User's Guide

TPS23755EVM-894 Evaluation Module

ABSTRACT

This user's guide describes the TPS23755 evaluation module (EVM). The TPS23755 evaluation module (TPS23755EVM-894) contains evaluation and reference circuitry for the TPS23755 device. The TPS23755 device is an IEEE 802.3at Type 1 compliant, powered-device (PD) controller and power supply controller optimized for primary side regulation flyback converter topologies. TPS23755EVM-894 is targeted for a 12-V diode-rectified high efficiency 13-W PD solution.

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Trademarks

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1 Introduction

The TPS23755EVM-894 allows reference circuitry evaluation of the TPS23755 device. It contains input and output power connectors and an array of onboard test points for circuit evaluation.

1.1 Features

- IEEE802.3at Type 1 compliant PoE PD
- Class 3 12V/1A Primary Side Regulated CCM Flyback
- Advanced Startup
- Programmable Slew Rate and Frequency Dithering for EMI Reduction
- Secondary-side adapter priority control with smooth transition

1.2 Applications

- IP cameras
- Access Points
- Point-of-Sale
- Barcode Readers
- IP Phones
- Wireless LAN – wireless access points

2 Electrical Specifications

Table 2-1. TPS23755EVM-894 Electrical and Performance Specifications at 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER INTERFACE					
Input voltage	Applied to the power pins of connectors J1	37		57	V
	Applied to the power pins of connectors J5		12		V
Input UVLO, POE input J2	Rising input voltage			36	V
	Falling input voltage	30			
Detection voltage	At device terminals	2.7		10.1	V
Classification voltage	At device terminals	14.5		20.5	V
Classification current	R_{CLASS} = 45.3 Ω	26.5		29.3	mA
Inrush current-limit			140		mA
Operating current-limit			550		mA
DC-TO-DC CONVERTER					
Output voltage	V_{IN} = 48 V, $I_{LOAD} \le I_{LOAD}$ (max)		12		V
Output current	37 V ≤ V_{IN} ≤ 57 V		1		A
Output ripple voltage peak-to-peak	V_{IN} = 48 V, I_{LOAD} = 1 A		50		mV
Efficiency, end-to-end	V_{IN} = 48 V, I_{LOAD}= 100 mA		78		%
	V_{IN} = 48 V, I_{LOAD} = 500 mA		86		
	V_{IN} = 48 V, I_{LOAD} = 1 A		87		
Switching frequency			250		kHz

3 Description

The TPS23755EVM-894 enables full evaluation of the TPS23755 device. Refer to the schematic shown in Figure 4-1. Ethernet power is applied from J1 and is dropped to the bridge rectifier (D1, D2). The Power over Ethernet (PoE) transformer needed to transfer power or data is T1 . The Bob Smith Terminations help balance the Ethernet cable impedance and are critical for ESD and EMI or EMC performance. The EMI or EMC filter and transient protection for the TPS23755 device are at the output of the diode bridge.

Input power can also be applied at J5 from a DC source when power at J1 is not present.

The TPS23755 (U1) PD and DC-to-DC converter circuitry is shown in Figure 4-1. R17 provides the detection signature and R20 provides the classification (class 3) signature. The switched side of the PD controller is to the right of U1. The TPS23755 RTN pin provides inrush limited turn on and charge of the bulk capacitor, C12.

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

Output voltage feedback is provided with R16 and R21 on the bias winding. R14 provides a means for error injection to measure the frequency response of the converter.

4 Schematic

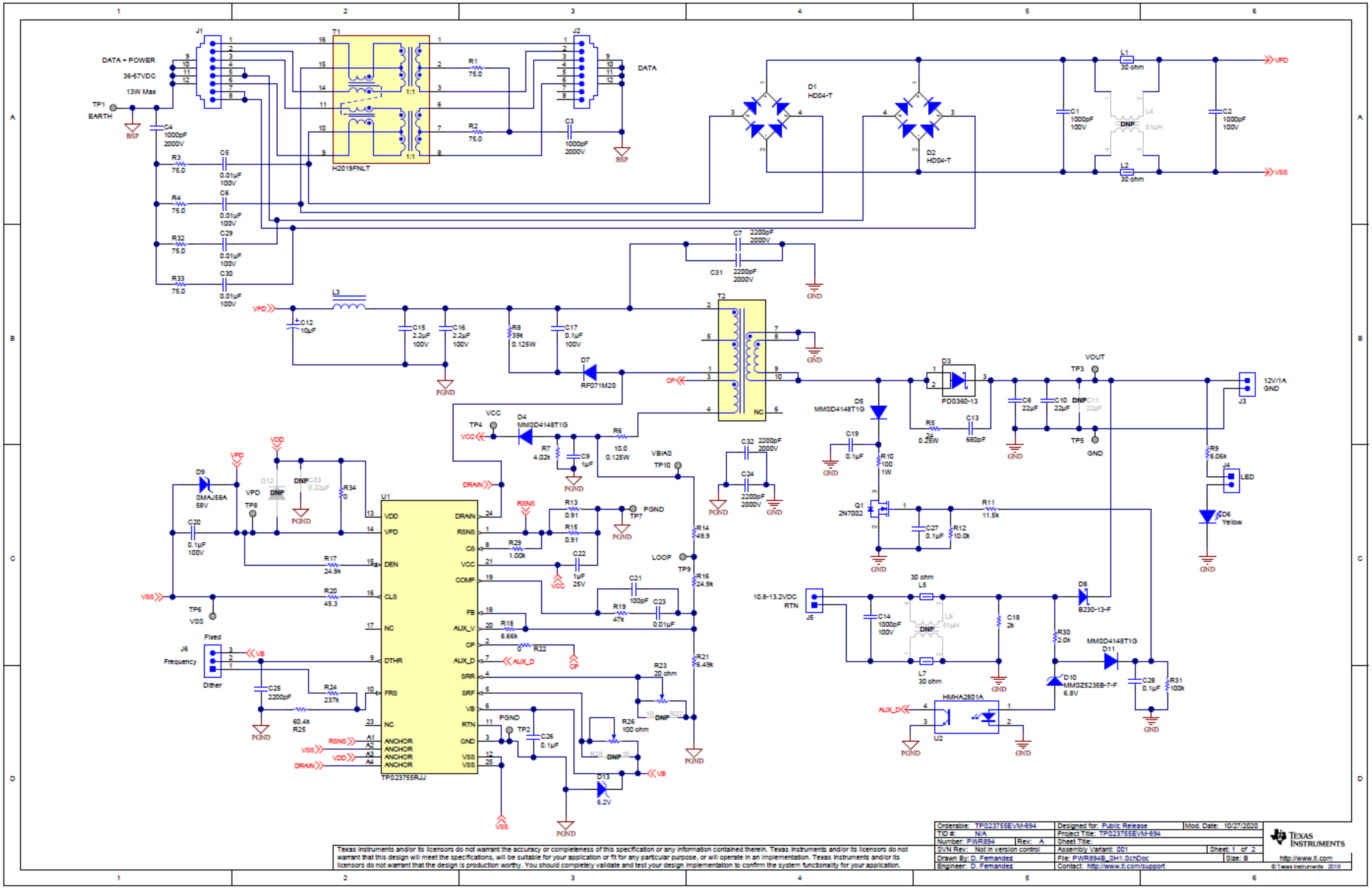

Figure 4-1. TPS23755EVM-894 Schematic

5 General Configuration and Description

5.1 Physical Access

Table 5-1 lists the EVM connector functionality. Table 5-2 describes the test point availability and jumper functionality.

Table 5-1. Connector Functionality

Connector	Label	Description
J1	PWR+DATA	PoE input; connect to PSE power and data source.
J2	DATA	Ethernet data passthrough; connect to downstream Ethernet device.
J3	Output	Output connector to loadx.
J5	Adapter Input	DC-to-DC converter input bypassing the PoE converter; connect a 12-V adapter.
J4	LED	Jump J4 to visually indicate the output voltage.
J6	FREQ	Jump to 'Fixed' for fixed frequency. Jump to 'Dither' to enable spread spectrum dithering.

Table 5-2. Test Points

Test Point	Label	Description
TP1	BS	Bob Smith Termination
TP2, TP7	PGND	Primary ground
TP3	VOUT	Output voltage
TP4	VCC	Bias voltage
TP5	GND	Secondary ground
TP6	VSS	PoE input return ground
TP8	VPD	Input voltage

6 TPS23755EVM-894 Performance Data

6.1 Startup to PSE and DCDC Startup

Figure 6-1 shows the startup response of the TPS23755EVM-894.

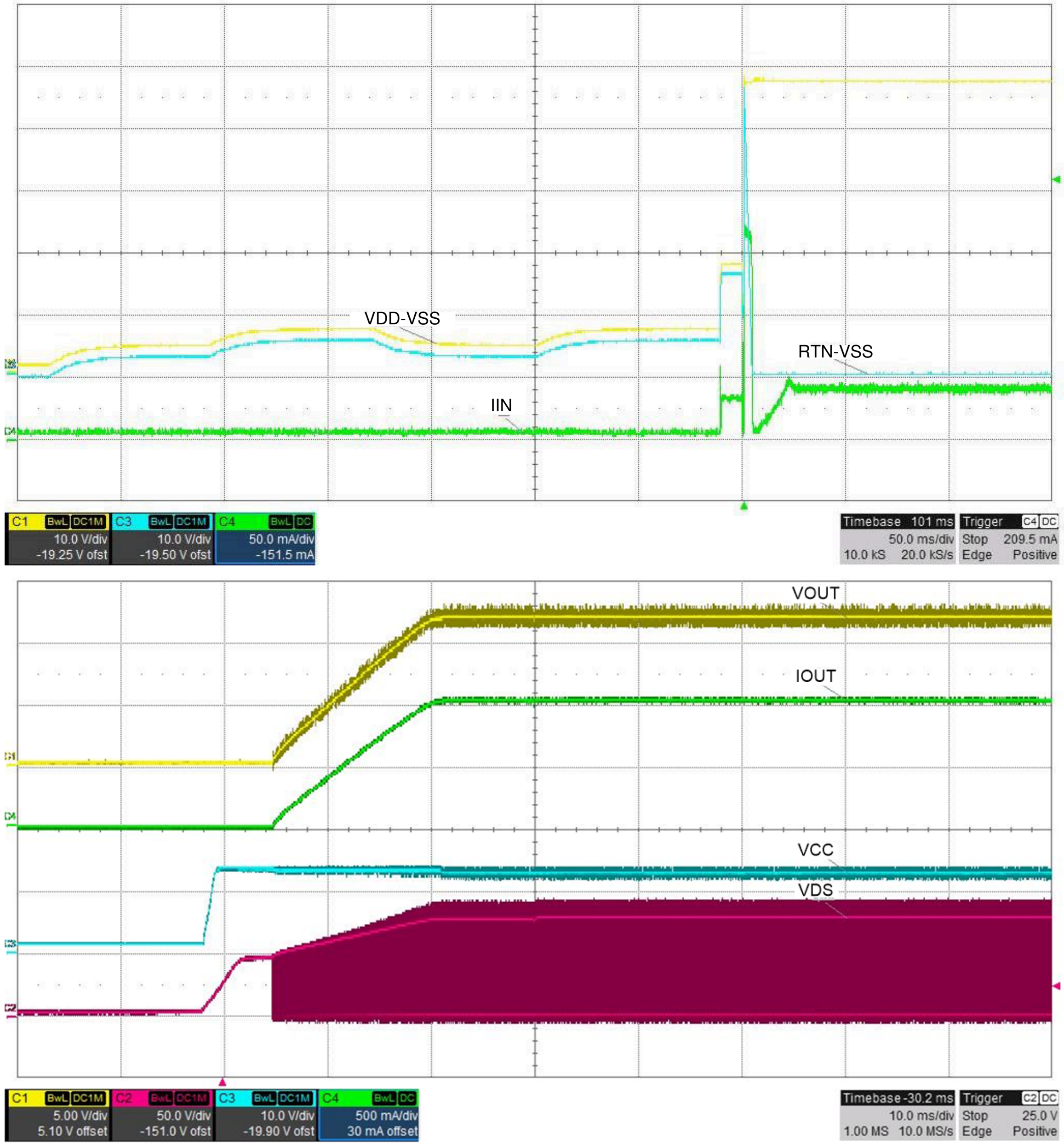

Figure 6-1. Startup Response When Connected to a PoE PSE (TPS23861) and DCDC Startup

6.2 Transient Response

Figure 6-2 shows the transient response of the TPS23755EVM-894.

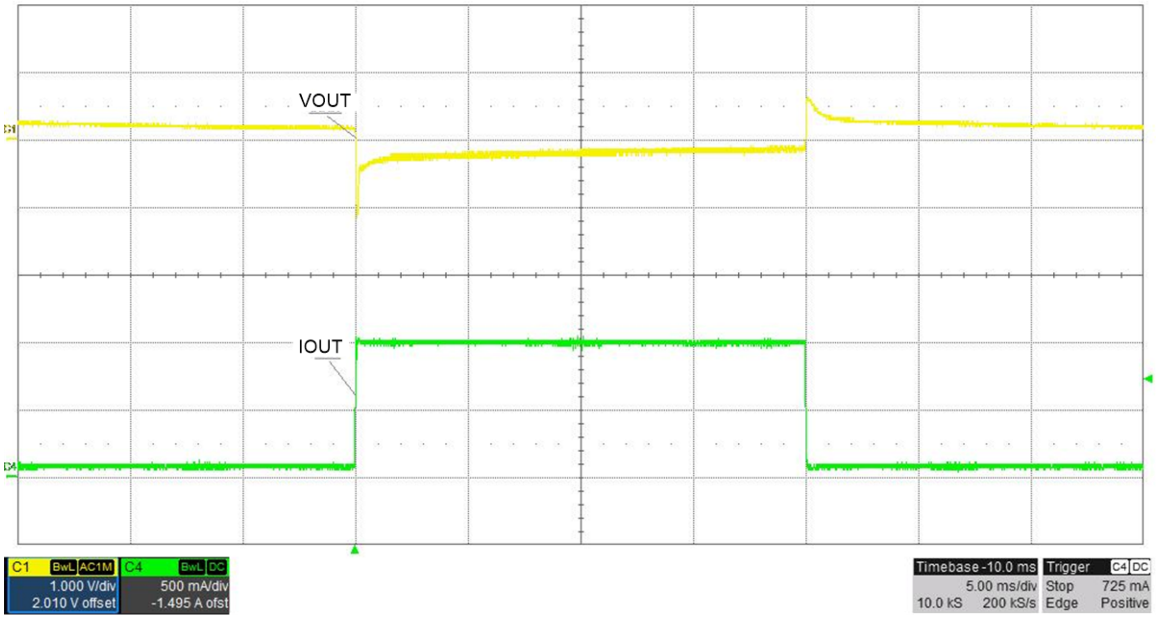

Figure 6-2. Transient Response from 100 mA to 1 A for a 48-V Input

6.3 Efficiency

Figure 6-3 shows the efficiency of the TPS23755EVM-894.

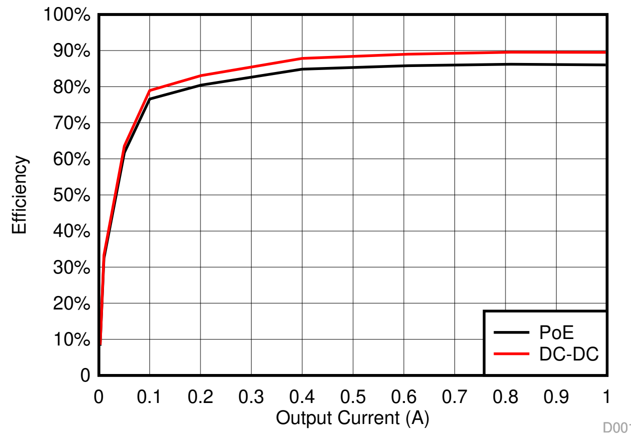

Figure 6-3. Efficiency of the TPS23755EVM-894

6.4 Load Regulation

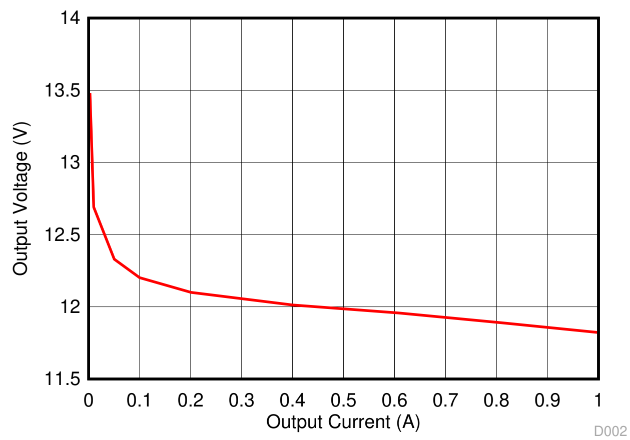

Figure 6-4. TPS23755EVM-894 Load Regulation

6.5 Recovery from VOUT Short

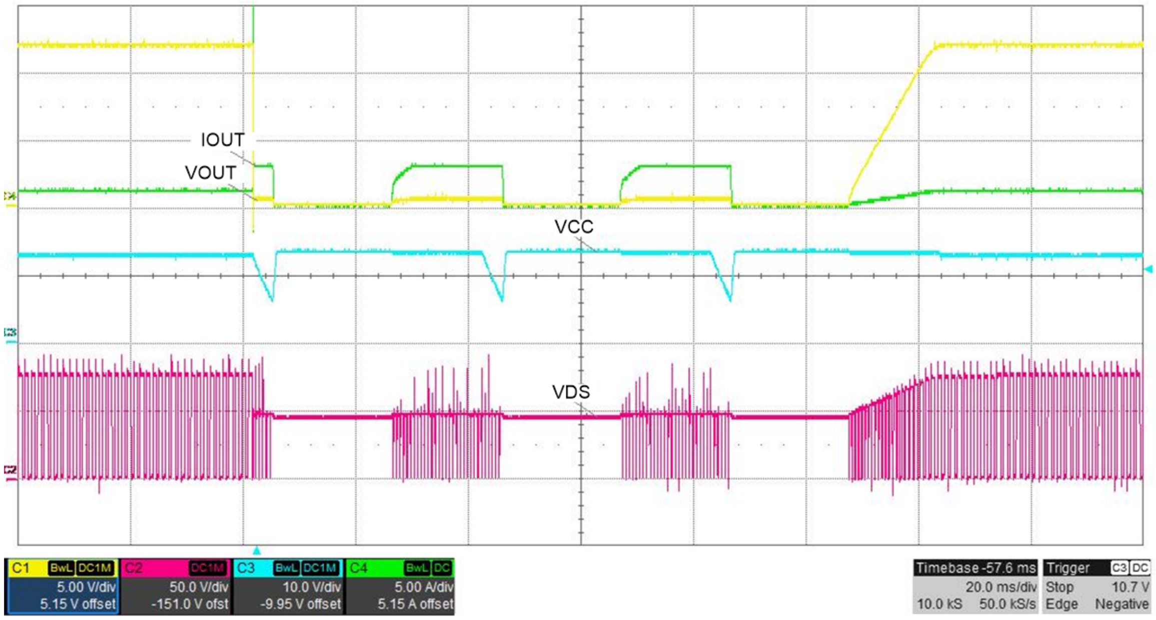

Figure 6-5. DCDC Recovery From Output Short

6.6 Slew Rate Adjust

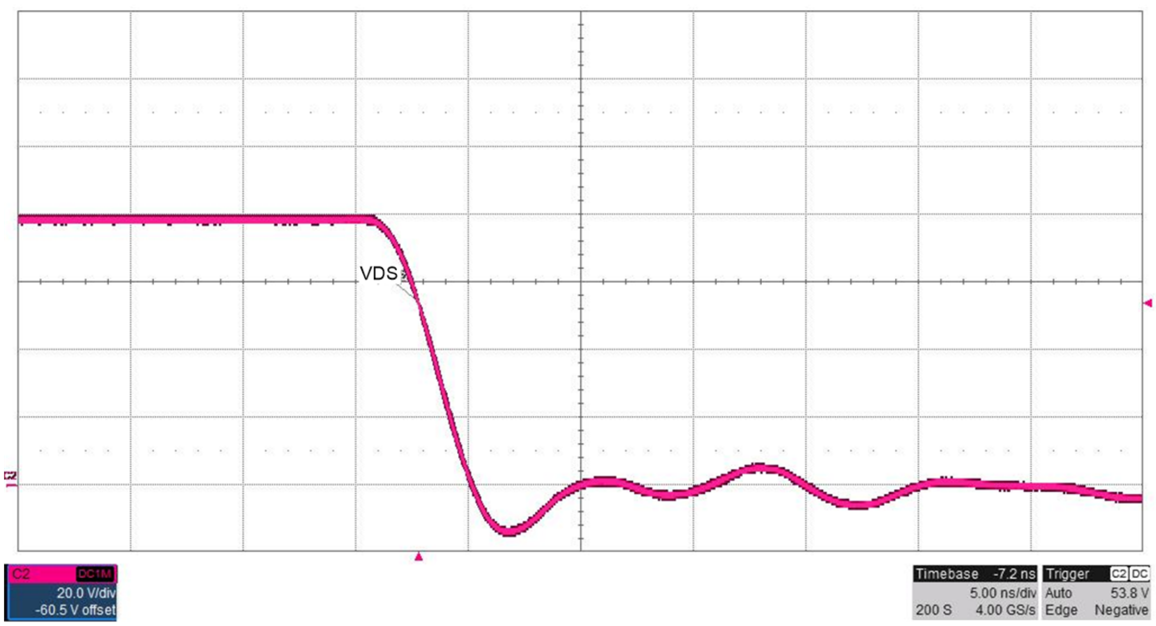

Figure 6-6. SRF = 0 Ω

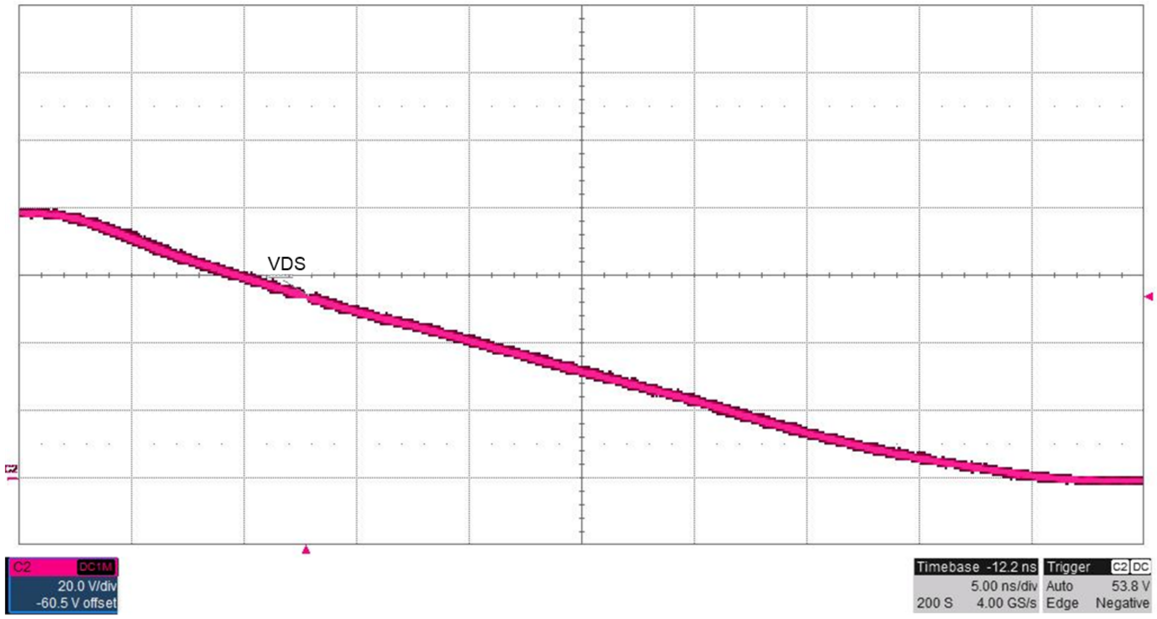

Figure 6-7. SRF = 100 Ω

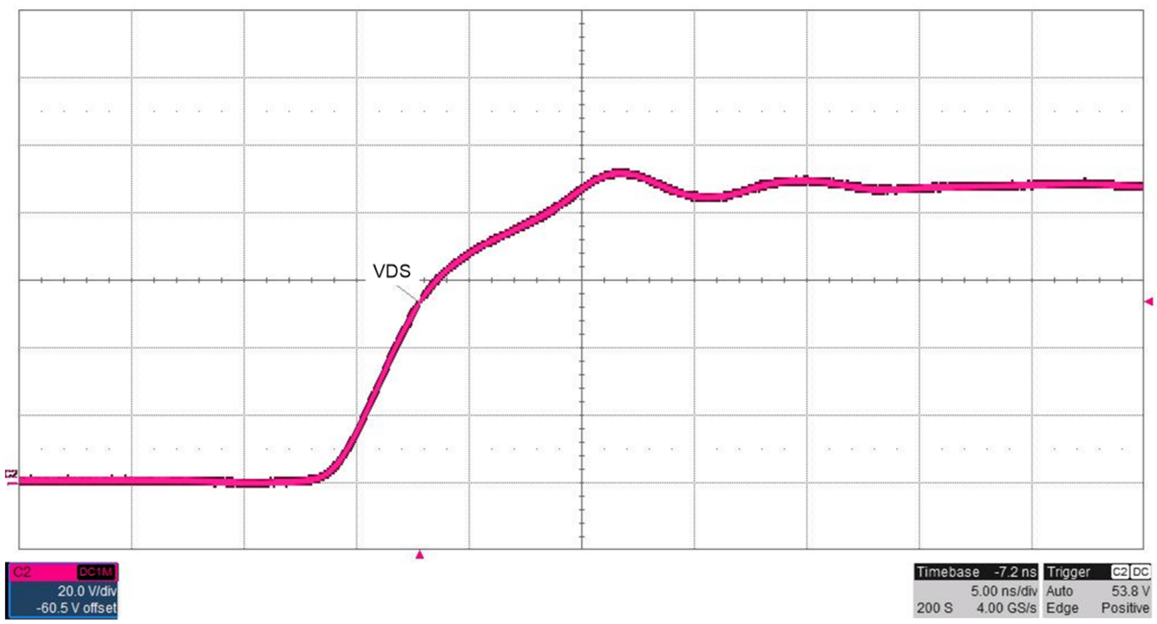

Figure 6-8. SRR = 0 Ω

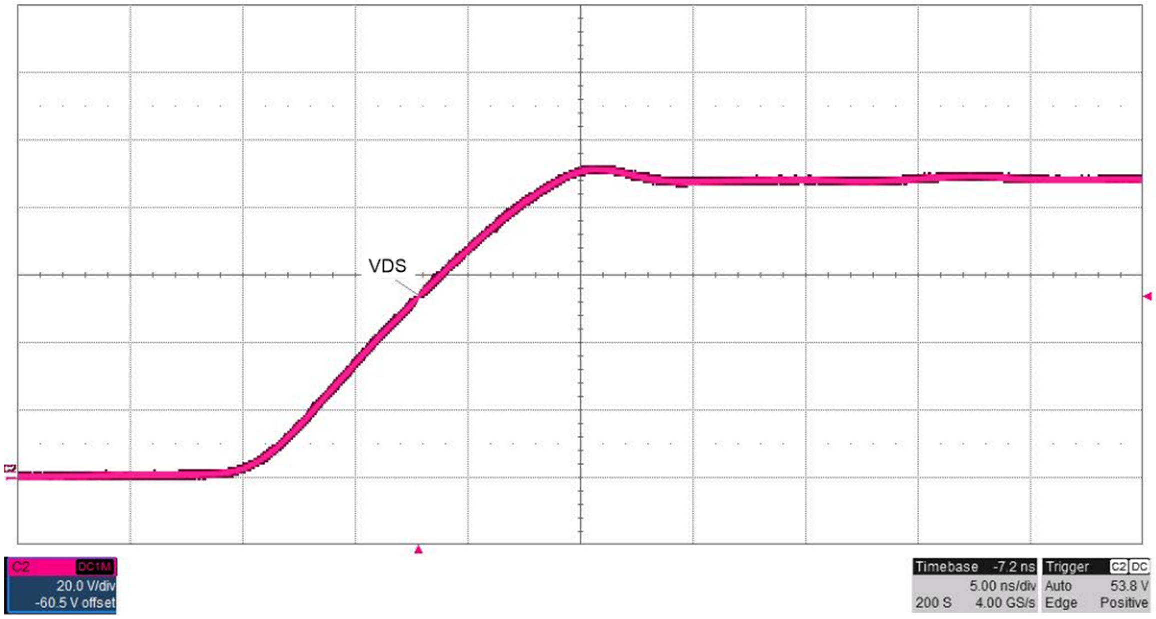

Figure 6-9. SRR = 15 Ω

7 EVM Assembly Drawings and Layout Guidelines

7.1 PCB Drawings

Figure 7-1 to Figure 7-4 show the component placement and layout of the TPS23755EVM-894.

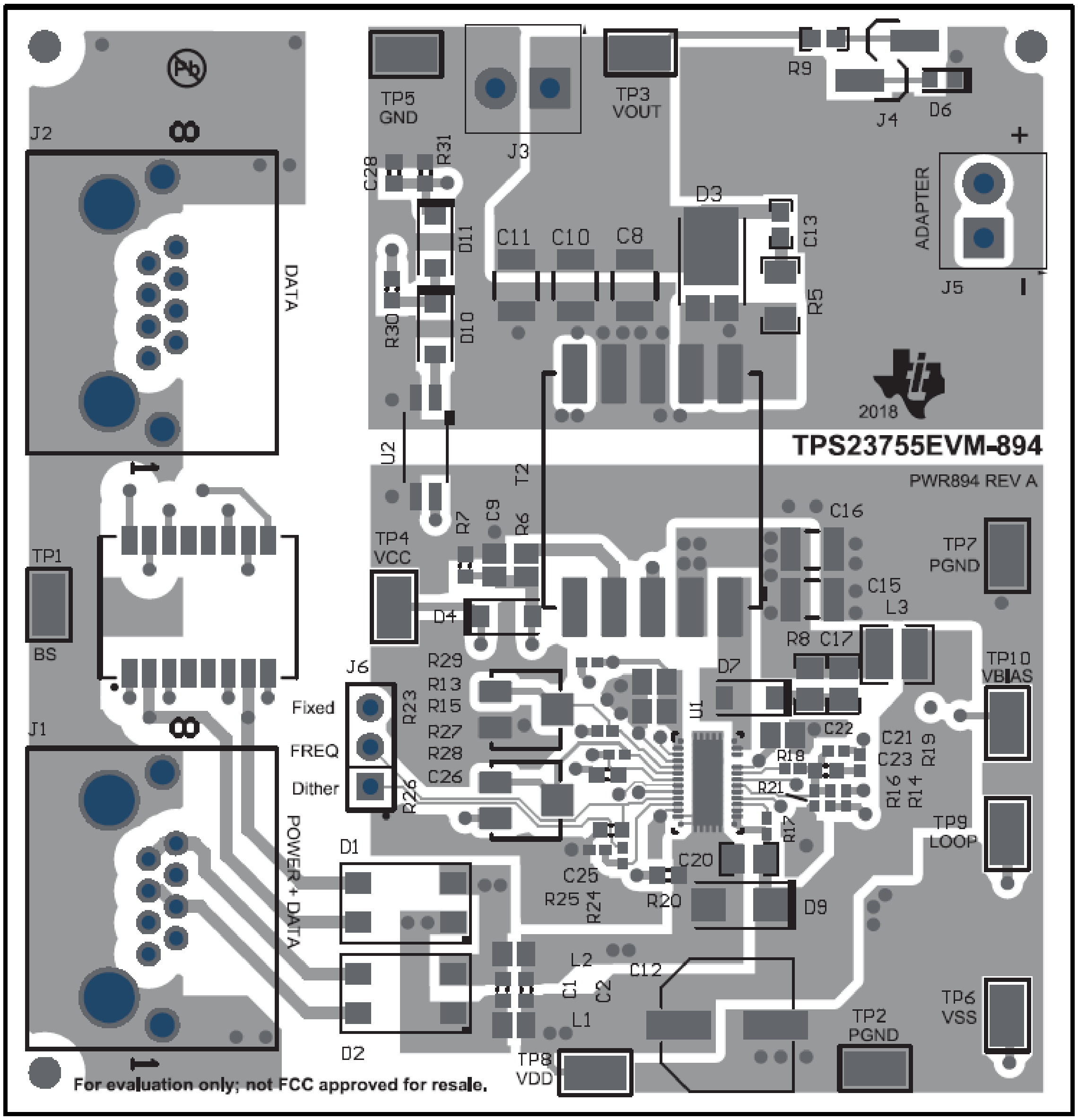

Figure 7-1. Top-Side Component Placement

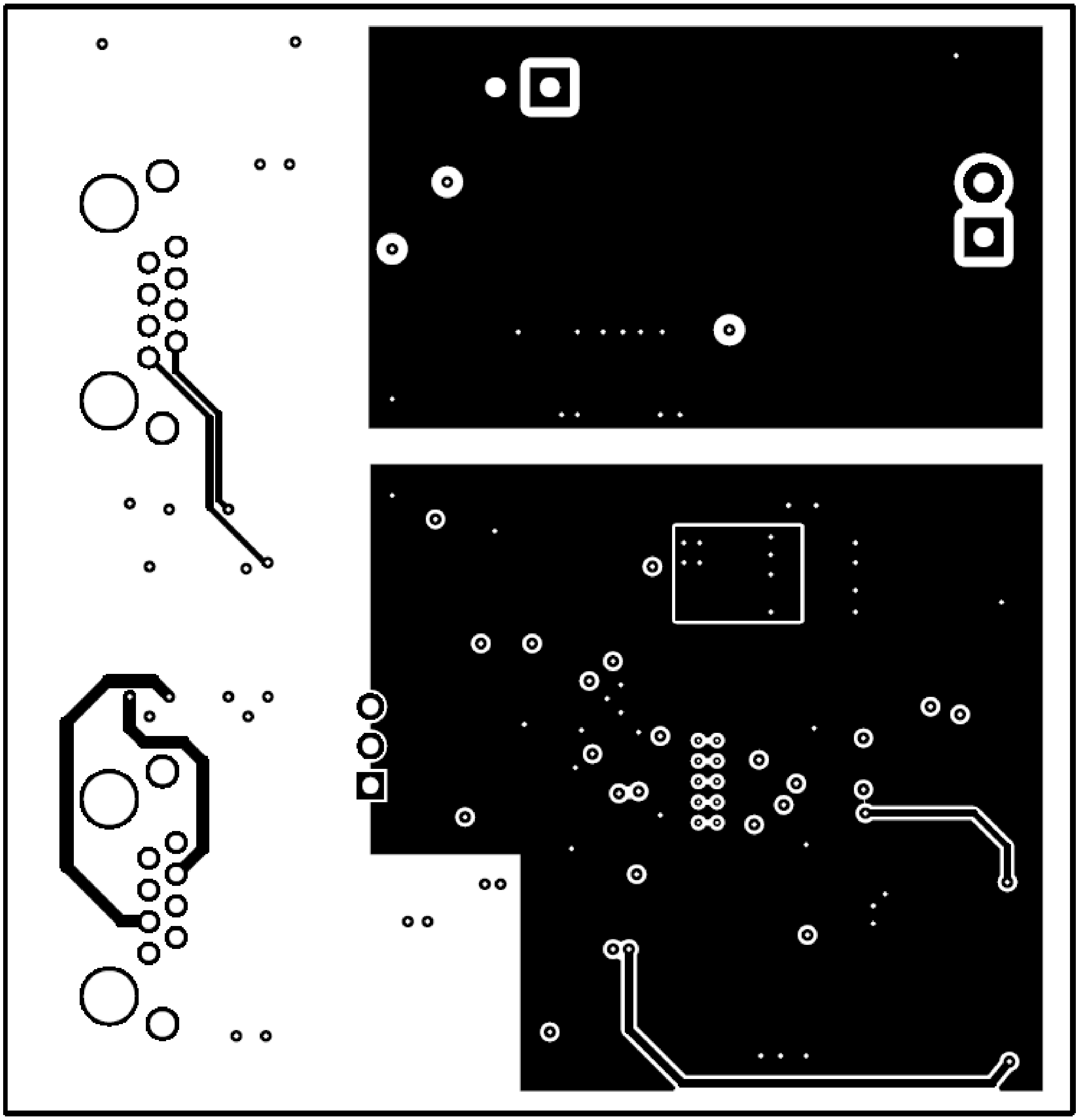

Figure 7-2. Layer 2 Routing

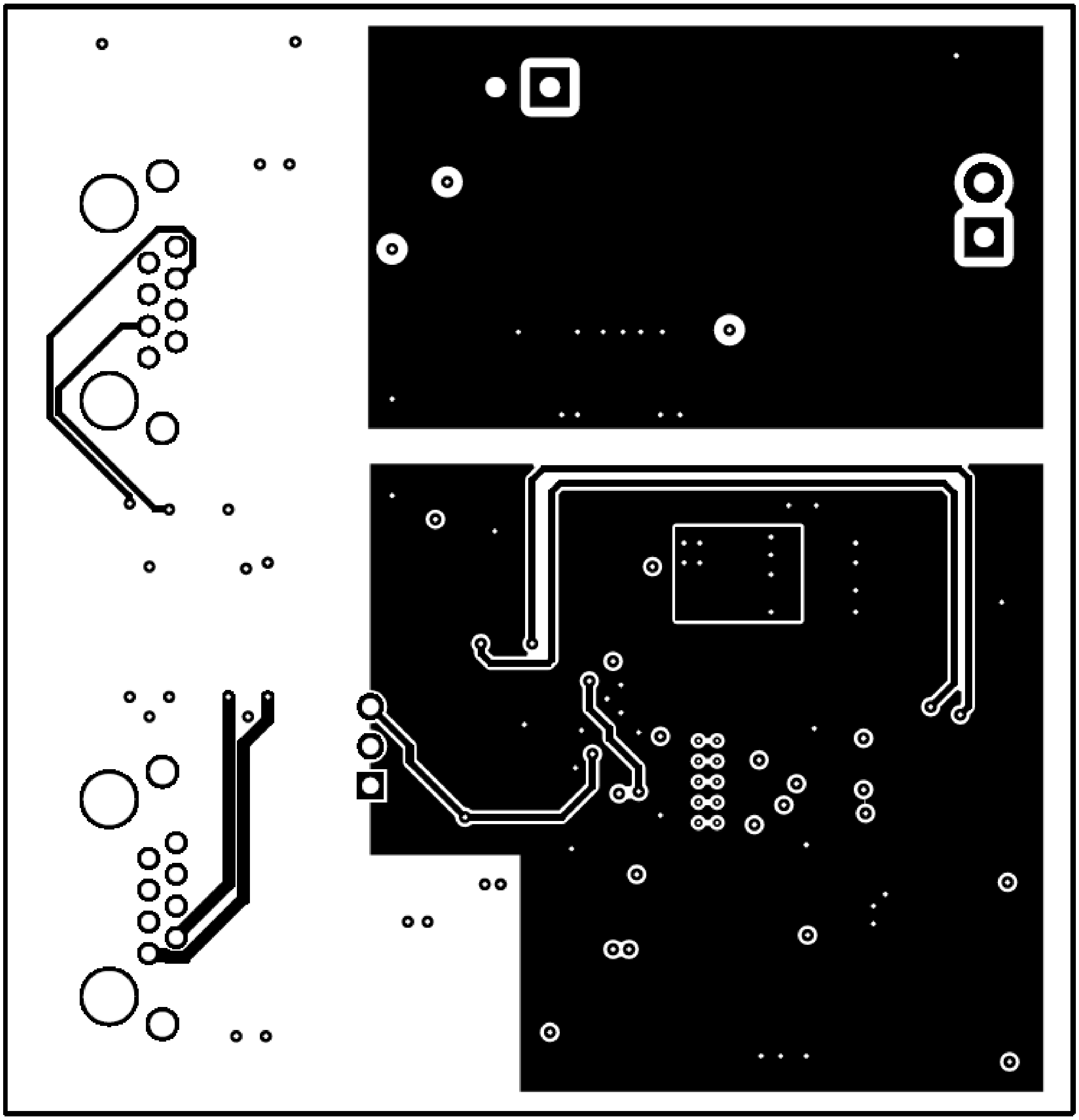

Figure 7-3. Layer 3 Routing

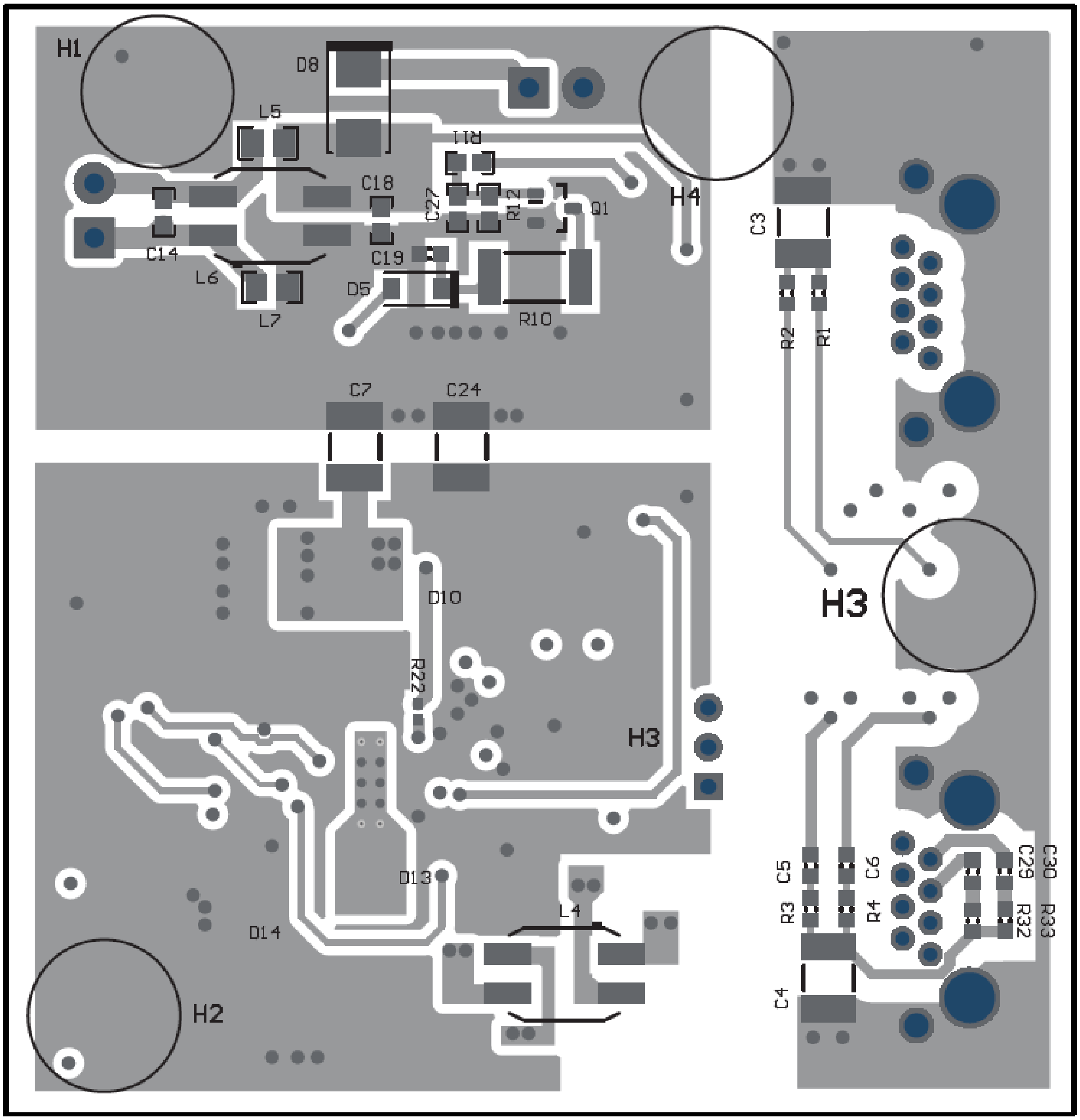

Figure 7-4. Bottom-Side Routing

7.2 Layout Guidelines

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

- Pin 22 of the TPS23755 is omitted from the IC to ensure high voltage clearance from Pin 24 (DRAIN). Therefore, the Pin 22 footprint should be removed when laying out the TPS23755.
- It is recommended having at least 8 vias (VSS) 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.
- The Pin 24 of the TPS23755 should be near the power transformer and the current sense resistor should be close to Pin 1 of the TPS23755 to minimize the primary 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 TPS23755 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.

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.
- Having at least 6 vias (secondary ground) near the power transformer pin connected to secondary ground 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.

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). 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).

8 Bill of Materials

Table 8-1. TPS23755EVM-894 BOM

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		PWR894	Any	-	-
C1, C2, C14	3	1000 pF	CAP, CERM, 1000 pF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A102KA01D	MuRata		
C3, C4	2	1000 pF	CAP, CERM, 1000 pF, 2000 V, +/- 10%, X7R, 1812	1812	GR443QR73D102KW01L	MuRata		
C5, C6, C29, C30	4	0.01 uF	CAP, CERM, 0.01 µF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A103KA01D	MuRata		
C7, C24, C31, C32	4	2200 pF	CAP, CERM, 2200 pF, 2000 V, +/- 10%, X7R, 1812	1812	C4532X7R3D222K130KA	TDK		
C8, C10	2	22 uF	CAP, CERM, 22 µF, 25 V,+/- 20%, X5R, 1812	1812	C4532X5R1E226M250KA	TDK		
C9, C22	2	1 uF	CAP, CERM, 1 µF, 25 V, +/- 10%, X7R, 0805	0805	GRM21BR71E105KA99L	MuRata		
C12	1	10 uF	CAP, AL, 10 µF, 100 V, +/- 20%, AEC-Q200 Grade 3, SMD	SMT Radial E	EEE-2AA100UP	Panasonic		
C13	1	680 pF	CAP, CERM, 680 pF, 100 V, +/- 10%, X7R, 0603	0603	06031C681KAT2A	AVX		
C15, C16	2	2.2 uF	CAP, CERM, 2.2 µF, 100 V, +/- 10%, X7R, 1210	1210	GRM32ER72A225KA35L	MuRata		
C17, C20	2	0.1 uF	CAP, CERM, 0.1 µF, 100 V, +/- 10%, X7R, 0805	0805	C2012X7R2A104K125AA	TDK		
C18	1	2.00 k	RES, 2.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0603	0603	RNCP0603FTD2K00	Stackpole Electronics Inc		
C19	1	0.1 uF	CAP, CERM, 0.1 µF, 25 V,+/- 10%, X7R, 0603	0603	06033C104KAT2A	AVX		

Table 8-1. TPS23755EVM-894 BOM (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
C21	1	100 pF	CAP, CERM, 100 pF, 50 V,+/- 5%, C0G/NP0, 0402	0402	885012005061	Wurth Elektronik		
C23	1	0.01 uF	CAP, CERM, 0.01 µF, 100 V,+/- 20%, X7R, 0603	0603	06031C103MAT2A	AVX		
C25	1	2200 pF	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H222KA01D	MuRata		
C26	1	0.1 uF	CAP, CERM, 0.1 µF, 25 V, +/- 10%, X7R, 0603	0603	C1608X7R1E104K080AA	TDK		
C27, C28	2	0.1 uF	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, 0603	0603	06035C104KAT2A	AVX		
D1, D2	2	400 V	Diode, Switching-Bridge, 400 V, 0.8 A, MiniDIP	MiniDIP	HD04-T	Diodes Inc.		
D3	1	60 V	Diode, Schottky, 60 V, 3 A, PowerDI5	PowerDI5	PDS360-13	Diodes Inc.		
D4, D5, D11	3	100 V	Diode, Switching, 100 V, 0.2 A, SOD-123	SOD-123	MMSD4148T1G	ON Semiconductor		
D6	1	Yellow	LED, Yellow, SMD	LED_0603	150060YS75000	Wurth Elektronik		
D7	1	200 V	Diode, Ultrafast, 200 V, 1 A, SOD-123	SOD-123	RF071M2S	Rohm		
D8	1	30 V	Diode, Schottky, 30 V, 2 A, SMB	SMB	B230-13-F	Diodes Inc.		
D9	1	58 V	Diode, TVS, Uni, 58 V, 400 W, SMA	SMA	SMAJ58A	Diodes Inc.		
D10	1	6.8 V	Diode, Zener, 6.8 V, 500 mW, SOD-123	SOD-123	MMSZ5235B-7-F	Diodes Inc.		
D13	1	6.2 V	Diode, Zener, 6.2 V, 500 mW, SOD-123	SOD-123	MMSZ5234B-7-F	Diodes Inc.		
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.375 X 0.235, Black	Black Bumpon	SJ61A2	3M		
J1, J2	2		RJ-45, No LED, tab up, R/A, TH	16.26 x 14.54 x 15.75	1-406541-1	TE Connectivity		

Table 8-1. TPS23755EVM-894 BOM (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
J3, J5	2		Terminal Block, 6 A, 3.5-mm Pitch, 2-Pos, TH	7.0 x 8.2 x 6.5 mm	ED555/2DS	On-Shore Technology		
J4	1		Header, 2.54 mm, 2 x 1, Gold, R/A, SMT	Header, 2.54 mm, 2 x 1, R/A, SMT	0878980204	Molex		
J6	1		Header, 100 mil, 3 x 1, Gold, TH	3 x 1 Header	TSW-103-07-G-S	Samtec		
L1, L2, L5, L7	4	30 ohm	1.5 A Ferrite Bead, 30 ohm @ 100 MHz, SMD	0805	MMZ2012R300A	TDK	MMZ2012R300AT000	
L3	1	3.3 uH	Inductor, Drum Core, Ferrite, 3.3 µH, 1.6 A, 0.14 ohm, SMD	ME3220	ME3220-332MLB	Coilcraft		
Q1	1	60 V	MOSFET, N-CH, 60 V, 115 A, SOT-23	SOT-23	2N7002	Fairchild Semiconductor		None
R1, R2, R3, R4, R32, R33	6	75.0	RES, 75.0 ohm, 1%, 0.1 W, 0603	0603	CRCW060375R0FKEA	Vishay-Dale		
R5	1	24	RES, 24, 5%, 0.25 W, 1206	1206	CRCW120624R0JNEA	Vishay-Dale		
R6	1	10.0	RES, 10.0, 1%, 0.125 W, 0805	0805	RC0805FR-0710RL	Yageo America		
R7	1	4.02 k	RES, 4.02 k, 1%, 0.1 W, 0603	0603	CRCW06034K02FKEA	Vishay-Dale		
R8	1	39 k	RES, 39k ohm, 5%, 0.125 W, 0805	0805	CRCW080539K0JNEA	Vishay-Dale		
R9	1	8.06 k	RES, 8.06 k, 1%, 0.1 W, 0603	0603	CRCW06038K06FKEA	Vishay-Dale		
R10	1	100	RES, 100, 5%, 1 W, AEC-Q200 Grade 0, 2512	2512	CRCW2512100RJNEG	Vishay-Dale		
R11	1	11.5 k	RES, 11.5 k, 1%, 0.1 W, 0603	0603	CRCW060311K5FKEA	Vishay-Dale		
R12	1	10.0 k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R13, R15	2	0.91	RES, 0.91, 1%, 0.25 W, 0805	0805	CRM0805-FX-R910ELF	Bourns		

Table 8-1. TPS23755EVM-894 BOM (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
R14	1	49.9	RES, 49.9, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	RMCF0402FT49R9	Stackpole Electronics Inc		
R16, R17	2	24.9 k	RES, 24.9 k, 1%, 0.063 W, 0402	0402	CRCW040224K9FKED	Vishay-Dale		
R18	1	8.66 k	RES, 8.66 k, 1%, 0.063 W, 0402	0402	CRCW04028K66FKED	Vishay-Dale		
R19	1	47 k	RES, 47 k, 5%, 0.063 W, 0402	0402	CRCW040247K0JNED	Vishay-Dale		
R20	1	45.3	RES, 45.3, 1%, 0.1 W, 0603	0603	CRCW060345R3FKEA	Vishay-Dale		
R21	1	6.49 k	RES, 6.49 k, 1%, 0.063 W, 0402	0402	CRCW04026K49FKED	Vishay-Dale		
R22	1	0	RES, 0, 5%, 0.063 W, 0402	0402	RC0402JR-070RL	Yageo America		
R23	1	20 ohm	3314 - 4-mm Square Trimpot Trimming Potentiometer	5 x 4.5 mm	3314J-1-200E	Bourns		
R24	1	237 k	RES, 237 k, 1%, 0.063 W, 0402	0402	CRCW0402237KFKED	Vishay-Dale		
R25	1	60.4 k	RES, 60.4 k, 1%, 0.063 W, 0402	0402	CRCW040260K4FKED	Vishay-Dale		
R26	1	100 ohm	3314 - 4-mm Square Trimpot Trimming Potentiometer	5 x 4.5 mm	3314J-1-101E	Bourns		
R29	1	1.00 k	RES, 1.00 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1001X	Panasonic		
R30	1	2.0 k	RES, 2.0 k, 5%, 0.1 W, 0603	0603	CRCW06032K00JNEA	Vishay-Dale		
R31	1	100 k	RES, 100 k, 1%, 0.1 W, 0603	0603	RC0603FR-07100KL	Yageo America		
R34	1	0	RES, 0, 5%, 0.125 W, 0603	0603	MCT06030Z0000ZP500	Vishay/Beyschlag		
SH-J1, SH-J2	2	1 x 2	Shunt, 100 mil, Gold plated, Black	Shunt	969102-0000-DA	3M	SNT-100-BK-G	Samtec
T1	1	350 uH	Transformer, 350 uH, SMT	358 x 236 x 500 mil	H2019FNLT	Pulse Engineering		

Table 8-1. TPS23755EVM-894 BOM (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
T2	1	150 uH	Transformer, 150 uH, SMT	14 x 15.1 mm	LDT0950-50	Linkcom Manufacturing Co.	750317728	Wurth Elektronik
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	10		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone		
U1	1		IEEE 802.3at PoE PD with No-Opto Flyback DC-DC Controller, RJJ0023B (VQFN-23)	RJJ0023B	TPS23755RJJ	Texas Instruments		Texas Instruments
U2	1		Optocoupler, 3.75 kV, 80-160% CTR, SMT	Mini Flat Package	HMHA2801A	Fairchild Semiconductor		
C11	0	22 uF	CAP, CERM, 22 µF, 25 V,+/- 20%, X5R, 1812	1812	C4532X5R1E226M250KA	TDK		
C33	0	0.22 uF	CAP, CERM, 0.22 µF, 100 V,+/- 10%, X5R, 1206	1206	C3216X5R2A224K115AA	TDK		
D12	0	100 V	Diode, Switching, 100 V, 0.2 A, SOD-123	SOD-123	MMSD4148T1G	ON Semiconductor		
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A		
L4, L6	0	51 uH	Coupled inductor, 51 µH, A, 0.14 ohm, SMD	7.1 x 6mm	B82793S513N201	TDK		
R27, R28	0	10	RES, 10, 5%, 0.063 W, 0402	0402	CRCW040210R0JNED	Vishay-Dale		

Revision History

Changes from Revision * (July 2018) to Revision A (December 2020) **Page**