User's Guide

TPS23731EVM-095 Evaluation Module

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ABSTRACT

This user's guide describes the TPS23731 evaluation module (EVM). The TPS23731 evaluation module (TPS23731EVM-095) contains evaluation and reference circuitry for the TPS23731, which is a IEEE802.3bt Class 4 PoE PD, EA Gen 2 Ready, controller suitable for Class 4 (25.5 W) PoE PD applications. The TPS23731EVM-095 is targeted for 5-V primary side regulated synch flyback with high efficiency 25-W solutions.

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Trademarks

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1 Introduction

The TPS23731EVM-095 allows reference circuitry evaluation of the TPS23731 device. It contains input and output power connectors and an array of onboard test points for circuit evaluation.

1.1 Features

- IEEE802.3bt Class 4 compliant PoE PD
- Integrated PWM controller for active clamp forward configuration
- Frequency dithering for EMI reduction
- Soft-start control with advanced startup and Hiccup mode overload protection
- Soft-stop shutdown

1.2 Applications

- IEEE 802.3bt compliant devices up to Class 4
- Video and VoIP telephones
- Access points
- Pass-through system
- Security cameras

2 Electrical Specifications

Table 2-1. TPS23731EVM-095 Electrical and Performance Specifications at 25°C

Design Example Specifications					
Parameter	**Test Conditions**	**MIN**	**TYP**	**MAX**	**Unit**
Power interface					
Input voltage range	Applied to the PoE Input	37	48	57	V
	Applied ot the Adapter Input		48		
Detection voltage	At device terminals	2.7		10.1	
Classification voltage	At device terminals	14.5		20.5	
Classification			4		
Inrush current limit			140		mA
Operating current limit			0.925		A
DC-to-DC Converter					
Output voltage	V_{IN} = 48 V, iload ≤ iload (MAX)		5		V
Output current	37 V ≤ V_{IN} ≤ 57 V		5		A
Output ripple voltage peak-to-peak	V_{IN} = 48 V, iload = 1 A		30		mV
Efficiency, end to end	V_{IN} = 48 V, iload = 500 mA		58		%
	V_{IN} = 48 V, iload = 2.5 A		86		
	V_{IN} = 48 V, iload = 5 A		89		
Switching frequency			250		kHz

3 Description

The TPS23731VM-095 enables full evaluation of the TPS23731 device. Refer to the schematic shown in Figure 7-1 and Figure 7-2. Ethernet power is applied from J1 and is dropped to the bridge rectifier. The Power over Ethernet (PoE) transformer needed to transfer power or data is T1. The Bob Smith Terminations help balance the Ethernet cabled impedance and are critical for ESD and EMI or EMC performance. The EMI or EMC filter and transient protection for the TPS23731 device are at the output of the bridge rectifier.

Input power can also be applied at J3 from a DC source when power at J1 is not present.

The TPS23731 (U1) PD and DC-to-DC converter circuitry is shown in Figure 1. R28 provides the detection signature. The switched side of the PD controller is to the right of U1. The TPS23731 RTN pin(s) provides inrush limited turn on and charge of the bulk capacitor, C12.

The DC-to-DC converter is a high-efficiency primary side regulated synch flyback.

R34 provides a means for error injection to measure the frequency response of the converter.

4 General Configuration and Description

4.1 Physical Access

Table 4-1 lists the EVM connector inputs. Table 4-2 describes the jumper functionality.

Table 4-1. Connector Inputs

Connector	Description
J1	PoE (Power+Data) input
J2	Data-only Ethernet
J3	Adapter input
J4	Output voltage connector

Table 4-2. Jumper Functionality

Jumper	Description
J7	APD selection. Short Pins 1 and 2 to turn OFF APD, Short Pins 2 and 3 to turn ON APD. Leave floating for input voltage related APD threshold
J14	Dithering selection. Short Pins 1 and 2 to turn OFF Dithering, Short Pins 2 and 3 to turn ON Dithering. Do NOT leave floating.
J18	Short to disable autoMPS. Float to enable autoMPS
J6	Logic or visual signal for APDO and T2P. Short Pins 1 and 2 visual LED signal, Short Pins 2 and 3 to use a logic voltage signal.
J11	Short to bypass the output inductor (recommended).
J15	Output LED indicator

5 TPS23731EVM-095 Performance Data

5.1 Startup Response

Figure 5-1 shows the DC/DC startup response of the TPS23731EVM-095.

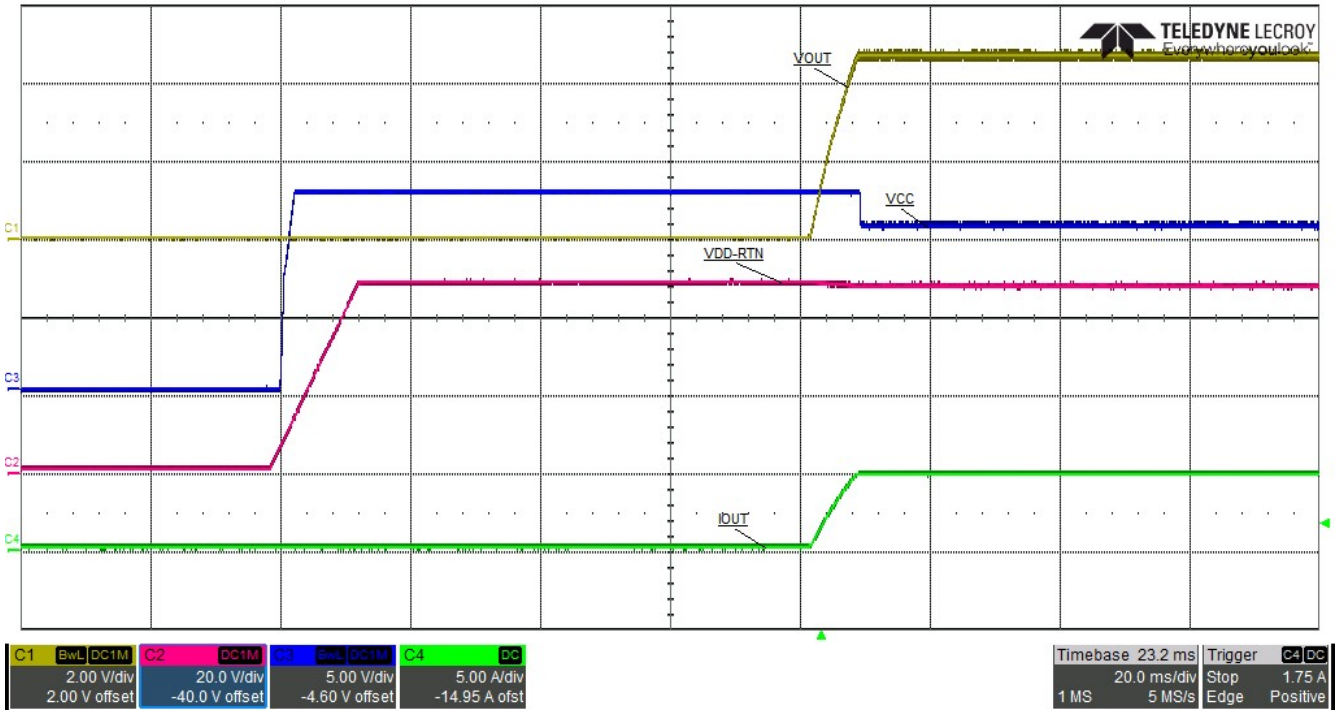

Figure 5-1. DC/DC Startup

5.2 Transient Response

Figure 5-2 shows the transient response of the TPS23731EVM-095.

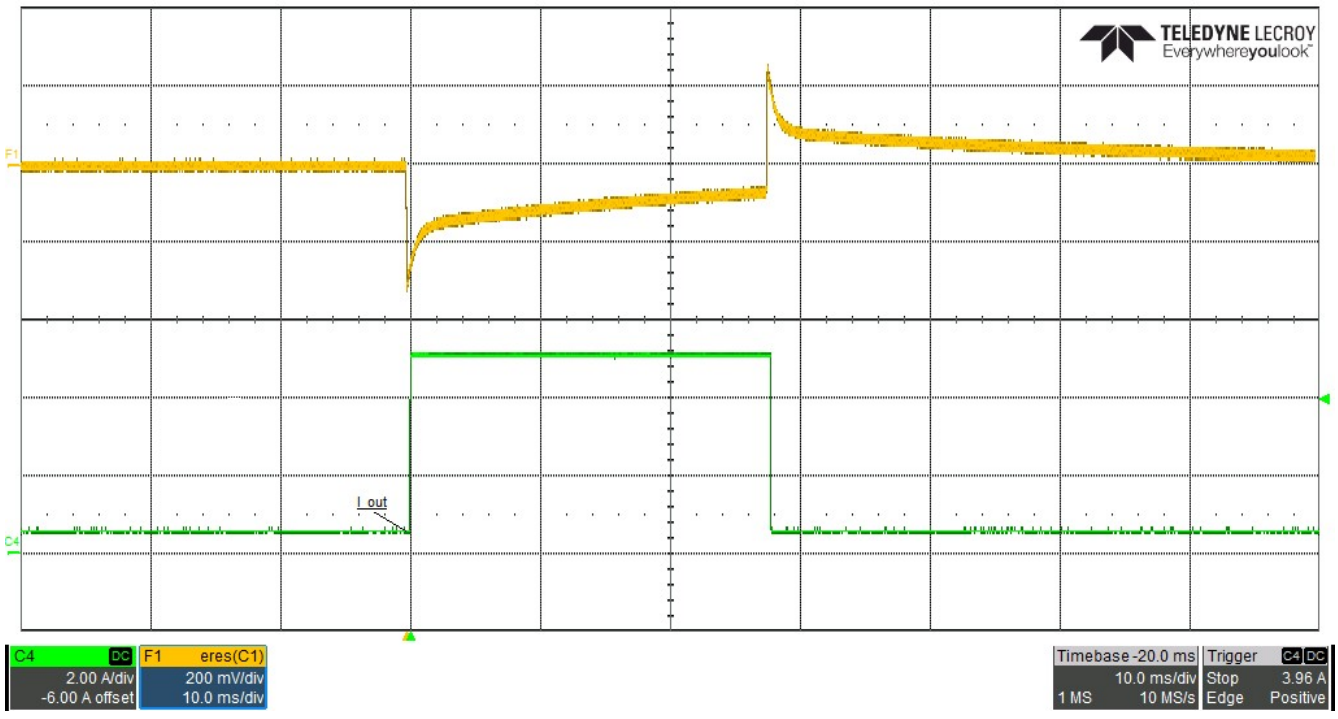

Figure 5-2. Transient Response from 500 mA to 5 A for a 48-V Input

5.3 Efficiency

Figure 5-3 shows the efficiency of the TPS23731EVM-095

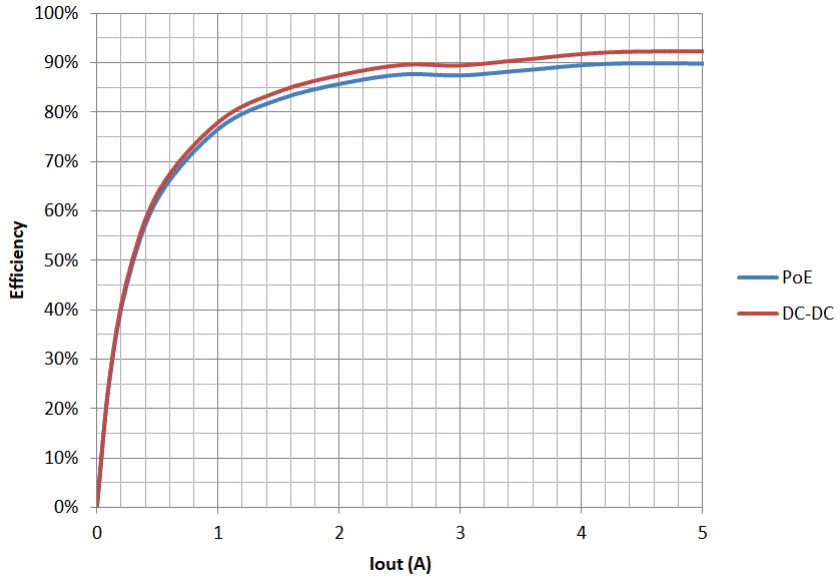

Figure 5-3. Efficiency of the TPS23731EVM-095

5.4 Load Regulation

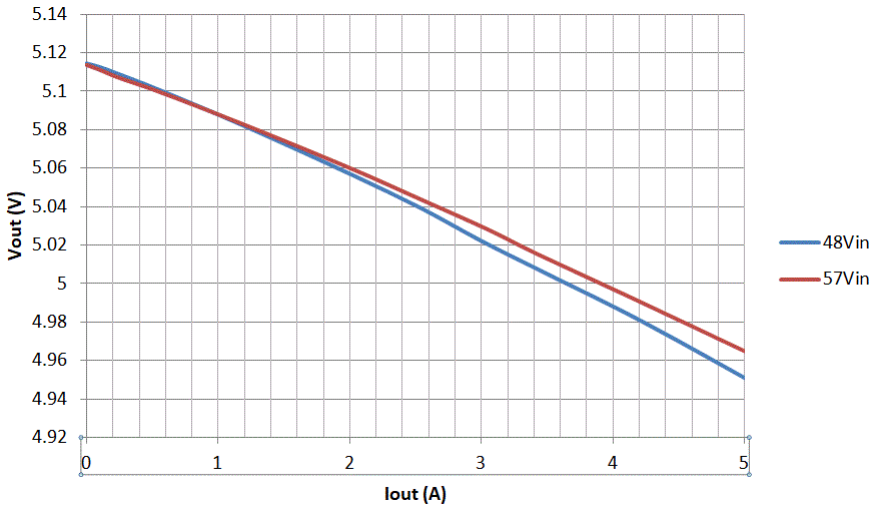

Figure 5-4. TPS23731EVM-095 Load Regulation

5.5 Hiccup Performance During an Output Short and Recovery

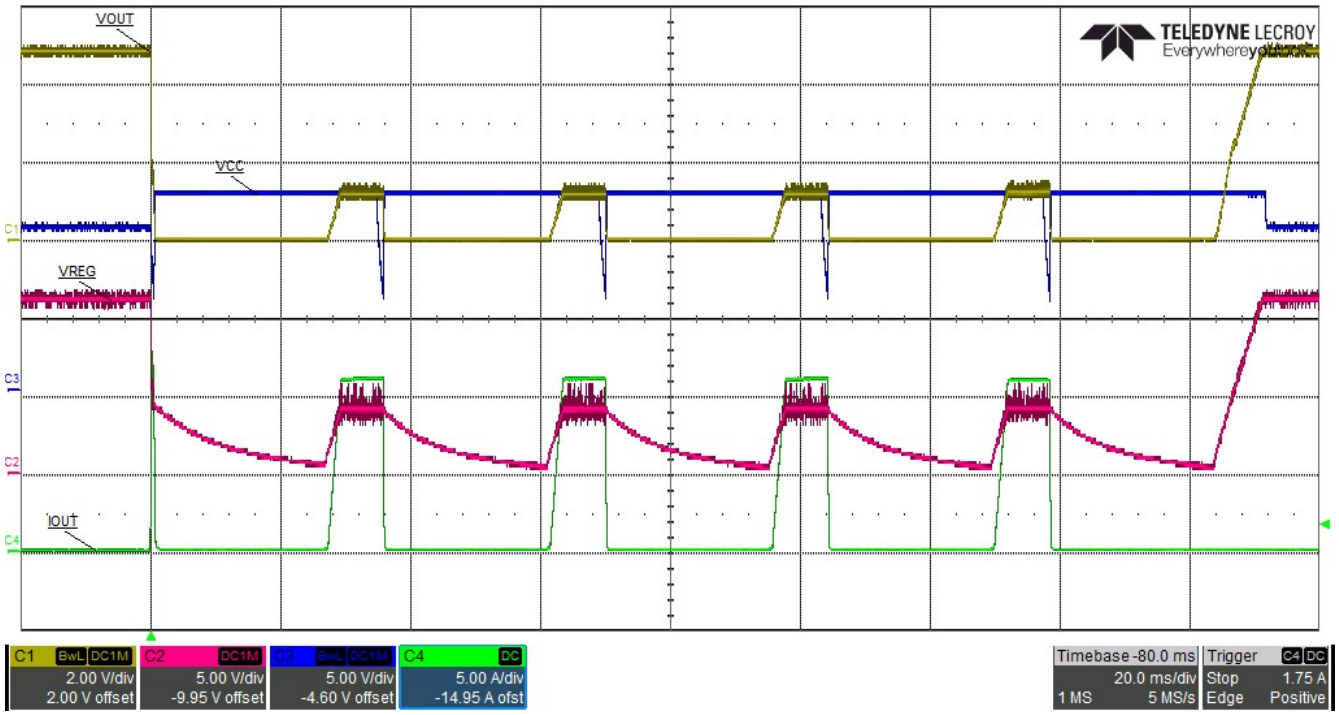

Figure 5-5. DC/DC Hiccup Performance During an Output Short

5.6 Bode Plots

Figure 5-6 show the 500mA- and 5-A load bode plots.

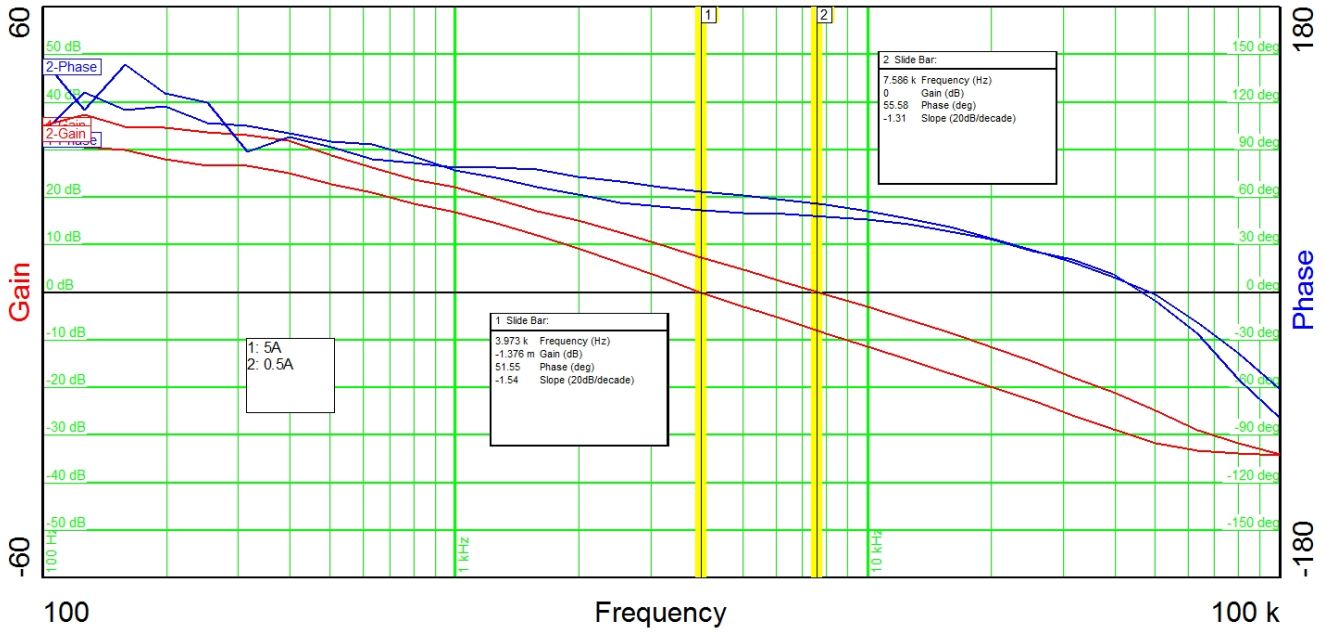

Figure 5-6. Bode Plot Response of the TPS23731EVM-095

6 EVM Assembly Drawings and Layout Guidelines

6.1 PCB Drawings

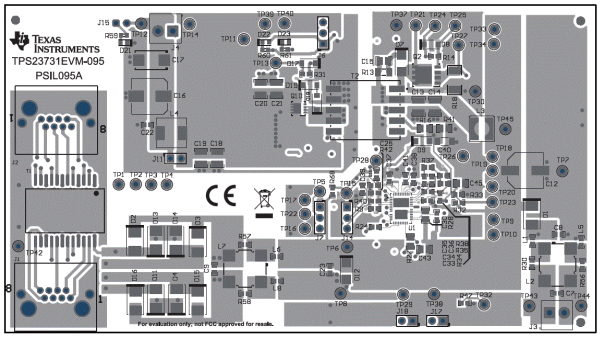

Figure 6-1. Top-Side Routing and Component Placement

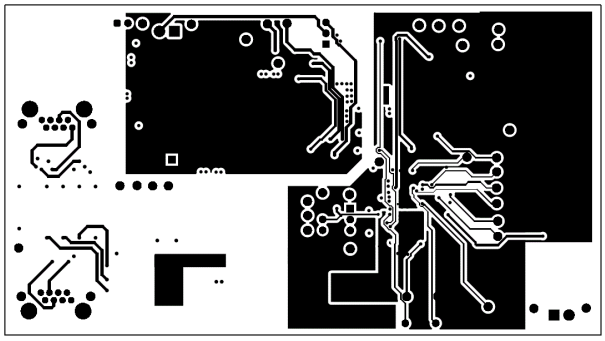

Figure 6-2. Layer 2 Routing

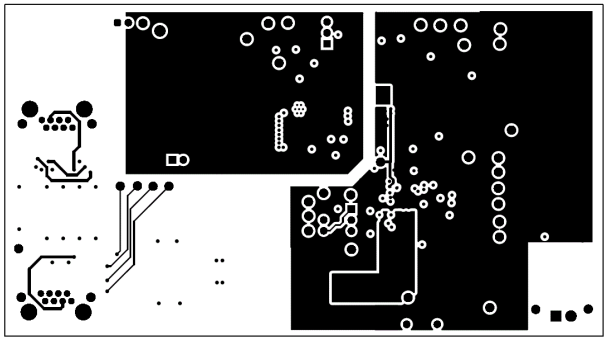

Figure 6-3. Layer 3 Routing

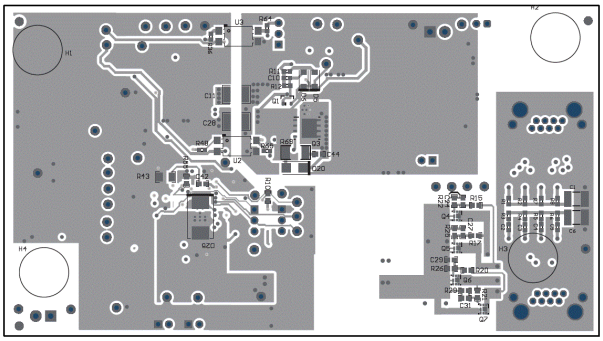

Figure 6-4. Bottom Side Routing and Component Placement

6.2 Layout Guidelines

The layout of the PoE front end should follow power and EMI or ESD best-practice guidelines. A basic set of recommendations includes:

- It is recommended having at least 8 vias (PAD G) and 5 vias on (PAD S) connecting the exposed thermal pad through a top layer plane (2 oz copper recommended) to a bottom VSS plane (2 oz. copper recommended) to help with thermal dissipation.
- Place the primary MOSFET near the power transformer and keep the current sense resistor close to source of the MOSFET to minimize the primary loop. The same is true for the secondary MOSFETs. Keep the MOSFETs close to the transformer, and associated components as close together as possible to minimize the loop.
- Parts placement must be driven by power flow in a point-to-point manner; RJ-45, Ethernet transformer, diode bridges, TVS and 0.1-µF capacitor, and TPS23731 converter input bulk capacitor.
- Make all leads as short as possible with wide power traces and paired signal and return.
- No crossovers of signals from one part of the flow to another are allowed.
- Spacing consistent with safety standards like IEC60950 must be observed between the 48-V input voltage rails and between the input and an isolated converter output.
- Use large copper fills and traces on SMT power-dissipating devices, and use wide traces or overlay copper fills in the power path.
- Place the Schotty diode between VSS and RTN as close to the IC as possible, preferably on directly on the opposite side of the board (ex. The TPS23731EVM-095 places the IC on the top side, so the diode is on the bottom side directly underneath it).

The DC-to-DC converter layout benefits from basic rules such as:

- Having at least 4 vias (VDD) near the power transformer pin connected to VDD through multiple layer planes to help with thermal dissipation of the power transformer.
- Pair signals to reduce 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 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
- Proper spacing around the high-voltage sections of the converter

6.3 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). Hide copper associated with switching nodes under shielded magnetics, where possible
- Use copper ground planes (possible stitching) and top-layer copper floods (surround circuitry with ground floods)
- Use a 4-layer PCB, if economically feasible (for better grounding)
- Minimize the amount of copper area associated with input traces (to minimize radiated pickup)
- 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 input side of PCB (creating a phantom or literal earth ground)
- Use LC filter at DC-to-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 of EMI bridge capacitor across isolation boundary (isolated topologies)
- Observe the polarity dot on inductors (embed noisy end)
- Use of 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 versus 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)

7 Schematic

Figure 7-1 and Figure 7-2 illustrate the EVM schematics.

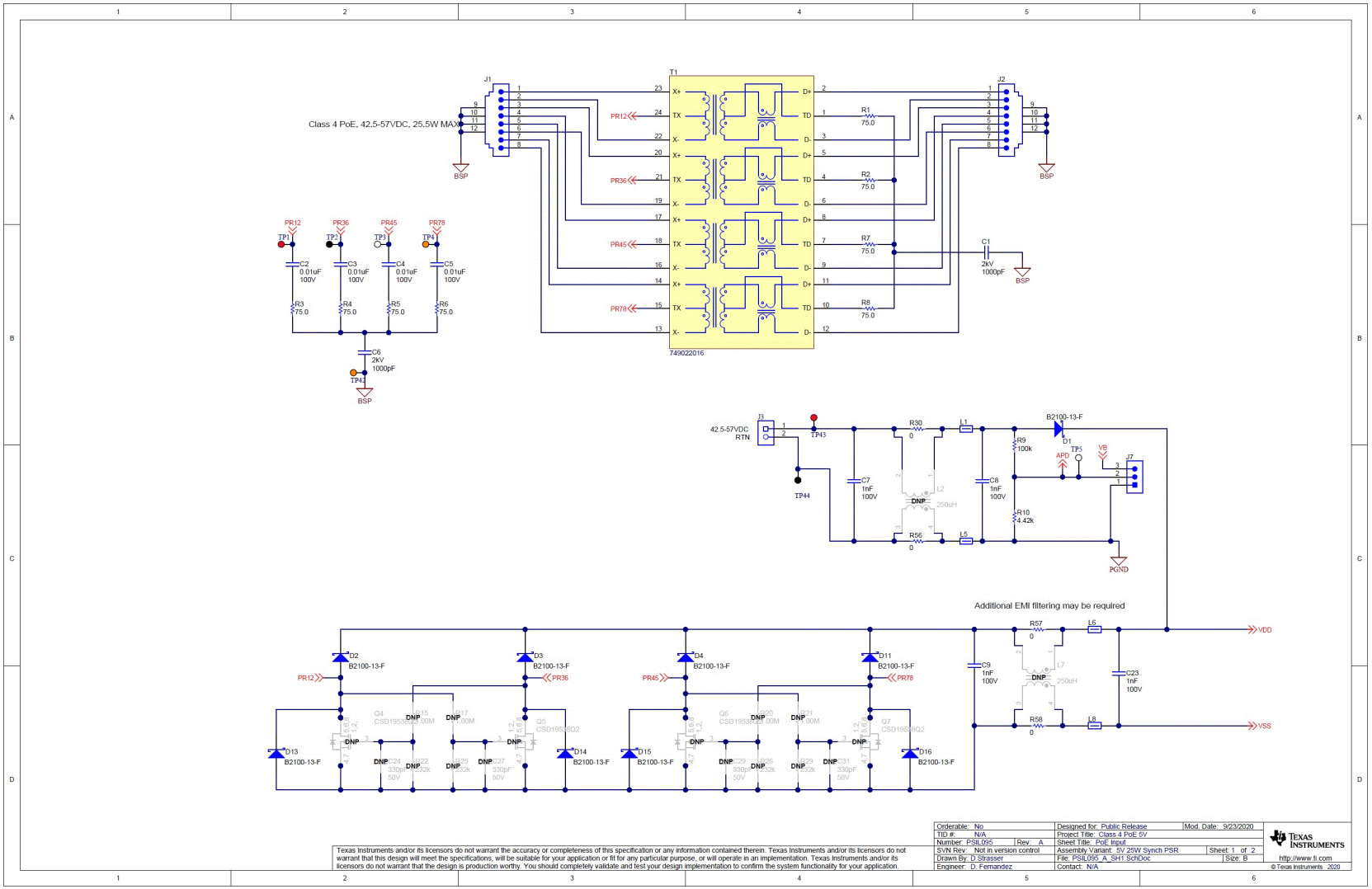

Figure 7-1. TPS23731EVM-095 Schematic Page One

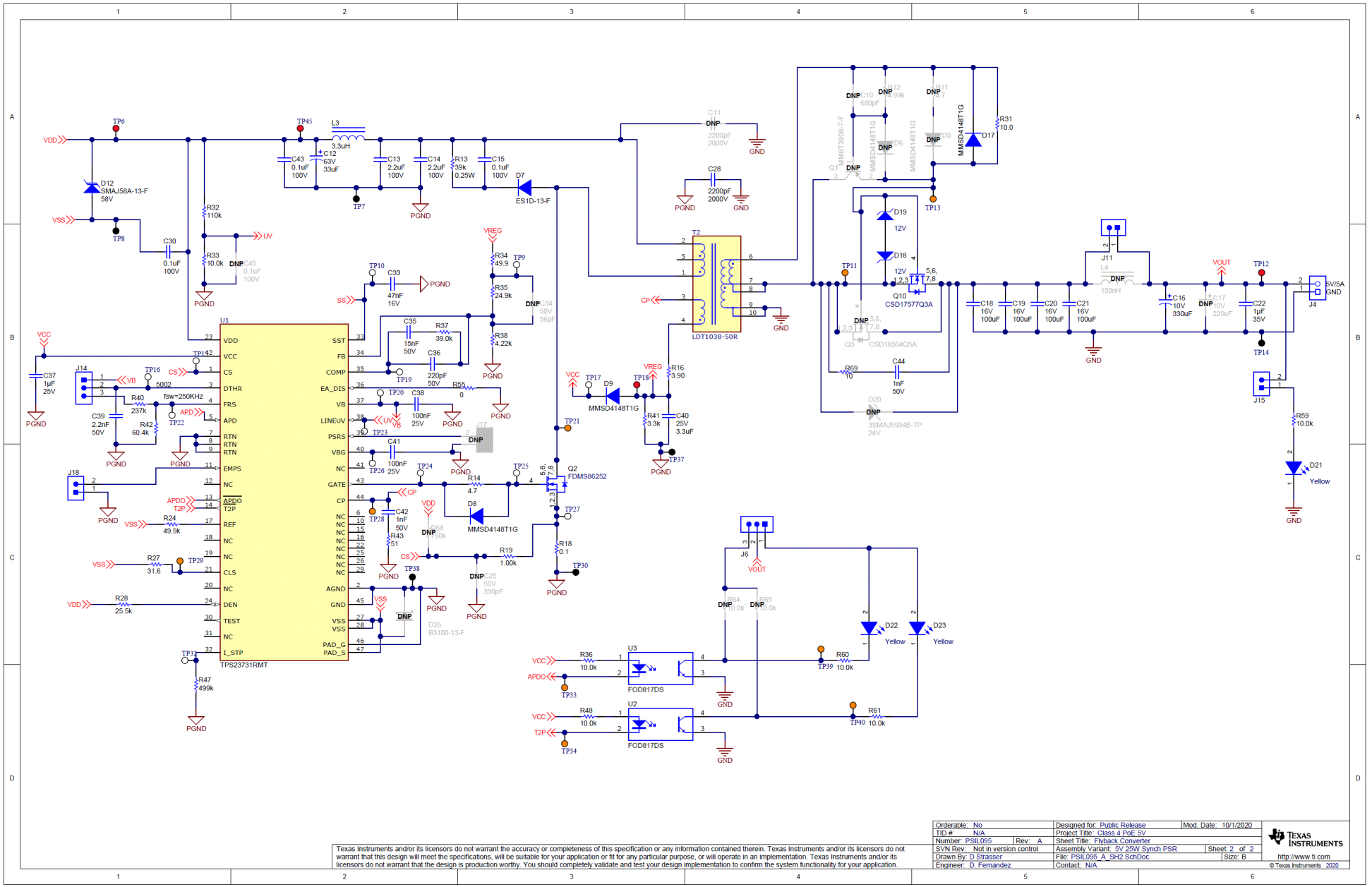

Figure 7-2. TPS23731EVM-095 Schematic Page Two

8 Bill of Materials

Table 8-1 lists the TPS23731EVM-095 Bill of Materials (BOM).

Table 8-1. TPS23731EVM-095 Bill of Materials

Designator	QTY	Value	Description	PackageReference	PartNumber	Manufacturer
!PCB1	1		Printed Circuit Board		PSIL095	Any
C1, C6	2	1000pF	CAP, CERM, 1000 pF, 2000 V, +/- 10%, X7R, 1812	1812	GR443QR73D102KW01L	MuRata
C2, C3, C4, C5	4	0.01uF	CAP, CERM, 0.01 uF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A103KA01D	MuRata
C7, C8, C9, C23	4	1000pF	CAP, CERM, 1000 pF, 100 V, +/- 10%, X7R, 0603	0603	C1608X7R2A102K080AA	TDK
C12	1	33uF	CAP, AL, 33 uF, 63 V, +/- 20%, 0.65 ohm, AEC-Q200 Grade 2, SMD	SMT Radial F	EEE-FK1J330P	Panasonic
C13, C14	2	2.2uF	CAP, CERM, 2.2 uF, 100 V, +/- 10%, X7R, 1210	1210	GRM32ER72A225KA35L	MuRata
C15, C30, C43	3	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 0805	0805	C2012X7R2A104K125AA	TDK
C16	1	330uF	CAP, Aluminum Polymer, 330 uF, 10 V, +/- 20%, 0.017 ohm, 8x10 SMD	8x10	10SVP330M	Panasonic
C18, C19, C20, C21	4	100uF	CAP, CERM, 100 uF, 16 V, +/- 20%, X5R, 1210	1210	C1210C107M4PAC7800	Kemet
C22	1	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 0, 0603	0603	GMK107AB7105KAHT	Taiyo Yuden
C28	1	2200pF	CAP, CERM, 2200 pF, 2000 V, +/- 10%, X7R, 1812	1812	C4532X7R3D222K130KA	TDK
C33	1	0.047uF	CAP, CERM, 0.047 uF, 16 V, +/- 10%, X7R, 0603	0603	GRM188R71C473KA01D	MuRata
C35	1	0.015uF	CAP, CERM, 0.015 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	C1608X7R1H153K080AA	TDK
C36	1	220pF	CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H221KA01D	MuRata
C37	1	1uF	CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, 0603	0603	GRJ188R71E105KE11D	MuRata
C38, C41	2	0.1uF	CAP, CERM, 0.1 uF, 25 V, +/- 5%, X7R, 0603	0603	C0603C104J3RACTU	Kemet
C39	1	2200pF	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C222K5RAC	Kemet
C40	1	3.3uF	CAP, CERM, 3.3 uF, 25 V, +/- 10%, X7R, 1206	1206	GRM31CR71E335KA88L	MuRata
C42, C44	2	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H102KA01D	MuRata
D1, D2, D3, D4, D11, D13, D14, D15, D16	9	100V	Diode, Schottky, 100 V, 2 A, SMB	SMB	B2100-13-F	Diodes Inc.
D7	1	200V	Diode, Ultrafast, 200 V, 1 A, SMA	SMA	ES1D-13-F	Diodes Inc.
D8, D9, D17	3	100V	Diode, Switching, 100 V, 0.2 A, SOD-123	SOD-123	MMSD4148T1G	ON Semiconductor
D12	1	58V	Diode, TVS, Uni, 58 V, SMA	SMA	SMAJ58A-13-F	Diodes Inc.
D18, D19	2	12V	Diode, Zener, 12 V, 500 mW, SOD-123	SOD-123	MMSZ5242B-7-F	Diodes Inc.
D21, D22, D23	3	Yellow	LED, Yellow, SMD	LED_0603	150060YS75000	Wurth Elektronik
FID1, FID2, FID3, FID4, FID5, FID6	6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

Table 8-1. TPS23731EVM-095 Bill of Materials (continued)

Designator	QTY	Value	Description	PackageReference	PartNumber	Manufacturer
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J2	2		RJ45, No LED, tab up, R/A, TH	16.26x14.54x15.75	1-406541-1	TE Connectivity
J3, J4	2		Terminal Block, 3.5mm Pitch, 2x1, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology
J6, J7, J14	3		Header, 100mil, 3x1, Tin, TH	Header, 3x1, 100mil, TH	5-146278-3	TE Connectivity
J11, J18	2		Header, 100mil, 2x1, Tin, TH	Header, 2x1, 100mil, TH	5-146278-2	TE Connectivity
J15	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
L1, L5, L6, L8	4	300 ohm	Ferrite Bead, 300 ohm @ 100 MHz, 2 A, 0603	0603	742792641	Wurth Elektronik
L3	1	3.3uH	Inductor, Shielded Drum Core, Ferrite, 3.3 uH, 1.8 A, 0.055 ohm, SMD	WE-TPC-M1	744042003	Wurth Elektronik
Q2	1	150V	MOSFET, N-CH, 150 V, 4.6 A, PQFN08A	PQFN08A	FDMS86252	Fairchild Semiconductor
Q10	1	30V	MOSFET, N-CH, 30 V, 19 A, DNH0008A (VSONP-8)	DNH0008A	CSD17577Q3A	Texas Instruments
R1, R2, R3, R4, R5, R6, R7, R8	8	75.0	RES, 75.0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060375R0FKEA	Vishay-Dale
R9	1	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R10	1	4.42k	RES, 4.42 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034K42FKEA	Vishay-Dale
R13	1	39k	RES, 39 k, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW120639K0JNEA	Vishay-Dale
R14	1	4.7	RES, 4.7, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034R70JNEA	Vishay-Dale
R16	1	3.90	RES, 3.90, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6RQF3R9V	Panasonic
R18	1	0.1	RES, 0.1, 1%, 0.5 W, 2010	2010	ERJ-L1DKF10CU	Panasonic
R19	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	RC0603FR-071KL	Yageo
R24	1	49.9k	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060349K9FKEA	Vishay-Dale
R27	1	31.6	RES, 31.6, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW080531R6FKEA	Vishay-Dale
R28	1	25.5k	RES, 25.5 k, 1%, 0.1 W, 0603	0603	RC0603FR-0725K5L	Yageo
R30, R55, R56, R57, R58	5	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3GEY0R00V	Panasonic
R31	1	10.0	RES, 10.0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
R32	1	110k	RES, 110 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603110KFKEA	Vishay-Dale
R33	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0710KL	Yageo
R34	1	49.9	RES, 49.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060349R9FKEA	Vishay-Dale
R35	1	24.9k	RES, 24.9 k, 1%, 0.1 W, 0603	0603	RC0603FR-0724K9L	Yageo
R36, R48, R59, R60, R61	5	10.0k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R37	1	39.0k	RES, 39.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0739KL	Yageo
R38	1	4.22k	RES, 4.22 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034K22FKEA	Vishay-Dale

Table 8-1. TPS23731EVM-095 Bill of Materials (continued)

Designator	QTY	Value	Description	PackageReference	PartNumber	Manufacturer
R40	1	237k	RES, 237 k, 1%, 0.1 W, 0603	0603	RC0603FR-07237KL	Yageo
R41	1	3.3k	RES, 3.3 k, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08053K30JNEA	Vishay-Dale
R42	1	60.4k	RES, 60.4 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060360K4FKEA	Vishay-Dale
R43	1	51	RES, 51, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW120651R0JNEA	Vishay-Dale
R47	1	499k	RES, 499 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603499KFKEA	Vishay-Dale
R69	1	10	RES, 10, 5%, 0.75 W, AEC-Q200 Grade 0, 2010	2010	CRCW201010R0JNEF	Vishay-Dale
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	6		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
T1	1	350uH	Transformer, PoE+, SMT	Transformer, SOIC-24 Wide	749022016	Wurth Elektronik
T2	1		Flyback transformer for PoE applications	SMD10	LDT1038-50R	LinkCom
TP1, TP6, TP12, TP18, TP43, TP45	6		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP2, TP7, TP8, TP14, TP30, TP37, TP38, TP44	8		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
TP3, TP5, TP9, TP10, TP15, TP16, TP17, TP19, TP20, TP22, TP23, TP24, TP25, TP26, TP27, TP32	16		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone
TP4, TP11, TP13, TP21, TP28, TP29, TP33, TP34, TP39, TP40, TP42	11		Test Point, Miniature, Orange, TH	Orange Miniature Testpoint	5003	Keystone
U1	1		IEEE 802.3bt Type 3 Class 1-4 PoE PD with No-Opto Flyback DC-DC Controller	VQFN45	TPS23731RMT	Texas Instruments
U2, U3	2		Optocoupler, 5 kV, 300-600% CTR, SMT	DIP-4L Gullwing	FOD817DS	Fairchild Semiconductor
C10	0	680pF	CAP, CERM, 680 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H681KA01D	MuRata
C11	0	2200pF	CAP, CERM, 2200 pF, 2000 V, +/- 10%, X7R, 1812	1812	C4532X7R3D222K130KA	TDK
C17	0	220uF	CAP, Tantalum Polymer, 220 uF, 10 V, +/- 20%, 0.025 ohm, 7343-30 SMD	7343-30	10TPE220ML	Panasonic
C24, C25, C27, C29, C31	0	330pF	CAP, CERM, 330 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H331JA01D	MuRata
C34	0	56pF	CAP, CERM, 56 pF, 50 V, +/- 1%, C0G/NP0, 0603	0603	06035A560FAT2A	AVX
C45	0	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 0805	0805	C2012X7R2A104K125AA	TDK
D5, D6	0	100V	Diode, Switching, 100 V, 0.2 A, SOD-123	SOD-123	MMSD4148T1G	ON Semiconductor
D20	0	24V	Diode, Zener, 24 V, 3 W, SMA	SMA	3SMAJ5934B-TP	Micro Commercial Components
D25	0	100V	Diode, Schottky, 100 V, 3 A, SMC	SMC	B3100-13-F	Diodes Inc.

Table 8-1. TPS23731EVM-095 Bill of Materials (continued)

Designator	QTY	Value	Description	PackageReference	PartNumber	Manufacturer
J17	0		Header, 100mil, 2x1, Tin, TH	Header, 2x1, 100mil, TH	5-146278-2	TE Connectivity
L2, L7	0	250uH	Coupled inductor, 250 uH, A, 0.035 ohm, SMD	8.7x10mm	744272251	Wurth Elektronik
L4	0	150nH	Inductor, Shielded Drum Core, Ferrite, 150 nH, 30 A, 0.000235 ohm, SMD	7x5x7mm	744302015	Wurth Elektronik
Q1	0	40 V	Transistor, PNP, 40 V, 0.2 A, SOT-23	SOT-23	MMBT3906-7-F	Diodes Inc.
Q3	0	40V	MOSFET, N-CH, 40 V, 15 A, DQJ0008A (VSONP-8)	DQJ0008A	CSD18504Q5A	Texas Instruments
Q4, Q5, Q6, Q7	0	100V	MOSFET, N-CH, 100 V, 4.5 A, DQK0006C (WSON-6)	DQK0006C	CSD19538Q2	Texas Instruments
R11	0	4.7	RES, 4.7, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034R70JNEA	Vishay-Dale
R12	0	4.99k	RES, 4.99 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034K99FKEA	Vishay-Dale
R15, R17, R20, R21	0	1.00Meg	RES, 1.00 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031M00FKEA	Vishay-Dale
R22, R25, R26, R29	0	232k	RES, 232 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603232KFKEA	Vishay-Dale
R64, R65	0	10.0k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R68	0	750k	RES, 750 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603750KJNEA	Vishay-Dale

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