

TPS23752EVM-145: Evaluation Module for TPS23752

This User's Guide describes the evaluation module (EVM) for the TPS23752 (TPS23752EVM-145). The TPS23752 is a type 2, Power over Ethernet (PoE) powered device (PD) controller and integrated current-mode DC/DC controller with sleep mode. The TPS23752 is optimized specifically for applications requiring high efficiency over a wide load range.

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1 Introduction

This EVM allows reference circuitry evaluation of the TPS23752 PD controller, DC/DC controller, and sleep mode functionality.

1.1 Features

- High-efficiency synchronous-flyback design including enhanced light-load operation (with synchronous rectifier disable and variable frequency operation)
- Sleep mode capability including PSE DC and Pulsed MPS signature, wake, and status LED
- 24- and 48-V adapter input capability
- Gigabit Ethernet pass-through interface
- IEEE 802.3at type-2 hardware classification with secondary side status flag (T2P) and LED
- Robust 100-V, 0.5- Ω , internal-hotswap MOSFET
- 5-V, 5-A, 25-W dc output

1.2 Applications

- IEEE 802.3at-compliant devices
- Video and VoIP telephones
- Multiband access points
- Security cameras
- Pico-base stations

2 Electrical Specifications

Table 1. TPS23752EVM-145 Electrical and Performance Specifications

Parameter	Test Conditions	Min	Typ	Max	Unit	
POWER INTERFACE						
Input Voltage	Applied to the power pins of connectors J1 or J3	0		57	V	
Input UVLO, PoE input J1	Rising input voltage			40	V	
	Falling input voltage	30				
Input UVLO, adapter J3	Rising input voltage		18.7		V	
Detection voltage	At device terminals	1.4		10.1	V	
Classification voltage	At device terminals	11.9		23.0	V	
Classification current	Rclass = 63.4 Ω	38		42	mA	
Inrush current-limit		100		180	mA	
Operating current-limit		850		1200	mA	
DC/DC CONVERTER						
Output voltage	21.6V \leq Vin \leq 57 V, ILOAD \leq ILOAD (max)	5-V output	4.85	5.00	5.15	V
Output current	21.6V \leq Vin \leq 57 V	5-V output			5.0	A
Output ripple voltage, peak-to-peak	Vin = 44 V, ILOAD = 5 A	5-V output		30		mV
Efficiency, dc-dc converter	Vin = 54 V, ILOAD = 5 A	5-V output		93%		
Efficiency, end-to-end	Vin = 54 V, ILOAD = 5 A	5-V output		90%		
Switching frequency	PWM mode		225		275	kHz

3 Description

The EVM enables full evaluation of the TPS23752 device. Refer to the schematics shown in [Figure 1](#) and [Figure 2](#). Ethernet power is applied from J1 to T1 and is dropped to the diode bridges (D1/D2/D7/D8 or D3/D4/D9/D10) from the T1 center taps. The series R-C circuits from each center tap help balance the Ethernet cable impedance and are critical for ESD and EMI/EMC performance. These circuits are terminated at TP7 (EGND) through the high-voltage capacitor, C10. At the output of the diode bridges is the EMI/EMC filter and transient protection for the TPS23752.

Input power can also be applied at J3 from a dc source. EMI/EMC filtering is provided at this connector as well and diode D5 provides reverse-voltage protection. R5 and R10 provide a threshold for the TPS23752 APD pin so that the TPS23752 internal MOSFET is disabled when the voltage at J3 is above approximately 18 V. This ensures that the adapter has priority over the PSE source.

Below the PoE diode bridges in [Figure 1](#) are four opto-isolated circuits. U1, U2, U3, and associated circuits support the sleep or low-power mode of the TPS23752. The U4 circuit indicates when an adapter or type 2 PoE source is present.

The TPS23752 (U5) PD and dc/dc converter circuitry is shown in [Figure 2](#). R23 provides the detection signature and R26 provides the classification (class 4) signature. To the right of the U5 is the switched side of the PD controller. The TPS23752 RTN pin provides inrush limited turn on and charge of the bulk capacitor, C16. During inrush, the TPS23752 dc/dc controller is disabled.

The dc/dc converter is a driven synchronous, isolated flyback topology. The flyback converter operates in either variable-frequency (VFO) or pulse-width modulated (PWM) modes depending on output loading to boost wide load range efficiency. The primary (Q5) and secondary (Q3) switching MOSFETs are driven from the U5 GATE pin. MOSFET gate-drive buffering and phasing is provided by Q6/D16/R32 (primary) and T3/Q4/D18/R38 (secondary), respectively. In addition to Q3, D17 provides secondary side rectification when the converter is in VFO mode. R25/D15/C27/C29 form the auxiliary 12-V output for the U5 dc/dc controller and D13/R22/C19 provide peak voltage clamp protection for Q5.

Output voltage feedback is provided with the U7 and associated error amplifier (U8) circuitry. R46 provides a means for error injection when measuring the frequency response of the converter. This feedback circuit drives the U5 CTL pin providing a voltage proportional to the output load current. The voltage on the CTL pin can also detect the desired mode transition point by comparing this with the voltage on the SRT pin (set by R31 and R35). As output load decreases, the CTL pin voltage also decreases. When CTL crosses the transition point (going into VFO mode), the converter disables Q3 and allows D17 to rectify. This is accomplished with the U5 SRD pin, U6, and Q7/Q8/Q9. In VFO mode, Q9 is ON and Q8 is OFF. This effectively extinguishes the Q3 gate drive allowing D17 to rectify. When output load increases, the converter goes back to PWM mode and allows Q3 to provide rectification.

4 Schematic

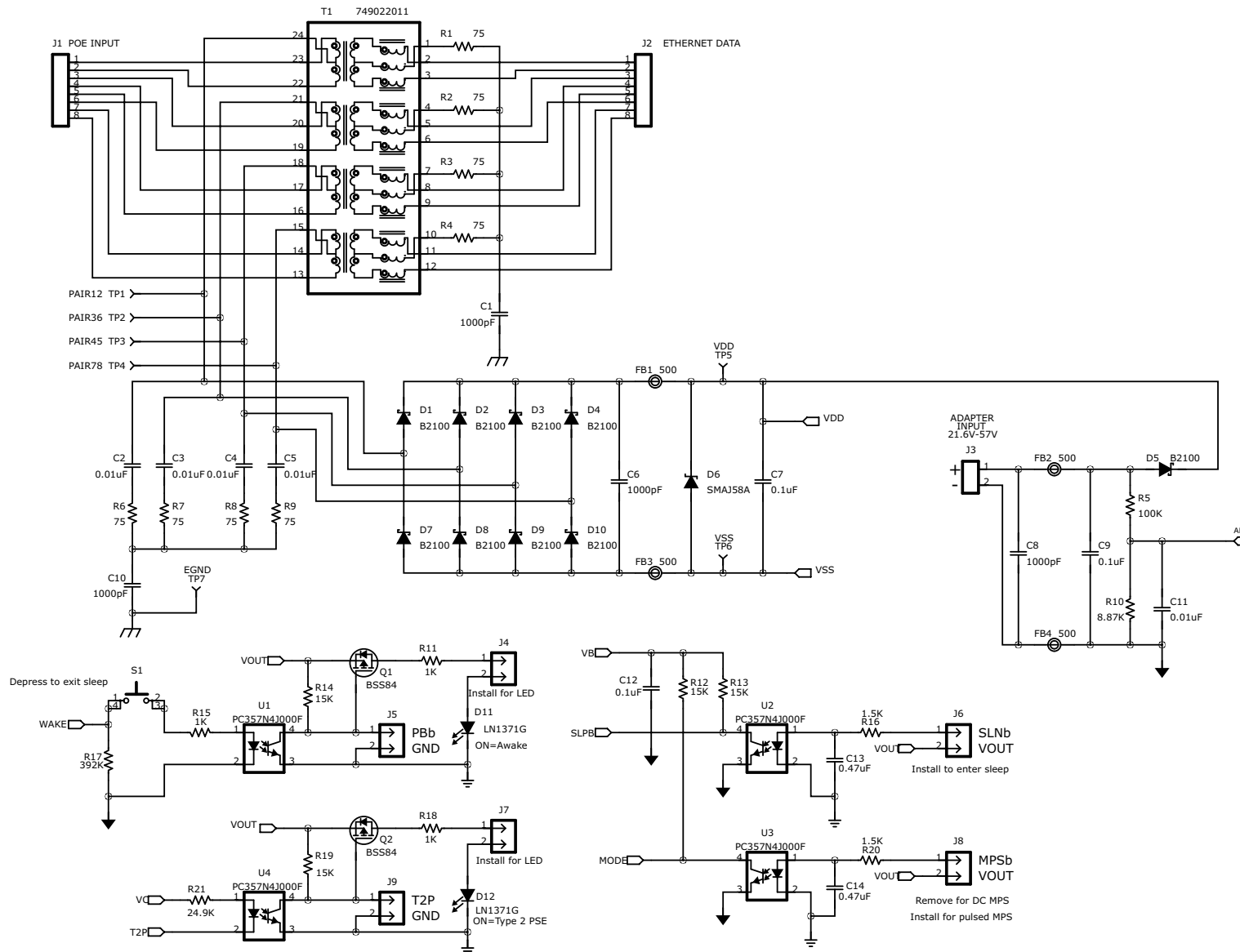


Figure 1. TPS23752EVM-145 Schematic

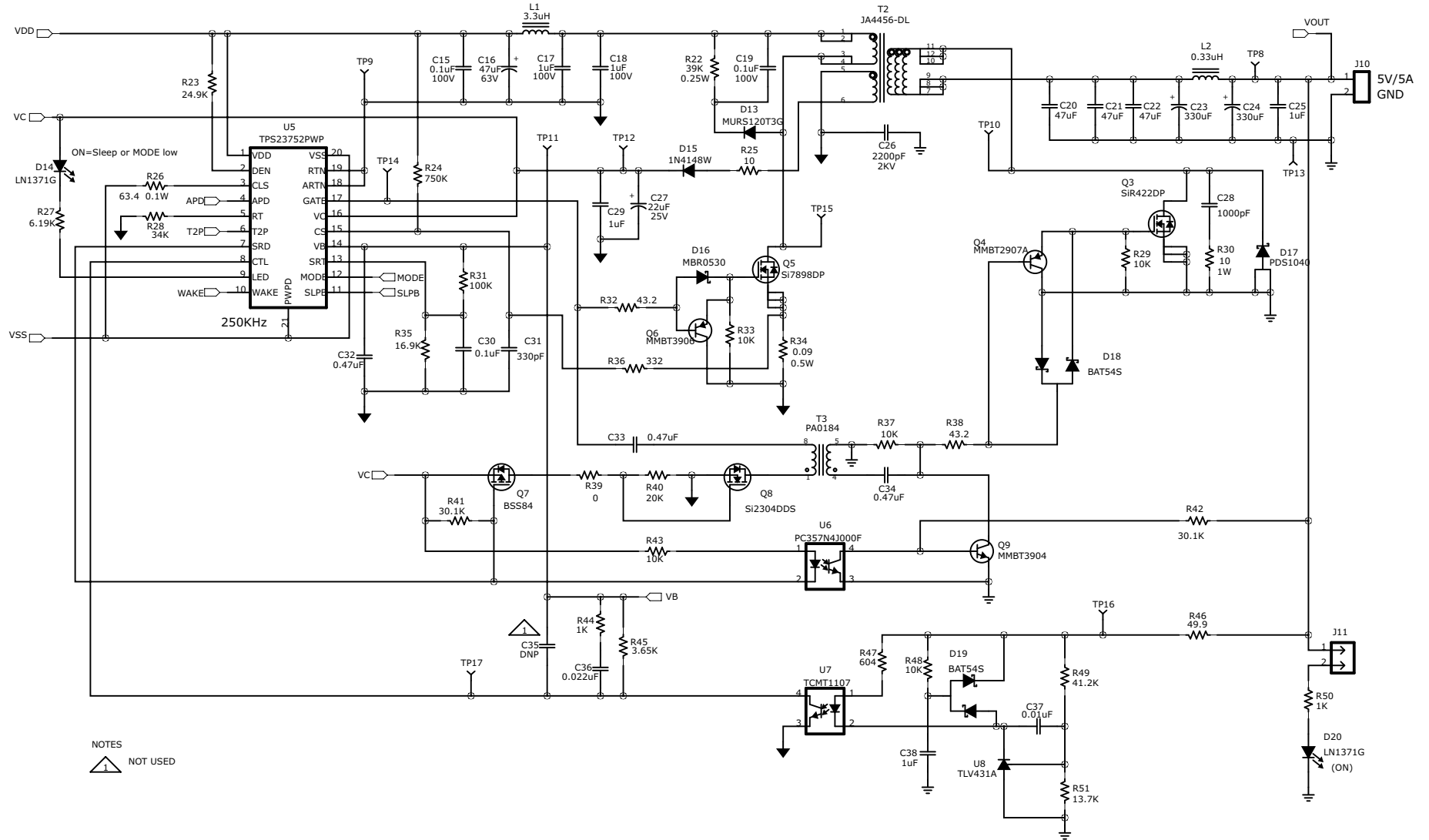


Figure 2. TPS23752EVM-145 Schematic (2)

5 General Configuration and Description

5.1 Physical Access

Table 2 lists the EVM connector functionality, Table 3 describes the test point availability, and Table 4 describes the jumper functionality.

Table 2. Connector Functionality

Connector	Label	Description
J1	PWR + DATA	Power over ethernet (POE) input. Connect to power-sourcing equipment (PSE) power and data source.
J2	DATA	Ethernet data pass through. Connect to downstream Ethernet device.
J5	WAKE	Low voltage on pin 1 with respect to pin 2 indicates that S1 is being depressed.
J6	SLP	Momentarily shorting pin 1 to pin 2 causes the TPS23752 to enter sleep mode
J8	MODE	Install a shunt on J8 while J6 is shorted to enable pulsed maintain power signature (MPS). Remove shunt from J8 while J6 is shorted, enabling DC MPS.
J9	T2P	Low voltage on pin 1 with respect to pin 2 indicates that a type 2 PSE or an adapter is present
J10	OUTPUT	Output connector to load.
S1	WAKE	Depressing S1 when the TPS23752 is in sleep mode restarts the dc/dc converter.
D11 (GRN)	WAKE	D11 is ON when S1 is depressed and held
D12 (GRN)	T2P	T2P (type 2 PSE) LED. When ON this indicates that a type 2 PSE or an adapter is present.
D20 (GRN)	OUTPUT	TPS23752 output powered.
D14 (GRN)	D14	Sleep mode status indicator. D14 is ON when TPS23752 is in sleep mode or when a shunt is installed on J8

Table 3. Test Points

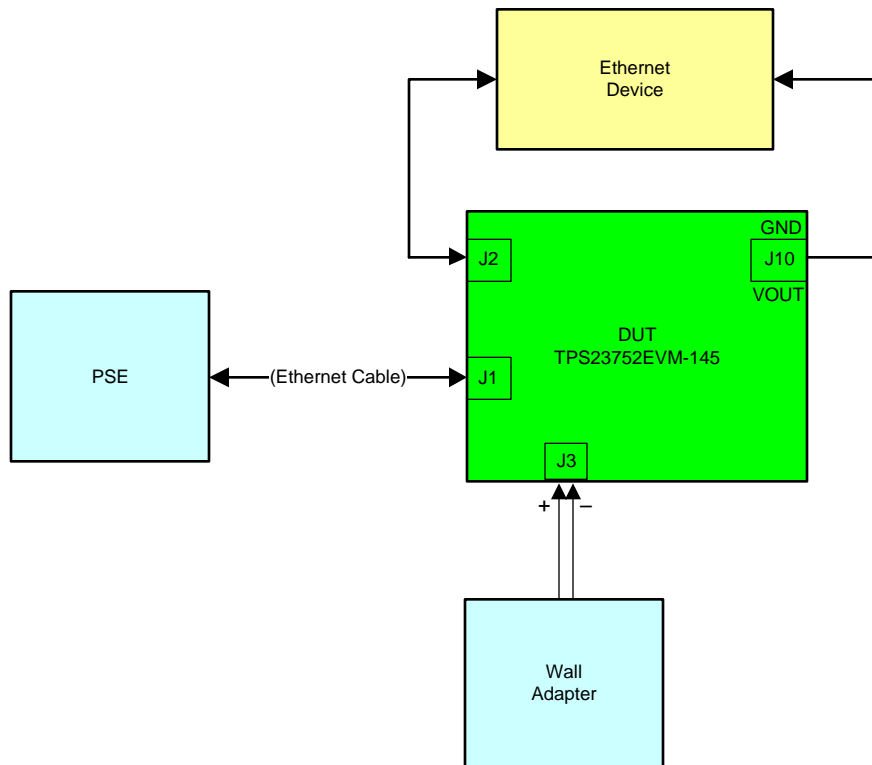
Test Point	Color	Label	Description
TP1	RED	PAIR12	Data pair from pins 1 and 2 of J1
TP2	ORG	PAIR36	Data pair from pins 3 and 6 of J1
TP3	RED	PAIR45	Spare pair from pins 4 and 5 of J1
TP4	ORG	PAIR78	Spare pair from pins 7 and 8 of J1
TP5	RED	VDD	High-side output from bridge
TP6	BLK	VSS	Low-side output from bridge
TP8	RED	VOUT	Converter output voltage with respect to TP13
TP9	BLK	RTN	Switched low side from TPS23752
TP10	ORG	SDRN	Secondary side switching waveform
TP11	RED	VB	TPS23752 5-V bias voltage
TP12	RED	VC	TPS23752 12-V auxiliary input voltage
TP13	BLK	GND	Converter output ground with respect to TP8
TP14	WHT	GATE	TPS23752 GATE drive output
TP15	ORG	DRN	Primary side switching waveform
TP16	ORG	LOOP	Feedback loop injection point, use with TP8 and TP13
TP17	WHT	CTL	CTL pin input to TPS23752
TP7	SM	EGND	Earth or chassis ground point

Table 4. Jumpers

Jumper	Label	Description
J4	J4	D11 LED bias jumper. Installing enables WAKE LED.
J7	J5	D12 LED bias jumper. Installing enables T2P LED. Shunt may be removed when making efficiency measurements.
J11	J11	D20 LED bias jumper. Installing enables OUTPUT LED. Shunt may be removed when making efficiency measurements.

5.2 Test Setup

Figure 3 shows a typical test setup for the EVM. Connect J1 to the power sourcing equipment (PSE). Power for the Ethernet device is available at J10 and the pass-through Ethernet data is available at J2.


Figure 3. Typical TPS23752EVM-145 Test Setup

6 TPS23752EVM-145 Performance Data

6.1 Efficiency

Figure 4, Figure 5, and Figure 6 illustrate the efficiency of the EVM. Figure 4 efficiency is measured between the J1 input interface and J10 output connector while Figure 5 and Figure 6 are measured between TP5/TP6 and J10 to exclude the diode bridge and Ethernet transformer losses. Figure 6 demonstrates the light-load efficiency improvement provided by the VFO mode.

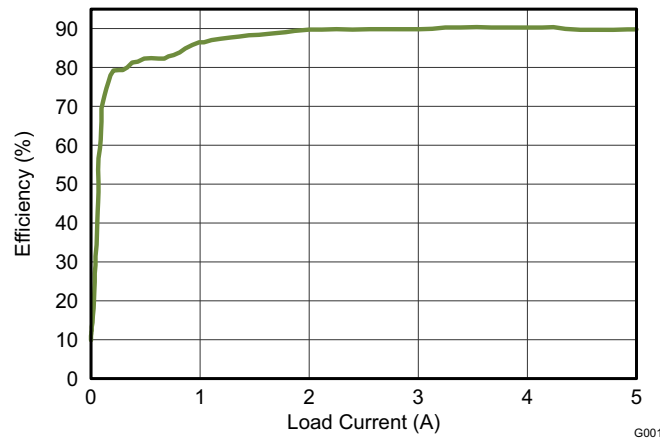


Figure 4. PoE End-End Efficiency

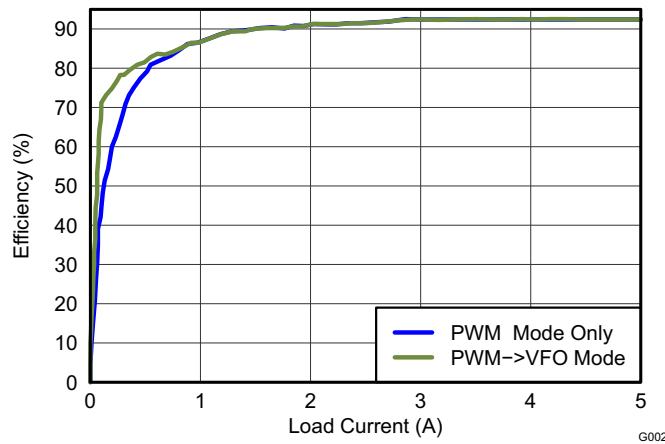


Figure 5. DC/DC Converter Efficiency

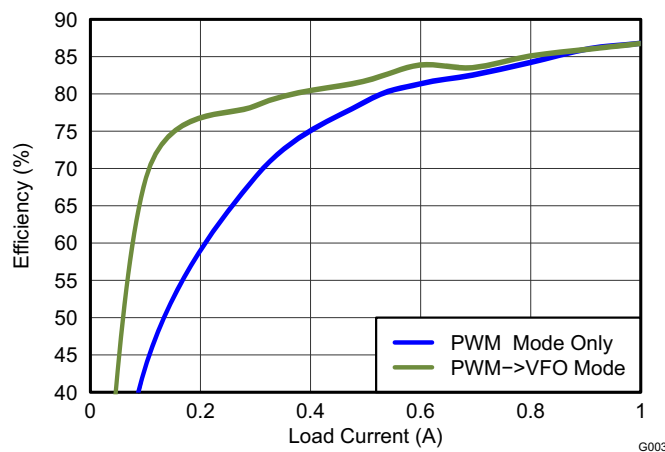


Figure 6. DC/DC Converter Light-Load Efficiency

7 EVM Assembly Drawings and Layout Guidelines

7.1 PCB Drawings

Figure 7 through Figure 12 show component placement and layout.

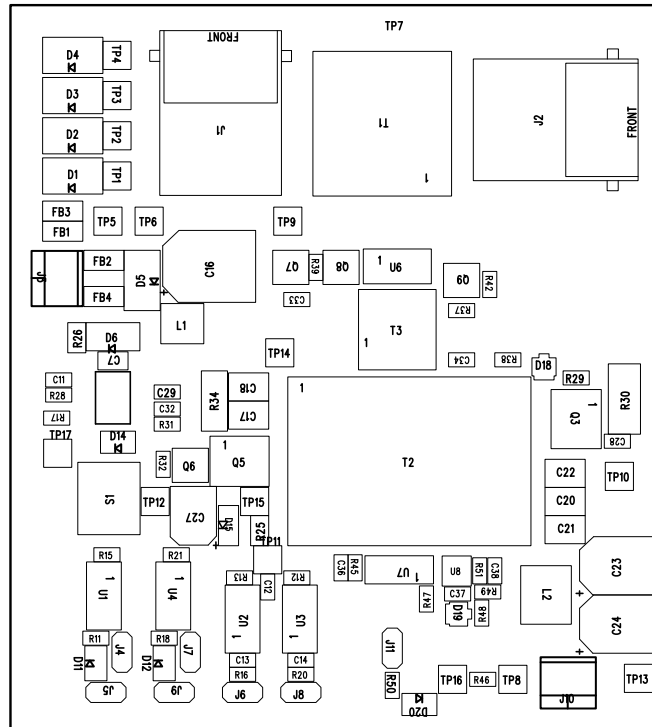


Figure 7. Top-Side Placement

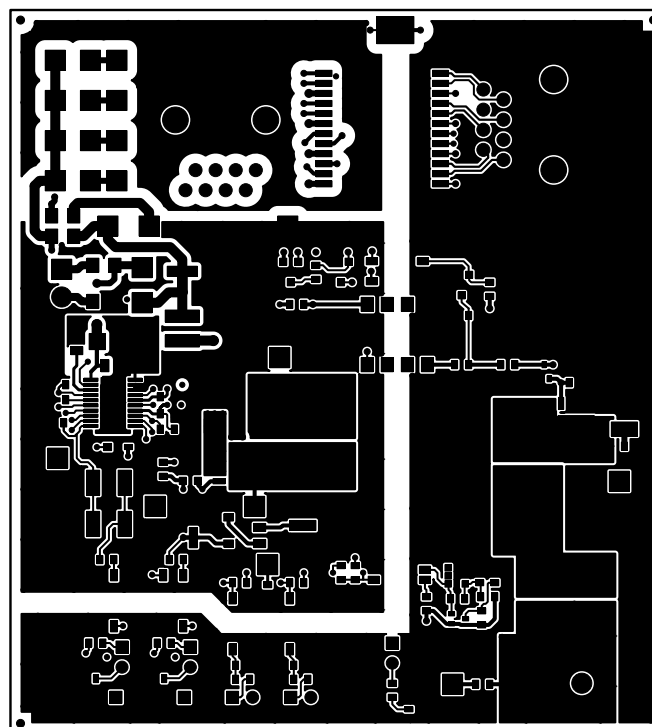


Figure 8. Top-Side Routing

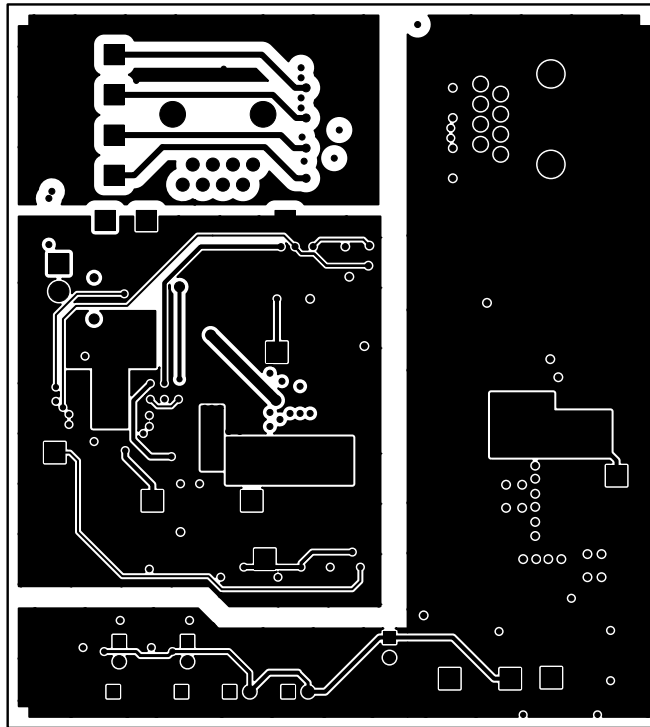


Figure 9. Layer Two Routing

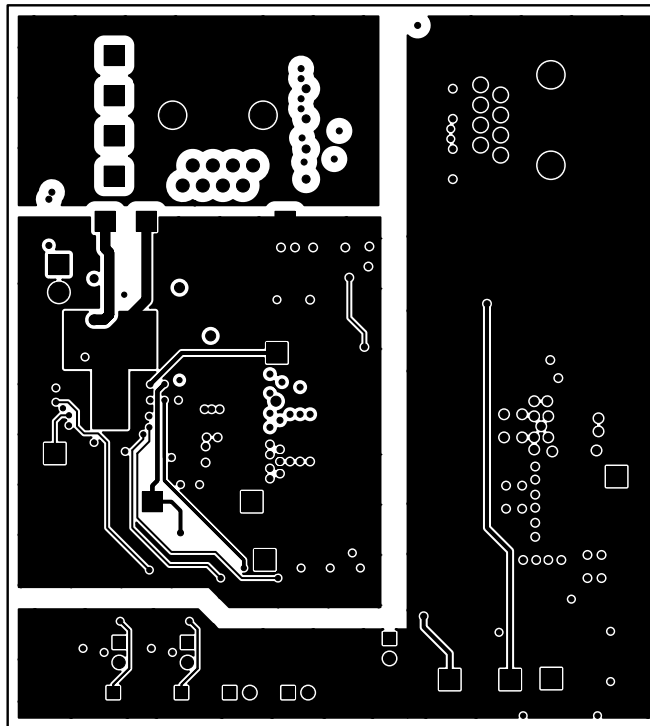


Figure 10. Layer Three Routing

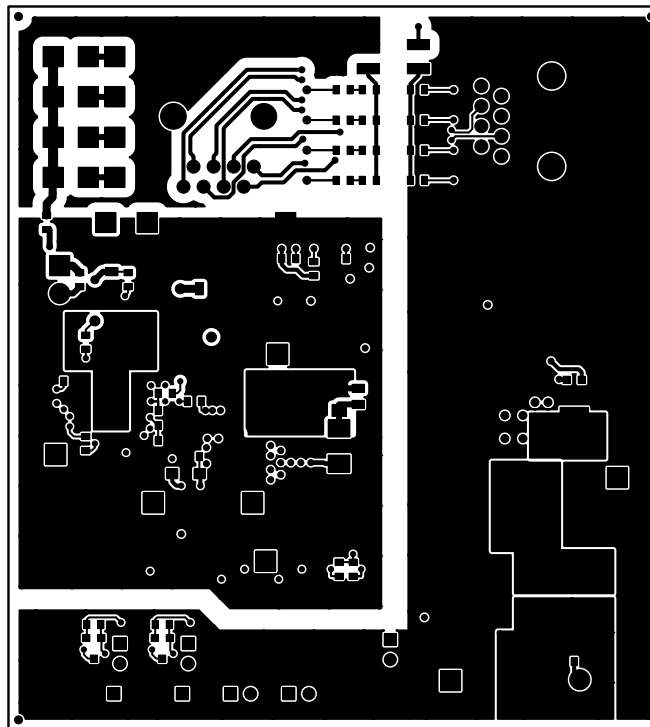


Figure 11. Bottom-Side Routing

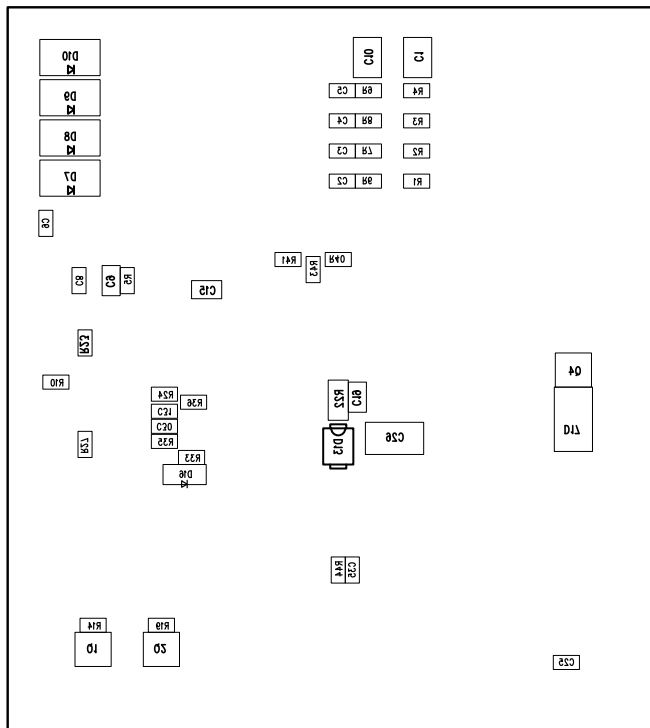


Figure 12. Bottom-Side Placement

7.2 Layout Guidelines

Follow power and EMI/ESD best practice guidelines for the layout of the PoE front end. A basic set of recommendations include:

- Parts placement must be driven by power flow in a point-to-point manner; RJ-45, Ethernet transformer, diode bridges, TVS and 0.1- μ F capacitor, and TPS23752 converter input bulk capacitor.
- Make all leads as short as possible with wide power traces and paired signal and return.
- No crossovers of signals are allowed from one part of the flow to another.
- Observe spacing consistent with safety standards, like IEC60950, between the 48-V input voltage rails and between the input and an isolated-converter output.
- Place the TPS23752 over split, local ground planes referenced to VSS for the PoE input and to RTN for the converter. Whereas the PoE side may operate without a ground plane, the converter side must have one. Make sure no logic ground and power layers are present under the Ethernet input or the converter primary side.
- Use large copper fills and traces on SMT power-dissipating devices, and use wide traces or overlay copper fills in the power path.

The DC/DC Converter layout benefits from basic rules, such as:

- Pair signals, reducing emissions and noise, especially the paths that carry high-current pulses which include the power semiconductors and magnetics.
- Minimize the trace length of high current, power semiconductors, and magnetic components.
- Use vertical pairing, where possible.
- Use the ground plane for the switching currents carefully.
- Keep the high-current and high-voltage switching away from low-level sensing circuits, including those outside the power supply.
- Maintain proper spacing around the high-voltage sections of the converter.

7.3 EMI Containment

- Use compact loops for dv/dt and di/dt circuit paths (power loops and gate drives)
- Use minimal, yet thermally adequate, copper areas for heat sinking of components tied to switching nodes (minimize exposed radiating surface).
- Use copper-ground planes (possible stitching) and top-layer copper floods (surround circuitry with ground floods)
- Use 4-layer PCB, if economically feasible (for better grounding)
- Minimize the amount of copper area associated with input traces (minimizing radiated pickup)
- Hide copper associated with switching nodes under shielded magnetics, where possible
- Heat sink the *quiet side* of components instead of the *switching side*, where possible (like the output side of inductor)
- Use Bob Smith terminations, Bob Smith EFT capacitor, and Bob Smith plane
- Use Bob Smith plane as a ground shield on the input side of the PCB (creating a phantom or literal earth ground)
- Use an LC filter at the DC/DC input
- Dampen high frequency ringing on all switching nodes, if present (allow for possible snubbers)
- Control rise times with gate-drive resistors and possibly snubbers
- Switching frequency considerations
- Use an EMI bridge capacitor across isolation boundary (isolated topologies)
- Observe the polarity dot on inductors (embed noisy end)
- Use ferrite beads on input (allow for possible use of beads or 0-Ω resistors)
- Maintain physical separation between input-related circuitry and power circuitry (use ferrite beads as boundary line)
- Balance efficiency vs acceptable noise margin
- Possible use of common-mode inductors
- Possible use of integrated RJ-45 jacks (shielded with internal transformer and Bob Smith terminations)
- End-product enclosure considerations (shielding)

8 Bill of Materials
Table 5. TPS23752EVM-145 Bill of Materials

COUNT	REFDES	VALUE	DESCRIPTION	SIZE	PART NUMBER	SUPPLIER
2	C1, C10	1000 pF	Capacitor, ceramic, 2 kV, X7R, 15%	1210	Std	STD
2	C12, C30	0.1 µF	Capacitor, ceramic, 25 V, X7R, 10%	603	Std	Std
5	C13-14, C32-34	0.47 µF	Capacitor, ceramic, 16 V, X7R, 10%	603	STD	Std
1	C16	47 µF	Capacitor, Aluminum, 63 V, ±20%	0.328 x 0.390 in	EEE-FK1J470P	Panasonic
2	C17-18	1 µF	Capacitor, ceramic, 100 V, X7R, 10%	1210	Std	STD
3	C20-22	47 µF	Capacitor, ceramic, 10 V, X5R, 15%	1210	Std	Std
2	C23-24	330 µF	Capacitor, aluminum, 6.3 V, 20%	0.260 x 0.276 in	EEE-FK0J331XP	Panasonic
6	C2-5, C11, C37	0.01 µF	Capacitor, ceramic, 100 V, X7R, 10%	603	STD	STD
2	C25, C38	1 µF	Capacitor, ceramic, 16 V, X7R, 10%	603	STD	Std
1	C26	2200 pF	Capacitor, ceramic, 2 kV, X7R, 15%	1812	Std	Std
1	C27	22 µF	Capacitor, Aluminum, 25 V, 20%	5 x 5.8 mm	EEE-FK1E220R	Panasonic
1	C29	1 µF	Capacitor, ceramic, 25 V, X7R, 10%	603	STD	Std
1	C31	330 pF	Capacitor, ceramic, 50 V, C0G, 10%	603	STD	Std
0	C35	0.1 µF	Capacitor, ceramic, 50 V, X7R, 10%	603	STD	Std
1	C36	0.022 µF	Capacitor, ceramic, 50 V, X7R, 10%	603	STD	Std
3	C6, C8, C28	1000 pF	Capacitor, ceramic, 100 V, X7R, 10%	603	STD	STD
4	C7, C9, C15, C19	0.1 µF	Capacitor, Ceramic, 100 V, X7R, 10%	805	STD	STD
4	D11-12, D14, D20	LN1371G	Diode, LED, Green, 10 mA, 2.6 mcd	0.114 x 0.049 in	LN1371G	Panasonic
1	D13	MURS120T3G	Diode, ultra-fast rectifier, 1 A, 200 V	SMB	MURS120T3G	On Semi
1	D15	1N4148W-7-F	Diode, signal, 300 mA, 75 V, 350 mW	SOD-123	1N4148W-7-F	Diodes
9	D1-5, D7-10	B2100-13-F	Diode, Schottky, 2 A, 100 V	SMB	B2100-13-F	Diodes
1	D16	MBR0530	Diode, Schottky, 0.5 A, 30 V	SOD-123	MBR0530T1G	On Semi
1	D17	PDS1040	Diode, Schottky, 10 A, 40 V	Power DI 5	PDS1040-13	Diodes, Inc
2	D18-19	BAT54S	Diode, Dual Schottky, 200 mA, 30 V	SOT323	BAT54SWT1G	On Semi
1	D6	SMAJ58A	Diode, TVS, 58-V, 1W	SMA	SMAJ58A-13-F	Diodes
4	FB1-4	500	Bead, ferrite, 2000 mA, 60 mΩ	1206	MI1206L501R-10	Steward
2	J1-2	5520252-4	Connector, jack, modular, 8 POS	0.705 x 0.820 inch	5520252-4	AMP
2	J3, J10	ED555/2DS	Terminal block, 2 pin, 6 A, 3.5 mm	0.27 x 0.25 inch	ED555/2DS	OST
7	J4-9, J11	PEC02SAAN	Header, male 2 pin, 100 mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
1	L1	3.3uH	Inductor, SMT, 1.9 A, 80 mΩ	4 x 4 mm	LPS4018-332ML	Coilcraft
1	L2	0.33uH	Inductor, SMT, 19.2 A, 3.52 mΩ	5.3 x 5.5 mm	XAL5030-331ME	Coilcraft
3	Q1-2, Q7	BSS84	MOSFET, Pch, -50 V, -0.13 A, 10 Ω	SOT23	BSS84LT1C	Infineon
1	Q3	SiR422DP	MOSFET, NChan, 40 V, 40 A, 6.6 mΩ	PWRPAK S0-8	SIR422DP-T1-GE3	Vishay
1	Q4	MMBT2907A	Trans, PNP, 40 V, 200 mA, 225 mW	SOT23	MMBT2907ALT1G	On Semi
1	Q5	Si7898DP	MOSFET, NChannel, 150 V, 4.8 A, 85 mΩ	PWRPAK S0-8	SI7898DP-T1-E3	Vishay
1	Q6	MMBT3906	Trans, PNP, 40 V, 200 mA, 225 mW	SOT23	MMBT3906LT1G	On Semi
1	Q8	Si2304DDS	MOSFET, N-ch, 30 V, 3.6 A, 60 mΩ	SOT23	SI2304DDS	Vishay
1	Q9	MMBT3904	Trans, NPN, 40 V, 200 mA, 225 mW	SOT23	MMBT3904LT1G	On Semi

Table 5. TPS23752EVM-145 Bill of Materials (continued)

COUNT	REFDES	VALUE	DESCRIPTION	SIZE	PART NUMBER	SUPPLIER
1	R10	8.87 kΩ	Resistor, chip, 1/16W, 1%	603	STD	STD
5	R11, R15, R18, R44, R50	1 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
4	R12-14, R19	15 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
8	R1-4, R6-9	75 Ω	Resistor, chip, 1/16W, 1%	603	STD	STD
2	R16, R20	1.5 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R17	392 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R21	24.9 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R22	39 kΩ	Resistor, chip, 1/4W, 5%	1206	Std	Std
1	R23	24.9 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R24	750 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R25	10 Ω	Resistor, chip, 1/10W, 5%	805	STD	STD
1	R26	63.4 Ω	Resistor, chip, 1/10W, 1%	805	Std	Std
1	R27	6.19 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R28	34 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
4	R29, R33, R37, R48	10 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R30	10 Ω	Resistor, chip, 1W, 5%	2512	Std	Std
2	R5, R31	100 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
2	R32, R38	43.2 Ω	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R34	0.09 Ω	Resistor, chip, 1/2W, 1%	2010	Std	Std
1	R35	16.9 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R36	332 Ω	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R39	0 Ω	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R40	20 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
2	R41, R42	30.1 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R43	10 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R45	3.65 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R46	49.9 Ω	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R47	604 Ω	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R49	41.2 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	R51	13.7 kΩ	Resistor, chip, 1/16W, 1%	603	STD	Std
1	S1	KT11P2JM34LFS	Switch, SPST, PB Momentary, Sealed Washable	0.245 x 0.251 in	KT11P2JM34LFS	C & K
1	T1	749022011 or H6096NL	PoE Plus Gigabit Ethernet Transformer	S024	749022011 or H6096NL	Würth Electronics or Pulse
1	T2	JA4456-DL	Transformer, SMT For PoE/PD, 25 W, 2.8 A	0.810 x 1.181 in	JA4456-DL	Coilcraft
1	T3	PA0184	XFMR, SMT gate drive	0.355 x 0.340 in	PA0184NL	Pulse
6	TP1, TP3, TP5, TP8, TP11-12	5010	Test point, red, thru hole	0.125 x 0.125 in	5010	Keystone
2	TP14, TP17	5012	Test point, white, thru hole	0.125 x 0.125 in	5012	Keystone

Table 5. TPS23752EVM-145 Bill of Materials (continued)

COUNT	REFDES	VALUE	DESCRIPTION	SIZE	PART NUMBER	SUPPLIER
5	TP2, TP4, TP10, TP15-16	5013	Test point, orange, thru hole	0.125 x 0.125 in	5013	Keystone
3	TP6, TP9, TP13	5011	Test point, black, thru hole	0.125 x 0.125 in	5011	Keystone
1	TP7	5016	Test point, SM, 0.150 x 0.090	0.185 x 0.135 in	5016	Keystone
5	U1-4, U6	PC357N4J000F	Photocoupler, 300-600% CTR, 3.75 kV isolation	MF4	PC357N4J000F	Sharp
1	U5	TPS23752PWP	IC, IEEE 802.3 AT PoE interface & green mode DC-DC controller	HTSSOP	TPS23752PWP	TI
1	U7	TCMT1107	IC, photocoupler, 3750 VRMS, 80-160% CTR	MF4	TCMT1107	Vishay
1	U8	TLV431A	IC, shunt regulator, 6 V, 10 mA, 1%	SOT23-5	TLV431ACDBVR	TI
3	--		Shunt, black	100-mil	STC02SYAN	Sullins Connector Solutions
1	--		PCB, 3.5 in x 1.7 in x 0.062 in		PWR145	Any

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 this Product 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>

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2. 実験局の免許を取得後ご使用いただく。
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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 2 4 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. 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.

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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.

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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 this Product in Japan】

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

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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.

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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

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

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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. 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.

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TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

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