User's Guide

TPS54232 Step-Down Converter Evaluation Module User's Guide

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1 Introduction

This user's guide contains background information for the TPS54232 as well as support documentation for the TPS54232EVM-415 evaluation module (HPA415). Also included are the performance specifications, the schematic, and the bill of materials for the TPS54232EVM-415.

1.1 Background

The TPS54232 dc/dc converter is designed to provide up to a 2 A output from an input voltage source of 3.5 V to 28 V. Rated input voltage and output current range for the evaluation module are given in Table 1-1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS54232 regulator. The switching frequency is internally set at a nominal 1000 kHz. The high-side MOSFET is incorporated inside the TPS54232 package along with the gate drive circuitry. The low drain-to-source on resistance of the MOSFET allows the TPS54232 to achieve high efficiencies and helps keep the junction temperature low at high output currents. The compensation components are external to the integrated circuit (IC), and an external divider allows for an adjustable output voltage. Additionally, the TPS54232 provides adjustable slow start and undervoltage lockout inputs. The absolute maximum input voltage is 30 V for the TPS54232EVM-415.

Table 1-1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54232EVM-415	VIN = 5 V to 15 V	0 A to 2 A

1.2 Performance Specification Summary

A summary of the TPS54232EVM-415 performance specifications is provided in Table 1-2. Specifications are given for an input voltage of V_{IN} = 12 V and an output voltage of 2.5 V, unless otherwise specified. The TPS54232EVM-415 is designed and tested for V_{IN} = 5 V to 15 V. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 1-2. TPS54232EVM-415 Performance Specification Summary

SPECIFICATION	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN} voltage range			5	12	15	V
Output voltage set point				2.5		V
Output current range	V_{IN} = 5 V to 15 V		0		2	A
Line regulation	I_O = 1 A, V_{IN} = 5 V to 15 V			±0.02%		
Load regulation	V_{IN} = 12 V, I_O = 0.2 A to 2 A			±0.25%		
Load transient response	I_O = 0.5 A to 1.5 A	Voltage change		–40		mV
		Recovery time		400		µs
	I_O = 1.5 A to 0.5 A	Voltage change		60		mV
		Recovery time		400		µs
Loop bandwidth	V_{IN} = 12 V, I_O = 1 A			36		kHz
Phase margin	V_{IN} = 12 V , I_O = 1 A			54		°
Input ripple voltage	I_O = 2 A			160		mVpp
Output ripple voltage	I_O = 2 A			10		mVpp
Output rise time				6		ms
Operating frequency				1000		kHz
Maximum efficiency	TPS54232EVM-415, V_{IN} = 5 V, I_O = 0.5 A			88.6%		

1.3 Modifications

These evaluation modules are designed to provide access to the features of the TPS54232. Some modifications can be made to this module.

1.3.1 Output Voltage Set Point

To change the output voltage of the EVM, it is necessary to change the value of resistor R_6. Changing the value of R_6 can change the output voltage above 0.8 V. The value of R_6 for a specific output voltage can be calculated using Equation 1.

$$R_6 = 10.2 \ k\Omega \times \frac{0.8 \ V}{V_{OUT} - 0.8 \ V}$$

(1)

Table 1-3 lists the R_6 values for some common output voltages. Note that V_{IN} must be in a range so that the minimum on-time is greater than 130 ns, and the maximum duty cycle is less than 91%. The values given in Table 1-3 are standard values, not the exact value calculated using Equation 1.

Table 1-3. Output Voltages Available

Output Voltage (V)	R_6 Value (kΩ)
1.8	8.25
2.5	4.75
3.3	3.24
5	1.96

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54232EVM-415 evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input / Output Connections

The TPS54232EVM-415 is provided with input/output connectors and test points as shown in Table 2-1. A power supply capable of supplying 2 A must be connected to J1 through a pair of 20 AWG wires. The load must be connected to J4 through a pair of 20 AWG wires. The maximum load current capability must be 2 A. Wire lengths must be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the V_{IN} input voltages with TP2 providing a convenient ground reference. TP5 is used to monitor the output voltage with TP6 as the ground reference.

Table 2-1. EVM Connectors and Test Points

Reference Designator	Function
J1	V_{IN} (see Table 1-1 for V_{IN} range)
J2	2-pin header for enable. Connect EN to ground to disable, open to enable.
J3	2-pin header for slow start monitor and GND.
J4	V_{OUT}, 2.5 V at 2 A maximum
TP1	V_{IN} test point at V_{IN} connector
TP2	GND test point at V_{IN}
TP3	PH test point
TP4	Test point between voltage divider network and output. Used for loop response measurements.
TP5	Output voltage test point at OUT connector
TP6	GND test point at OUT connector

2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 0.5 A with V_{IN} = 5 V, and then decreases as the load current increases towards full load. Figure 2-1 shows the efficiency for the TPS54232EVM-415 at an ambient temperature of 25°C.
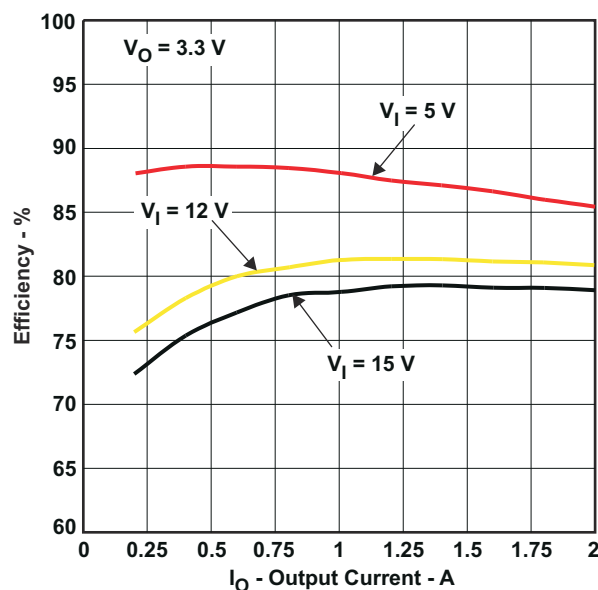

Figure 2-1. TPS54232EVM-415 Efficiency

Figure 2-2 shows the efficiency for the TPS54232EVM-415 at lower output currents between 0.02 A and 0.20 A at an ambient temperature of 25°C.
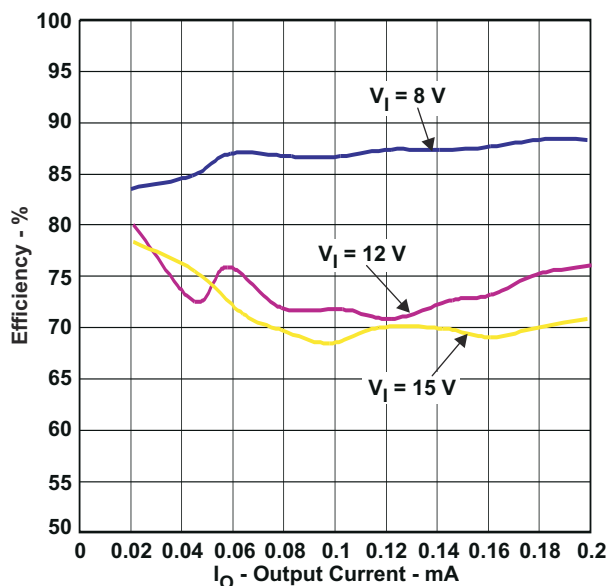
Figure 2-2. TPS54232EVM-415 Low Current Efficiency

The efficiency may be lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the internal MOSFET.

2.3 Output Voltage Load Regulation

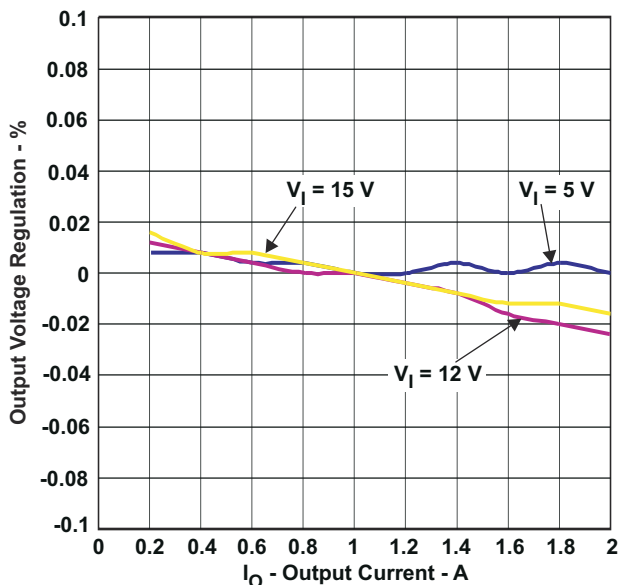The load regulation for the TPS54232EVM-415 is shown in Figure 2-3.

Figure 2-3. TPS54232EVM-415 Load Regulation

Measurements are given for an ambient temperature of 25°C.

2.4 Output Voltage Line Regulation

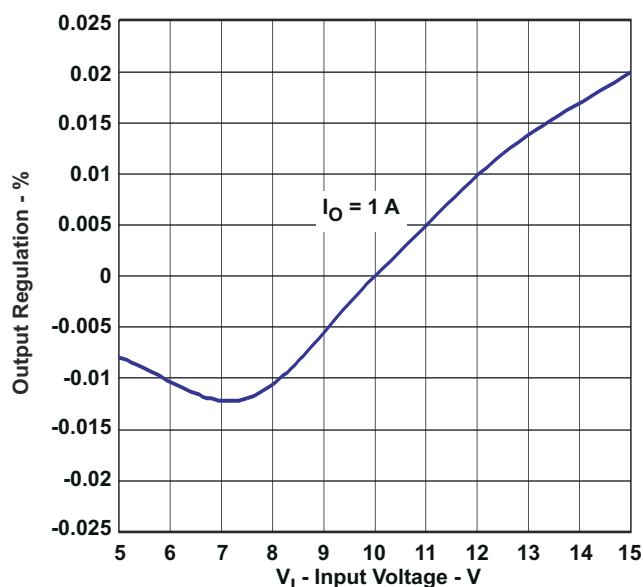The line regulation for the TPS54232EVM-415 is shown in Figure 2-4.

Figure 2-4. TPS54232EVM-415 Line Regulation

2.5 Load Transients

The TPS54232EVM-415 response to load transients is shown in Figure 2-5. The current step is from 25% to 75% of maximum rated load at 15V input. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.
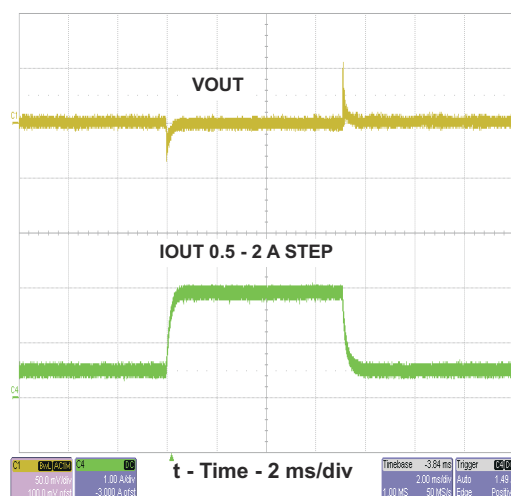

Figure 2-5. TPS54232EVM-415 Transient Response

2.6 Loop Characteristics

The TPS54232EVM-415 loop-response characteristics are shown in Figure 2-6 . Gain and phase plots are shown for V_{IN} voltage of 15 V. Load current for the measurement is 1 A.
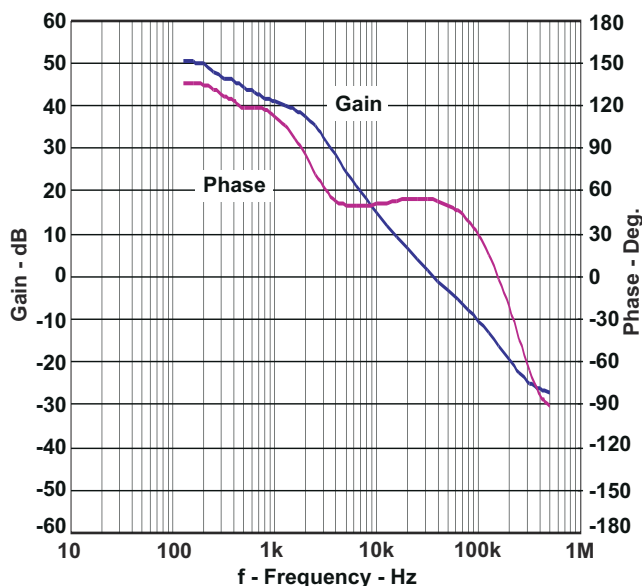
Figure 2-6. TPS54232EVM-415 Loop Response

2.7 Output Voltage Ripple

The TPS54232EVM-415 output voltage ripple is shown in Figure 2-7 . The output current is the rated full load of 2 A and V_{IN} = 15 V. The ripple voltage is measured directly across the output capacitors.

Figure 2-7. TPS54232EVM-415 Output Ripple

2.8 Input Voltage Ripple

The TPS54232EVM-415 input voltage ripple is shown in Figure 2-8 . The output current is the rated full load of 2 A and V_{IN} = 15 V. The ripple voltage is measured directly across the input capacitors.
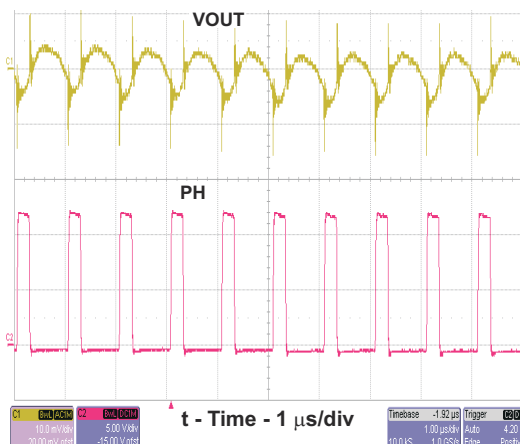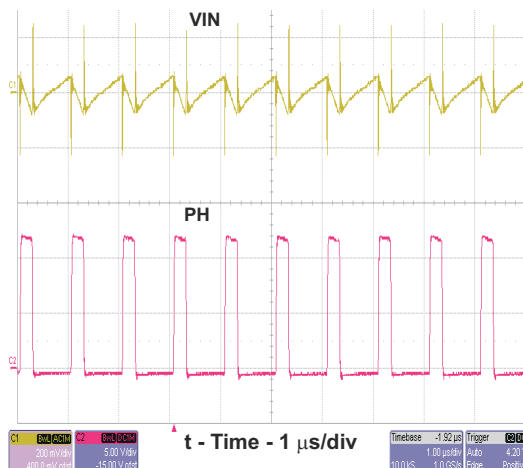

Figure 2-8. TPS54232EVM-415 Input Ripple

2.9 Powering Up

The start-up waveforms are shown in Figure 2-9 and Figure 2-10. In Figure 2-9, the top trace shows V_{OUT} , and the bottom trace shows V_{IN}. In Figure 2-10 , the top trace shows V_{OUT} whereas the bottom trace shows the slow start voltage . In Figure 2-10, the input voltage is initially applied and the output is inhibited by using a jumper at J2 to tie EN to GND. When the jumper is removed, EN is released. When the EN voltage reaches the enable-threshold voltage of 1.25 V, the start-up sequence begins and the output ramps up at the externally set rate toward the set value of 2.5 V. The input voltage for these plots is 12 V and there is no load.
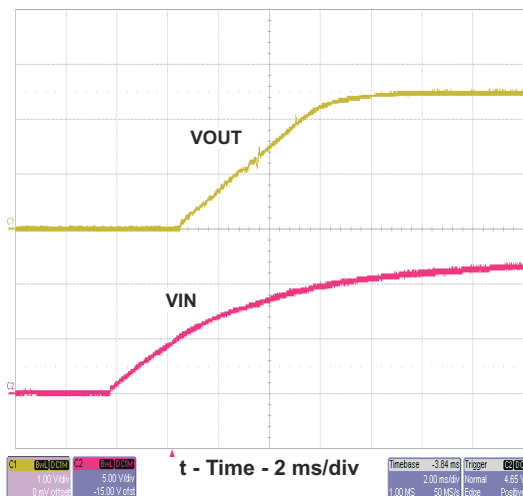

Figure 2-9. TPS54232EVM-415 Start-Up Relative to V_{IN}

Figure 2-10. TPS54232EVM-415 Start-Up Relative to Enable

2.10 Eco-mode Operation

At light load currents, the TPS54232 is designed to operate in pulse skipping Eco-mode. When the peak inductor current is lower than 100 mA typical, the device enters Eco-mode.

Figure 2-11 shows Eco-mode operation, channel 1(C1) shows the output voltage while channel 2(C2) shows the switching node (PH).
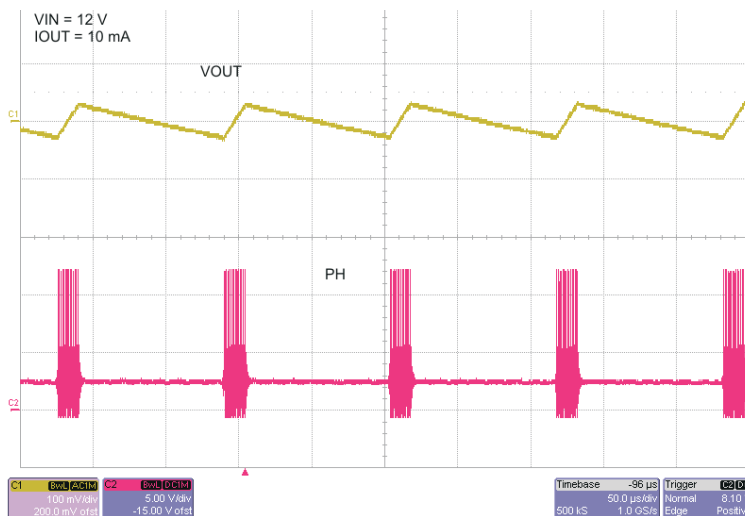

Figure 2-11. TPS54232EVM-415 Eco-mode Operation

3 Board Layout

This section provides a description of the TPS54232EVM-415, board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS54232EVM-415 is shown in Figure 3-1 through Figure 3-3. The topside layer of the EVM is laid out in a manner typical of a user application. The top and bottom layers are 2-oz. copper.

The top layer contains the main power traces for V_{IN}, V_{OUT}, and VPHASE. Also on the top layer are connections for the remaining pins of the TPS54232 and a large area filled with ground. The bottom layer contains ground and a signal route for the BOOT capacitor. The top and bottom and internal ground traces are connected with multiple vias placed around the board including ten vias directly under the TPS54232 device to provide a thermal path from the top-side ground plane to the bottom-side ground plane.

The input decoupling capacitor (C1, C2 is not used) and bootstrap capacitor (C4) are all located as close to the IC as possible. In addition, the voltage set-point resistor divider components are also kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, the copper V_{OUT} trace past the output capacitor (C3, C8 is not used). For the TPS54232, an additional input bulk capacitor may be required, depending on the EVM connection to the input supply.
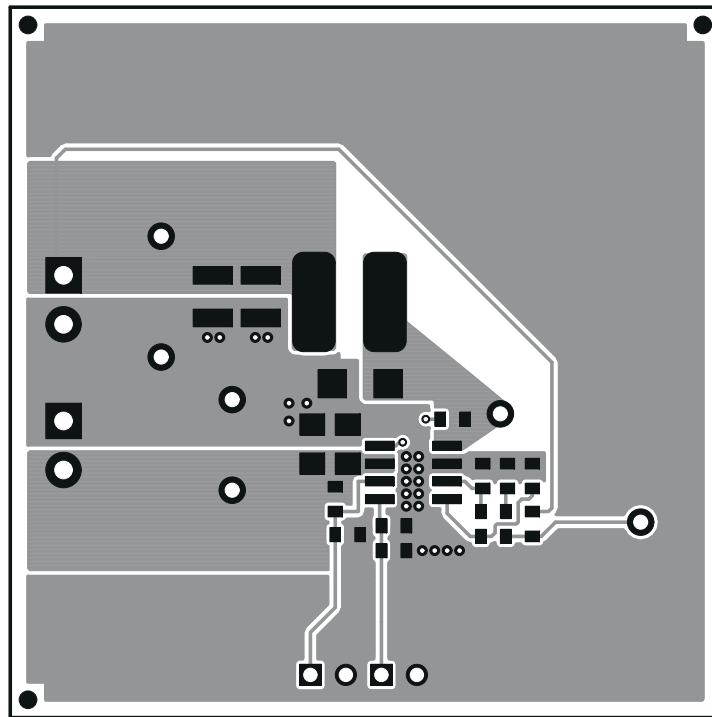

Figure 3-1. TPS54232EVM-415 Top-Side Layout

Figure 3-2. TPS54232EVM-415 Bottom-Side Layout

Figure 3-3. TPS54232EVM-415 Top-Side Assembly

3.2 Estimated Circuit Area

The estimated printed circuit board area for the components used in this design is 0.44 in^2. This area does not include test point or connectors.

4 Schematic and Bill of Materials

This section presents the TPS54232EVM-415 schematic and bill of materials.

4.1 Schematic

is the schematic for the TPS54232EVM-415.

Figure 4-1. TPS54232EVM-415 Schematic

4.2 Bill of Materials

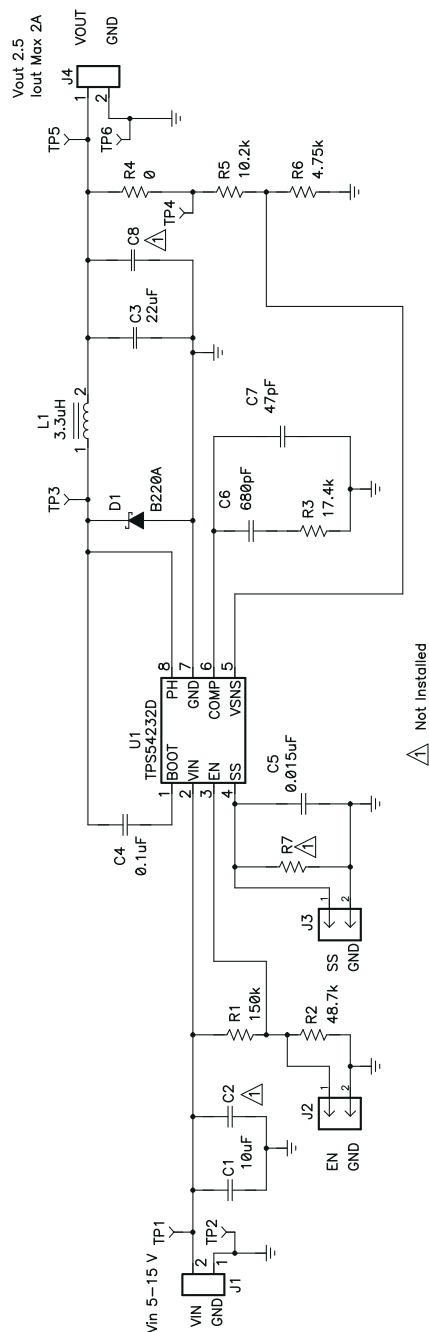Table 4-1 presents the bill of materials for the TPS54232EVM-415.

Table 4-1. TPS54232EVM-415 Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	4.7 µF	Capacitor, Ceramic, 25 V, X5R, 10%	1206	GRM31CR61E106KA12	muRata
0	C2	Open	Capacitor, Ceramic, 25 V, X5R, 10%	1206	GRM31CR61E106KA12	muRata
1	C3	22 µF	Capacitor, Ceramic, 10 V, X7R, 10%	1210	Std	Std
1	C4	0.1 µF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
1	C5	0.015 µF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
1	C6	680 pF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
1	C7	47 pF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
0	C8	Open	Capacitor, Ceramic, 10 V, X5R, 10%	1210	Std	TDK
1	D1	B220A	Diode, Schottky, 2 A, 20 V	SMA	B220A	Diodes Inc
2	J1, J4	ED1514	Terminal Block, 2-pin, 6 A, 3.5 mm	0.27 × 0.25 inch	ED1514	OST
2	J2, J3	PTC36SAAN	Header, 2 pin, 100 mil spacing, (36-pin strip)	0.100 × 2	PTC36SAAN	Sullins
1	L1	3.3 µH	Inductor, SM Toroid, 3.72 A, 20 mΩ	0.287 × 0.287 inch	MSS7341-332	Coilcraft
1	R1	150 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	48.7 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	17.4 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	10.2 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R6	4.75 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R7	Open	Resistor, Chip, 1/16W, 1%	0603	Std	Std
3	TP1, TP3, TP5	5000	Test Point, Red, Thru Hole Color Keyed	0.100 × 0.100 inch	5000	Keystone
3	TP2, TP4, TP6	5001	Test Point, Black, Thru Hole Color Keyed	0.100 × 0.100 inch	5001	Keystone
1	U1	TPS54232D	IC, DC-DC Converter, 28 V, 2 A	SO-8	TPS54232D	TI
1	—		PCB, 2 inch × 2 inch × 0.062 inch	2.0" × 2.0" × 0.062"	HPA415	Any

5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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