ISL73847SEHDEMO6Z

The ISL73847SEHDEMO6Z demonstration board demonstrates the performance of two ISL73847SEH dual-phase buck controller, four ISL73041SEH GaN half-bridge drivers, and twelve ISL70020SEH 40V GaN FETs in a 4-phase, 100A configuration. It is designed for the VERSAL VC1902 VCCINT core rail. The evaluation board is designed for a 5V PVIN power rail and an auxiliary VDD supply for the controller/driver VDD and on-board clock generator circuits.

Features

- On-board 2MHz clock generator for synchronization
- Power-Good (PG) LED indicator
- Integrated LDO (VCC)
- Load-line DROOP regulation
- Differential remote sensing

Specifications

- Buck power supply input (PVIN): 5V, ±5%
- Analog Supply input (VDD)
  - 5V to 13.2V when clocks come from an off-board external clock
  - 9V to 13.2V when using the on-board clock generator circuit
- Preset output voltage (no-load): 0.809V
- Preset Switching Frequency: 1MHz
- Maximum output current: 100A (25A/phase)
- Preset DROOP regulation: 2.6%
- Number of Board Layers: 8
- PCB Thickness: 2oz outer, 1oz inner

Figure 1. Block Diagram

Contents

1. Functional Description

The ISL73847SEH is a dual-phase PWM Controller that interfaces with the ISL73041SEH GaN half-bridge drivers to control the ISL70020SEH GaN FETs for point-of-load buck regulation in low-voltage, high-current applications such as FPGA core rails. Each PWM Controller is a dual-phase IC; therefore, the design is a 4-phase solution. Each ISL73847SEH controller operates its two phases at 180 degrees phase shift. Using an external clock with a 50% duty cycle and an inverted and non-inverted input to the SYNC-I pins of the ISL73847SEH provides the 90 degrees phase shift needed for 4-phase operation. Each phase delivers 25A RMS for a total 100A solution.

1.1 Operating Range

The ISL73847SEHDEMO6Z evaluation board requires two supply rails to operate properly. One rail for the two ISL73847SEH controller's analog supply input, the four ISL73041SEH GaN half-bridge drivers, and clock generator circuits (VDD). The other rail is for the on-board buck power supply input (PVIN).

The VDD rail is the TP3 jumper on the board. The VDD rail accepts an input range of 9V to 13.2V when using the on-board clock circuit because of the minimum VDD of the ISL78841A in that circuit. If using a custom external clock circuit to supply the clocks to the SYNC-I pins of both controllers, the VDD rail can be 5V to 13.2V or simply tied to the PVIN rail to be powered by a single 5V supply. The PVIN should be set to 5V. The buck regulator circuit is preset for a 0.809V output voltage and a switching frequency of 1MHz. This board can provide 100A of output current.

1.2 Two Controller 4-Phase Configuration

The ISL73847SEH is a stand-alone PWM Controller, but with proper configuration it can be connected together to provide multi-phase operation to deliver higher load current and reduce output ripple voltage. The configuration diagram of connecting two controllers together is shown in Figure 2.
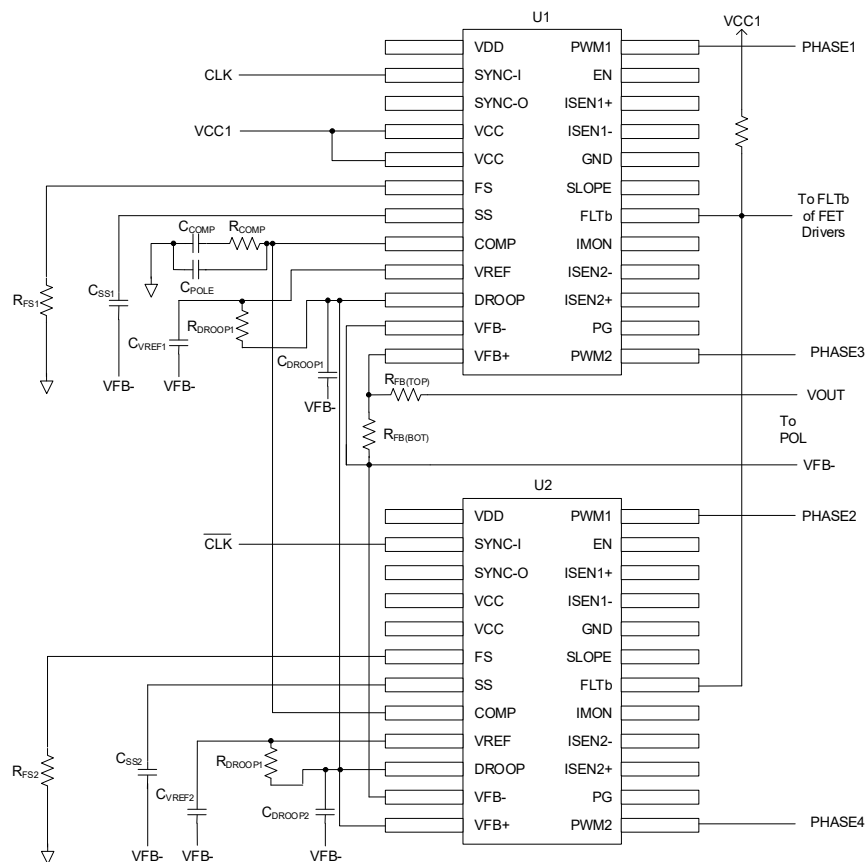

Figure 2. 4-Phase Configuration

To connect two ISL73847SEH controllers for a 4-phase configuration, use the following connections.

- For 90° phase shifted operation in a 4-phase Buck, an external Clock at twice the switching frequency with 50% duty cycle and its complimentary is necessary. See On-Board Clock Generator for Synchronization on generating the clock and complementary signal for this demonstration board.

- The error amplifier of the second controller (U2) is disabled by tying its DROOP (EA+) and VFB+ (EA-) pins together so it outputs zero current. This allows the first controller's (U1) COMP signal to drive its own PWM comparator in addition to the U2 controller when the COMP pins of the two controllers are connected together.

- RCOMP, CCOMP, and CPOLE are connected to the first controller's (U1) COMP pin. Depopulate the RCOMP, CCOMP, and CPOLE of the second controller (U2) and tie its COMP pin to the first controller's COMP pin.

- When using droop regulation, determine the amount of droop resistance needed on each controller by using the *ISL73847SEH Datasheet* or by using the *ISL73847 Design Calculator*.

- Connect the DROOP pins of the two controllers together. The VREF of each controller supplies the droop current needed into the DROOP pins and the voltage on DROOP includes the average of the VREF voltage on the two controllers.

- Connect the VFB- pins of the two controllers together so they have a common differential reference voltage.

- Connect the FLTb pins of the two controllers and four ISL73041SEH drivers together to a single pull-up resistor. The resistor can connect to VCC of either controller.

- Because the ISL73847SEH controller has 180° phase shift between its own two phases and a 4-phase system has 90° phase shift, the phases are interleaved between the two controllers. For example, U1 controller is Phase 1/Phase 3 and U2 controller is Phase 2/Phase 4.

1.3   Quick-Start Guide

1. To use the on-board clock generator short jumpers JP201 and JP202.

2. Apply a 5V voltage to the PVIN pads as shown in Figure 3. To monitor PVIN on the board use TP1.

3. Apply a 9V to 13.2V voltage to the VDD TP3 jumper as shown in Figure 3 to use the on-board clock generator. If using a custom external clock generator VDD can be 5V to 13.2V.

4. If required, a resistor or electronic load can be connected to the VOUT pads as shown in Figure 3. If using an electronic load, you can add 4W sense lines on the TP2 test jumper.
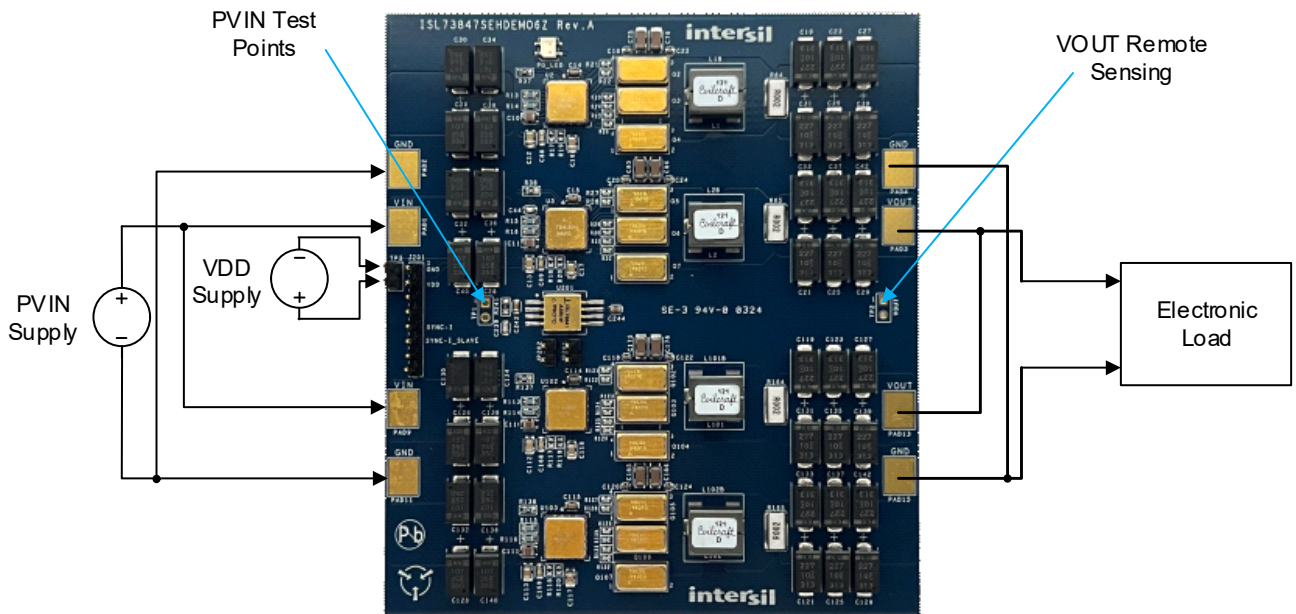

Figure 3. ISL73847SEHDEMO6ZBoard Setup

1.4 On-Board Clock Generator for Synchronization

The ISL73847SEHDEMO6Z is designed with 1MHz switching frequency, therefore a 2MHz clock is needed. For proper 4-phase 90° phase shifted operation, the ISL73847SEHDEMO6Z uses an external clock synchronization circuit to output complimentary clocks on the SYNC-I pins of the ISL73847SEH controller. The external clock solution is implemented with an ISL78841ASRH current mode PWM controller. Timing is made through the RTCT pin, which provides a square wave clock signal at the OUT pin. The inverted clock output is generated by putting the clock signal into the ISL70040 GaN FET driver, which offers an INB input that provides the inverted clock signal at OUTH/OUTL. While the 2MHz clock generated by the ISL78841ASRH works under a nominal case, it cannot be guaranteed over full operational range. Renesas recommends using a dedicated clock generator instead. The ISL70040 GaN FET driver can be used to generate the inverted clock signal.

To use the On-board clock synchronization circuit, ensure the JP201 and JP202 jumpers are shorted.

1.5 Soft-Start Adjustment

The ISL73847SEHDEMO6Z is configured for a 2ms soft-start time by two 22nF bypass capacitors (C_9 and C_{210}) connected to each controller's SS pin. Renesas recommends keeping the SS pins separate to prevent start-up issues that prevent the FLTb pins of the controller's from going logic HIGH and initiating a soft start. The SS time can be adjusted from 2ms to 200ms by changing these capacitors. If you need to select a different soft-start time, use Equation 1 to calculate the capacitance given the required soft-start time, where CSS is the soft-start capacitance in Farads, t_{SS} is the required soft-start time in seconds, and V_{REF} is the reference voltage, which is nominally 0.6V.

(EQ. 1) $$C_{SS} = \frac{t_{SS} \times 1 \times 10^{-5}}{V_{REF}}$$

For more information about SS, refer to the *ISL73847SEH Datasheet.*

1.6 Droop Regulation

The ISL73847SEHDEMO6Z is configured to minimize peak-to-peak transient response excursions by using a 392Ω resistor connected between VREF and DROOP pin of each controller (R_1 and R_{101}). For more information about the droop regulation, refer to the *ISL73847SEH Datasheet*.

1.7 Enabling/Disabling

The ISL73847SEHDEMO6Z is configured to automatically enable when VDD reaches the VEN Rising Threshold level (1.8V typical) on power-up through a 4.99kΩ resistor on each controller connected to VDD (R_{61} and R_{64}). For more information about enabling and disabling the controller, refer to the *ISL73847SEH Datasheet.*

1.8 Custom External Clock Circuit

J1 is provided to supply clocks from a customer's own external clock circuit. Before running external clocks from an external circuit, remove JP201 and JP202. This will prevent the on-board clocks from interfering with the external clocks.

2. Changing VIN, VOUT, IOUT, and transient parameters

The ISL73847SEHDEMO6Z displays a multi-phase converter design for the VERSAL VC1902 VCCINT core rail for V_{IN} = 5V, V_{OUT} = 0.8V, and I_{LOAD} = 100A. However, the design can be adjusted for different PVIN, VOUT, and I_{LOAD} parameters by changing various components throughout the board. Renesas highly recommends using the ISL73847 design tool to quickly determine component values for the design.

2.1   Increasing the Maximum Output Current

For higher output currents, the ISL73847SEHDEMO6Z can be modified by changing various components. For example, to increase the per-phase current from 25 to 35A for a total 140A solution, make the following changes to the ISL73847SEHDEMO6Z board:

Note: The dissipative elements in the power stage (GaN FETs and inductor) see a higher temperature rise due to the increased load current.

1. Operation of 140A on the ISL73847SEHDEMO6Z is recommended only for low duty cycle transient durations. If the customer requires 140A continuous operation, Renesas recommends using a separate PCB design to accommodate more GaN FETs in parallel and increase the number of PCB layers to manage the extra current.

2. Decrease the Rsense (R64, R65, R164, R165) resistor from 2mΩ down to 1.43mΩ so that a 50mV full-scale input to the ISENSE+/ISENSE- pins of the ISL73847SEH is developed with 35A RMS of load current. The Susumu resistors have a 3mΩ available, therefore, two in parallel can be used for 1.5mΩ.

3. Reduce the inductor value. The inductor Coilcraft SLR1070 120nH was used. There is no smaller inductance in this family. However, the Coilcraft SLC1049 offers a 75nH inductor with adequate saturation and RMS current ratings that can be substituted. The SLC1049 recommended PCB land pattern is slightly different but can be mounted onto the PCB board.

4. Use the additional DNP placeholders for tantalum capacitors on the 0.8V rail if needed. A minimum of 6x220µF per phase is needed for 140A operation.

5. Change the slope compensation, error amp compensation, and droop compensation per the loop design calculator. At minimum, change C_comp from 4.7nF to 3.9nF.

6. Adjust the timing circuit on ISL78841A U201 from ~1MHz to 875kHz to comply with the maximum inductor value recommended in the loop design calculator. Change C239 from 10pF to 22pF and R241 from 11kΩ to 30.9kΩ.

7. It is not necessary to change the single ISL70020SEH GaN FET on the high-side and two ISL70020SEH GaN FET on the low-side per phase. The high-side operates at ~16% duty cycle, and the increase in per-phase current does not necessitate changing the FETs for evaluating 140A transient load steps.
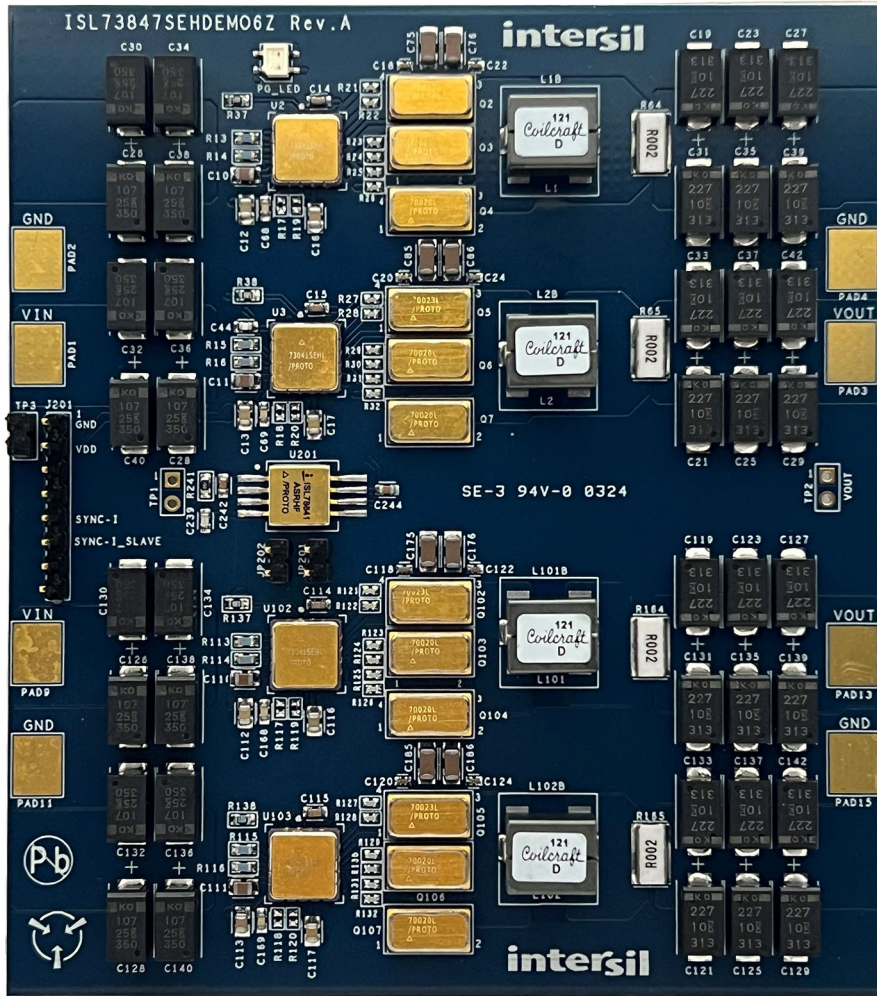
3. Board Design

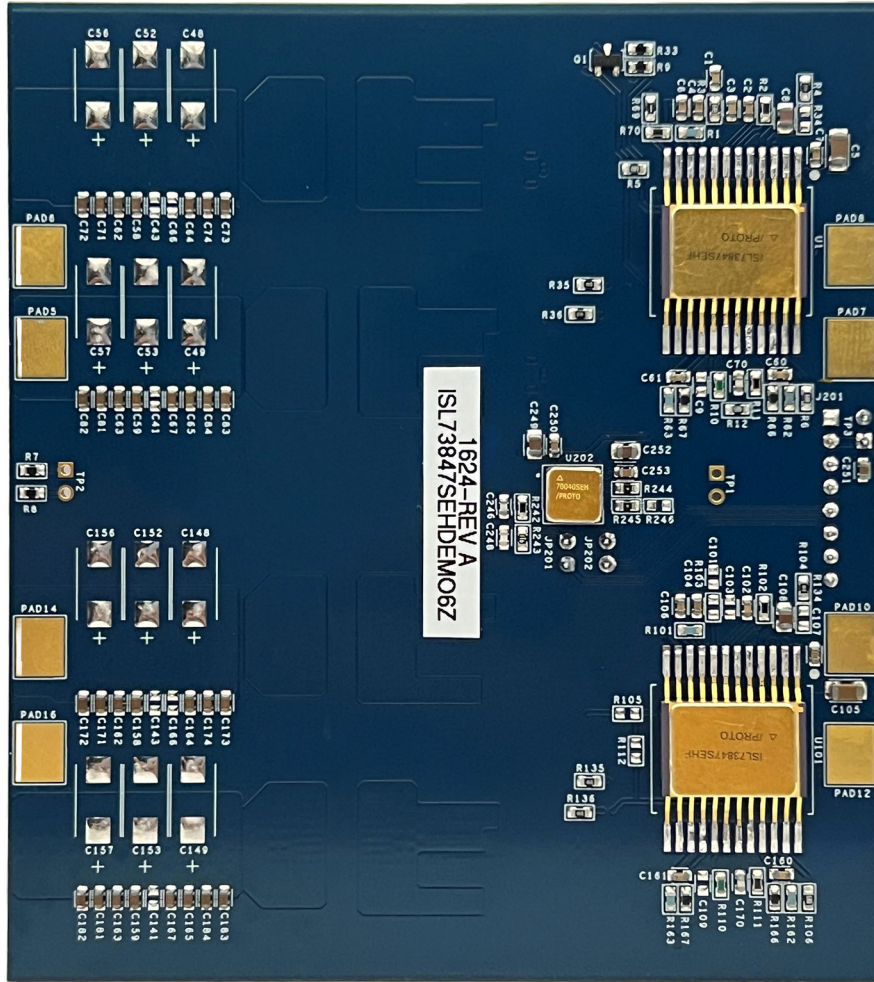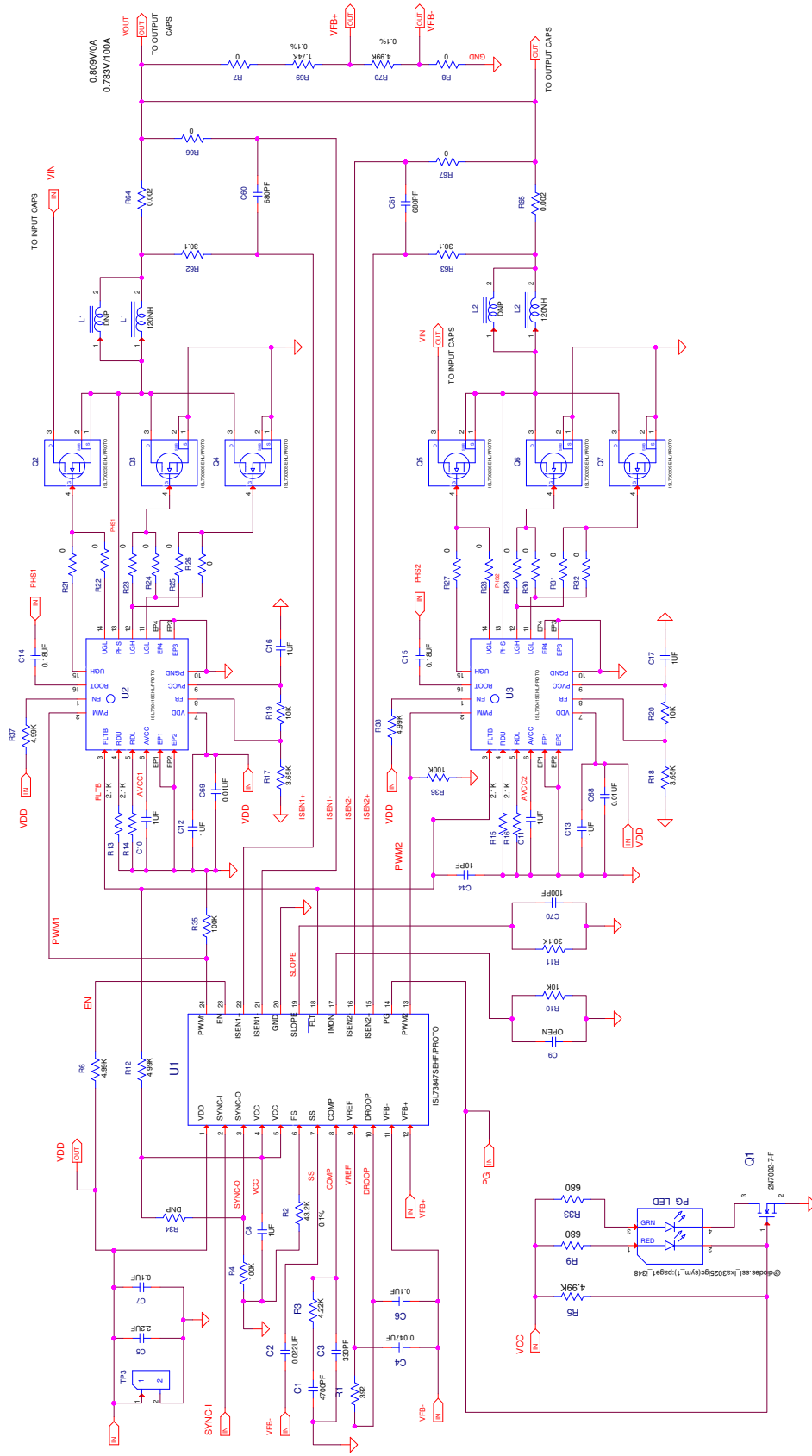**Figure 4. ISL73847SEHDEMO6Z Evaluation Board (Top)**

Figure 5. ISL73847SEHDEMO6Z Evaluation Board (Bottom)

3.1   Schematic Diagrams

Figure 6. ISL73847SEHDEMO6Z Schematic (Phases 1 & 2)
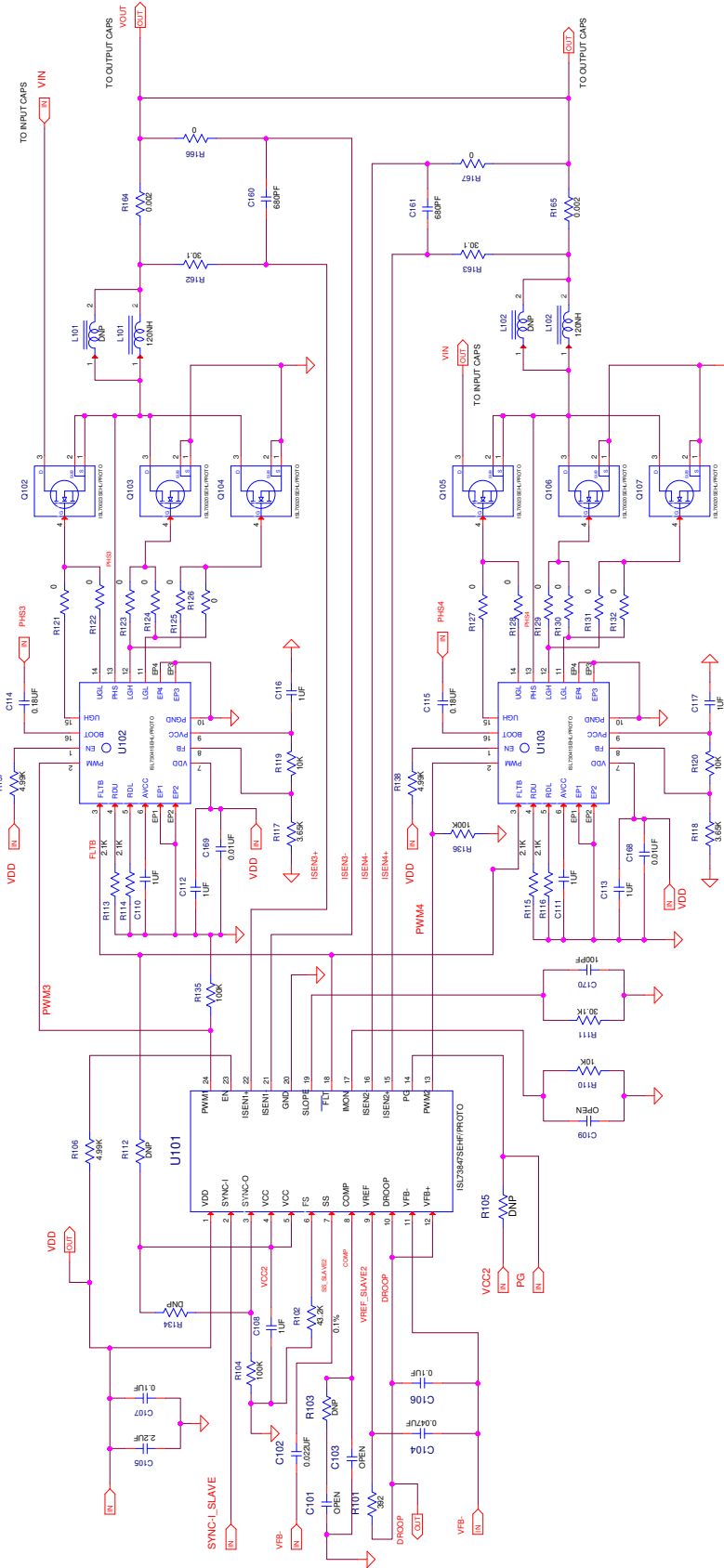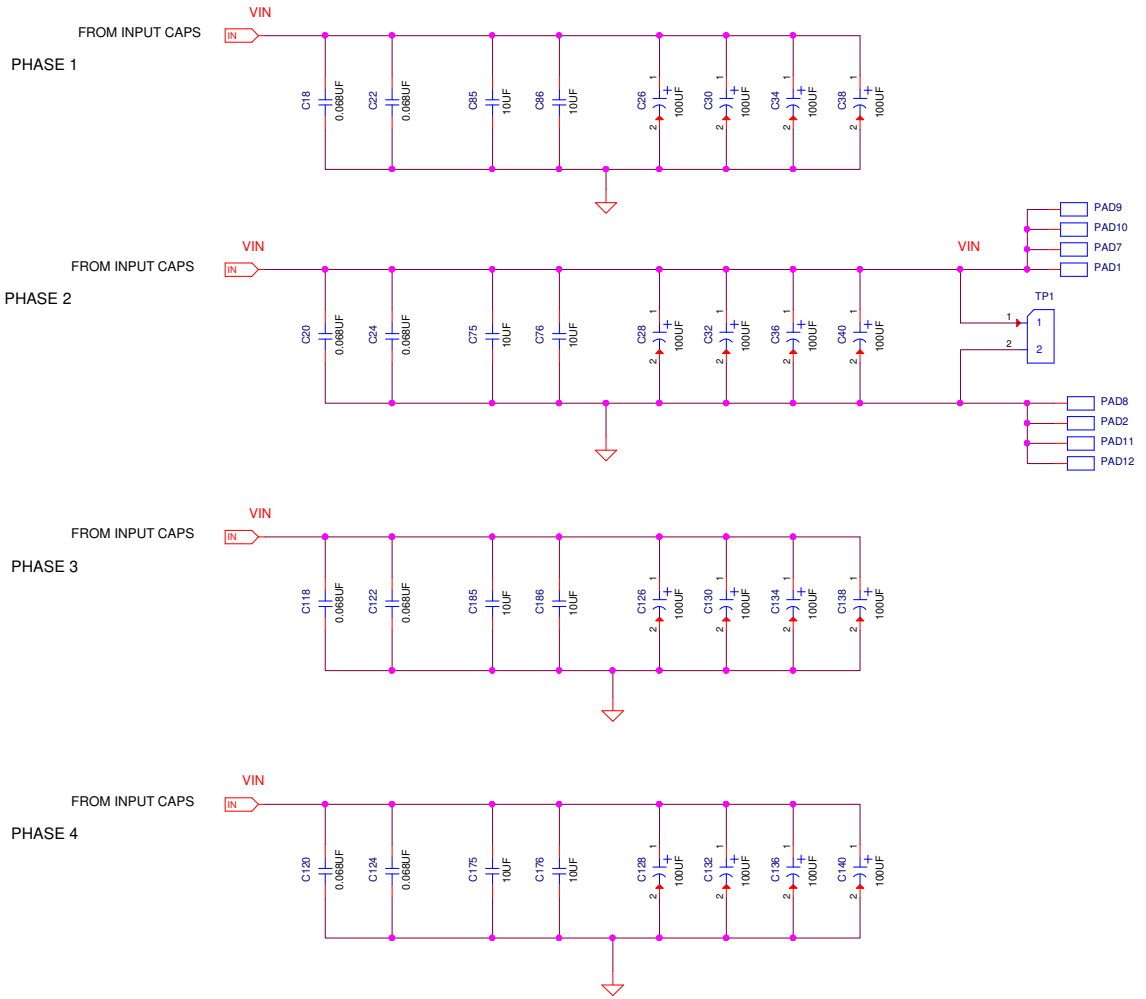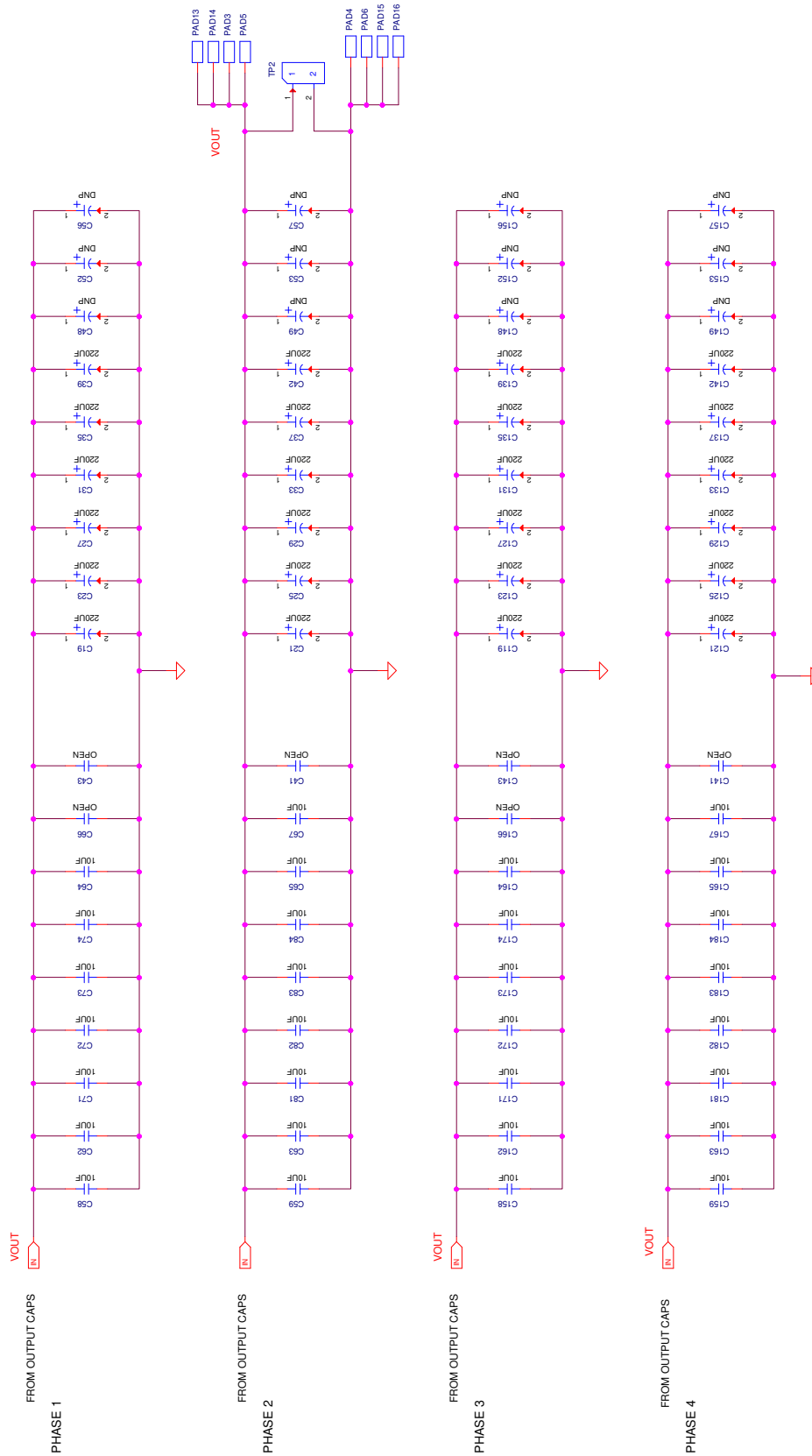
Figure 7. ISL73847SEHDEMO6Z Schematic (Phases 3 & 4)

PHASES 3 & 4

INPUT PHASES 1 TO 4

Figure 8. ISL73847SEHDEMO6Z Schematic (Input Phases 1 to 4)

Figure 9. ISL73847SEHDEMO6Z Schematic (Output Phases 1 to 4)
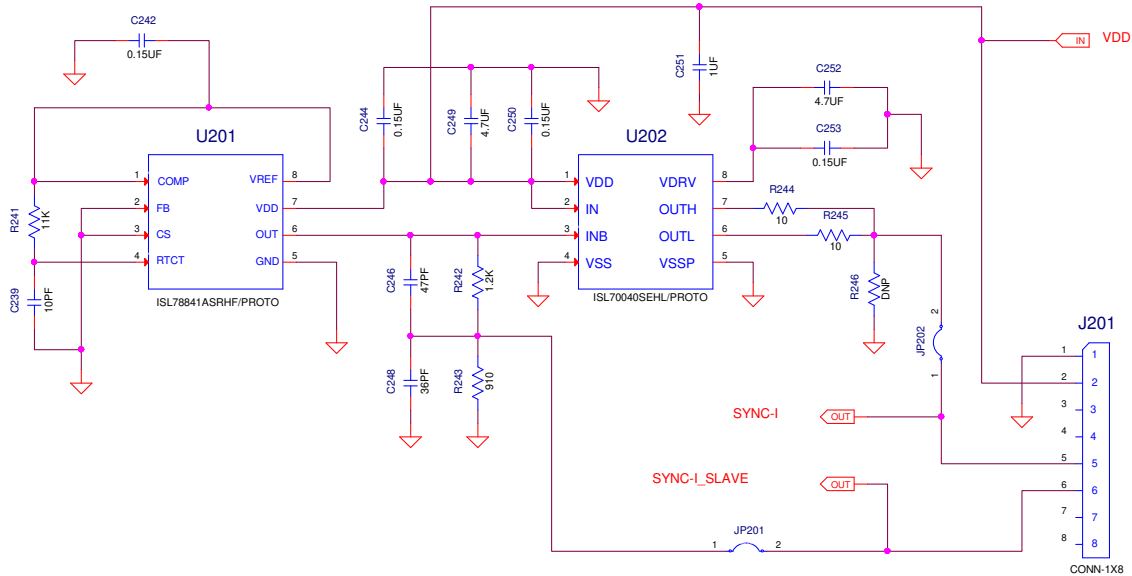
CLOCK SYNCHRONIZATION CIRCUIT

Figure 10. ISL73847SEHDEMO6Z Schematic (Clock Synchronization Circuit)

3.2 Bill of Materials

Qty	Ref Des	Description	Manufacturer	Part Number
1	C1	Multilayer Cap, 4700PF, 10%, 25V, 0603	Kemet	C0603C472K3RAC7867
8	C12, C13, C16, C17, C112, C113, C116, C117	Multilayer Cap, 1μF, 10%, 25V, 0805	AVX	08053C105KAT2A
4	C14, C15, C114, C115	Ceramic Chip Cap (Automotive), 0.18μF, 10%, 50V, 0603	Murata	GCJ188R91H184KA01D
8	C18, C20, C22, C24, C118, C120, C122, C124	Multilayer Cap (Automotive), 0.068μF, 10%, 50V, 0402	Murata	GCM155R71H683KE02J
24	C19, C21, C23, C25, C27, C29, C31, C33, C35, C37, C39, C42, C119, C121, C123, C125, C127, C129, C131, C133, C135, C137, C139, C142	Ripple 6500ma ESR 6m ohms High Capacitance Low ESR Tantalum SMD Cap, 220μF, 20%, 10V	Kemet	T530D227M010ATE006
2	C2, C102	Multilayer Capacitor, 0.022μF, 10%, 25V, 0603	AVX	KGM15AR71E223KT
1	C239	Multilayer Capacitor (AEC-Q200), 10pF, 10%, 100V, 0603	Vishay	VJ0603A100KXBAC31
4	C242, C244, C250, C253	Multilayer Cap, 0.15μF, 10%, 50V, 0603	TDK	CGA3E3X7R1H154K080AB
1	C246	Ceramic Chip Cap, 47pF, 10%, 100V, 0603	Kemet	C0603C470K1GACAUTO

Qty	Ref Des	Description	Manufacturer	Part Number
1	C248	Multilayer Cap (Automotive), 36pF, 10%, 50V, 0603	Kemet	C0603C360K5HACAUTO
2	C249, C252	CERAMIC CHIP CAP (Automotive AEC-Q200), 4.7µF, 10%, 25V, 0805	Kemet	C0805C475K3RACAUTO
1	C251	Ceramic Chip Cap, 1µF, 10%, 25V, 0603	Murata	GRM188R71E105KA12
16	C26, C28, C30, C32, C34, C36, C38, C40, C126, C128, C130, C132, C134, C136, C138, C140	ESR 30mΩ Conductive Polymer Capacitor, 100µF, 20%, 25V, SMD	Kemet	T521X107M025ATE030
1	C3	Multilayer Cap, 330pF, 10%, 25V, 0603	AVX	KGM15AR71E33KT
2	C4, C104	Multilayer Cap, 0.047µF, 10%, 50V, 0603	Walsin	0603B473K500CT
1	C44	Multilayer Cap, 10pF, 10%, 25V, 0603	Kemet	C0603C100K3GAC7867
12	C48, C49, C52, C53, C56, C57, C148, C149, C152, C153, C156, C157	Ripple 5000mA ESR 10mΩ High Capacitance Low ESR Tantalum SMD Cap, DNP, 20%, SMD	Kemet	T530D227M010ATE010-DNP
2	C5, C105	CERAMIC CAP (Automotive AEC-Q200), 2.2µF, 10%, 25V, 1206, X7R	Murata	GCJ31MR71E225KA21L
30	C58, C59, C62-C65, C67, C71-C74, C81-C84, C158, C159, C162-C165, C167, C171-C174, C181-C184	Multilayer Cap, 10µF10%, 10V, 0603, X7R	Cal-Chip	GRC10X7R106K10NT
4	C6, C7, C106, C107	Ceramic Chip Capacitor, 0.1µF, 10%, 25V, 0603, X7R	Kemet	C0603X104K3RACTU
4	C60, C61, C160, C161	Multilayer Cap, 680pF, 10%, 50V, 0603, X7R	AVX	KGM15AR71E681KT
4	C68, C69, C168, C169	Multilayer Cap, 0.01µF, 10%, 25V, 0603, X7R	Kemet	C0603C103K3RAC7411
2	C70, C170	Multilayer Capacitor, 100pF, 10%, 50V, 0603, X7R	Yageo	CC0603KPX7R9BB101
8	C75, C76, C85, C86, C175, C176, C185, C186	Multilayer Cap, 10µF, 10%, 25V, 1206, X7R	TDK	C3216X7R1E106K160AB
6	C8, C10, C11, C108, C110, C111	Multilayer Ceramic Chip Capacitor, 1µF, 10%, 25V, 0805, X7R	TDK	C2012X7R1E105K
10	C9, C41, C43, C66, C101, C103, C109, C141, C143, C166	Multilayer Cap, Open, 5%, Open, 0603, X7R	Various	Generic
1	J201	Male In-line 8 pins X 0.1 inch Connector Strip, IN-LINE	Various	Generic
2	JP201, JP202	100 mil Spacing Two Pin Jumper, THOLE	Various	Generic

Qty	Ref Des	Description	Manufacturer	Part Number
4	L1, L2, L101, L102	Shielded Power Inductor (RoHS Compliant), 120nH, 10%, 86A, SMD	CoilCraft	SLR1070-121KE
4	L1B, L2B, L101B, L102B	(Do Not Populate) 4mm×4mm Shielded Power Inductor, DNP, 20%, SMD	CoilCraft	XAL1010-DNP
16	PAD1-PAD16	200X250 Surface Mount Pad, SMD	Various	Generic
1	PG_LED	3x2.5mm Surface Mount Red/Green LED, SMD	Lumex	SSL-LXA3025IGC
1	Q1	N-Channel EMF Effect Transistor (Pb-Free), SOT23	Fairchild	2N7002-7-F
4	Q2, Q5, Q102, Q105	100V 60A Enhancement Mode GaN Power Transistor, 4CLCC	Renesas	ISL70023SEHL/PROTO
8	Q3, Q4, Q6, Q7, Q103, Q104, Q106, Q107	40V 60A Enhancement Mode GaN Power Transistor, 4CLCC	Renesas	ISL70020SEHL/PROTO
2	R1, R101	Thick Film Chip Resistor, 392Ω, 1%, 1/10W, 0603	Panasonic	ERJ3EKF3920V
2	R10, R110	Thin Film Chip Resistor, 10k, 0.1%, 1/10W, 0603	Vishay	TNPW060310K0BEEA
2	R11, R111	Metal Film Chip Resistor, 30.1k, 0.1%, 1/10W, 0603	Susumu	RG1608P-3012-B-T5
8	R13-R16, R113-R116	Thick Film Chip Resistor (Automotive AEC-Q200), 2.1k, 1%, 1/10W, 0603	KOA	RK73H1JTTD2101F
4	R17, R18, R117, R118	Thick Film Chip Resistor (Automotive AEC-Q200), 3.65k, 1%, 1/16W, 0402	Stackpole	RMCF0402FT3K65
4	R19, R20, R119, R120	Thick Film Chip Resistor (Automotive AEC-Q200), 10k, 1%, 1/16W, 0402	Yageo	AC0402FR-0710KL
2	R2, R102	Thin Film Chip Resistor, 43.2k, 0.1%, 1/10W, 0603	Panasonic	ERA-3AEB4322V
24	R21-R32, R121-R132	Jumper Thin Film Chip Resistor, 0Ω, Jumper, 1/16W, 0402	Vishay	MCS04020Z0000ZE000
1	R241	Thick Film Chip Resistor (AEC-Q200 Automotive), 11k, 1%, 1/10W, 0603	Stackpole	RMCF0603FT11K0
1	R242	Thick Film Chip Resistor, 1.2kΩ, 1%, 1/10W, 0603	Panasonic	ERJ-3EKF1201V
1	R243	Thick Film Chip Resistor (Automotive AEC-Q200), 910Ω, 1%, 1/10W, 0603	Yageo	AC0603FR-07910RL
2	R244, R245	Thick Film Chip Resistor, 10Ω, 1%, 1/10W, 0603	Rohm	KTR03EZPF10R0
1	R3	Thick Film Chip Resistor (Automotive AEC-Q200), 4.22k, 1%, 1/10W, 0603	Yageo	AC0603FR-074K22L

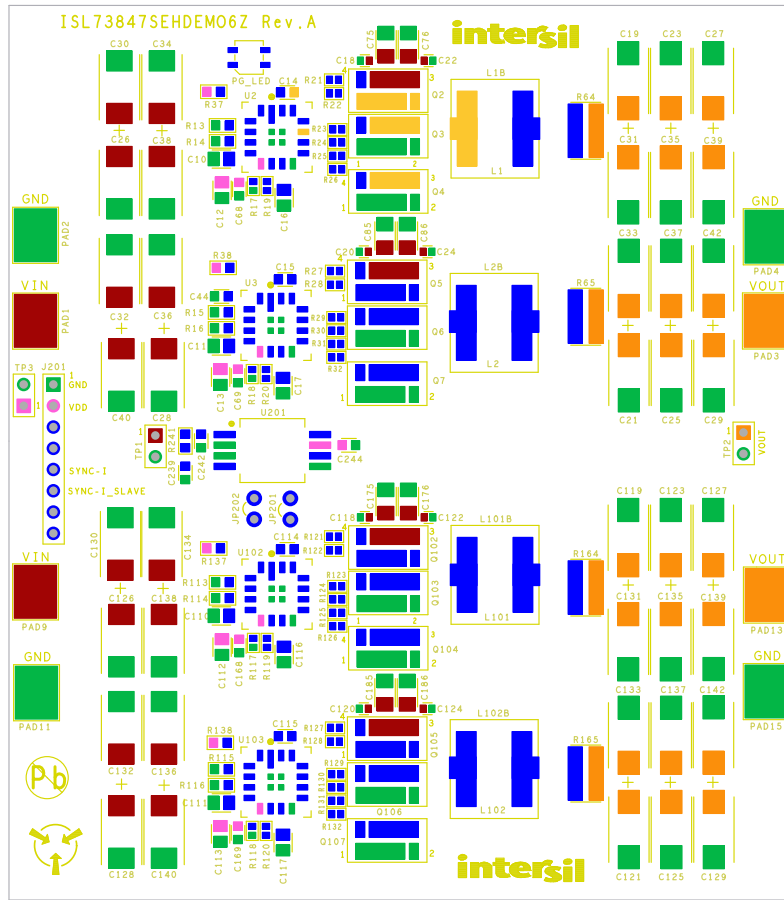| Qty	Ref Des	Description	Manufacturer	Part Number
6	R34, R103, R105, R112, R134, R246	Metal Film Chip Resistor (Do Not Populate), DNP, 1%, 0603	Various	Generic
6	R4, R35, R36, R104, R135, R136	Film Chip Resistor, 100k, 1%, 1/10W, 0603	Stackpole	RMCF0603FT100K
8	R5, R6, R12, R37, R38, R106, R137, R138	Thick Film Chip Resistor, 4.99k, 1%, 1/10W, 0603	Yageo	RC0603FR-074K99L
4	R62, R63, R162, R163	Thick Film Chip Resistor (Automotive AEC-Q200), 30.1, 1%, 1/8W, 0603	KOA	RK73H1JTTD30R1V
4	R64, R65, R164, R165	Wide Metal Foil Current Sense Chip Resistor, 0.002, 1%, 3W, 2512	SSM	KRL6432E-M-R002-G-F-T1
1	R69	Thin Film Chip Resistor (Automotive QEC-Q200), 1.74k, 0.1%, 1/10W, 0603	Panasonic	ERA-3AEB1741V
6	R7, R8, R66, R67, R166, R167	Thick Film Chip Resistor, 0Ω, 0%, 1/4W, 0603	Vishay	RCS06030000Z0EA
1	R70	Thin Film Chip Resistor, 4.99k, 0.1%, 1/10W, 0603	KOA Speer	RN73R1JTTD4991B25
2	R9, R33	Thick Film Chip Resistor, 680Ω, 1%, 1/10W, 0603	VISHAY	CRCW0603680RFKEA
2	TP1, TP2	(Do Not Populate) Test Point 2 Pin Header 2.54mm (0.100) Pitch	FCI	68000-236 DNP TESTPOINT
1	TP3	Test Point 2 Pin Header 2.54mm (0.100) Pitch	FCI	68000-236 TESTPOINT
2	U1, U101	Rad Hard Single/Dual Phase Current Mode PWM Controller, CDFP24	Renesas	ISL73847SEHF/PROTO
4	U2, U3, U102, U103	Radiation Harden 12V Half Bridge GaN FET Driver, CLCC16-4EP	Renesas	ISL73041SEHL/PROTO
1	U201	Current Mode PWM Controller UVLO 7.0V 50% DC, 8FP	Renesas	ISL78841ASRHF/PROTO
1	U202	Radiation Tolerant Single Low Side GaN FET Driver, 8CLCC	Renesas	ISL70040SEHL/PROTO

3.3   Board Layout
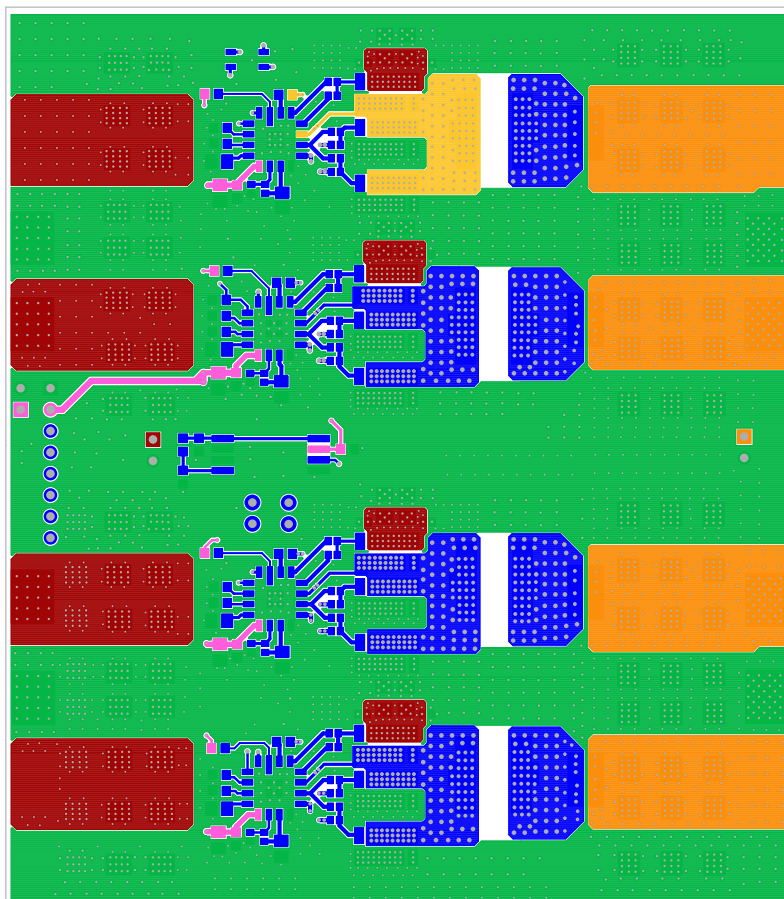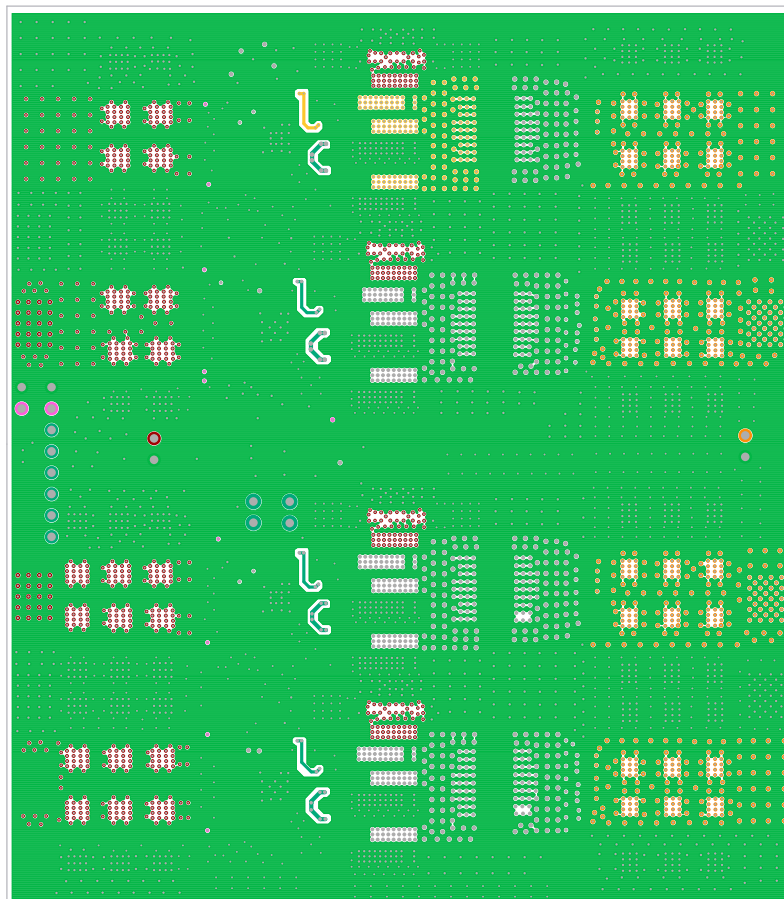

Figure 11. Silkscreen Top Layer

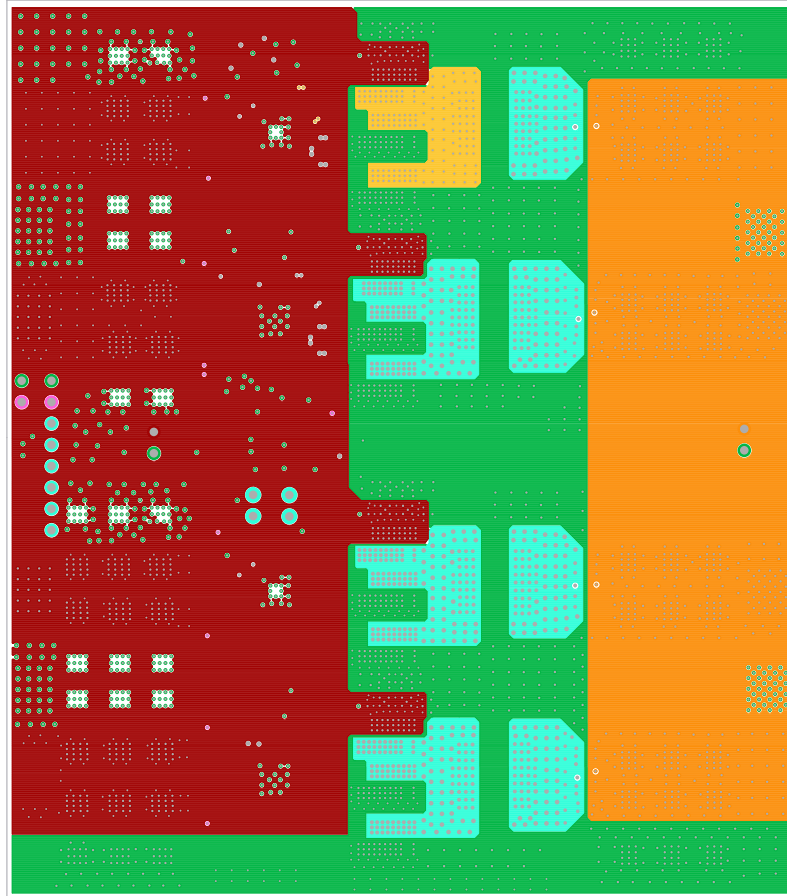**Figure 12. Top Layer**
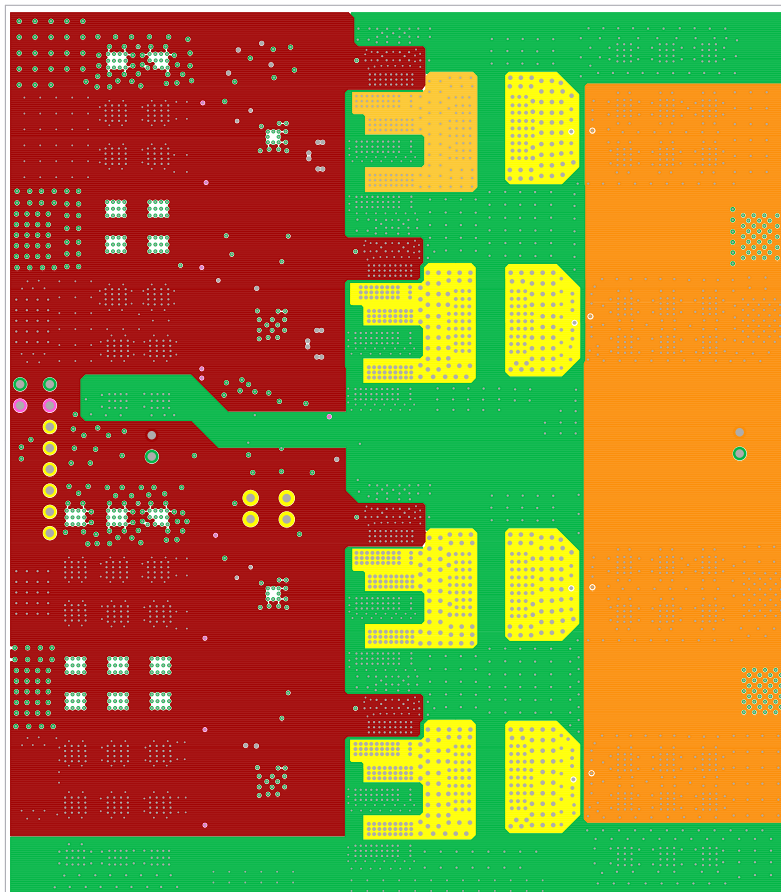
Figure 13. Layer 2
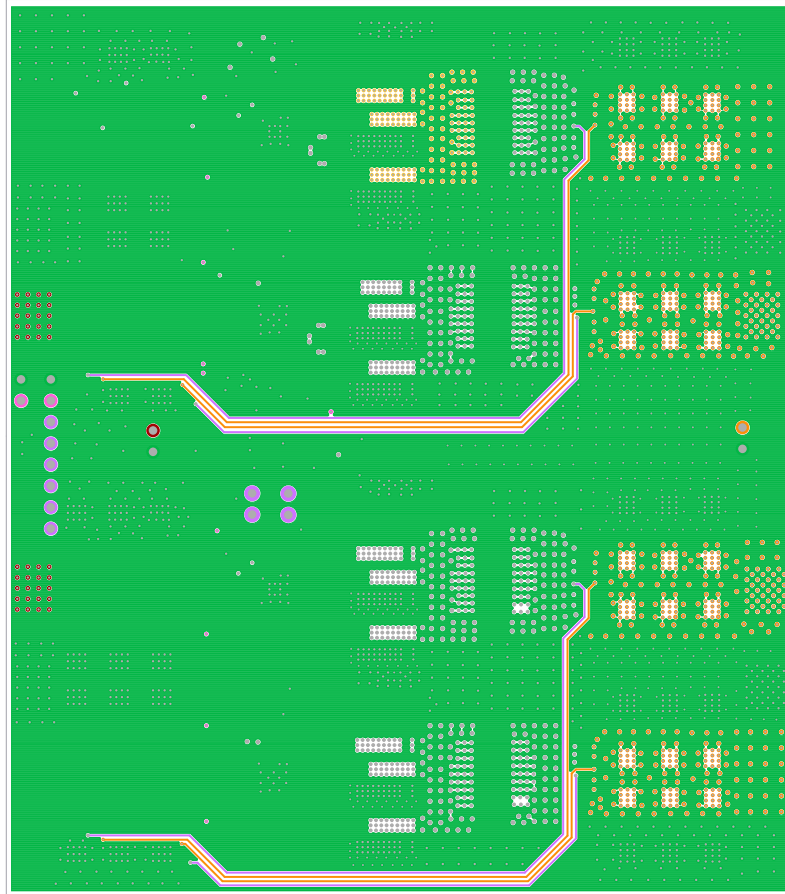
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Figure 14. Layer 3
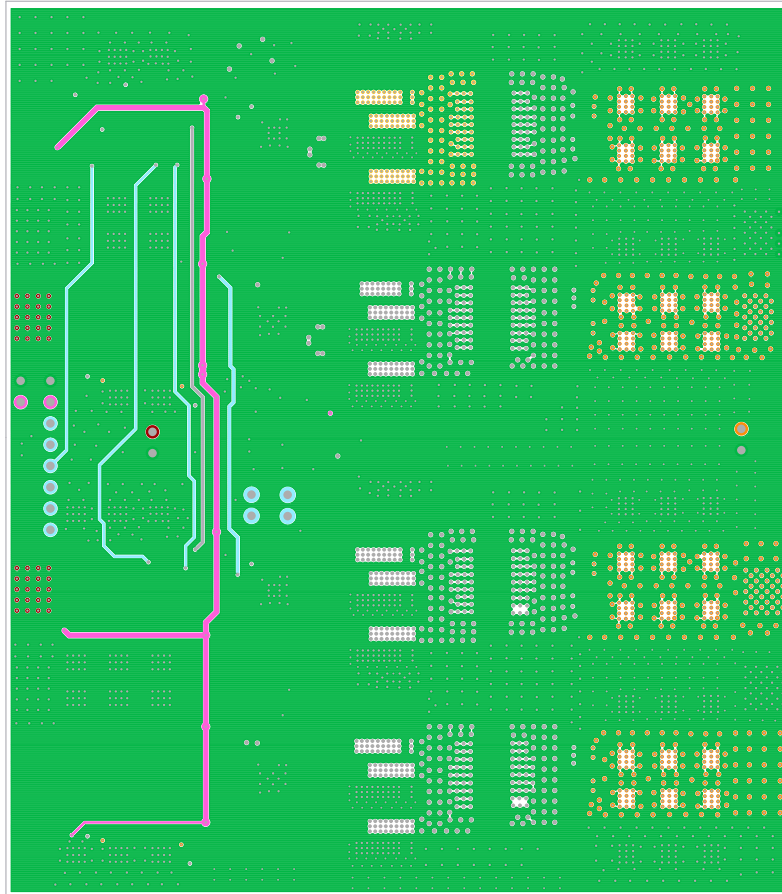
Figure 15. Layer 4

Figure 16. Layer 5

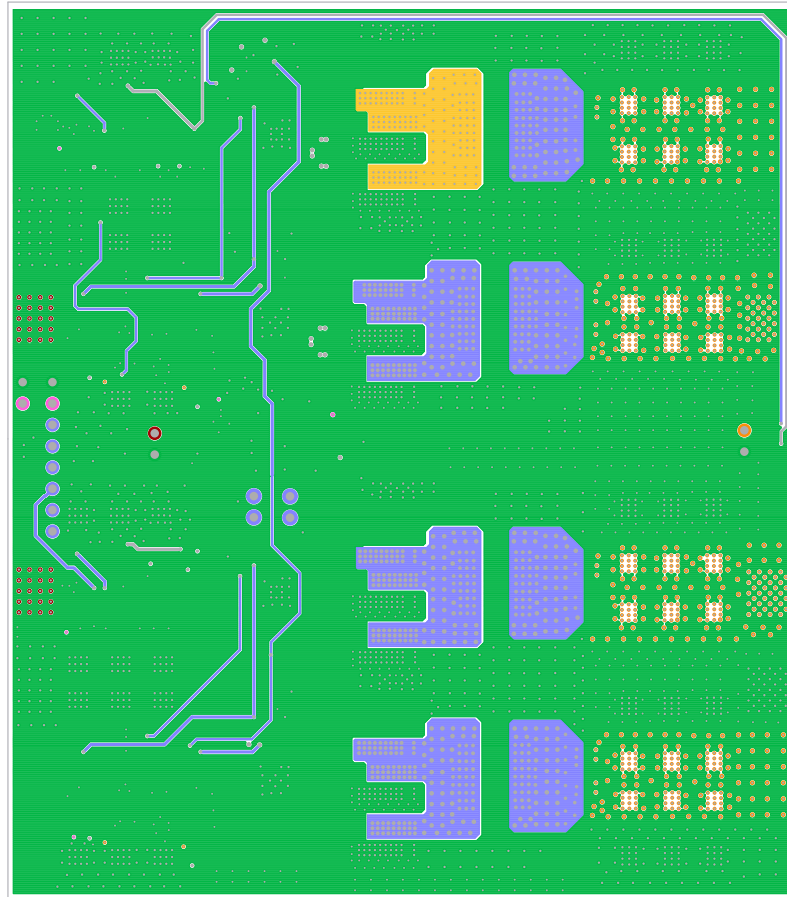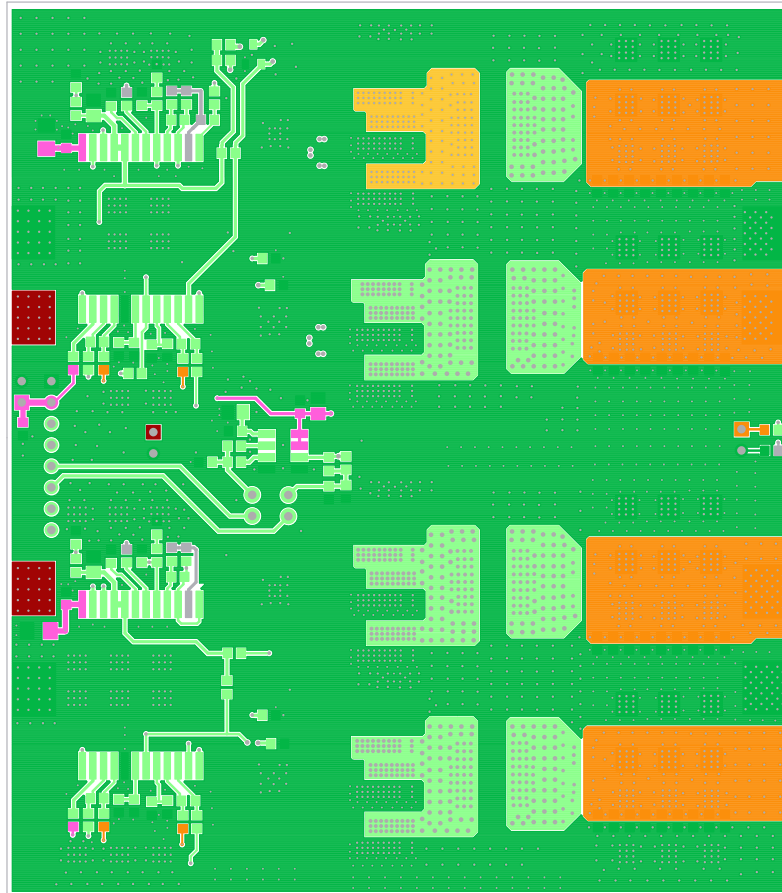**Figure 17. Layer 6**

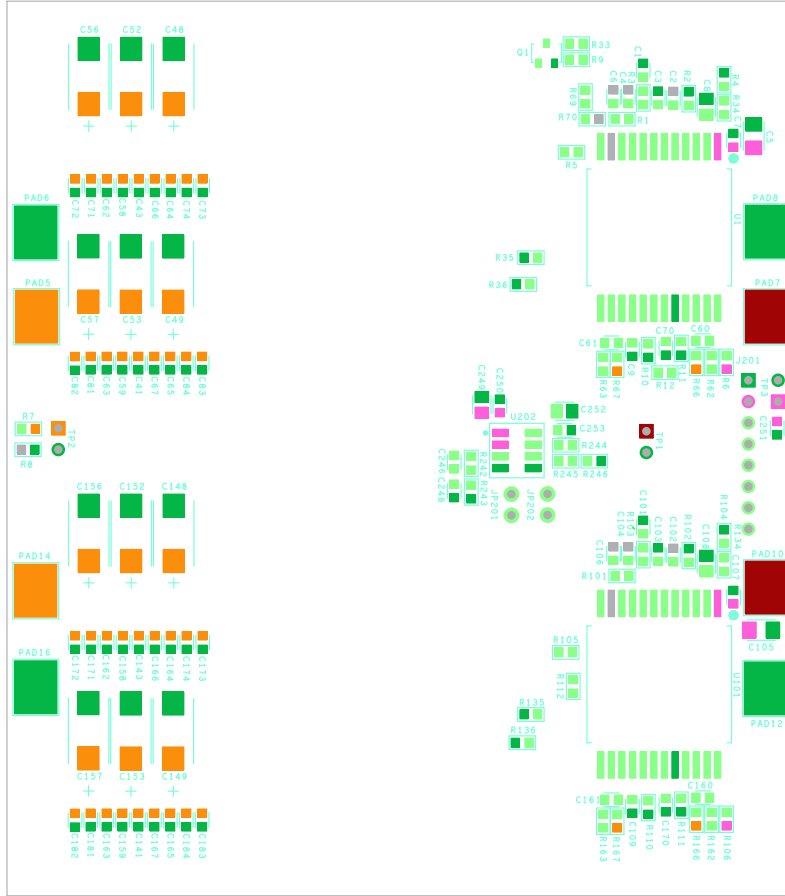**Figure 18. Layer 7**

Figure 19. Bottom Layer

Figure 20. Silkscreen Bottom Layer

4.   Typical Performance Graphs

Unless otherwise noted, V_{DD} = 12V, P_{VIN}= 5V, $V_{OUT(no-load)}$ = 0.807V; L_{OUT} = 120nH per phase, C_{OUT} = 1.54mF per phase, C_{DROOP} = 47nF, C_{VREF} = 100nF, R_{DROOP} = 392Ω, R_{FS} = 43.2kΩ, C_{SS} = 22nF, C_{COMP} = 4.7nF, R_{COMP} = 4.22kΩ, C_{POLE} = 330pF, C_{VCC} = 1µF, R_{SLP} = 30.1kΩ, C_{SLP} = 100pF, T_A = +25°C
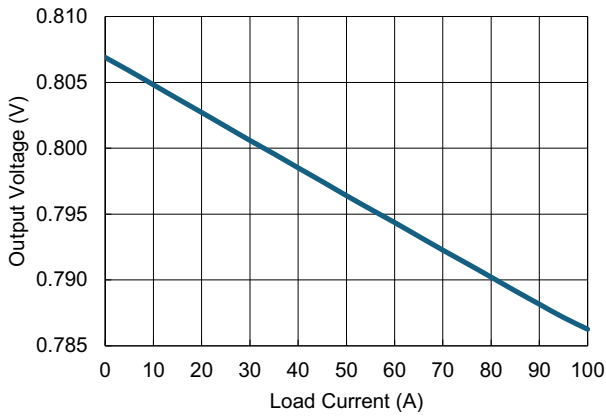

Figure 21. Load Regulation with DROOP (f_{SW} = 1MHz)
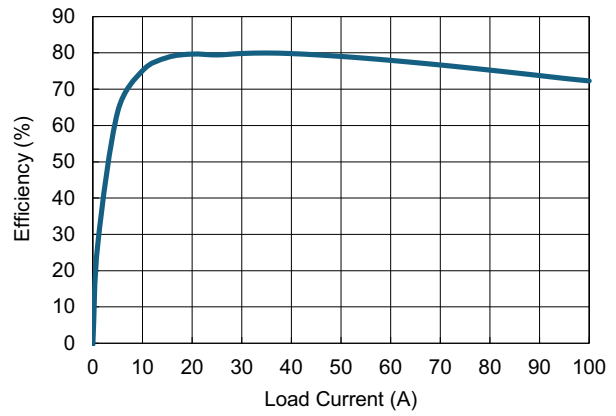
Figure 22. Conversion Efficiency vs Load Current (f_{SW} = 1MHz)

5.   Ordering Information

Part Number	Description
ISL73847SEHDEMO6Z	ISL73847SEH demonstration board

6.   Revision History

Revision	Date	Description
1.00	Jun 6, 2024	Initial release

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