47, R48, R49, R50, R55	RES, SMD, 0603, DNP-PLACE HOLDER, ROHS		
2	R51, R57	RES, SMD, 1206, 10Ω, 1/4W, 1%, TF, ROHS	VENKEL	CR1206-4W-10R0FT
1	R2	RES, SMD, 1206, 1M, 1/4W, 1%, TF, ROHS	VENKEL	CR1206-4W-1004FT
1	R17	RES, SMD, 1206, 154k, 1/4W, 1%, TF, ROHS	YAGEO	RC1206FR-07154KL
1	R45	RES, SMD, 1206, 205k, 1/4W, 1%, TF, ROHS	YAGEO	RC1206FR-07205KL
0	R52, R56	RES, SMD, 1206, DNP, DNP, DNP, TF, ROHS		
4	R1, R6, R58, R59	RES-AEC-Q200, SMD, 1206, 0.012Ω, 3/4W, 1%, ROHS	SUSUMU CO., LTD	KRL1632E-M-R012-F-T5
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
0	Q1, Q4, Q6, Q7	DO NOT POPULATE OR PURCHASE		
0	TP3	DO NOT POPULATE OR PURCHASE		

### 3.4 Board Layout

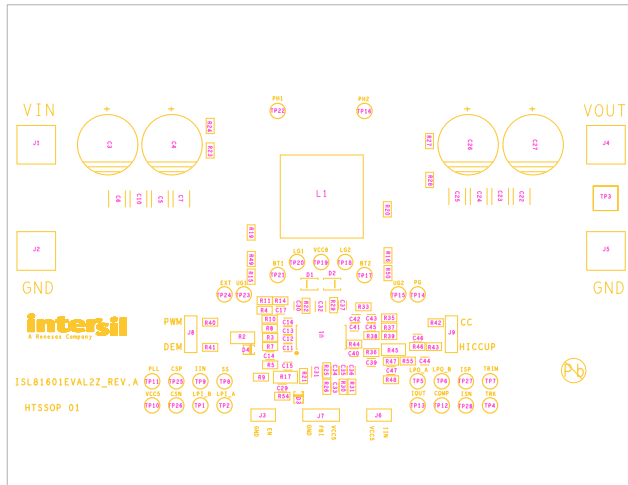


Figure 8. Silkscreen Top

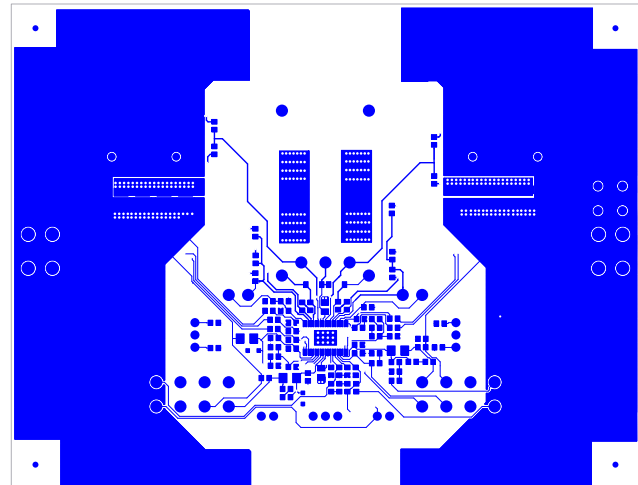


Figure 9. Top Layer

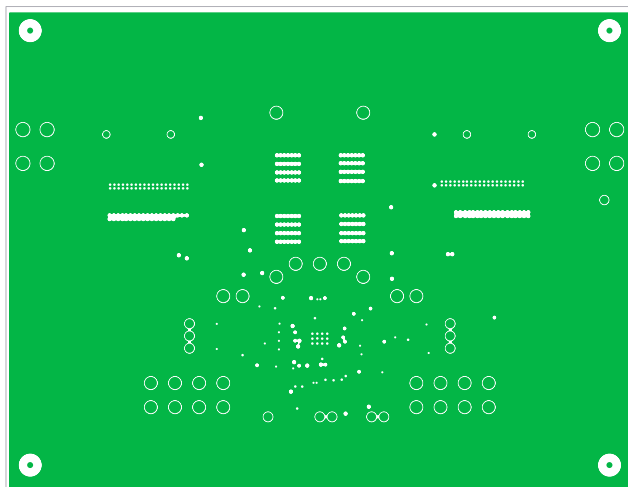


Figure 10. Second Layer (Solid Ground)

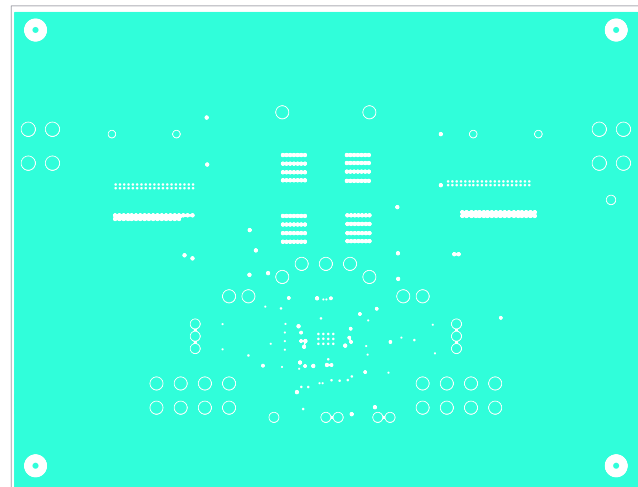


Figure 11. Third Layer

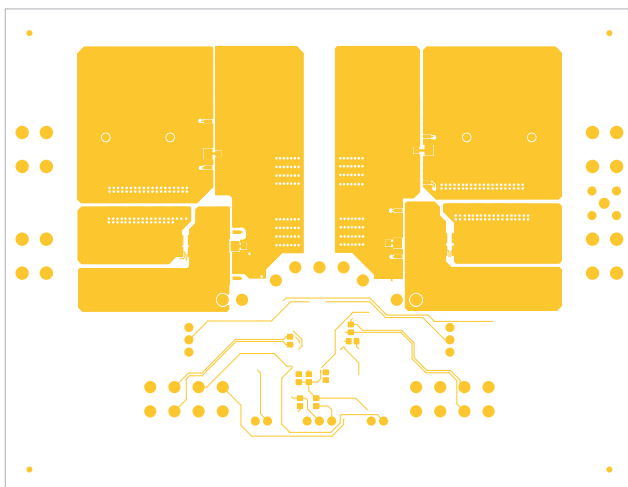


Figure 12. Bottom Layer

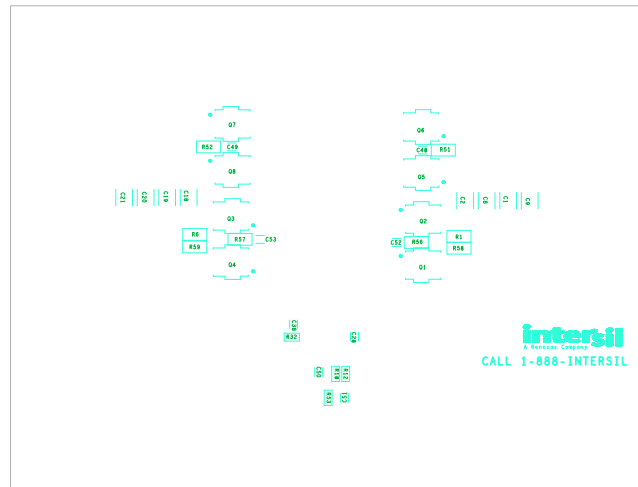


Figure 13. Silkscreen Bottom

## 4. Typical Performance Curves

$V_{IN} = 48V$ , unless otherwise noted.

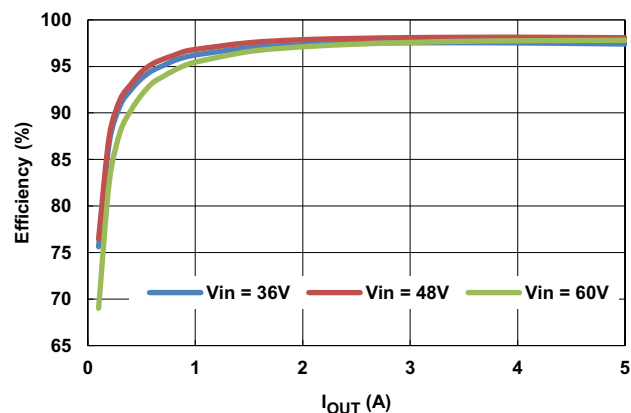


Figure 14. Efficiency, CCM

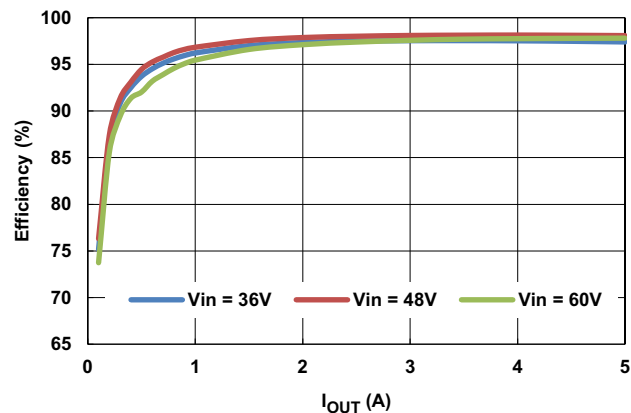


Figure 15. Efficiency, DEM

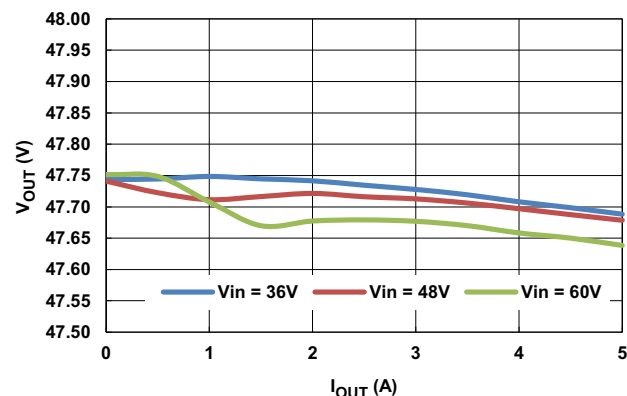


Figure 16. Load Regulation, CCM

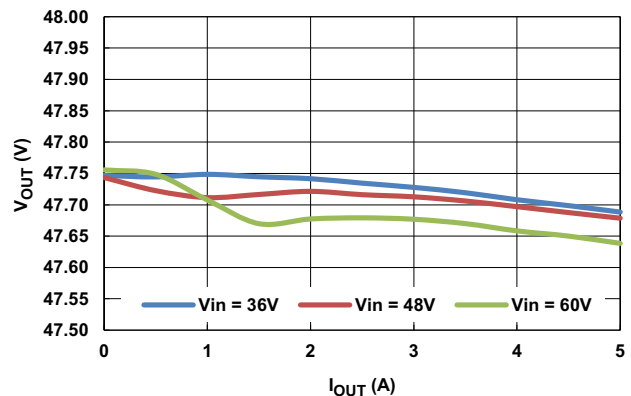


Figure 17. Load Regulation, DEM

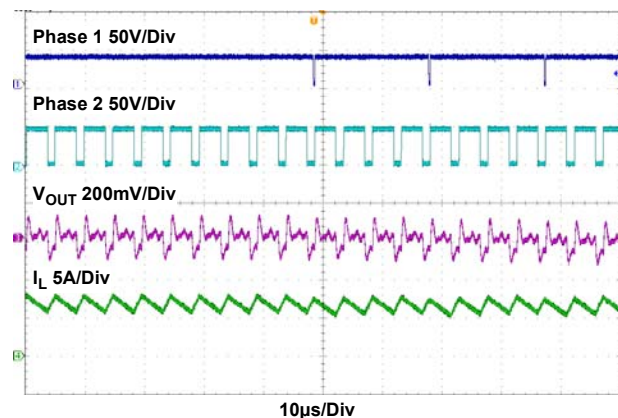


Figure 18. Phase 1, Phase 2,  $V_{OUT}$  and Inductor Current,  $V_{IN} = 36V$   $I_{OUT} = 5A$

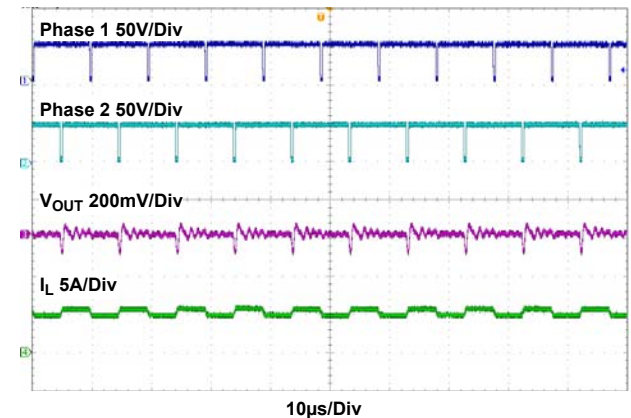


Figure 19. Phase 1, Phase 2,  $V_{OUT}$  and Inductor Current,  $V_{IN} = 48V$   $I_{OUT} = 5A$

$V_{IN} = 48V$ , unless otherwise noted. (Continued)

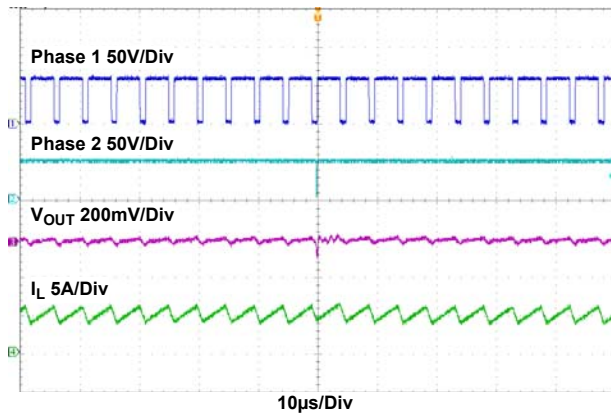


Figure 20. Phase 1, Phase 2,  $V_{OUT}$  and Inductor Current,  $V_{IN} = 60V$   $I_{OUT} = 5A$

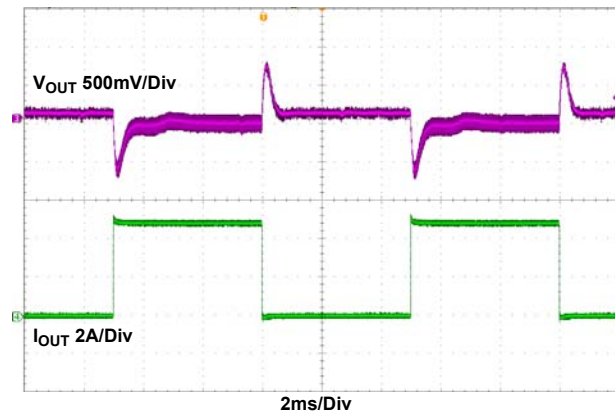


Figure 21. Load Transient,  $V_{IN} = 36V$   $I_{OUT} = 0A$  to 5A 2.5A/µs, CCM

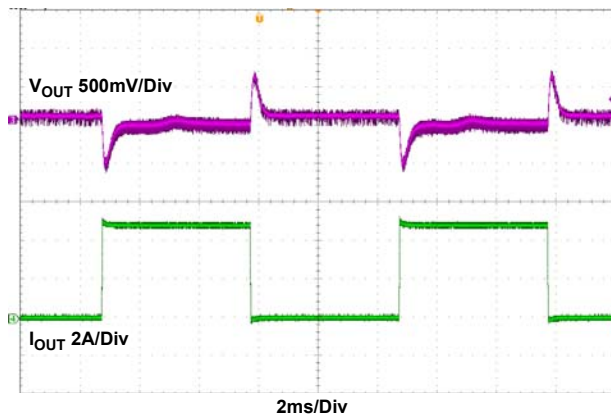


Figure 22. Load Transient,  $V_{IN} = 48V$   $I_{OUT} = 0A$  to 5A 2.5A/µs, CCM

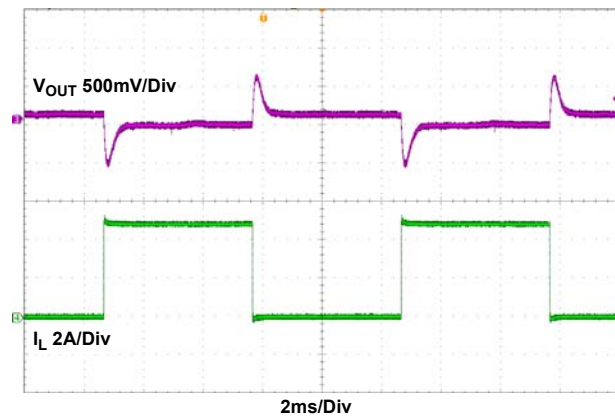


Figure 23. Load Transient,  $V_{IN} = 60V$   $I_{OUT} = 0A$  to 5A 2.5A/µs, CCM

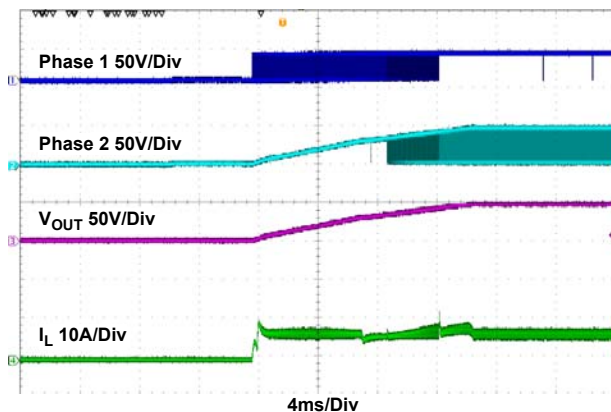


Figure 24. Start-Up Waveform,  $V_{IN} = 36V$   $I_{OUT} = 5A$ , CCM

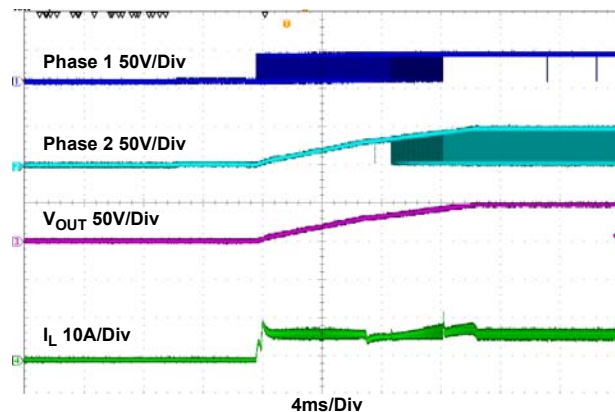


Figure 25. Start-Up Waveform,  $V_{IN} = 48V$   $I_{OUT} = 5A$ , CCM



$V_{IN} = 48V$ , unless otherwise noted. (Continued)

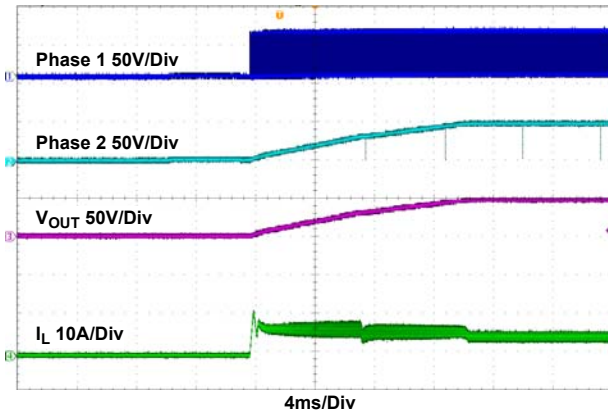


Figure 26. Start-Up Waveform,  $V_{IN} = 60V$ ,  $I_{OUT} = 5A$ , CCM

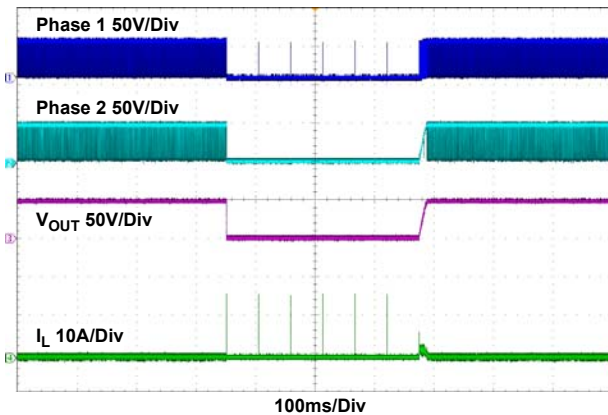


Figure 27. Short-Circuit Waveform

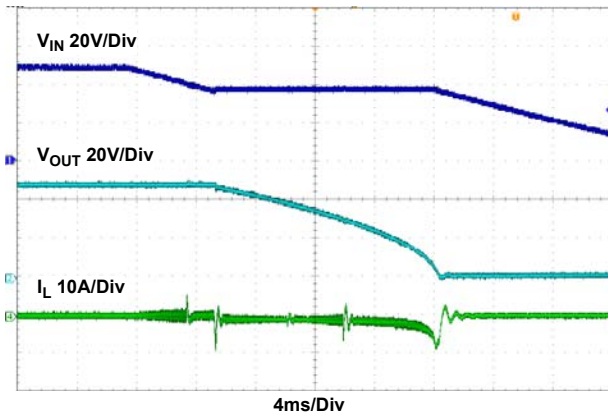


Figure 28. Bi-Direction Operation,  $V_{IN} = 48V$ ,  
 $V_{in\_limit} = 36V$ ,  $I_{IN} = 1A$

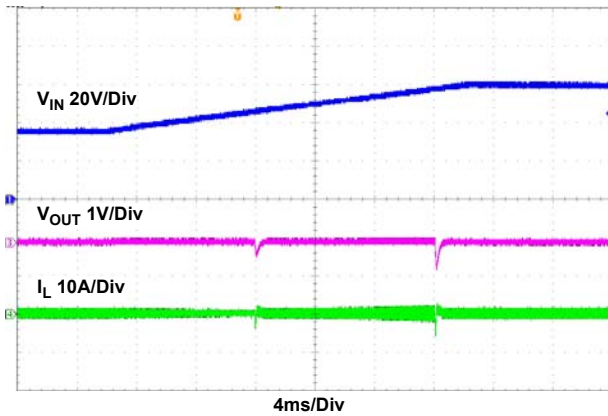


Figure 29. Line Transient,  $V_{IN} = 36V$  to  $60V$ ,  $1V/ms$ ,  
 $I_{OUT} = 0A$

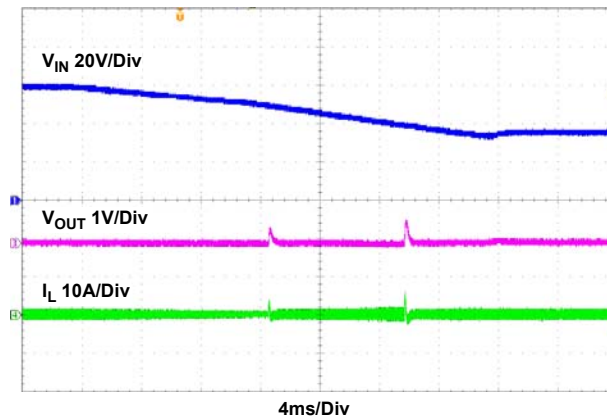


Figure 30. Line Transient,  $V_{IN} = 60V$  to  $36V$ ,  $1V/ms$ ,  $I_{OUT} = 0A$



## 5. Revision History

Rev.	Date	Description
0.00	Mar 23, 2018	Initial release

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