[David Strasser](#)

TI Designs

Class 4, Wide Input Range, 15-W Power over Ethernet (PoE) Converter Reference Design

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize and system. TI Designs help ***you*** accelerate your time to market

Design Resources

PMP6659	Tool Folder Containing Design Files
TPS23756	Product Folder
TL431	Product Folder

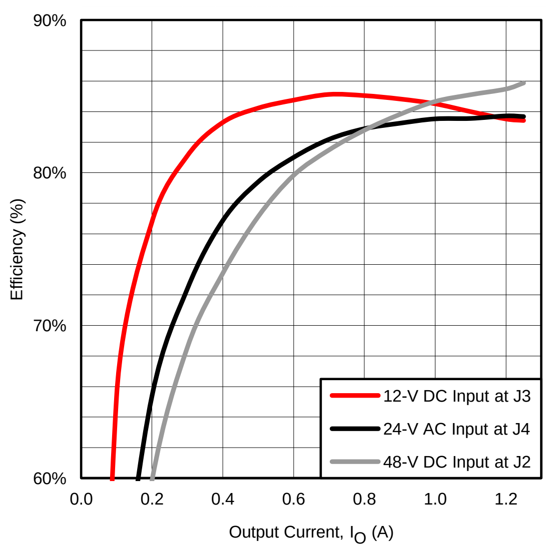
Design Features

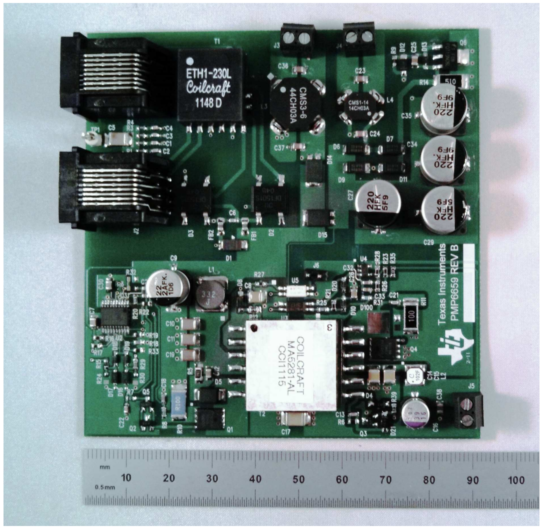
- Input voltage range: 10.8 to 57 VDC, 18 to 32VAC, or Power over Ethernet (PoE)
- 12-V at 1.25-A output
- Isolated flyback with synchronous rectifier for high efficiency
- Uses the TPS23756 high-power PoE interface and DC-DC controller
- Supports hardware Class 4 from the IEEE 802.3at standard

Featured Applications

- PoE Security Cameras
- Wireless LAN—Wireless Access Points

ASK Our Analog Experts
WebBench Calculator Tools





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Description

The Class 4—Wide Input Range, 15-W Power over Ethernet (PoE) Converter reference design is intended for users to develop end-products for various internet protocol (IP) industrial applications. The reference design provides a complete guide for the hardware design of a flyback converter with synchronous rectification used for Class 4 PoE applications where a wide input range is required. The design files include schematics, Bill of Materials (BOMs), layer plots, Altium files, Gerber Files, and Fabrication Files.

This reference design has an optimized wide input voltage range. The output power is 12-V at 1.25-A (15-W) from either an adapter input (10.8 to 57 VDC or 18 to 32 VAC) or PoE. The synchronous rectifier provides excellent efficiency with the wide input voltage range. The wide input voltage range and high efficiency makes this design compatible with legacy applications where 12-VDC, 24-VDC, or 24-VAC auxiliary power is used. This design gives customers a ready-to-use high efficiency, wide input power design for building automation applications. The input and output combination of the design is typically required for PoE security cameras.

The core of this reference design is the PoE interface and DC-DC controller from TI, the TPS23756 device, that interfaces with the AC or DC-adapter input or the PoE input. The TPS23756 device is compliant with the IEEE 802.3at Power over Ethernet standard.

1.1 TPS23756

The TPS23756 device has a combined power-over-ethernet (PoE) powered-device (PD) interface and current-mode DC-DC controller optimized specifically for isolated converters. The PoE interface supports the IEEE 802.3at standard.

The TPS23756 device supports a number of input voltage ORing options including highest voltage, external adapter preference, and PoE preference. These features allow the designer to determine which power source will carry the load under all conditions.

The PoE interface features the new extended hardware classification necessary for compatibility with high-power midspan power sourcing equipment (PSE) per IEEE 802.3at. The detection signature pin can also be used to force power from the PoE source off. Classification can be programmed to any of the defined types with a single resistor.

The DC-DC controller features two complementary gate drivers with programmable dead time. This simplifies the design of active-clamp forward converters or optimized gate drive for highly-efficient flyback topologies. The second gate driver may be disabled if desired for single MOSFET topologies. The controller also features internal softstart, bootstrap startup source, current-mode compensation, and a 78% maximum duty cycle. A programmable and synchronizable oscillator allows design optimization for efficiency and eases use of the controller to upgrade existing power supply designs. Accurate programmable blanking, with a default period, simplifies the usual current-sense filter design trade-offs.

1.2 TL431

The TL431 is a three-terminal adjustable shunt regulator with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V, with two external resistors. These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications, such as onboard regulation, adjustable power supplies, and switching power supplies.

2 Design Features

- Input voltage range of 10.8 to 57 VDC, 18 to 32 VAC, or Power over Ethernet (PoE)
- 12-V at 1.25-A output
- Isolated flyback with synchronous rectifier for high efficiency
- Uses the TPS23756 high-power PoE interface and DC-DC controller
- Supports hardware Class 4 from the IEEE 802.3at standard

3 Block Diagram

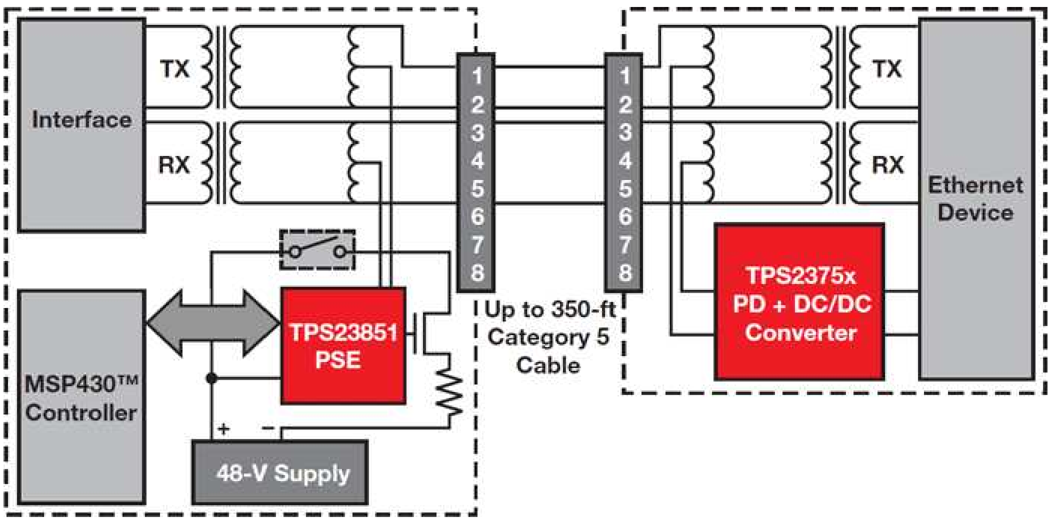


Figure 1. Block Diagram

4 Highlighted Products

The wide input range PoE converter reference design features the following devices:

- TPS23756
  - This device is a high-power and high-efficiency PoE interface and DC-DC controller.
- TL431
  - This device is an adjustable precision shunt-regulator.

For more information on each of these devices, see the respective product folders at www.TI.com.

4.1 TPS23756

- Powers up to 30-W (Input) PDs
- DC-DC control optimized for isolated converters
- Supports high-efficiency topologies
- Complete PoE interface
- Enhanced classification per IEEE 802.3at with status flag
- Adapter ORing support
- Programmable frequency with synchronization
- Robust 100-V, 0.5-Ω hotswap mOSFET
- –40°C to 125°C junction temperature range
- Industry standard PowerPAD™ TSSOP-20

4.2 TL431

- Equivalent full-range temperature coefficient, 30 ppm/°C
- 0.2-Ω typical output impedance
- Sink-current capability, 1 mA to 100 mA
- Low output noise
- Adjustable Output Voltage, V_{ref} to 36 V
- Available in a wide range of high-density packages

5 System Design Theory

5.1 PoE Hardware Classification

The reference design powered device (PD) supports hardware Class 4 from the IEEE 802.3at standard. This hardware classification allows PSE to determine a the power requirements of a PDF before powering. This classification also helps with power management once power is applied. A Type 2 hardware classification permits high power PSEs and PDs to determine whether the connected device can support high-power operation. A Type 2 PD presents Class 4 in hardware to indicate that the PD is a high-power device. A Type 1 PSE recognizes a Class 4 device as a Class 0 device which allows for 13 W if the PSE chooses to power the PD.

The maximum power entries in Table 1 determine the class classified by the PD. A Type 1 PD is not classified as Class 4. The PSE can disconnect a PD if the PD draws more than the power of the stated class, which is either the hardware class or a lower DLL-derived power level. The standard dictates that the PD draws limited-current peaks that increase the instantaneous power above the limited-current peaks listed in Table 1. However, the average power requirement always applies to the PD.

Table 1. Power[(1)(2)]

CLASS	CLASS REQUIREMENT		POWER AT PD		USAGE
	MIN (mA)	MAX (mA)	MIN (W)	MAX (W)	
0	0	4	0.44	12.95	Default
1	9	12	0.44	3.84	Optional
2	17	20	3.84	6.49	Optional
3	26	30	6.49	13	Optional
4	36	44	12.95	25.5	Only IEEE 802.3 at (Type 2) devices[(3)]

(1) For a more detailed PoE overview with the TPS23756 device, please refer to the PoE Overview Section in the TPS23756 datasheet (SLVS885).

(2) The yellow row indicates the PD classification for the PMP6659.

(3) The IEEE 802.3at standard is an update to IEEE 802.3-2008 clause 33 (PoE), adding high-power options and enhanced classification. Standards change and should always be referenced when making design decisions.

5.2 Wide Input Range

This reference design supports a wide input range of 10.8 to 57 VDC, 18 to 32 VAC, or Power over Ethernet. The wide input voltage range makes this design compatible with legacy applications where 12-VDC, 24-VDC, or 24-VAC auxiliary power is used. When operating from an adaptor the TPS23756 device has a lower internal PoE undervoltage-lockout (UVLO) circuit allowing it to work with wider inputs. The IEEE 802.3at standard states that the nominal operating conditions from the PSE is 48-VDC but may vary between 42.5 to 57 VDC with a maximum-generated current rating typically at 600-mA per mode to protect the Ethernet cable from overheating. The DC-DC converter, after the PoE interface, converts the input to the applications operating voltage defined for this reference design as 12 V with a 1.25-mA load.

5.3 Other Recommended Devices

This reference design addresses legacy applications where 12-VDC, 24-VDC, or 24-VAC auxiliary power is used. Applications requiring an optimized PD and DC-DC Controller solution with high efficiency and does not require a wide input range should use the TPS23751 device or the TPS23752 device. Both devices have an evaluation module, TPS23751EVM-104 and TPS23752EVM-145, which is used to evaluate the performance of the TPS23751/2 IEEE 802.3at PoE Interface and Green-mode DC-DC Controller. See Figure 2 for the TPS23751 and TPS23752 device light load efficiency versus mode.

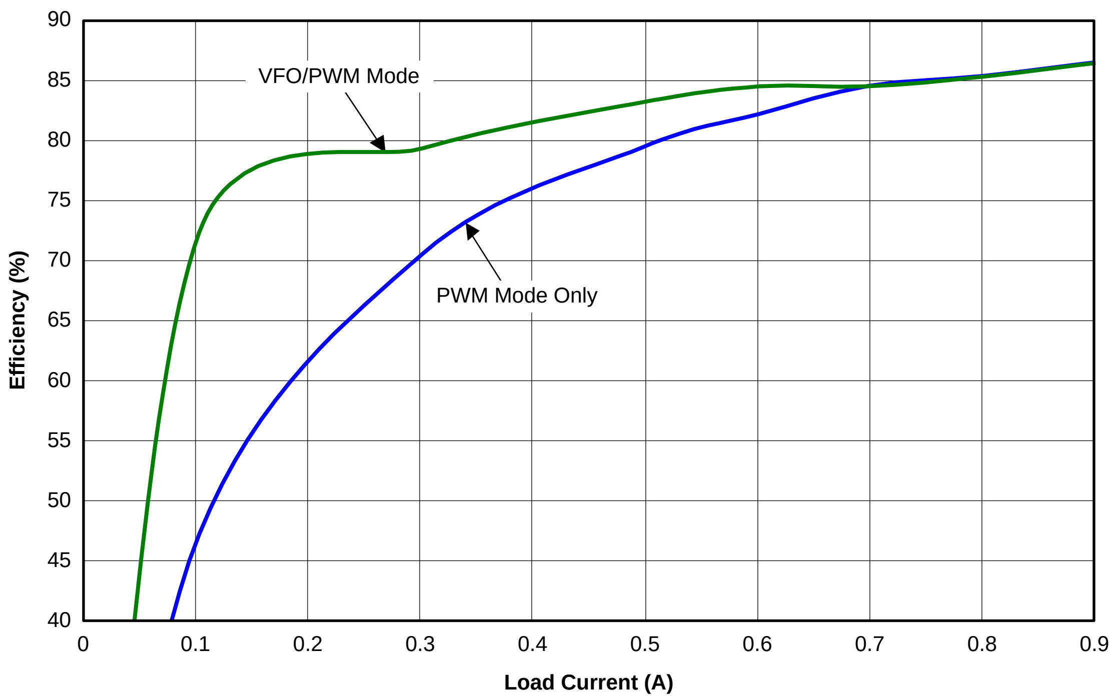


Figure 2. TPS23751 and TPS23752 Light Load Efficiency Versus Mode

5.4 Additional Application Notes

Description	TI Literature Number
Practical Guidelines to Designing an EMI Compliant PoE Powered Device with Isolated Flyback	SLUA469
Practical Guidelines to Designing an EMI Compliant PoE Powered Device with Non-Isolated DC/DC	SLUA454
PoE Powered Device for 24 VAC Building Power Applications	SLUA477
Using the TPS2398/99 Hot Swap Controller With Power Trends PT4485	SLUA306

6 Getting Started

6.1 Hardware

The reference design comprises of one board, shown in Figure 3, which has several input capabilities.

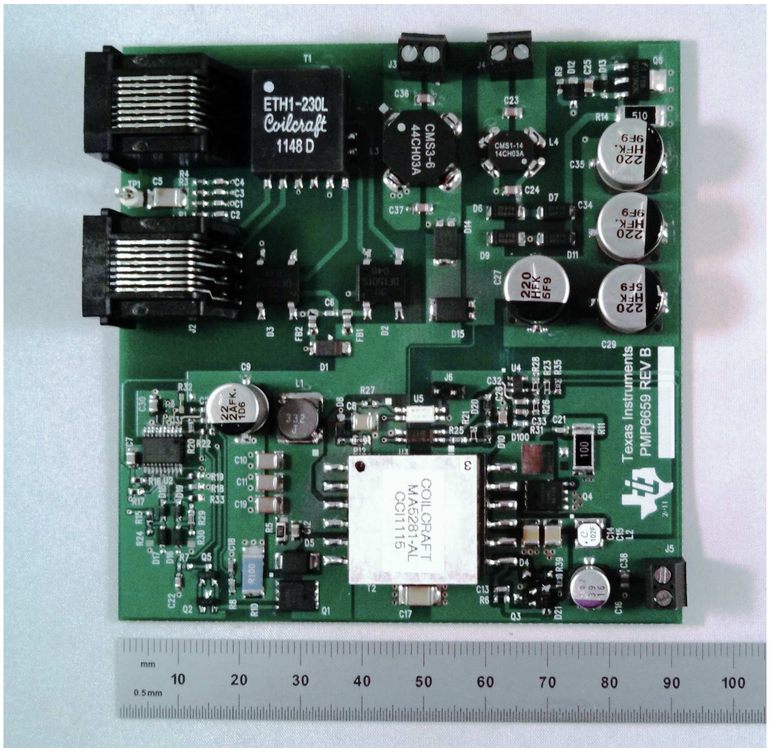


Figure 3. The PMP6659 Board (Revision B)

Figure 4 shows the partition of the PMP6659 board.

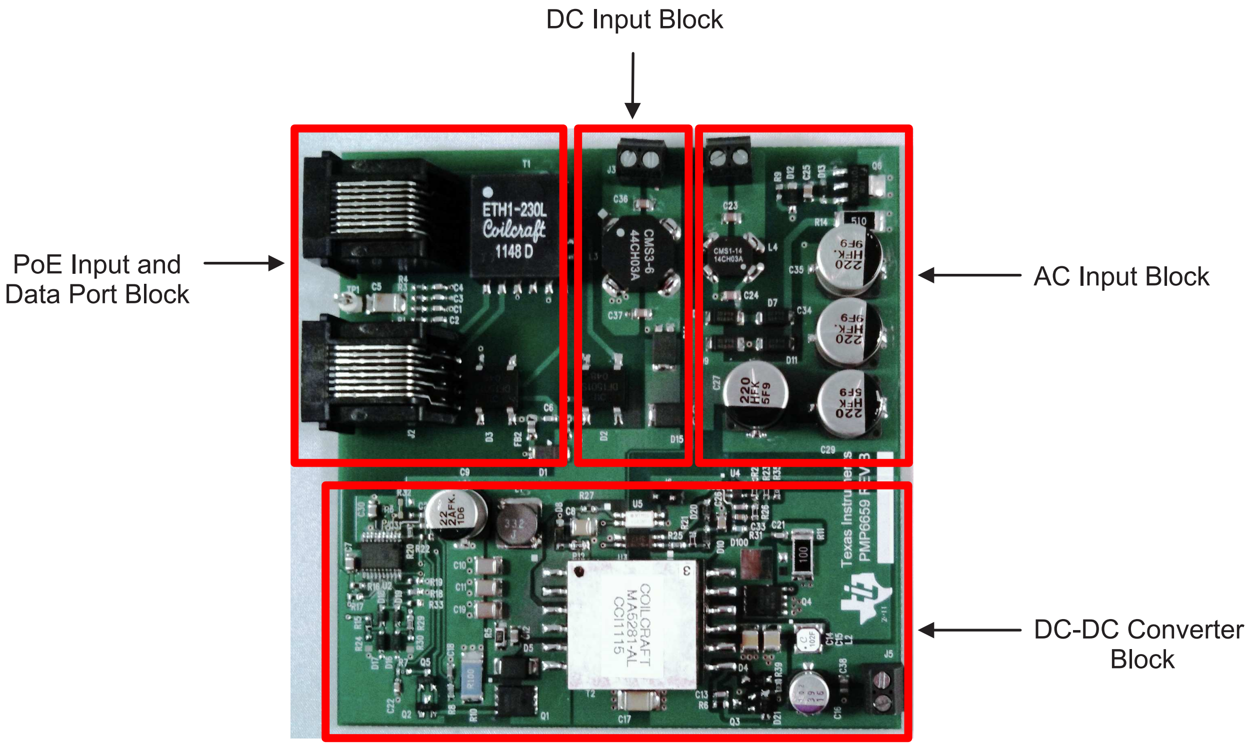


Figure 4. PMP6659 Partition

Figure 5 shows the adapter inputs, PoE input, data port, and the output.

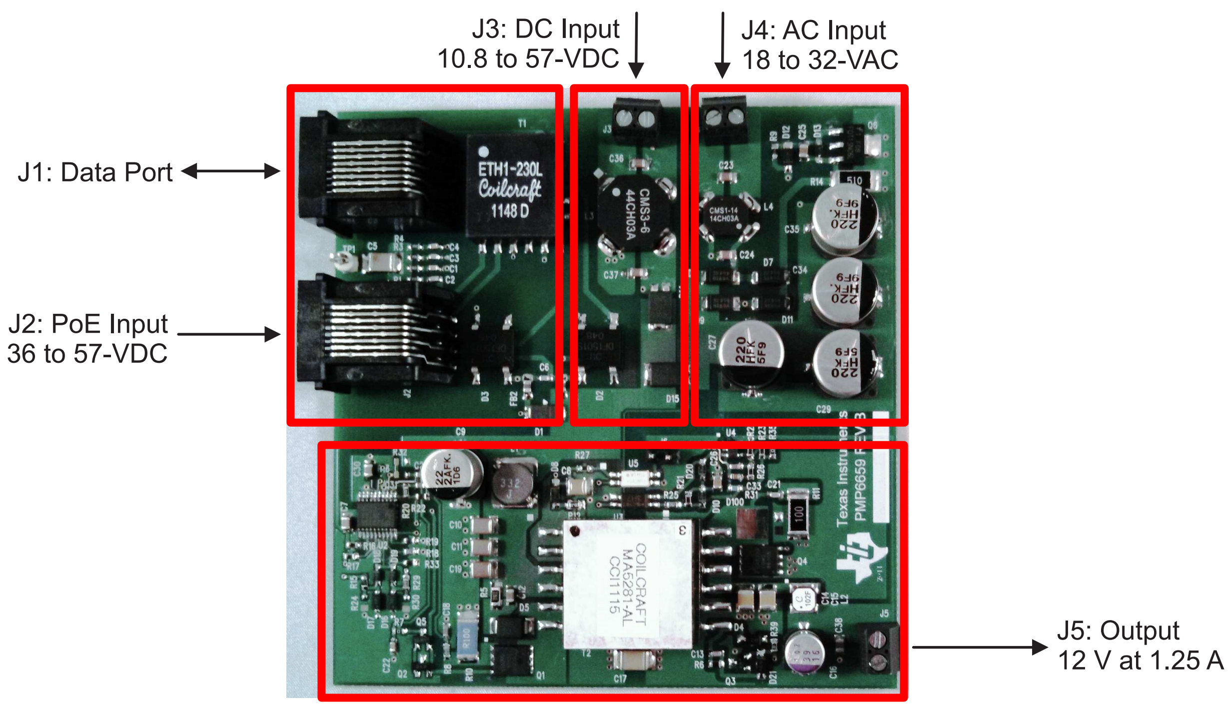


Figure 5. PMP6659 Inputs and Outputs

6.1.1 Hardware Setup

This section lists the different ways to apply power to the PMP6659 board.

6.1.1.1 Connect a DC Adapter Input

As shown in Figure 6 and Figure 7, connect an adapter input or bench supply of 10.8 to 57 VDC to J3 (see Section 8 for the PMP6659 schematic). The output power is transmitted from the J5 connector.

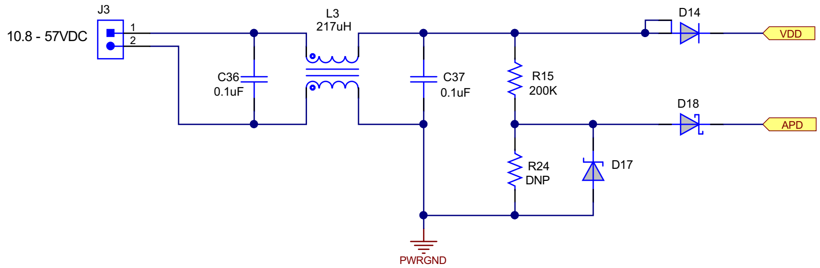


Figure 6. PMP6659 DC-Adaptor Input Schematic

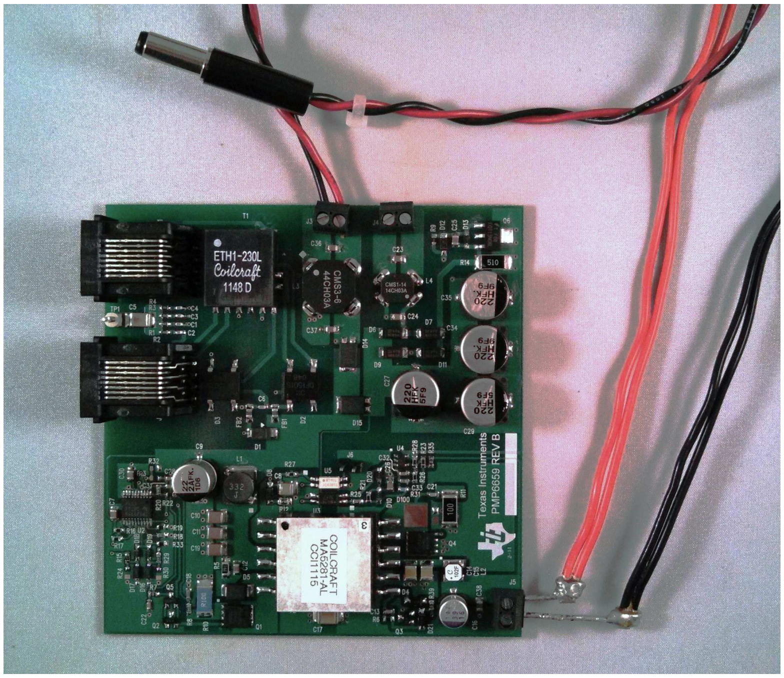


Figure 7. PMP6659 DC-Adaptor Input Setup

6.1.1.2 Connect an AC adapter input

As shown in Figure 8 and Figure 9, connect an adapter input of 18 to 32 VAC to J4 (see Section 8 for the PMP6659 schematic). The output power is transmitted from the J5 connector.

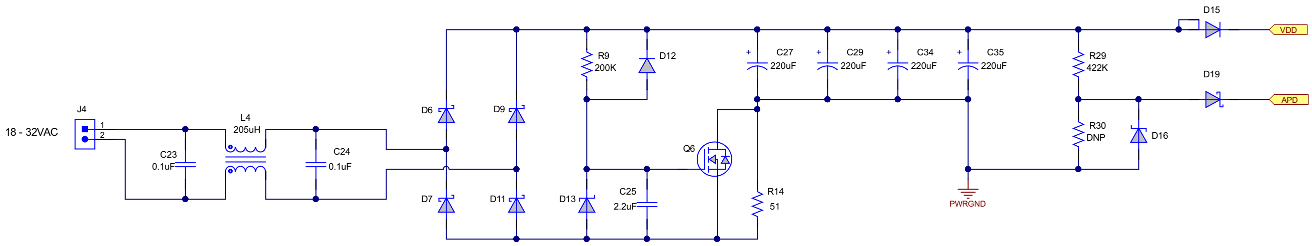


Figure 8. PMP6659 AC-Adaptor Input Schematic

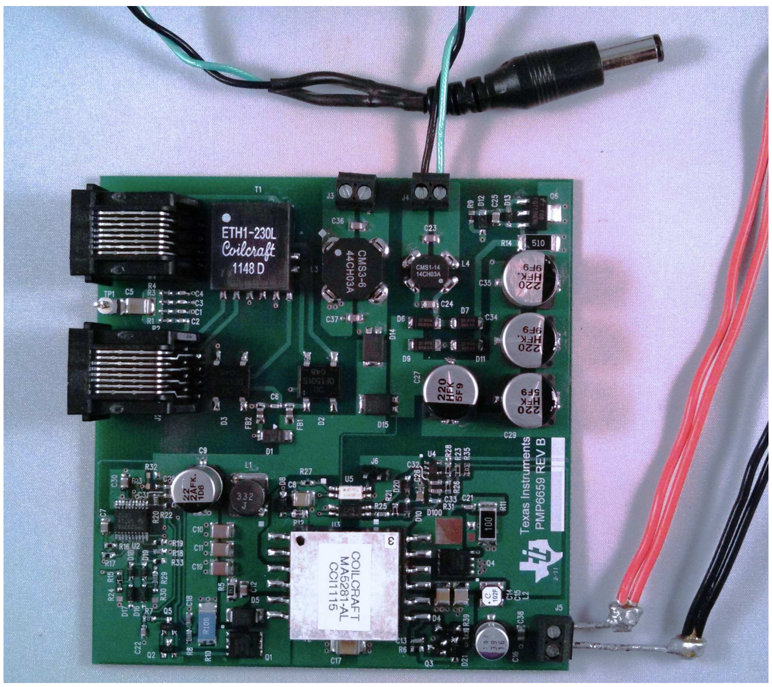


Figure 9. PMP6659 AC-Adapter Input Setup

6.1.1.3 Connect Power over Ethernet

As shown in Figure 10 and Figure 11, connect a Power over Ethernet input or a bench supply to J2 (see Section 8 for the PMP6659 schematic). The output power is transmitted from the J5 connector.

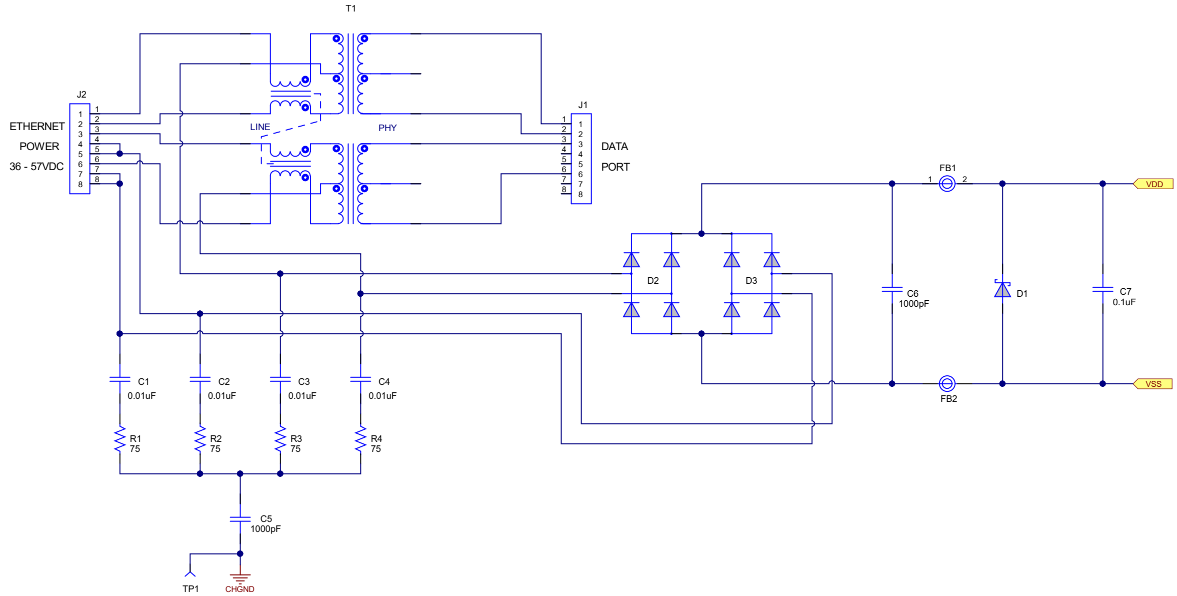


Figure 10. PMP6659 PoE Input Schematic

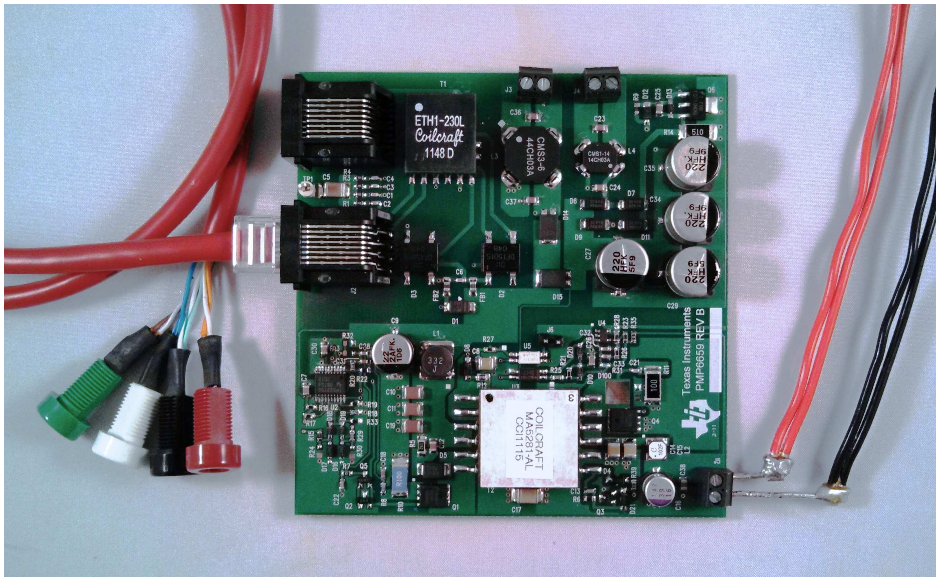


Figure 11. PMP6659 PoE Input Setup

7 Test Data

7.1 Efficiency versus Input Voltage

Figure 12 shows the efficiency of the converter with various inputs. The efficiency data is taken from three points

1. 48-VDC input at J2 (see Figure 10 and Figure 11)
2. 12-VDC input at J3 (see Figure 6 and Figure 7)
3. 24-VAC input at J4 (see Figure 8 and Figure 9)

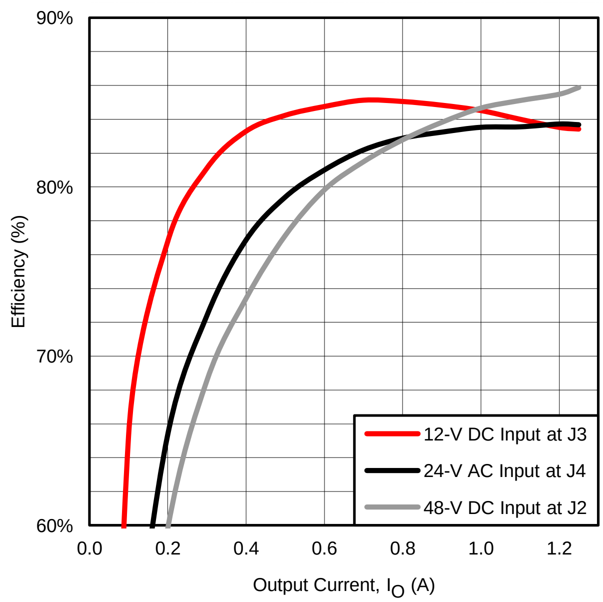


Figure 12. Efficiency of the PMP6659 Across a Wide Input Range

7.2 Input Ripple Voltage (Ripple and Noise Measurements)

Figure 13 and Figure 14 show the ripple voltage (J5 connector). The input ripple shown in Figure 13 and Figure 14 was measured with an input voltage of 48 VDC at J2, an output load at 1.25 A, and 20 MHz BWL.

NOTE: A short ground lead was required for the ripple measurement.

The oscilloscope was set to 20 MHz bandwidth limited.

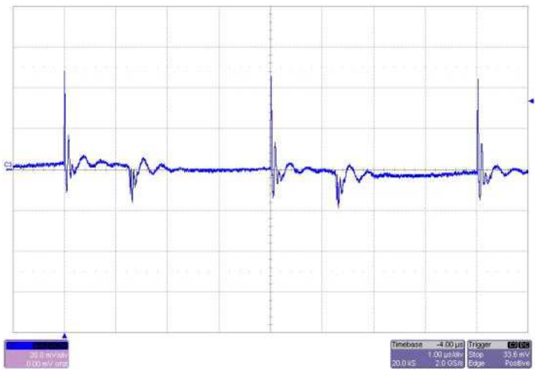


Figure 13. 12-V Ripple (C38), 20 mV/div, 1 µs/div

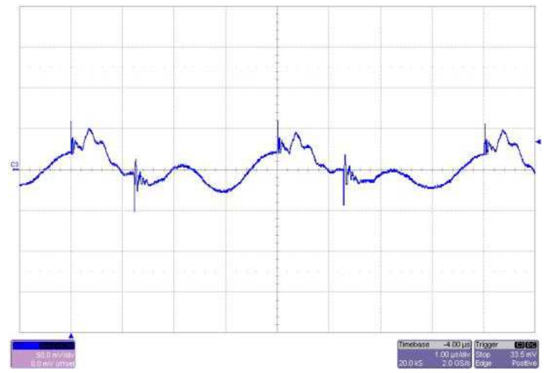


Figure 14. Input Ripple (D1), 10 mV/div, 1 µs/div

The input ripple shown in Figure 15 and Figure 16 was taken with an input voltage of 12 VDC at J3, the output loaded to 1.25 A, and 20 MHz BWL.

Figure 15. 12-V Ripple (C38), 20 mV/div, 1 µs/div

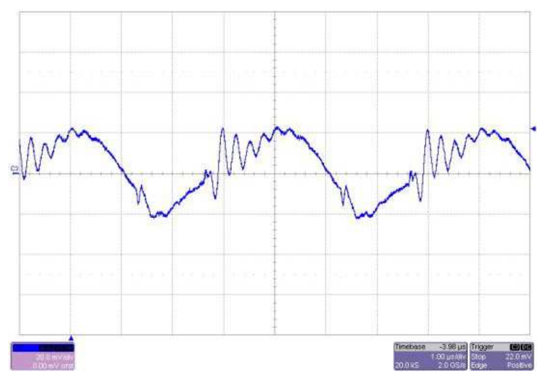


Figure 16. Input Ripple (C37), 10 mV/div, 1 µs/div

The input ripple shown in Figure 17 was taken with an input voltage of 24 VAC across C27.

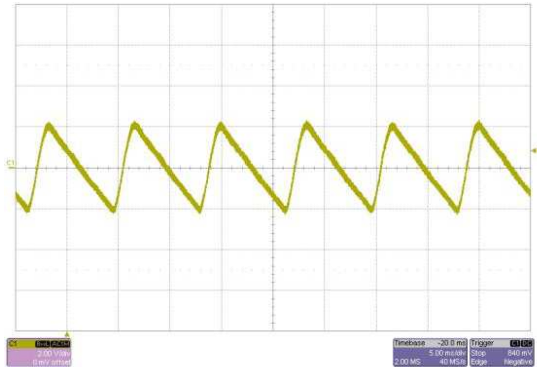


Figure 17. Input Ripple Across C27 with a 24-V AC Input, 2 V/div, 5 ms/div

7.3 Load Transients (Dynamic Loading)

Figure 18 shows the 12-V output voltage (at J5) when the load current pulses between 0.5 A and 1.25 A. The input voltage (V_I) is 48 VDC at J2.

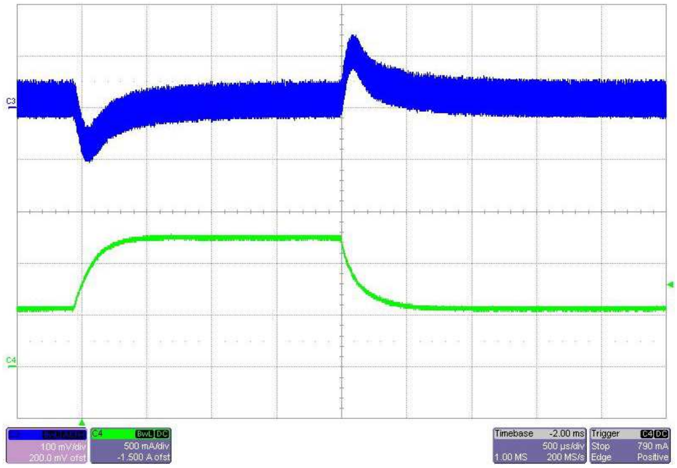


Figure 18. Load Step, 48 V_I at J2 100 mV/div, 500 µs/div

Figure 19 shows the 12-V output voltage (at J5) when the load current pulses between 0.5 A and 1.25 A. V_I is 12-VDC at J3.

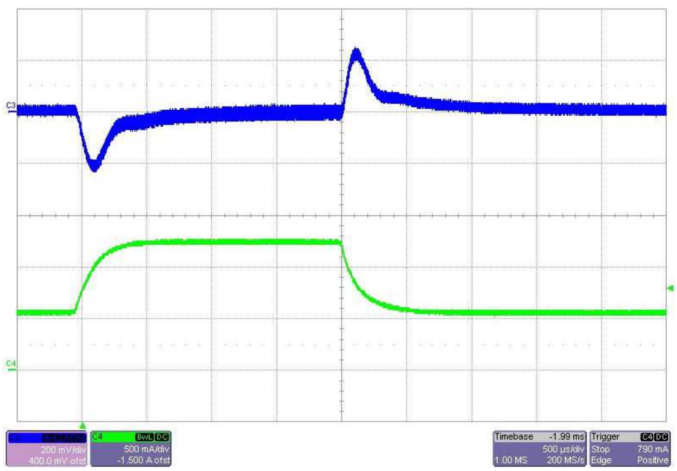


Figure 19. Load Step, 12 V_I at J3 200 mV/div, 1 ms/div

7.4 Turn-on Response

Figure 20 and Figure 21 show the 12-V output voltage start-up waveform after the application of 48 VDC at J2 (PoE). The output was loaded to 0 A (see Figure 20) and 1.25 A (see Figure 21).

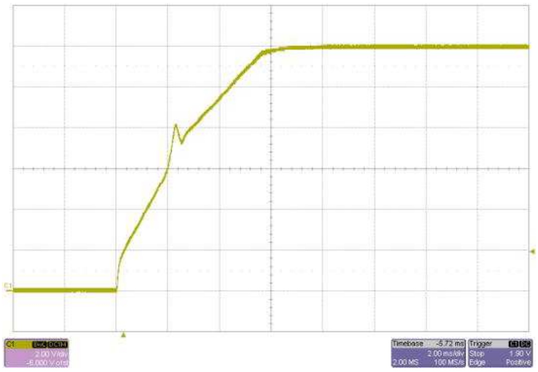


Figure 20. 48 V_I, 0-A Load, 2 ms/div

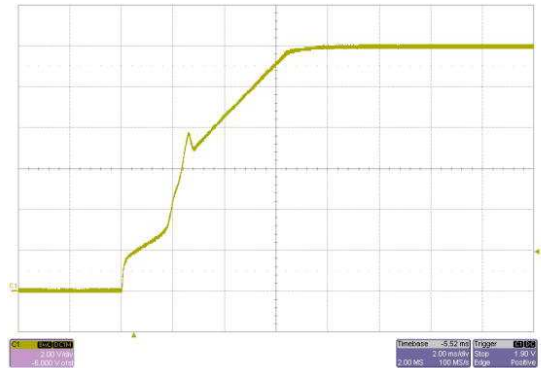


Figure 21. 48 V_I, 1.25-A Load, 2 ms/div

Figure 22 and Figure 23 show the 12-V output voltage start-up waveform after the application of 12 VDC at J3. The output was loaded to 0 A (see Figure 22) and 1.25 A (see Figure 23).

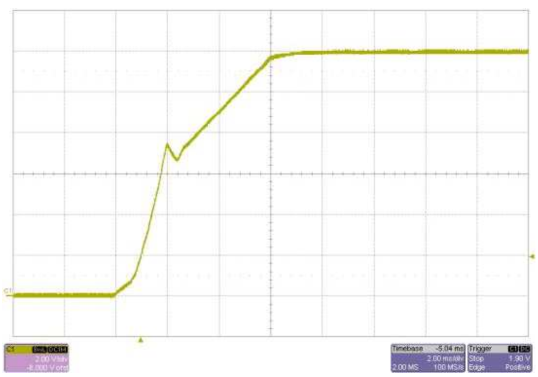


Figure 22. 12 V_I, 0-A Load, 2 ms/div

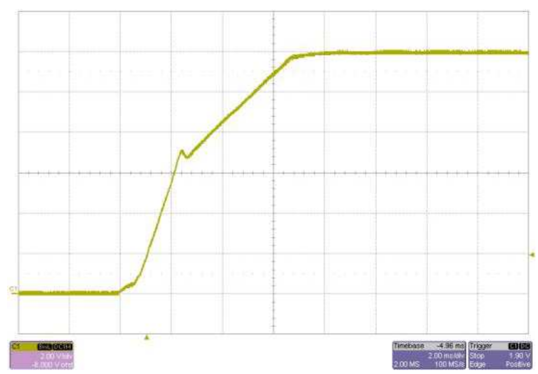


Figure 23. 12 V_I, 1.25-A Load, 2 ms/div

7.5 Control Loop Gain / Stability

Table 2 lists the loop gain and phase margin (see Figure 24). The output was loaded to 1.25 A.

Table 2. Loop Gain and Phase Margin at 48 V

Input Voltage	48-V	
Gain/Phase	Crossover	Phase Margin
PMP6659	6.4 kHz	58.3°

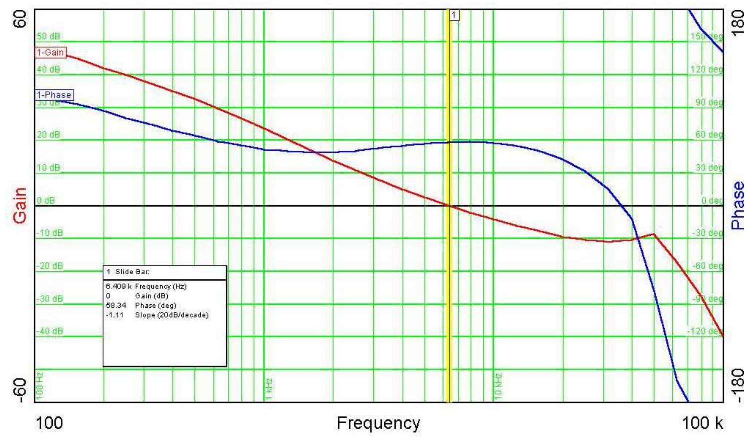


Figure 24. Loop Gain and Phase Margin at 48 V

Table 3 lists the loop gain and phase margin (see Figure 25). The output was loaded to 1.25 A.

Table 3. Loop Gain and Phase Margin at 12 V

Input Voltage	12-V	
Gain/Phase	Crossover	Phase Margin
PMP6659	3.3 kHz	36°

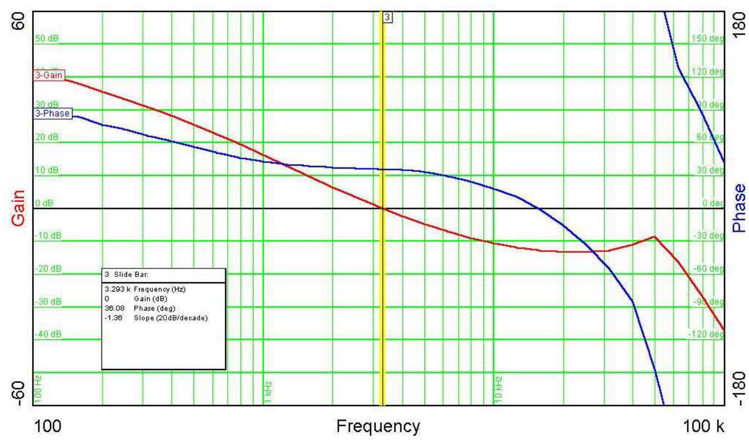


Figure 25. Loop Gain and Phase Margin at 12 V

7.6 Thermal Performance of the Design

A simple test confirmed the thermal performance of the design. Thermal measurements were taken at two data points: 48-V input with a 1.25-A load and 12-V input with a 1.25-A load.

Thermal-imaging camera hot spots were analyzed at 30 minutes after launching the application. The results of this test confirm that the design can effectively dissipate heat without localized heating.

As shown in Figure 26 and Figure 27, there is no localized heating observed in the system after the 30 minute period.

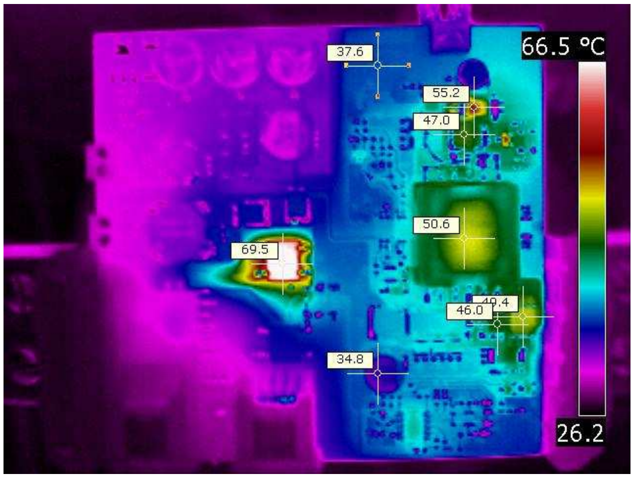


Figure 26. 48-V Input and 1.25-A Load

Figure 27. 12-V Input and 1.25-A Load

8 Schematics

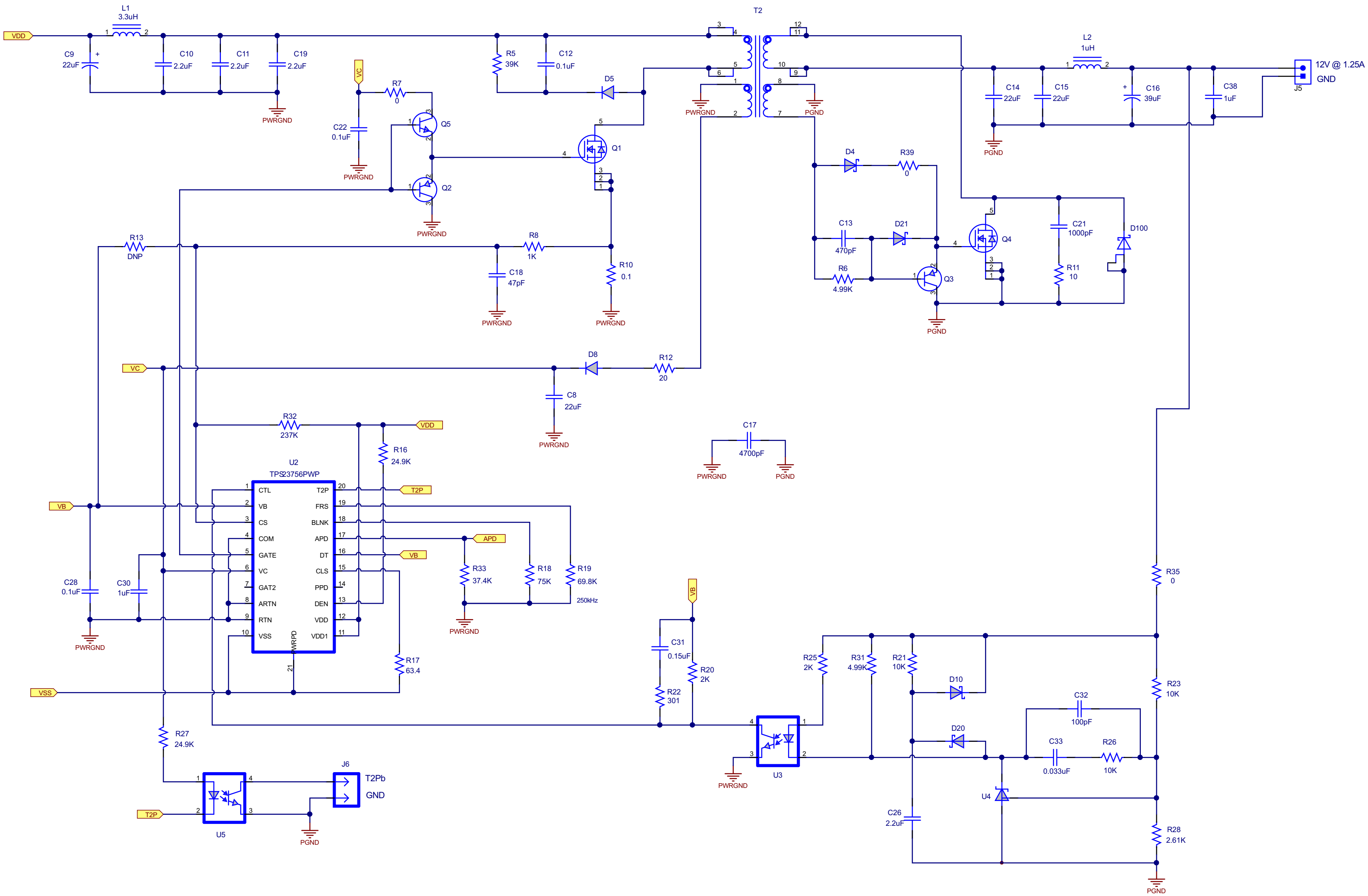


Figure 28. The DC-DC Converter

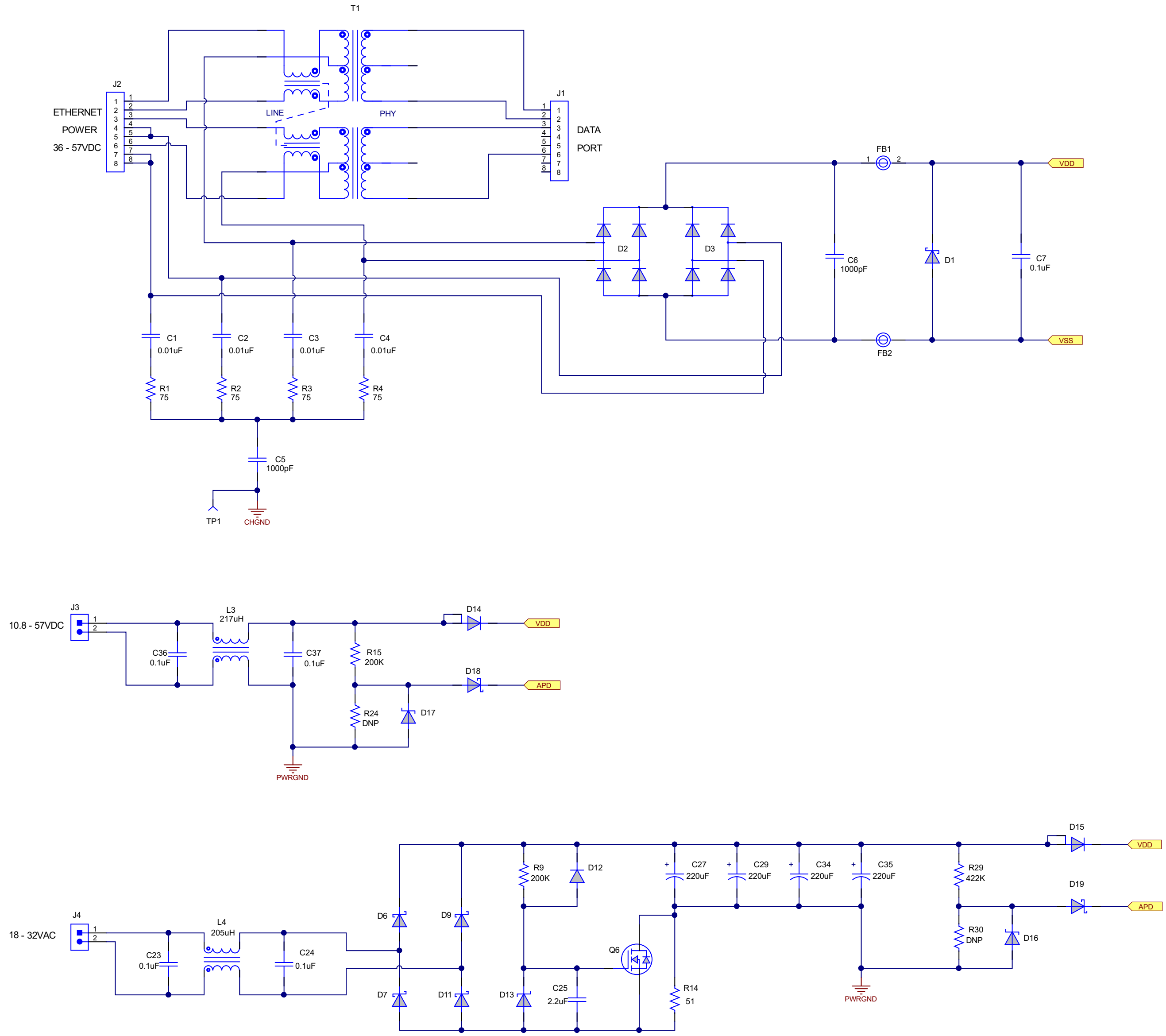


Figure 29. The Adapter Inputs, PoE Input, and Data Port

9 Bill of Materials

To download the bill of materials (BOM) for each board, see the design files at www.ti.com/tool/PMP6659. Table 4 lists the BOM for the PMP6659.

Table 4. BOM

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		PMP6659	Any
C1, C2, C3, C4	4	0.01 µF	Capacitor, Ceramic, 100 V, X7R, 10%	603	STD	STD
C5	1	1000 pF	Capacitor, Ceramic, 2 KV, X7R, 10%	1812	Std	Std
C6, C21	2	1000 pF	Capacitor, Ceramic, 100 V, C0G, 10%	603	STD	STD
C7, C12, C23, C24, C36, C37	6	0.01 µF	Capacitor, Ceramic, 100 V, X7R, 10%	805	STD	STD
C8, C14, C15	3	22 µF	Capacitor, Ceramic, 25 V, X7R, 10%	1210	Std	STD
C9	1	22 µF	Capacitor, Aluminum Electrolytic, 100 V, 20%	0.328 × 0.390 inch	EEVFKxxyyyF	Panasonic
C10, C11, C19	3	2.2 µF	Capacitor, Ceramic, 100 V, X7R, 10%	1210	Std	STD
C13	1	470 pF	Capacitor, Ceramic, 16 V, X7R, 10%	603	STD	STD
C16	1	39 µF	Capacitor, OS CON, 16 V, 50 mΩ, 20%	0.260 inch^2	vvSVPxxxM	Sanyo
C17	1	4700 pF	Capacitor, Ceramic, 2 KV, X7R, 10%	1812	Std	Std
C18	1	47 pF	Capacitor, Ceramic, 50 V, C0G, 10%	603	STD	STD
C22, C28	2	0.01 µF	Capacitor, Ceramic, 25V, X7R, 10%	603	STD	STD
C25, C26	2	2.2 µF	Capacitor, Ceramic, 16V, X7R, 10%	805	STD	STD
C27, C29, C34, C35	4	220 µF	Capacitor, Aluminum Electrolytic, 50V, 20%	0.457 × 0.406	EEVFKxxyyyP	Panasonic
C30, C38	2	1 µF	Capacitor, Ceramic, 25V, X7R, 10%	805	STD	STD
C31	1	0.15 µF	Capacitor, Ceramic, 16V, X7R, 10%	603	STD	STD
C32	1	100 pF	Capacitor, Ceramic, 25V, C0G, 10%	603	STD	STD
C33	1	0.033 µF	Capacitor, Ceramic, 25V, X7R, 10%	603	STD	STD
D1	1	SMAJ58A	Diode, SMT TVS 400W, 4.3-A, 58-V	SMA	SMAJxxxCA	Diodes
D2, D3	2	DF1501S	Bridge Rectifier, 100 V, 1.5 A, Glass Passivated, SMD	DF-S	DFXXXS	Diodes
D4, D21	2	MBR0530	Diode, Schottky, 0.5 A, 30 V	SOD-123	MBR0520L	Fairchild
D5	1	ES3CB	Diode, Rectifier, Ultra-fast, 3 A, 150 V	SMB	STD	STD
D6, D7, D9, D11	4	B260A	Diode, Schottky, 2 A, 60 V	SMA	STD	STD
D8, D12	2	MMSD4148	Diode, Switching, 100 V, 200 mA, 400 mW,	SOD-123	MMSD4148	On Semi
D10, D18, D19, D20	4	BAT54HT1	Diode, Schottky, 200 mA, 30 V, 200 mW	SOD323	BAT54HT1	On Semi
D13	1	10 V	Diode, Zener, 200 mW, 10 V	SOD-323	BZT52CxxxS	Conitnental Devices India Limited
D14, D15	2	PDU620	Diode, 6 A 200 V Ultra-Fast Recovery	PowerDI 5	PDU620	Diodes
D16, D17	2	5.1 V	Diode, Zener, 200 mW, 5.1 V	SOD-323	BZT52CxxxS	Conitnental Devices India Limited
D100	1	DNP	Diode, High Current,Trench MOS Barrier Schottky, 100V, 8A			
FB1, FB2	2	MMZ2102R150A	Bead, Ferrite, 1.5 A, 15 Ω	0805	MI0805KxxxR-00	Steward
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
J1, J2	2	520252	Connector, Jack, Modular, 8 POS			
J3, J4, J5	3		Terminal Block, 6 A, 3,5-mm Pitch, 2-Pos, TH	7,0 × 8,2 × 6,5 mm	ED555/2DS	On-Shore Technology
J6	1	PTC36SAAN	Header, Male 2-pin, 100 mil spacing, (36-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
L1	1	3.3 µH	Inductor, SMT, 3.95 A, 20 mΩ	0.287 × 0.287 inch	MSS7341-xxxML	Coilcraft

Table 4. BOM (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
L2	1	1 µH	Inductor, SMT, 1.8 A, 42 mΩ	0.153 × 0.153 inch	LPS4018-xxxxX	Coilcraft
L3	1	217 µH	Inductor, Common Mode, 2.85 A, 20 mΩ	0.550 × 0.550 inch	CMS-3 EMI	Cooper
L4	1	205 µH	Inductor, Common Mode, 850 mA, 186 mΩ	0.370 × 0.283 inch	CMS1-xx	Cooper
Q1	1	FDMS86200	MOSFET, NChan, 150 V, 9.6 A, 18 mΩ	POWER 56	FDMS8690	Fairchild
Q2, Q3	2	MMBT3906	Trans, PNP, 40 V, 200 mA, 225 mW	SOT23	MMBT3906LT1G	On Semi
Q4	1	FDMS86105	MOSFET, NChan, 100V, 6A, 34 mΩ	POWER 56	FDMS8690	Fairchild
Q5	1	MMBT3904	Trans, NPN, 40 V, 200 mA, 225 mW	SOT23	MMBT3904LT1G	On Semi
Q6	1	FQT13N06L	MOSFET, N-ch, 60 V, 2.8 A , 0.11 Ω	SOT223-4	FQT13N06L	Fairchild
R1, R2, R3, R4	4	75	Resistor, Chip, 1/16W, 1%	603	STD	STD
R5	1	39K	Resistor, Chip, 1/4W, 5%	1206	Std	Std
R6, R31	2	4.99K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R7, R35, R39	3	0	Resistor, Chip, 1/16W, 1%	603	STD	STD
R8	1	1K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R9, R15	2	200K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R10	1	0.1	Resistor, Chip, 1W, 5%	2512	STD	STD
R11	1	10	Resistor, Chip, 1W, 5%	2512	STD	STD
R12	1	20	Resistor, Chip, 1/10W, 5%	805	STD	STD
R13, R24, R30	3	DNP	Resistor, Chip, 1/16W, 1%	603	STD	STD
R14	1	51	Resistor, Chip, 1W, 5%	2512	STD	STD
R16, R27	2	24.9K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R17	1	63.4	Resistor, Chip, 1/16W, 1%	603	STD	STD
R18	1	75K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R19	1	69.8K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R20, R25	2	2K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R21, R23, R26	3	10K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R22	1	301	Resistor, Chip, 1/16W, 1%	603	STD	STD
R28	1	2.61K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R29	1	422K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R32	1	237K	Resistor, Chip, 1/16W, 1%	603	STD	STD
R33	1	37.4K	Resistor, Chip, 1/16W, 1%	603	STD	STD
T1	1	ETH1-230LD	Transformer, High Power PoE	S0 14 Wide	ETH1-230LD	Coilcraft
T2	1	MA5281-BL	Transformer, Flyback, 45uH	0.810 × 1.181 inch	MA5281-AL	Coilcraft
TP1	1	5012	Test Point, White, Thru Hole	0.125 × 0.125 inch	5012	Keystone
U2	1	TPS23756PWP	IC, IEEE 802.3at PoE Interface/Isolated Converter Controller	PWP20	TPS23754PWP	TI
U3	1	TCMT1107	IC, Photocoupler, 80-160% CTR	MF4	TCMT110x	Vishay
U4	1	TL431ACDBVR	IC, Precision Adjustable Shunt Regulator	SOT23-5	TL431DBVR	TI
U5	1	TCMT1109	IC, Photocoupler, 200-400% CTR	MF4	TCMT110x	Vishay

10 Layer Plots

To download the layer plots for each board, see the design files at www.ti.com/tool/PMP6659. Figure 30 shows the layer plots.

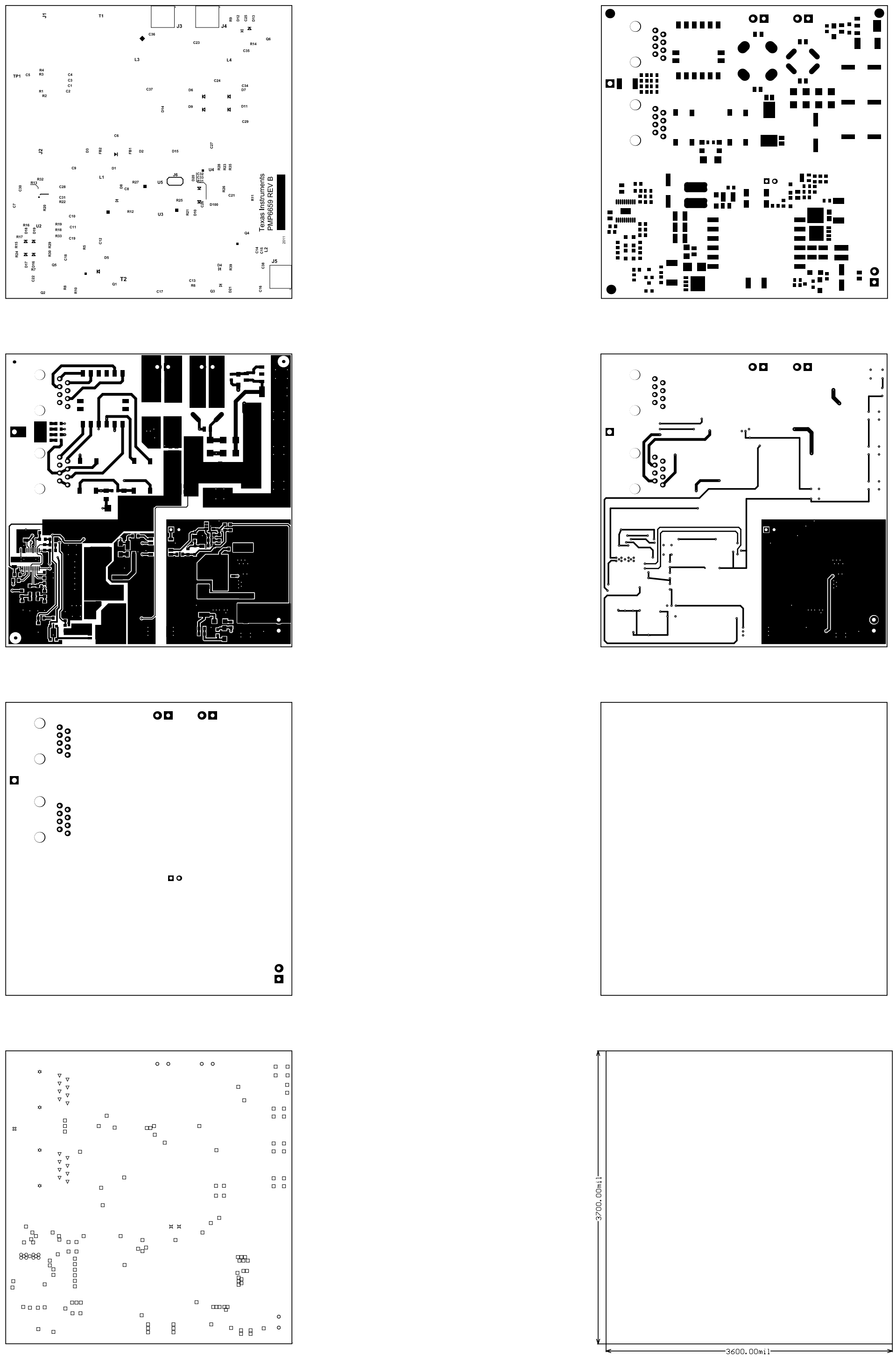


Figure 30. PMP6659 Layer Plot

11 Assembly Drawings

To download the assembly drawings, see the design files at www.ti.com/tool/PMP6659. Figure 31 shows the assembly drawing for the PMP6659 board.

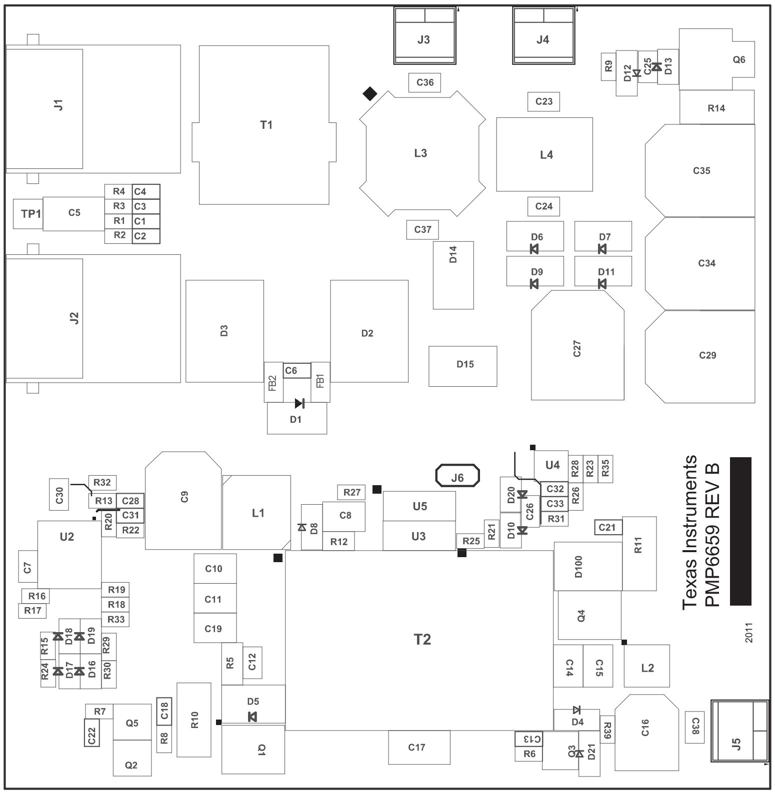


Figure 31. PMP6659 Assembly Drawing

12 Altium Project

To download the Altium project files, see the design files at www.ti.com/tool/PMP6659. Figure 32 shows the layout for the PMP6659.

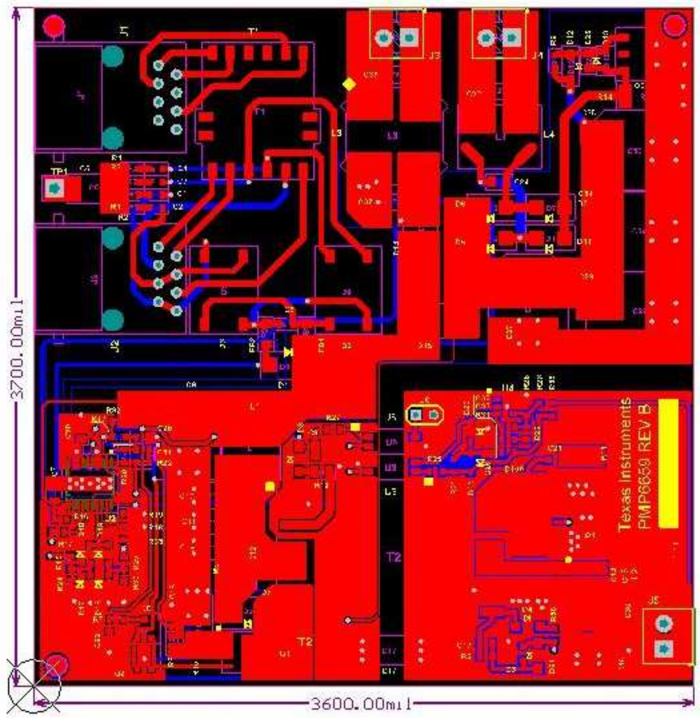


Figure 32. PMP6659 Layout

13 Gerber Files

To download the Gerber files for each board, see the design files at www.ti.com/tool/PMP6659

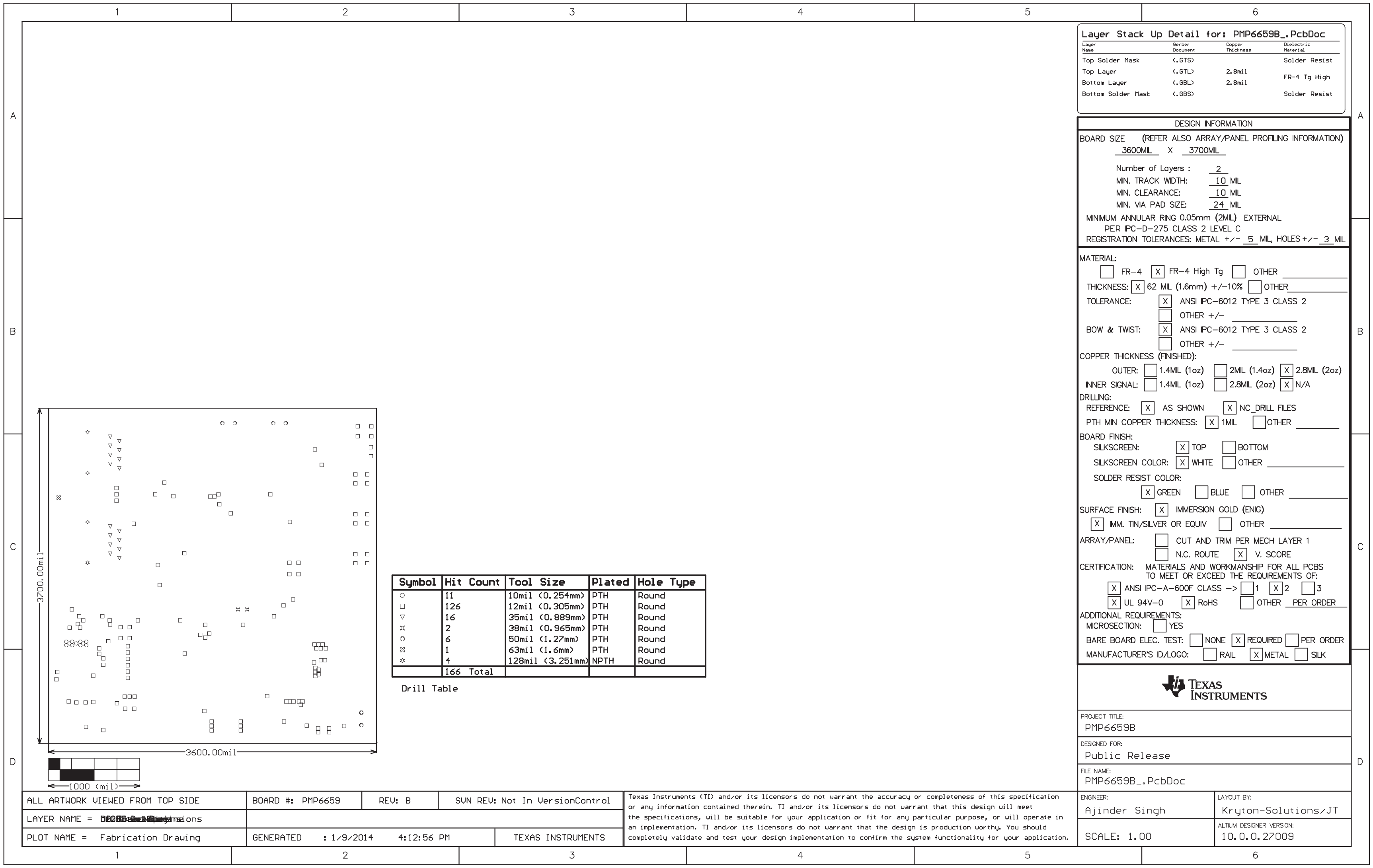


Figure 33. PMP6659 Fab Drawings

14 About the Author

David Strasser is a Senior Applications Engineer and Member Group Technical Staff at Texas Instruments where he is responsible for developing power reference designs across a wide array of markets. David brings to this role over 30 years of experience in power conversion design. David earned his Bachelor of Science in Electrical Engineering from Western Michigan University in Kalamazoo, Michigan and his Master of Science in Electrical Engineering from the Illinois Institute of Technology in Chicago, Illinois.

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used. TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l’autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

【Important Notice for Users of EVMs for RF Products in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

Texas Instruments Japan Limited
(address) 24-1, Nishi-Shinjuku 6 chome, Shinjuku-ku, Tokyo, Japan

http://www.tij.co.jp

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】

本開発キットは技術基準適合証明を受けておりません。

本製品のご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。

日本テキサス・インスツルメンツ株式会社
東京都新宿区西新宿６丁目２４番１号
西新宿三井ビル
http://www.tij.co.jp

EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265