Texas Instruments

TPS54672EVM-222 6-Amp
TPS54872EVM-222 8-Amp
TPS54972EVM-222 9-Amp

SWIFT Regulator Evaluation Module

User's Guide

November 2002

PMP EVMs

SLVU076

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Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. 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 55°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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Texas Instruments
Post Office Box 655303
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Preface

Read This First

About This Manual

This user's guide describes the characteristics, operation, and the use of the TPS54672EVM–222, TPS54872EVM–222, and TPS54972EVM–222 evaluation modules. It covers all pertinent areas involved to properly use this EVM board along with the devices that it supports. The physical PCB layout, schematic diagram and circuit descriptions are included.

How to Use This Manual

This document contains the following chapters:

- Chapter 1—Introduction
- Chapter 2—Test Setup and Results
- Chapter 3—Board Layout
- Chapter 4—Schematic and Bill of Materials

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Data Sheets:	**Literature Number:**
TPS54672	SLVS397
TPS54872	SLVS436
TPS54972	SLVS437

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Chapter 1

Introduction

This chapter contains background information for the TPS54672, TPS54872, and TPS54972 as well as support documentation for the TPS54672EVM-222, TPS54872EVM-222, and TPS54972EVM-222 evaluation modules (SLVP222). The TPS54x72EVM–222 performance specifications are given, as well as the schematic and bill of material for the TPS54x72EVM–222.

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1.1 Background

The TPS54x72EVM–222 evaluation modules use the TPS54672, TPS54872, or TPS54972 synchronous buck tracking/termination regulators to provide an output voltage of from 0.46 V to 1.75 V from a nominal 3.3 V input or 0.7 V to 1.75 V for a nominal 5-V input. Rated input voltage and output current range is given in . These evaluation modules are designed to demonstrate the small PCB areas that may be achieved when designing with the TPS54x72 family of regulators. The swicthing frequency is set at a nominal 700 kHz, allowing the use of a small footprint 0.65 µH output inductor. The MOSFETs of the TPS54x72 are incorporated inside the TPS54x72 package. This eliminates the need for external MOSFETs and their associated drivers. The low drain-to-source on resistance of the MOSFETs gives the TPS54x72 high efficiency and helps to keep the junction temperature low at high output currents. The compensation components are provided external to the IC, and allow for an adjustable output voltage and a customizable loop reponse.

Table 1–1. Input Voltage and Output Current Summary

EVM	Input Voltage Range	Output Current Range
TPS54672EVM-222	3.0 V to 6.0 V	–6 A to 6 A
TPS54872EVM-222	4.0 V to 6.0 V	–8 A to 8 A
TPS54972EVM-222	3.0 V to 4.0 V	–9 A to 9 A

1.2 Performance Specification Summary

A summary of the TPS54x72EVM–222 performance specifications is provided by Table 1–2, Table 1–3, and Table 1–4. All specifications are given for an an output voltage of 1.25 V and an ambient temperature of 25°C, unless otherwise noted.

Table 1–2. TPS54672EVM-222 Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Units
Input voltage range		3.0	3.3 or 5.0	6.0	V
Output voltage set point		0.42	1.25	1.75	V
Output current range	V_I = 3 V to 6 V	–6		6	A
Line regulation	I_O = 3 A		0.4		mV
Load regulation	V_I = 5 V, I_O = 0 A to 6 A		8.0		mV
Load transient response	I_O = 1.5 A to 4.5 A, t_r = 40 µs		–15		mV_{PK}
			100		µs
	I_O = 4.5 A to 1.5 A, t_f = 40 µs		15		mV_{PK}
			50		µs
Loop bandwidth	V_I = 3 V		80		kHz
Phase margin	V_I = 3 V		48		°
Loop bandwidth	V_I = 6 V		100		kHz
Phase margin	V_I = 6 V		47		°
Input ripple voltage			245	275	mV_{PP}
Output ripple voltage			7	10	mV_{PP}
Output rise time		4.7	8.4	15	ms
Operating frequency			700		kHz
Maximum efficiency	V_I = 5.0 V, Vo = 1.25 V, I_O = 2.5 A		86.2%		

Table 1–3. TPS54872EVM-222 Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Units
Input voltage range		4.0	5.0	6.0	V
Output voltage set point		0.56	1.25	1.75	V
Output current range	V_I = 4 V to 6 V	–8		8	A
Line regulation	I_O = 4 A		0.4		mV
Load regulation	V_I = 5 V, I_O = 0 A to 8 A		8.0		mV
Load transient response	I_O = 2 A to 6 A, t_r = 40 µs		–25		mV_{PK}
			75		µs
	I_O = 6 A to 2 A, t_f = 40 µs		25		mV_{PK}
			75		µs
Loop bandwidth	V_I = 4 V		80		kHz
Phase margin	V_I = 4 V		48		°
Loop bandwidth	V_I = 6 V		100		kHz
Phase margin	V_I = 6 V		46		°
Input ripple voltage			245	275	mV_{PP}
Output ripple voltage			7	10	mV_{PP}
Output rise time		4.7	8.4	15	ms
Operating frequency			700		kHz
Maximum efficiency	V_I = 5.0 V, Vo = 1.25 V, I_O = 2.5 A		85.5%		

Table 1–4. TPS54972EVM-222 Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Units
Input voltage range		3.0	3.3	4.0	V
Output voltage set point		0.42	1.25	1.75	V
Output current range	V_I = 3 V to 4 V	–9		9	A
Line regulation	I_O = 4.5 A		0.4		mV
Load regulation	V_I = 5 V, I_O = 0 A to 9 A		8.0		mV
Load transient response	I_O = 2.25 A to 6.75 A, t_r = 40 µs		–35		mV_{PK}
			75		µs
	I_O = 6.75 A to 2.25 A, t_f = 40 µs		40		mV_{PK}
			75		µs
Loop bandwidth	V_I = 3 V		71		kHz
Phase margin	V_I = 3 V		41		°
Loop bandwidth	V_I = 3.6 V		80		kHz
Phase margin	V_I = 3.6 V		42		°
Input ripple voltage			340	400	mV_{PP}
Output ripple voltage			7	10	mV_{PP}
Output rise time		4.7	8.4	15	ms
Operating frequency			700		kHz
Maximum efficiency	V_I = 3.3 V, Vo = 1.25 V, I_O = 2.5 A		89.7%		

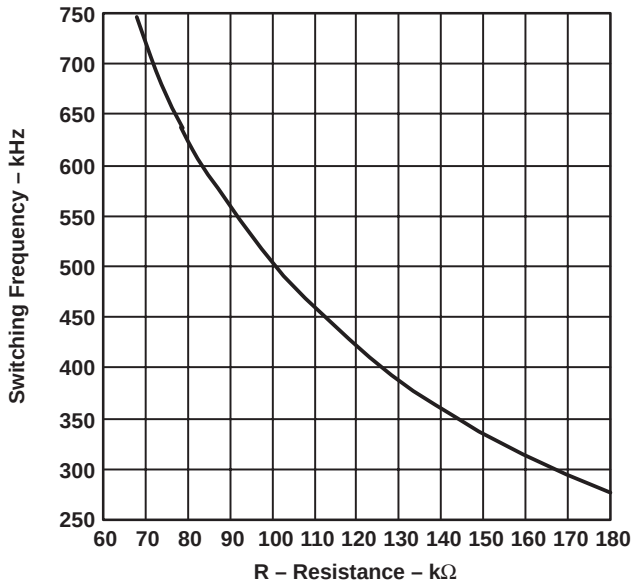
1.3 Modifications

The TPS54x72EVM–222 is designed to demonstrate the small size that can be attained when designing with the TPS54x72, so many of the features which allow for extensive modifications have been ommited from this EVM. Changing the $V_{(DDQ)}$ voltage from 0.92 V to 3.5 V can change the output voltage in the range of 0.46 V to 1.75 V. Output voltages above 1.75 V can be obtained by modifying the REFIN voltage divider of R6 and R7, and scaling the output feedback voltage into the VSENSE pin using the voltage divider of R1 and R9 (normally not used). To maintain the output-tracking rate of one half the $V_{(DDQ)}$ input, the R6/R7 divider should scale $V_{(DDQ)}$ by a factor of four and R1/R9 divder should scale $V_{(TTQ)}$ by a factor of two. To accomplish this, replace R6 with a 30.1 kΩ resistor and add R9 as a 10 kΩ resistor. The minimum output voltage is limited by the minimum controllable ontime of the device, 200 ns, and is dependent upon the duty cycle and operating frequency. The approximat minimum output voltage can be calculated using :

$$V_{OUTMIN} = 200\ ns \times f_s \times V_{INMIN} \quad (1)$$

The switching frequency may be trimmed to any value between 280 kHz and 700 kHz by changing the value of R5. Decreasing the switching frequency results in increased output ripple unless the value of L1 is increased. A plot of the value of RT versus the switching frequency is given in Figure 1–1.

Figure 1–1. Frequency Trimming Resistor Selection Graph



The slow start time is typically 3.6 ms, and is controlled internally. The slow start time cannot be made faster than 3.6 ms.

The TPS54x72EVM–222 EVM also supports alternate output filter configurations by means of pads located on the back side of the PCB. The positions for C15, C16, and C17 provide space for up to three electrolytic type surface mount capacitors, while the position for L2 accommodates popular inductors such as Vishay IHLP-5050 series with a 0.5 in. × 0.5 in. package. Since changes in the output filter affect the overall loop response, the user may find it desirable to change the values used in the compensation network (R1, R2, R3, C1, C2, and C3). The 0-Ω resistor R8 in the feedback path is provided as a convenient place to break the loop for testing any compensation value changes. While the provided compensation network can provide a stable output for a wide variety of output filter component values, it is always a good idea to verify any changes to the output filter or compensation network.

Chapter 2

Test Setup and Results

This chapter describes how to properly connect, set up, and use the TPS54x72EVM–222 evaluation module. The chapter also includes test results typical for the TPS54x72EVM–222 and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

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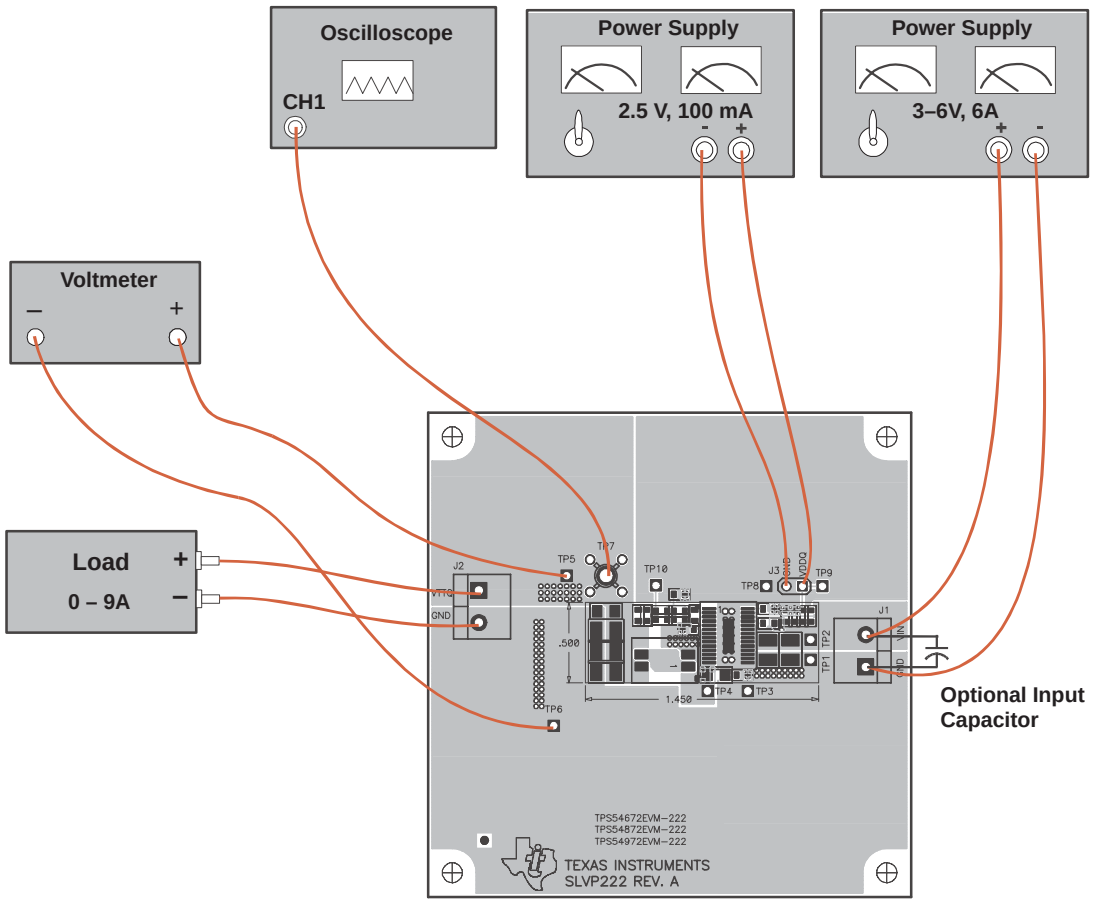
2.1 Input/Output Connections

The TPS54x72EVM–222 has the following four input/output connections: input, input return, output, and output return. A diagram showing the connection points is shown in Figure 2–1. A power supply capable of supplying 6 A should be connected to J1 through a pair of 20 AWG wires. The load should be connected to J2 through a pair of 16 AWG wires. The maximum load current may be reduced from 9 A if 6 A or 8 A versions of the TPS54x72EVM–222 are used. Wire lengths should be minimized to reduce losses in the wires. Test point TP7 provides a place to easily connect an oscilloscope voltage probe to monitor the output voltage. The TPS54X72 is intended to be used as a point of load regulator. In typical applications, it is usually located close to the input voltage source. When using the TPS54x72EVM–222 with an external power supply as the source for V_I, an additional bulk capacitor may be required, depending upon the output impedance of the source and length of the hookup wires. The test results presented were obtained using a 470 µF, 16-V additional input capacitor. Connection is shown for source current only. To sink current, increase the current capacity of the 2.5-V supply, and connect a load resistor between the positive load terminal and the positive terminal of the 2.5-V supply.

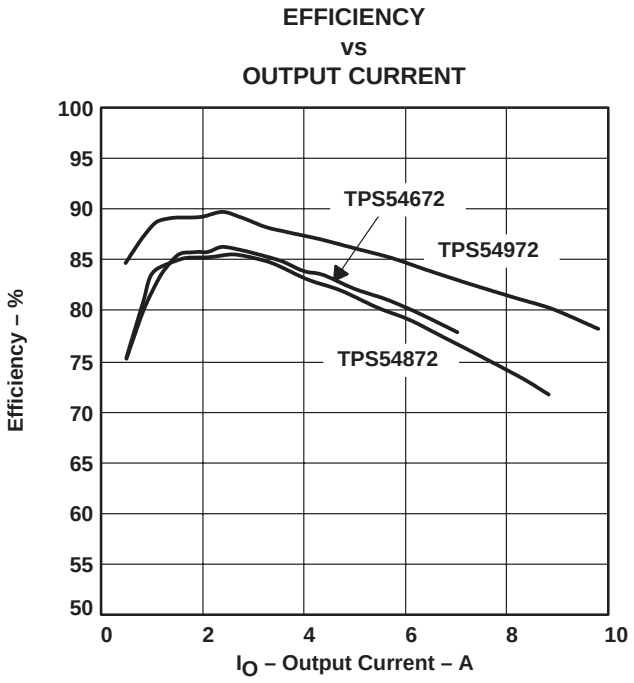
Figure 2–1. Connection Diagram



2.2 Efficiency

The TPS54x72EVM–222 efficiency peaks at load current of about 2 A, and then decreases as the load current increases towards full load. The efficiency shown in Figure 2–2 is for 5-V (TPS54672, TPS54872) and 3.3 V (TPS54972) inputs at an ambient temperature of 25°C. The efficiency is lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the MOSFETs. The efficiency is slightly lower at 700 kHz than at lower switching frequencies, due to the gate and switching losses in the MOSFETs.

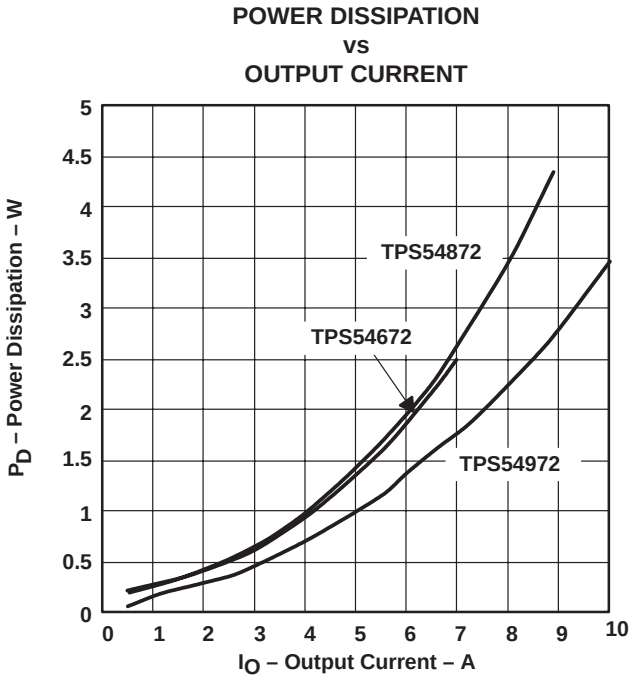
Figure 2–2. Measured Efficiency



2.3 Power Dissipation

The low junction-to-case thermal resistance of the PWP package, along with a good board layout, allows the TPS54x72EVM–222 EVMs to output full rated load current while maintaining safe junction temperatures. With a 3.3-V input source and a 6-A load, the junction temperture is approximately 60°C, while the case temperature is approximately 55°C. The total circuit losses at 25°C are shown in Figure 2–3. The input voltage for the TPS54972 is 3.3 V and for the TPS54672 and TPS54872, 5.0 V. Note that for a given output current the TPS54972 dissipates less power due to the lower drain-to-source on resistance of the MOSFETs. For additional information on the dissipation ratings of the devices, see the individual product data sheets.

Figure 2–3. Power Dissipation



2.4 Output Voltage Regulation

The output voltage load regulation of the TPS54x72EVM–222 is shown in Figure 2–4, while the output voltage line regulation is shown in Figure 2–5. Measurements are given for an ambient temperature of 25°C.

Figure 2–4. Load Regulation

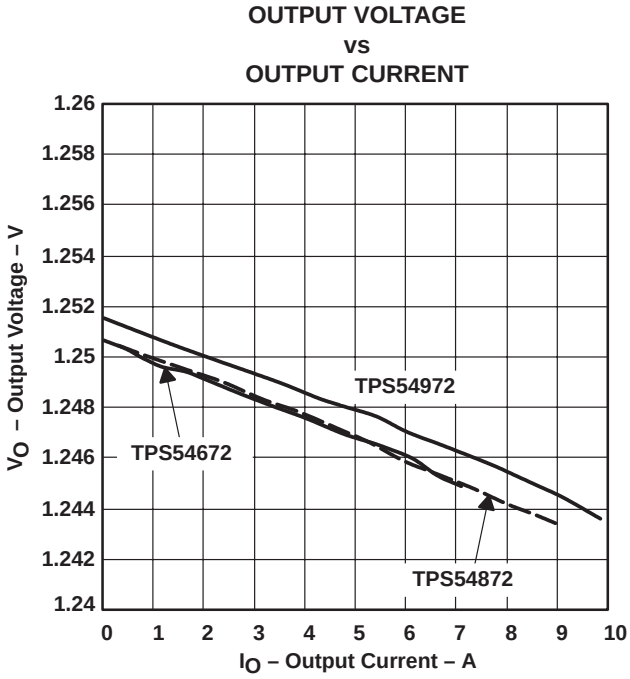
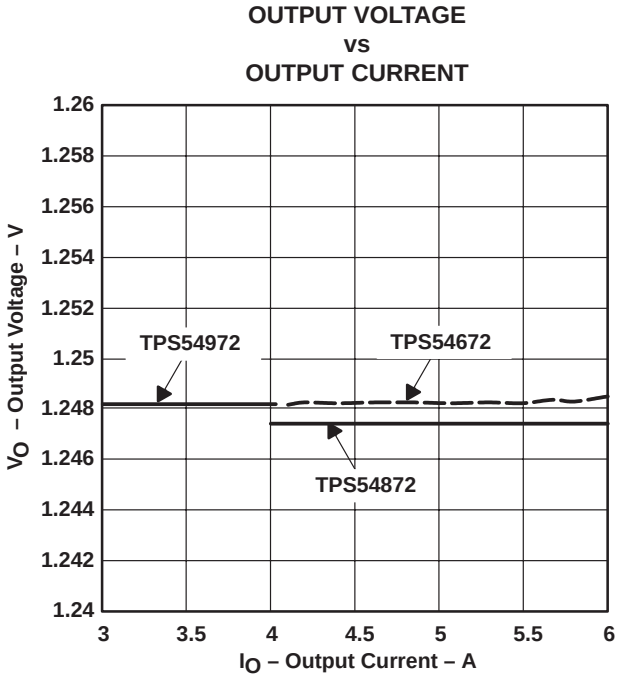


Figure 2–5. Line Regulation



2.5 Load Transients

The TPS54x72EVM–222 response to load transients is shown in Figure 2–6, Figure 2–7, and Figure 2–8. The current step is from 25 to 75 percent of maximum rated load. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

Figure 2–6. Load Transient Response, TPS54672

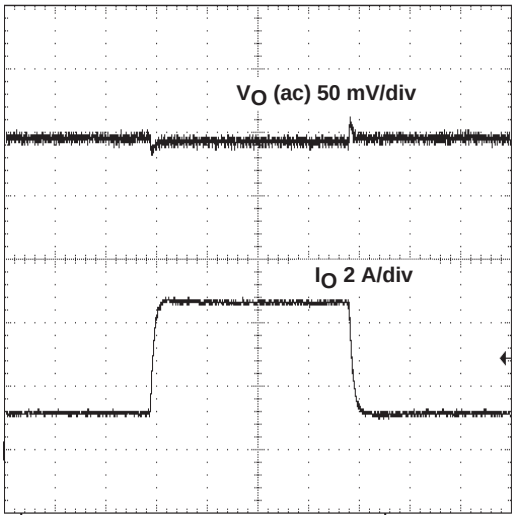


Figure 2–7. Load Transient Response, TPS54872

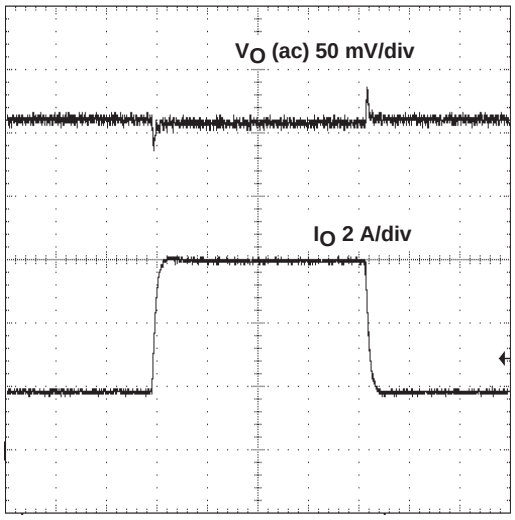
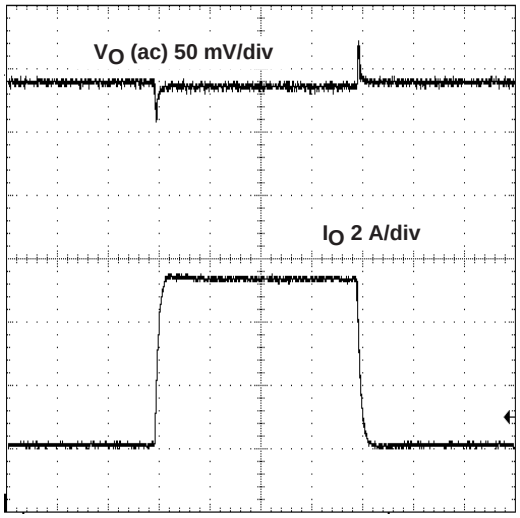


Figure 2–8. Load Transient Response, TPS54972



2.6 Source-Sink Transient Response

The TPS54x72EVM–222 response to source-sink current transients is shown in Figure 2–9, Figure 2–10, and Figure 2–11. The current step is from –50% to 50% of maximum rated load. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

Figure 2–9. Source-Sink Current Transient Response, TPS54672

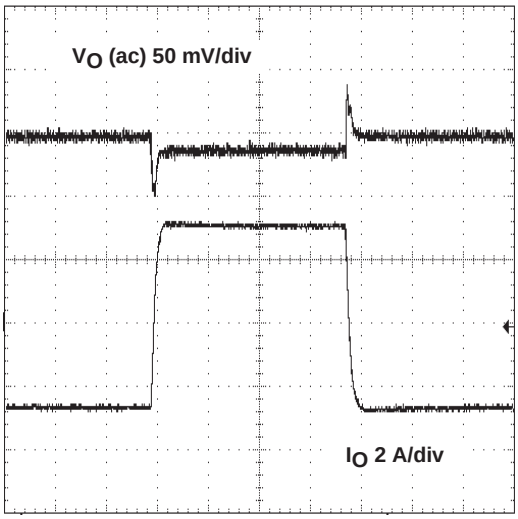


Figure 2–10. Source-Sink Current Transient Response, TPS54872

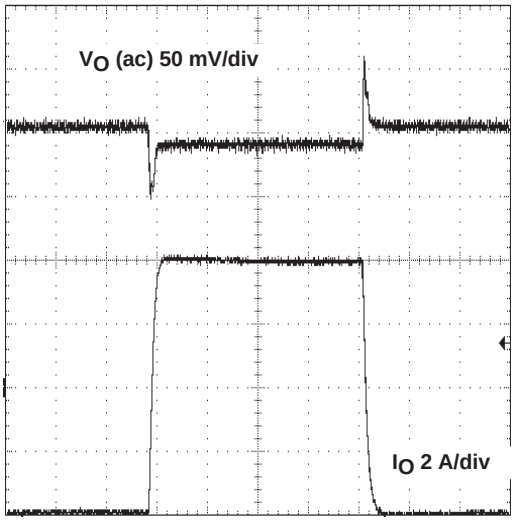
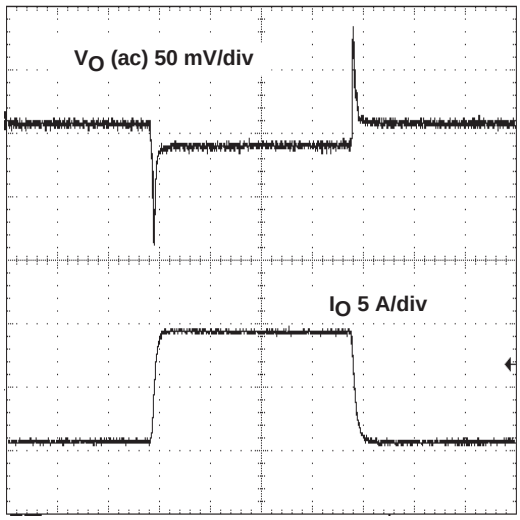


Figure 2–11. Source-Sink Current Transient Response, TPS54972



2.7 Loop Characteristics

The TPS54x72EVM–222 loop respnse characteristics are shown in Figure 2–12 through Figure 2–17. Gain and phase plots are shown for each device at minimum and maximum operating voltage.

Figure 2–12. Measured Loop Response, TPS54672, V_I = 3 V

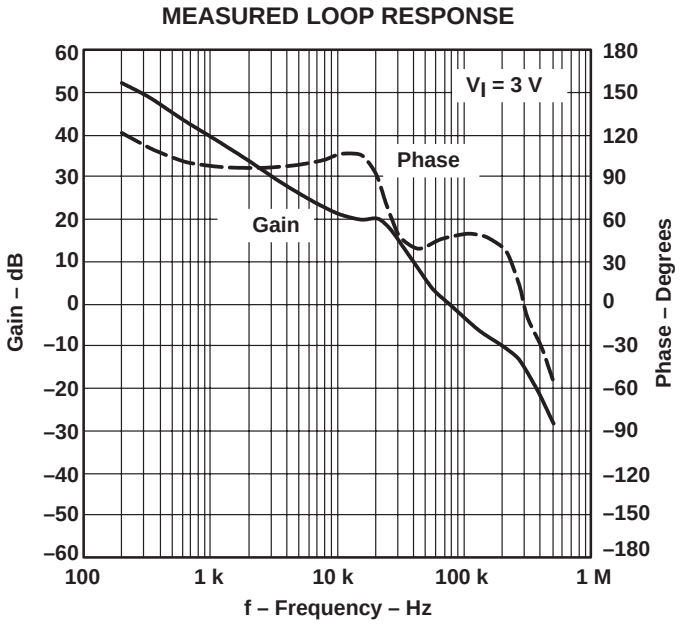


Figure 2–13. Measured Loop Response, TPS54672, V_I = 6 V

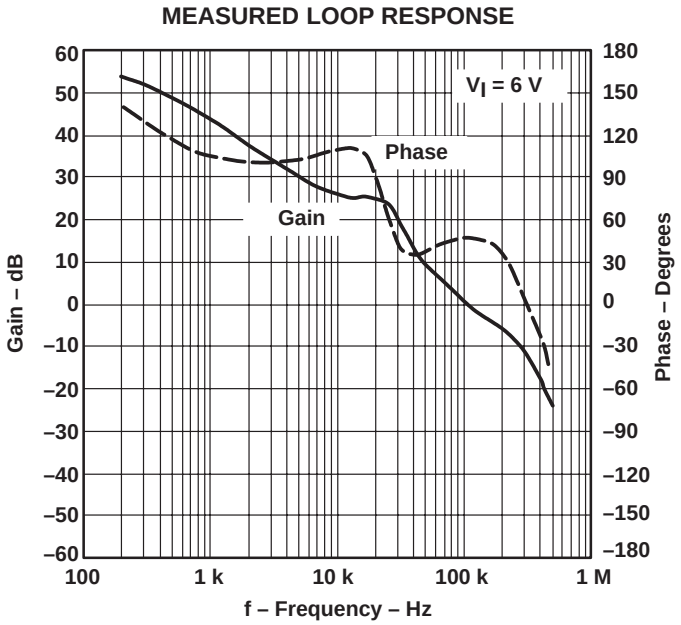


Figure 2–14. Measured Loop Response, TPS54872, V_I = 4 V

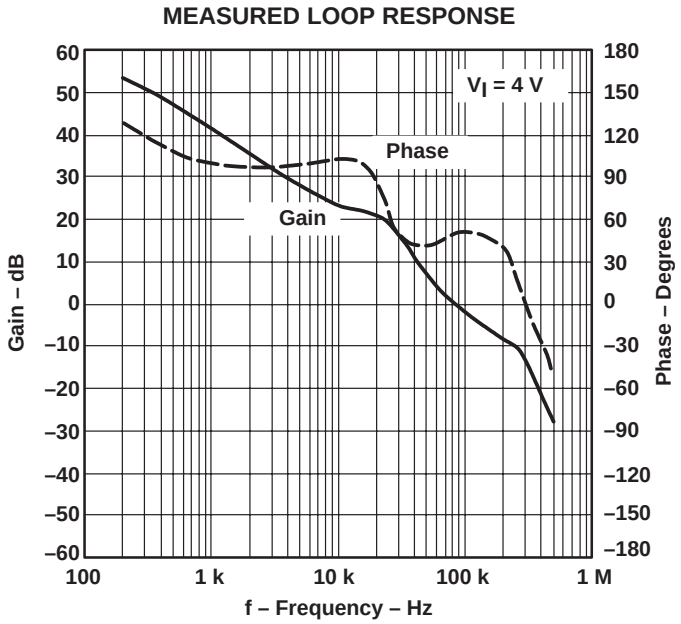


Figure 2–15. Measured Loop Response, TPS54872, V_I = 6 V

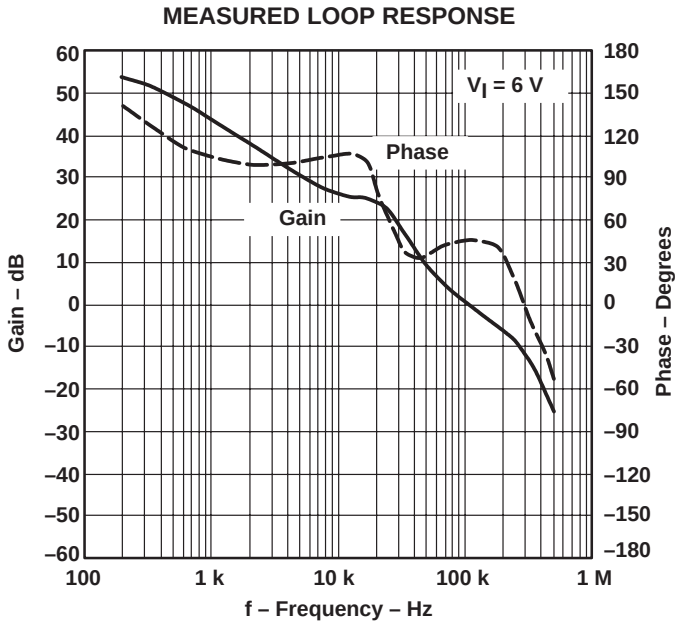


Figure 2–16. Measured Loop Response, TPS54972, V_I = 3 V

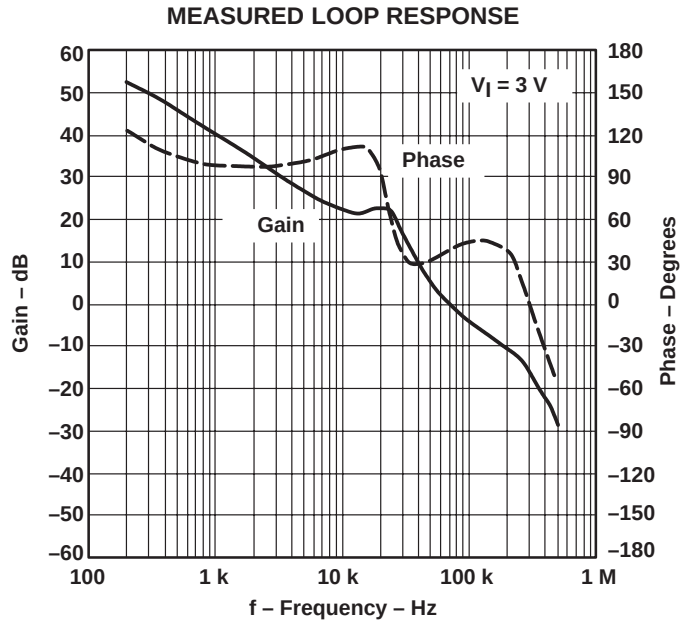
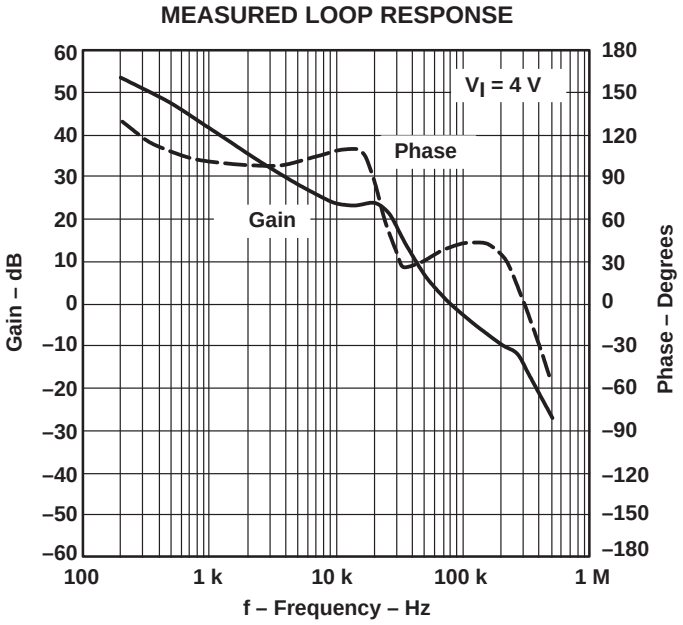


Figure 2–17. Measured Loop Response, TPS54972, V_I = 4 V



2.8 Output Voltage Ripple

The TPS54x72EVM–222 output voltage ripple is shown in Figure 2–18, Figure 2–19, and Figure 2–20 for each device type. The input voltage is 3.3 V for the TPS54672 and TPS54972. The input voltage is 5 V for the TPS54872. Output current for each device is the rated full load. Voltage is measured directly across output capacitors.

Figure 2–18. Measured Output Voltage Ripple, TPS54672

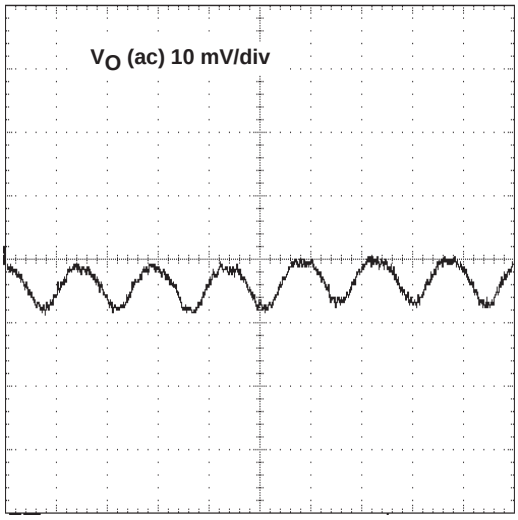


Figure 2–19. Measured Output Voltage Ripple, TPS54872

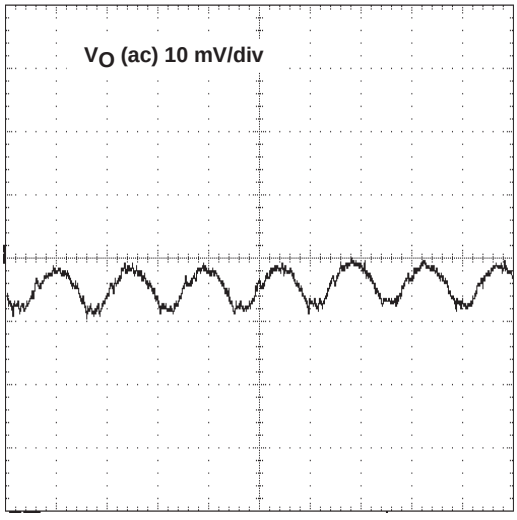
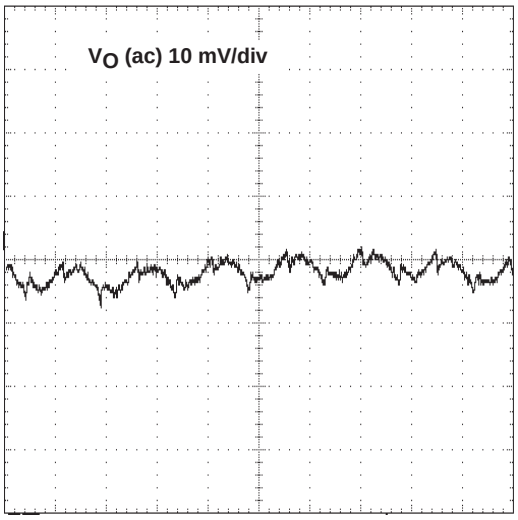


Figure 2–20. Measured Output Voltage Ripple, TPS54972



2.9 Input Voltage Ripple

The TPS54x72EVM–222 output voltage ripple is shown in Figure 2–21, Figure 2–22, and Figure 2–23 for each device type. The input voltage is 3.3 V for the TPS54672 and TPS54972. The input voltage is 5 V for the TPS54872. Output current for each device is rated full load.

Figure 2–21. Input Voltage Ripple, TPS54672

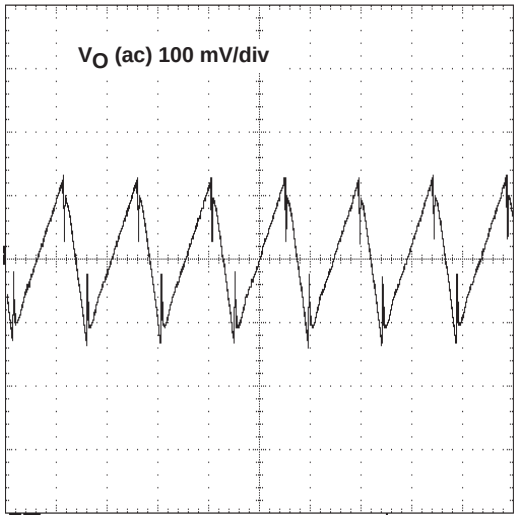


Figure 2–22. Input Voltage Ripple, TPS54872

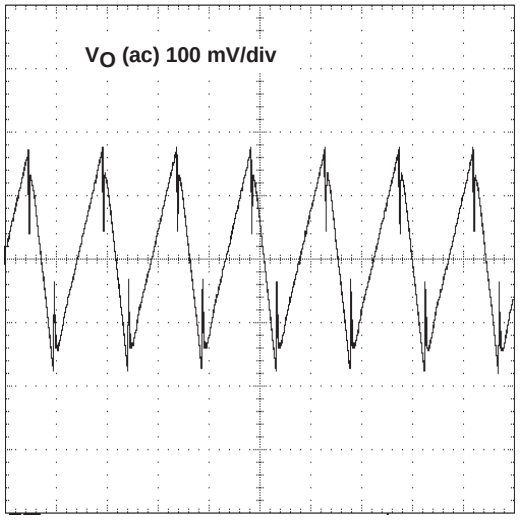
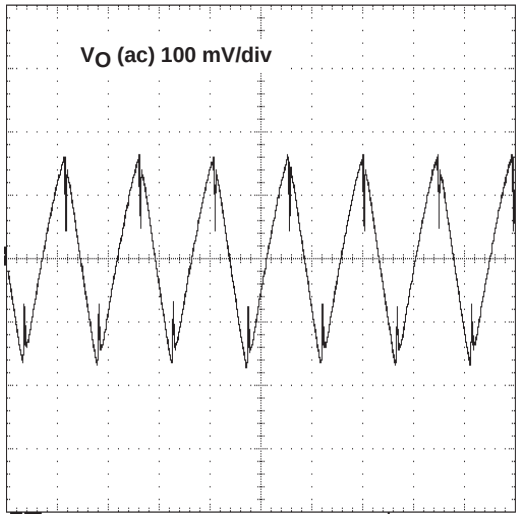


Figure 2–23. Input Voltage Ripple, TPS54972



2.10 Start-Up

The start-up voltage waveform of the TPS54x72EVM–222 is shown in Figure 2–24, Figure 2–25, and Figure 2–26. There is approximately a 3.6-ms delay after the input voltage rises above the 2.9 V (3.8 V for the TPS54872) startup voltage threshold until the output voltage begins to ramp up to the final value of 1.25 V. The output voltage tracks the greater of the internal and external slow start voltages, accounting for the change in ramp rates.

Figure 2–24. Measured Start-Up Waveform, TPS54672

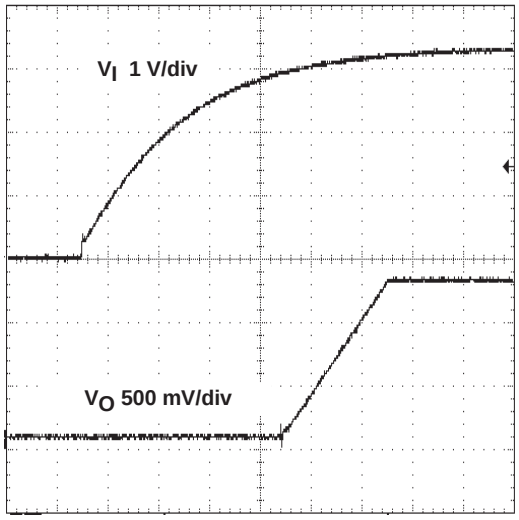


Figure 2–25. Measured Start-Up Waveform, TPS54872

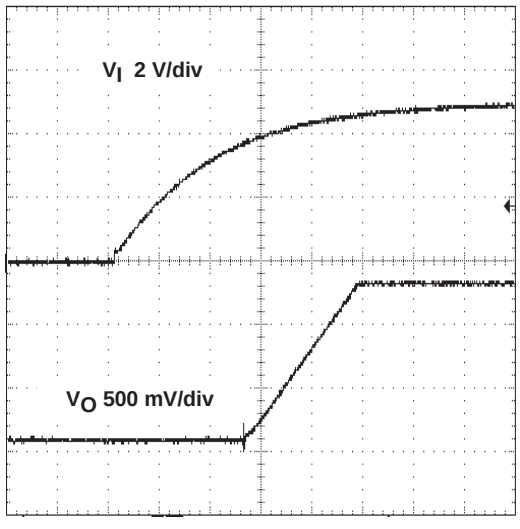
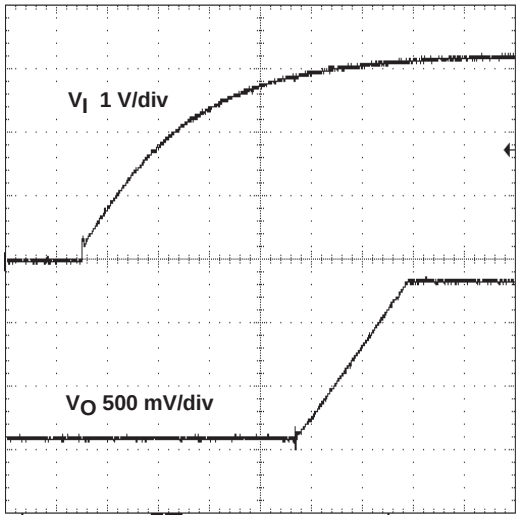


Figure 2–26. Measured Start-Up Waveform, TPS54972



Chapter 3

Board Layout

This chapter provides a description of the TPS54x72EVM–222 board layout and layer illustrations.

Topic **Page**

3.1 Layout

The board layout for the TPS54x72EVM–222 is shown in Figure 3–1 through Figure 3–6. The top side layer of the TPS54x72EVM–222 is laid out in a manner typical of a user application. The bottom layer of the TPS54x72EVM–222 is designed to accommodate an optional alternate output filter configuration. The top and bottom layers are 1.5 oz. copper, while the two internal layers are 0.5 oz. copper.

The top layer contains the main power traces for V_I, V_O, and $V_{(phase)}$. Also on the top layer are connections for the remaining pins of the TPS54x72 and a large area filled with ground. The two internal layers are identical and are dedicated ground planes. The bottom layer contains pads for an optional alternate output filter including space for three D3 or D4 case size electrolytic capacitors and an alternate inductor of 0.5 in. x 0.5 in. size ground traces. The top and bottom ground traces are connected to the internal ground planes with 45 vias placed around the board including 12 directly under the TPS54x72 device to provide a thermal path from the PowerPAD™ land to ground.

The input-decoupling capacitors (C4 and C8), bias-decoupling capacitor (C9), and boot-strap capacitor (C6) are all located as close to the IC as possible. In addition, the compensation components are also kept close to the IC. The compensation circuit ties to the output voltage at the point of regulation, adjacent to the high frequency bypass output capacitor.

Figure 3–1. Top-Side Layout

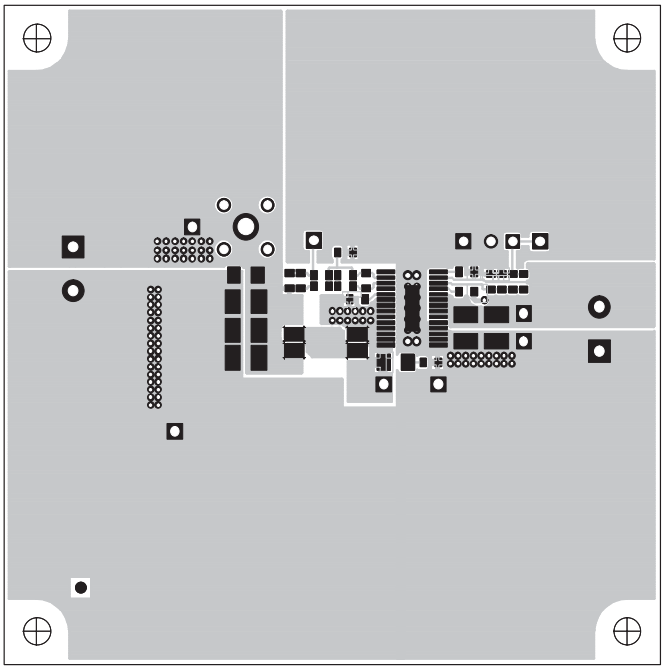


Figure 3–2. Internal Layer 1 Layout

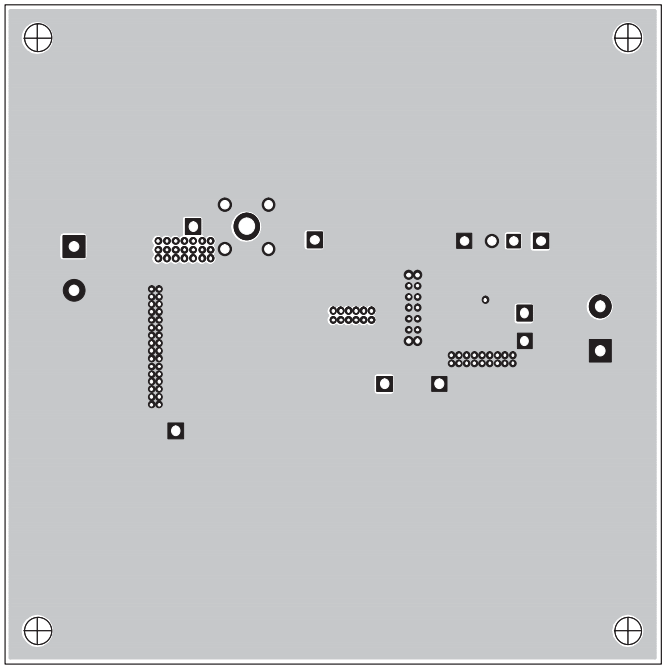


Figure 3–3. Internal Layer 2 Layout

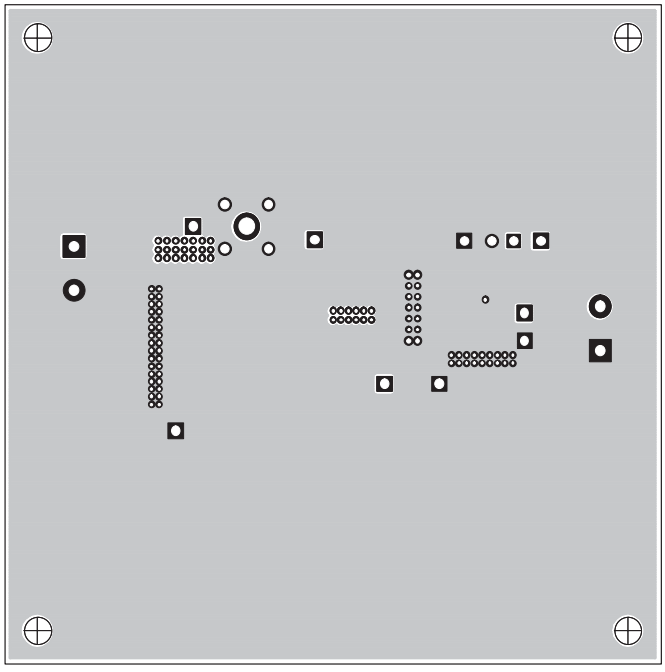


Figure 3–4. Bottom Side Layout (Looking From Top Side)

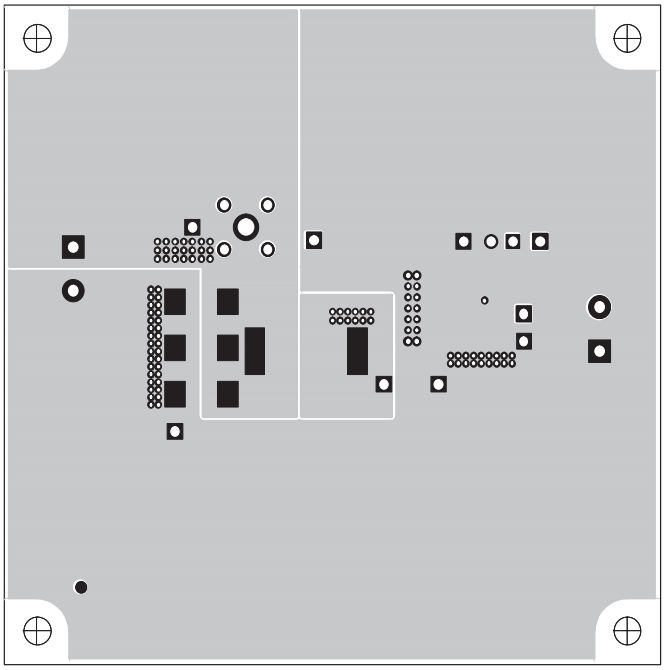


Figure 3–5. Top Side Assembly

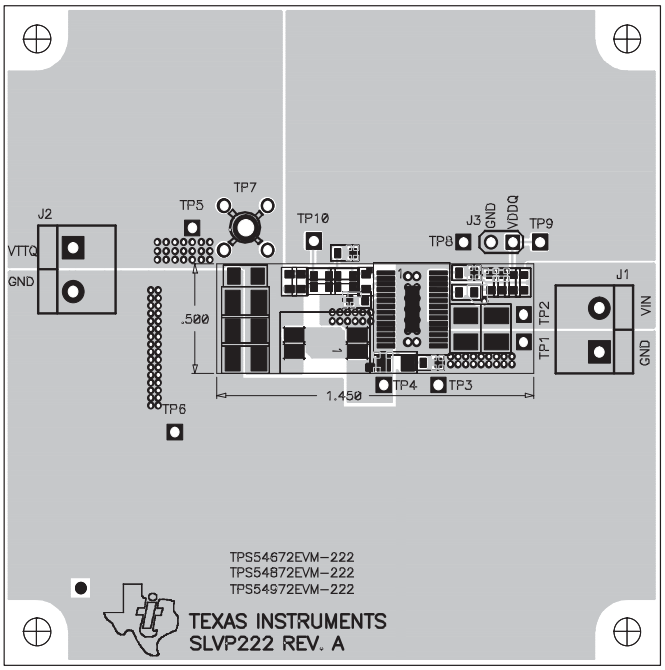
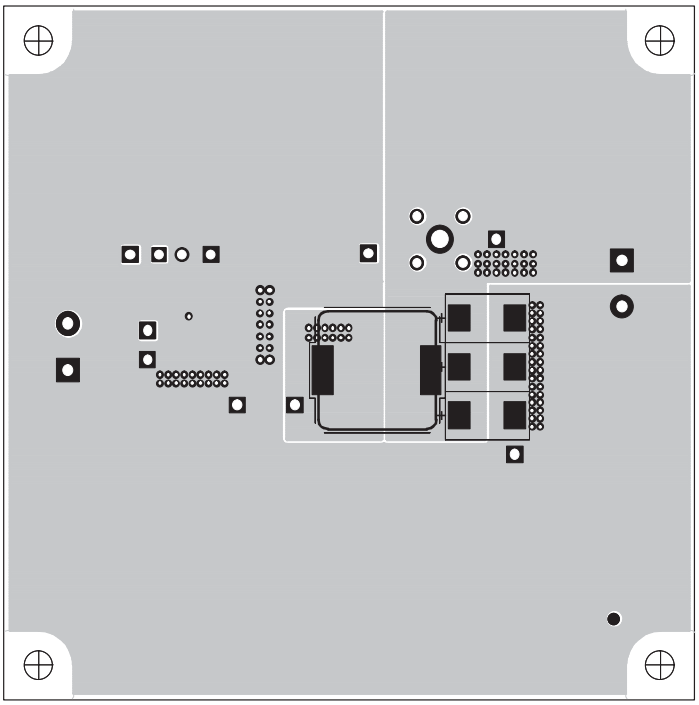


Figure 3–6. Bottom Side Assembly (Showing Optional Components)



Chapter 4

Schematic and Bill of Materials

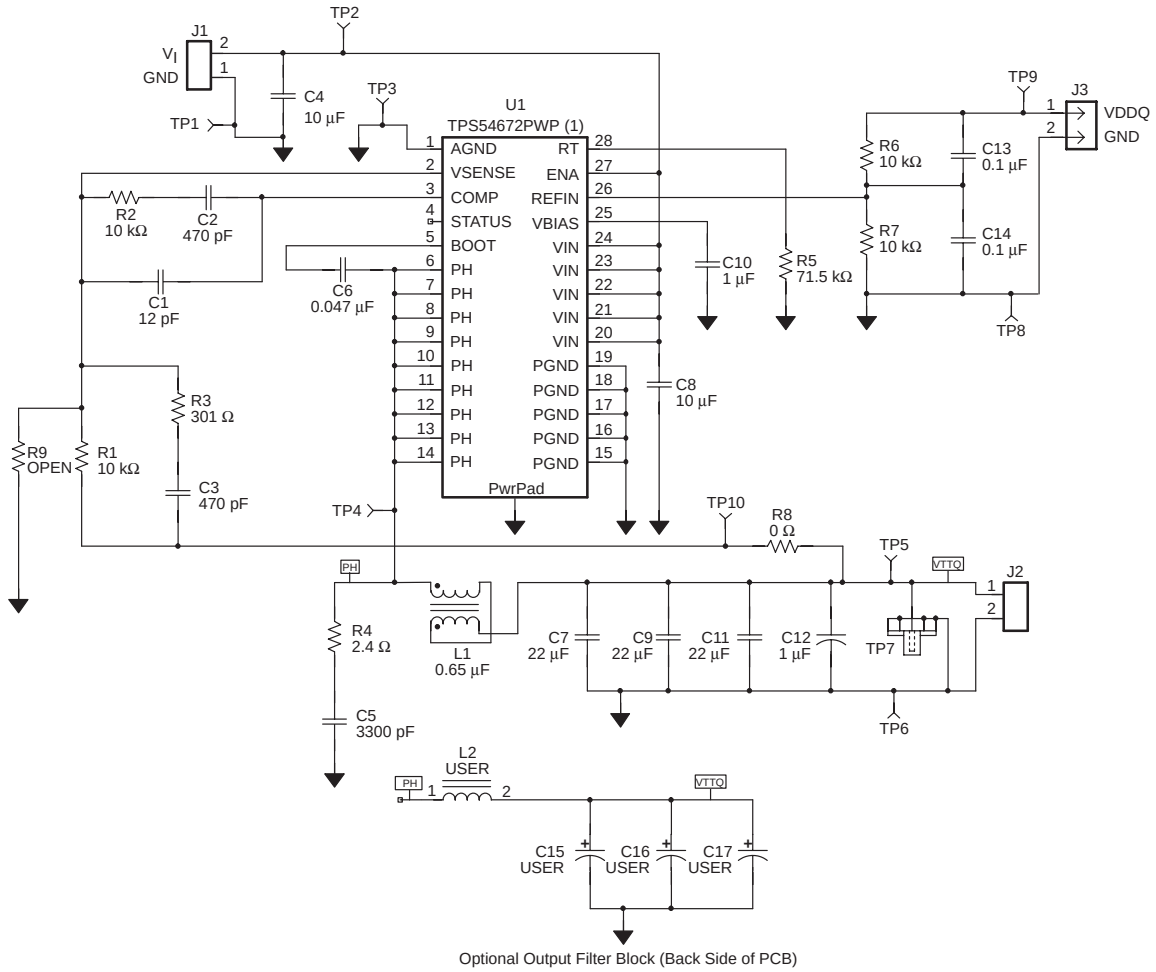
The TPS54x72EVM–222 schematic and bill of materials are presented in this chapter.

Topic **Page**

4.1 Schematic

The schematic for the TPS54x72EVM–222 is shown in Figure 4–1.

Figure 4–1. TPS54x72EVM–222 Schematic



(1) TPS54672 or TPS5472 or TPS54972

4.2 Bill of Materials

The bill of materials for the TPS54x72EVM–222 is shown in Table 4–1.

Table 4–1. TPS54x72EVM–222 Bill of Materials

Count							
–001	**–002**	**–003**	**RefDes**	**Description**	**SIZE**	**MFR**	**Part Number**
1	1	1	C1	Capacitor, ceramic, 12 pF, 50 V, C0G, 5%	603	Murata	GRM1885C1H120JZ01
1	1	1	C10	Capacitor, ceramic, 1.0 µF, 10 V, X5R, 20%	603	TDK	C1608X5R1A105K
1	1	1	C12	Capacitor, ceramic, 1.0 µF, 16 V, X7R, 10 %	1206	Panasonic	ECJ–3YB1C105K
2	2	2	C13, C14	Capacitor, ceramic, 0.1 µF, 25 V, X7R, 10%	603	Panasonic	ECJ–2VB1E104K
–	–	–	C15, C16, C17	Capacitor, polymer aluminum,	62100		
2	2	2	C2, C3	Capacitor, ceramic, 470 pF, 50 V, C0G, 5%	603	Panasonic	GRM1885C1H471JA01
2	2	2	C4, C8	Capacitor, ceramic, 10 µF, 10 V, X5R, 20%	1210	Taiyo Yuden	LMK325BJ106MN
1	1	1	C5	Capacitor, ceramic, 3300 pF, 50 V, X7R, 10%	603	Panasonic	ECJ–1VB1H332K
1	1	1	C6	Capacitor, ceramic, 0.047 µF, 25 V, X7R, 10%	603	Panasonic	ECJ–2VB1E473K
3	3	3	C7, C9, C11	Capacitor, ceramic, 22 µF, 6.3 V, X5R, 20%	1210	Taiyo Yuden	JMK325BJ226MN
2	2	2	J1, J2	Terminal block, 2 pin, 15 A, 5.1 mm	0.40 × 0.35	OST	ED1609
1	1	1	J3	Header, 2 pin, 100 mil spacing, (36-pin strip)	23100	Sullins	PTC36SAAN
1	1	1	L1	Inductor, 0.65 µH, 12 A	0.340×0.250	Pulse	PA0277
–	–	–	L2	Inductor, SMT, user defined	0.51 × 0.51		
4	4	4	R1, R2, R6, R7	Resistor, chip, 10.0 kΩ, 1/16–W, 1%	603	Std	Std
1	1	1	R3	Resistor, chip, 301 Ω, 1/16 W, 1%	603	Std	Std
1	1	1	R4	Resistor, chip, 2.4 Ω, 1/8 W, 1%	1206	Std	Std
1	1	1	R5	Resistor, chip, 71.5 kΩ, 1/16 W, 1%	603	Std	Std
1	1	1	R8	Resistor, chip,0 Ω, 1/16 W, 1%	603	Std	Std
1	1	1	R9	Resistor, chip, OPEN Ω, 1/16 W, 1%	603	Std	Std
4	4	4	TP1, TP3, TP6, TP8	Test point, black, 1 mm	0.038”, 6400”	Farnell	240–333
5	5	5	TP2, TP4, TP5, TP9, TP10	Test point, red, 1 mm	0.038”, 6400”	Farnell	240–345

1	1	1	TP7	Adaptor, 3,5-mm probe clip (or 131–5031–00)	72900	Tektronix	131–4244–00
1	–	–	U1	IC, tracking/termination synch. PWM switcher.	PWP28	TI	TPS54672PWP
–	1	–	U1	IC, tracking/termination synch. PWM switcher.	PWP28	TI	TPS54872PWP
–	–	1	U1	IC, tracking/termination synch. PWM switcher.	PWP28	TI	TPS54972PWP
1	1	1	–	PCB, 3 in. × 3 in. × 0.063 in.		Any	SLVP222

Note: SLVP222–001 is TPS54672EVM–222
SLVP222–002 is TPS54872EVM–222
SLVP222–003 is TPS54972EVM–222