

Using the TPS40222, a 5-V Input, 1.6-A Output, Nonsynchronous Buck Converter

The TPS40222EVM-001 evaluation module (EVM) is a nonsynchronous buck converter with a 4.5-V to 8-V input range with a built-in N-channel power FET, that can deliver 1.6 A of output current. The EVM is designed to operate with a minimum of components and yet has the features of more complex buck converters.

Contents

1	Description.....	1
2	Electrical Specifications.....	3
3	Schematic	3
4	TPS40222EVM Typical Performance Data and Characteristic Curves	7
5	EVM Assembly Drawings and Layout	9
6	List of Materials.....	10

List of Figures

1	TPS40222EVM-001 Schematic.....	3
2	TPS40222EVM-001 Recommended Test Setup	5
3	Output Ripple Measurement – Tip and Barrel Using TP15 and TP16.....	6
4	Control Loop Measurement Setup	6
5	TPS40222EVM-001 Efficiency 1.4 V Out ($V_{5V_IN} = 4.5\text{--}8\text{ V}$, $V_{1V4_OUT} = 1.4\text{ V}$, $I_{1V5_OUT} = 0\text{--}1.6\text{ A}$)	8
6	TPS40222EVM-001 Line and Load Regulation	8
7	TPS40222EVM-001 Switch Node and Output Ripple at 1.6 A	9
8	TPS40222EVM-001 Component Placement (Viewed From Top)	9
9	TPS40222EVM-001 Silkscreen (Viewed From Top)	10
10	TPS40222EVM-001 Top Copper (Viewed From Top)	10
11	TPS40222EVM-001 Bottom Copper (X-Ray View From Top)	10

List of Tables

1	Common Values for R2	4
2	TPS40222EVM-001 Bill of Materials	11

1 Description

The TPS40222EVM-001 is designed to use a 4.5- to 8-V input voltage to produce a high-current, regulated 1.4-V output at up to 1.6 A of load current. This application board is designed to demonstrate the TPS40222 in a typical voltage bus to low-voltage application while providing a number of test points to evaluate the performance of the IC. Users can modify the EVM to support output voltages from 0.8 V to 6.3 V by changing a single resistor. The TPS40222EVM-001 was built to the application example used in the TPS40222 data sheet with the internal clock operating at 1.25 MHz.

*Description***1.1 Features**

- 4.5-V to 8-V input range
- 0.8-V to 6.3-V output, adjustable with single resistor
- 1.6-Adc steady-state output current
- Internally compensated error amplifier
- Fixed 1.25-MHz switching frequency
- Internal N-channel FET
- Surface-mount design on a two-layer, 1.1 x 1.875-inch evaluation board
- Convenient test points for probing critical waveforms and noninvasive loop response testing

1.2 Applications

- Non-isolated point of load and low-voltage bus converters.
- Merchant power modules
- Disk drives
- Point of load power
- ASIC power supplies

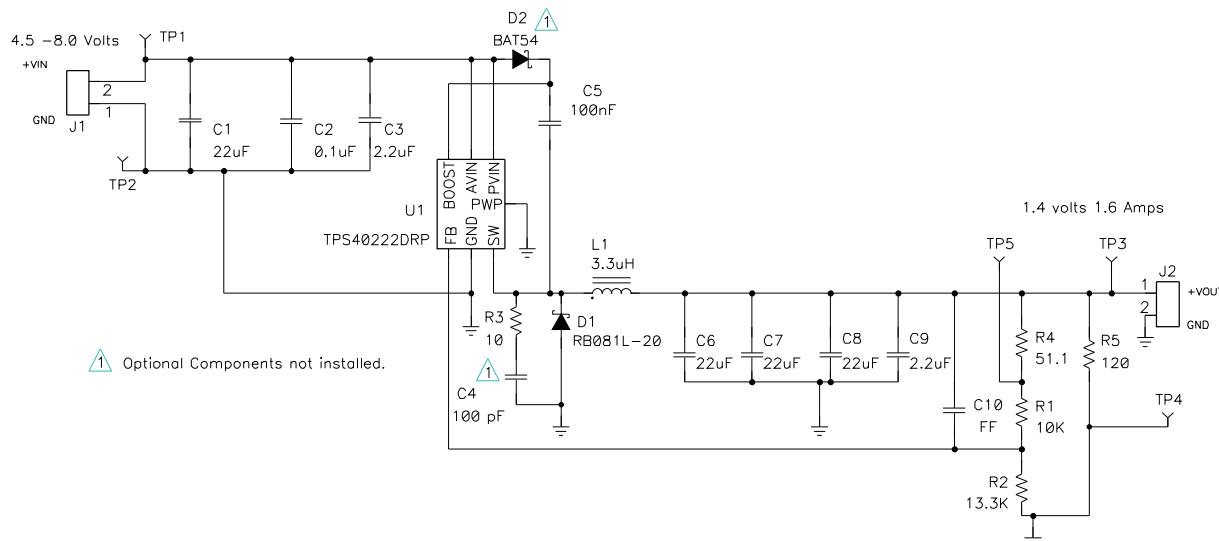
2 Electrical Specifications

2.1 TPS40222EVM-001 Electrical Performance Specifications

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS					
Input Voltage Range		4.5	8		V
Max Input Current	$V_{IN} = 5 \text{ V}$, $I_{OUT} = 1.0 \text{ A}$		0.375		A
No-Load Input Current	$V_{IN} = 5 \text{ V}$, $I_{OUT} = 0 \text{ A}$, $R_5 = 120 \Omega$ (10 mA Load)	11			mA
OUTPUT CHARACTERISTICS					
Output Voltage	$R_2 = 10.0 \text{ k}$ $R_1 = 7.5 \text{ k}$ ⁽¹⁾	1.358	1.40	1.442	V
Output Voltage Regulation	Line Regulation ($4.5 \text{ V} < V_{IN} < 5.5 \text{ V}$, $I_{OUT} = 1 \text{ A}$)	0.1%			
	Load Regulation ($0 \text{ A} < I_{OUT} < 1.0 \text{ A}$, $V_{IN} = 5 \text{ V}$)	0.15%			
Output Voltage Ripple	$V_{IN} = 5 \text{ V}$, $I_{OUT} = 1.0 \text{ A}$	10			mVpp
Output Load Current		0	1.6		A
Output Over Current		2.6			A
SYSTEM CHARACTERISTICS					
Switching Frequency		1.0	1.25	1.5 ⁽¹⁾	MHz
Peak Efficiency	$V_{OUT} = 3.3 \text{ V}$, $0.1 \text{ A} < I_{OUT} < 1.0 \text{ A}$	$V_{5V_IN} = 4.5 \text{ V}$	89%		
		$V_{5V_IN} = 5 \text{ V}$	90%		
		$V_{5V_IN} = 5.5 \text{ V}$	91%		
Full Load Efficiency	$V_{OUT} = 1.25 \text{ V}$, $I_{OUT} = 1.6 \text{ A}$	$V_{5V_IN} = 4.5 \text{ V}$	73%		
		$V_{5V_IN} = 5 \text{ V}$	74%		
		$V_{5V_IN} = 5.5 \text{ V}$	75%		

(1) Set-point accuracy determined by reference voltage and user-selected resistor accuracy.

3 Schematic



Schematic

3.1 Adjusting Output Voltage (R1 and R2)

The regulated output voltage can be adjusted within a limited range by changing the ground resistor in the feedback resistor divider (R1 and R2). The output voltage is given by [Equation 1](#):

$$V_{\text{out}} = V_{\text{FB}} \left(1 + \frac{R1}{R2} \right) \quad (1)$$

Where $V_{\text{FB}} = 0.800$ V and $R1 = 10$ k Ω

[Table 1](#) contains common values for R2 to generate popular output voltages. The TPS40222EVM-001 is stable through these output voltages with the efficiency improving with increasing output voltage.

Table 1. Common Values for R2

Output Voltage — V_{OUT}	R2, 1% (k Ω)
3.3	3.16
2.5	4.70
2.2	5.62
2	6.65
1.8	8.06
1.5	11.5
1.4	13.3
1.2	20

3.2 Test Setup

3.2.1 Equipment

3.2.1.1 Voltage Source

V_{5V_IN} — The input voltage source (V_{5V_IN}) should be a 0-V to 15-V variable DC source capable of 5 Adc. Connect V_{5V_IN} to J1 as shown in [Figure 2](#).

3.2.1.2 Meters

- A1: 0- to 5-Adc ammeter
- V1: V_{5V_IN} , 0-V to -15-V voltmeter
- V2: V_{1V4_OUT} , 0-V to 5-V voltmeter

3.2.1.3 Loads

LOAD1 — The Output Load (LOAD1) should be an electronic constant-current-mode load capable of 0—10 Adc at 1.4 V.

3.2.1.4 Recommended Wire Gauge

V_{5V_IN} to J1 — The connection between the source voltage, V_{5V_IN} and J1 of HPA163 can carry as much as 2 Adc. The minimum recommended wire size is 16 AWG with the total length of wire less than 4 feet (2 feet input, 2 feet return).

J2 to LOAD1 (Power) — The power connection between J2 of HPA163 and LOAD1 can carry as much as 3 Adc. The minimum recommended wire size is 2x 16 AWG, with the total length of wire less than 4 feet (2 feet output, 2 feet return).

OSCILLOSCOPE – A 60-MHz or faster oscilloscope can be used to determine the ripple voltage on 1V4_OUT. The oscilloscope should be set for $1\text{-M}\Omega$ impedance, AC coupling, 0.5- $\mu\text{s}/\text{division}$ horizontal resolution, 10-mV/division vertical resolution for taking output ripple measurements. TP3 and TP4 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP3 and holding the ground barrel to TP4 as shown in [Figure 3](#). For a hands-free approach, the loop in TP4 can be cut and opened to cradle the probe barrel. Using a leaded ground connection may induce additional noise due to the large ground loop area.

3.3 Equipment Setup

[Figure 3](#) shows the basic test setup recommended to evaluate the TPS40222EVM-001. Note that although the return for J1 and J2 are the same, the connections should remain separate as shown in [Figure 2](#).

3.3.1 Procedure

1. Working at an ESD workstation, ensure that any wrist straps, bootstraps, or mats are connected referencing the user to earth ground before power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.
2. Prior to connecting the DC input source, V_{5V_IN} , it is advisable to limit the source current from V_{5V_IN} to 2 A maximum. Ensure that V_{5V_IN} is initially set to 0 V and connected as shown in [Figure 2](#).
3. Connect the ammeter A1 (0–5-A range) between V_{5V_IN} and J1 as shown in [Figure 2](#).
4. Connect voltmeter V1 to TP1 and TP2 as shown in [Figure 2](#).
5. Connect LOAD1 to J2 as shown in [Figure 2](#). Set LOAD1 to constant-current mode to sink 0 Adc before V_{5V_IN} is applied.
6. Connect voltmeter, V2 across TP3 and TP4 as shown in [Figure 2](#).
7. Connect oscilloscope probe to TP3 and TP4 as shown in [Figure 3](#).

3.3.2 Diagram

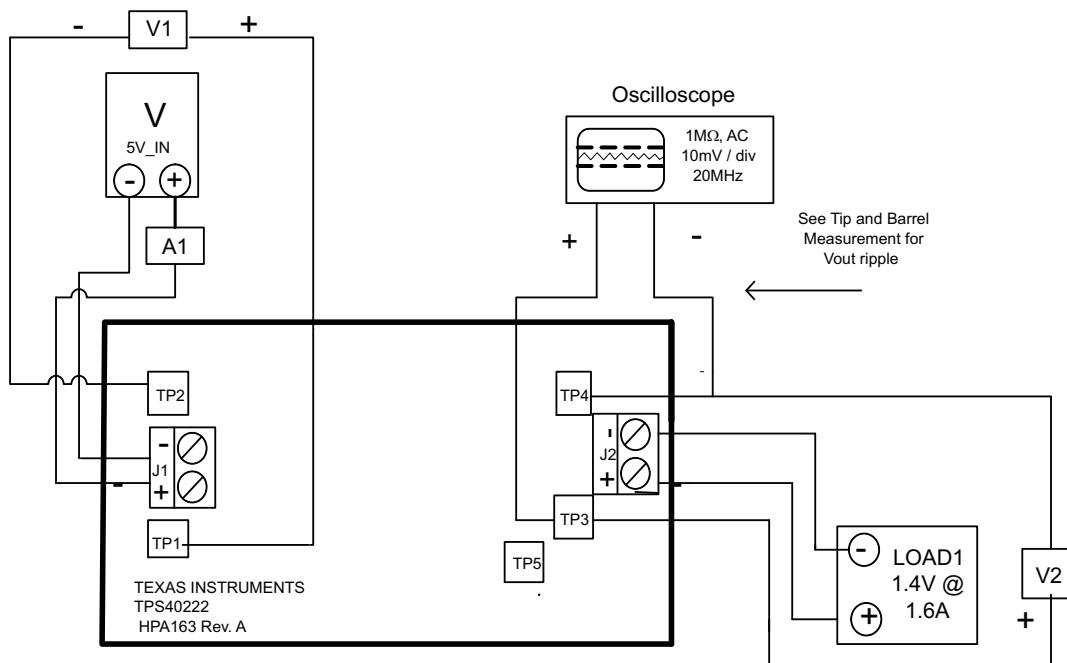


Figure 2. TPS40222EVM-001 Recommended Test Setup

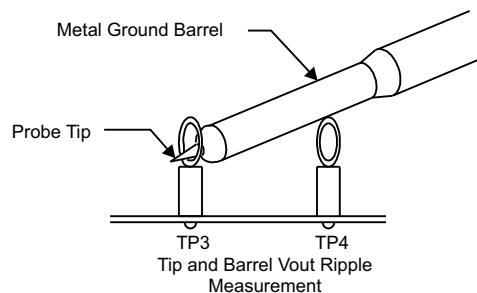
Schematic


Figure 3. Output Ripple Measurement – Tip and Barrel Using TP15 and TP16

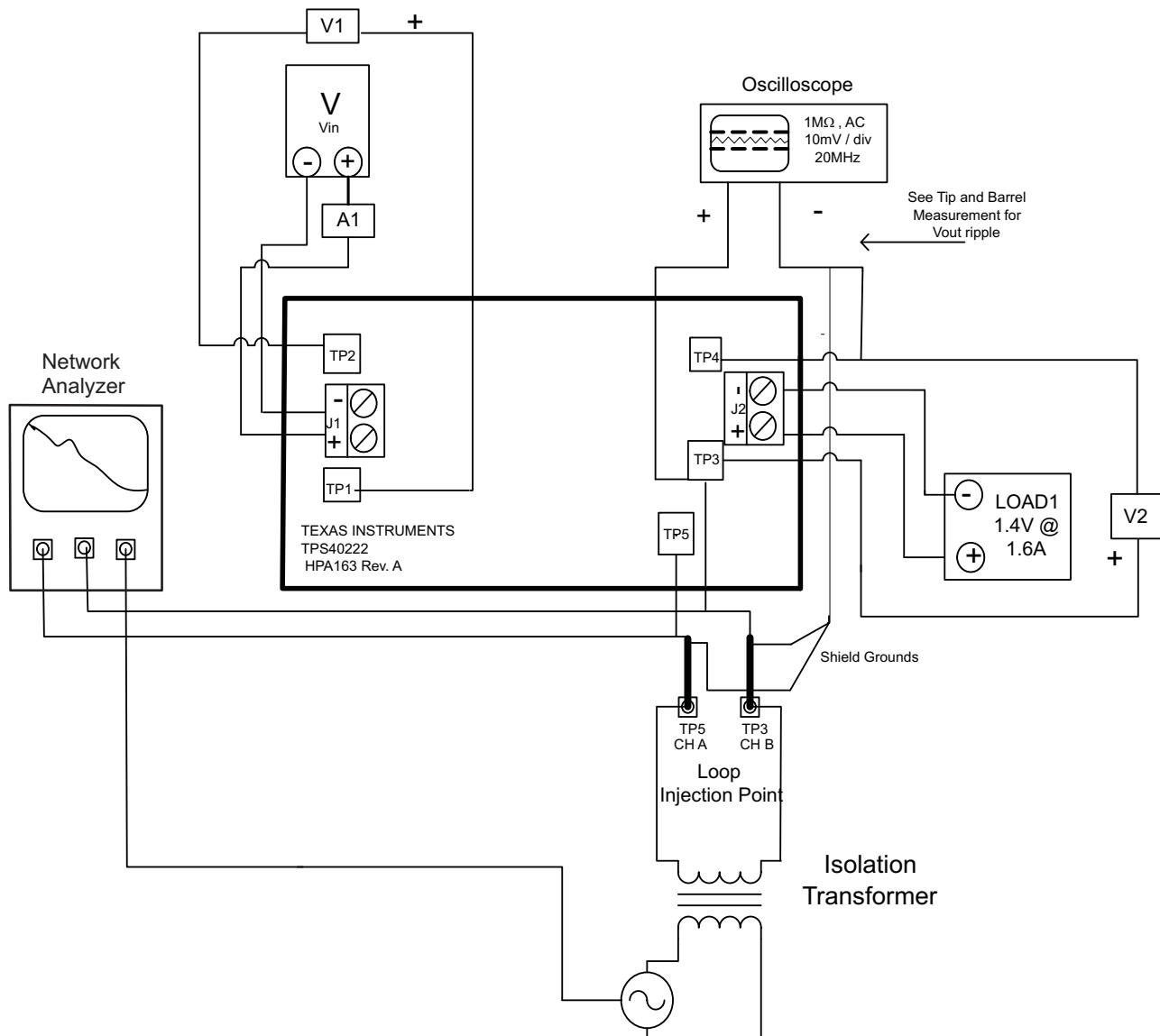


Figure 4. Control Loop Measurement Setup

3.4 Start -Up/Shutdown Procedure

1. Increase V_{5V_IN} (V1) from 0 V to 5 Vdc.
2. Vary LOAD1 from 0 to 1 Adc
3. Vary V_{5V_IN} (V1) from 5 Vdc to 8 Vdc
4. Decrease LOAD1 to 0 A.
5. Decrease V_{5V_IN} to 0 V.

3.5 Control Loop Gain and Phase Measurement Procedure

1. Connect 1-kHz to 1-MHz isolation transformer to TP5 and TP3 as show in [Figure 4](#).
2. Connect input signal amplitude measurement probe (Channel A) to TP5 as shown in [Figure 4](#).
3. Connect output signal amplitude measurement probe (Channel B) to TP3 as shown in [Figure 4](#).
4. Connect ground lead of channel A and channel B to TP4 as shown in [Figure 4](#).
5. Inject 25-mV or less signal across R4 through isolation transformer.
6. Sweep frequency from 1 kHz to 1 MHz with 10-Hz or lower post filter.

7. Control loop gain can be measured by:

$$20 \times \text{LOG}\left(\frac{\text{ChannelB}}{\text{ChannelA}}\right)$$

8. Control loop phase is measured by the phase difference between channel A and channel B disconnect isolation transformer from TP5 and TP3 before making other measurements (signal injection into feedback may interfere with accuracy of other measurements).

3.6 Equipment Shutdown

1. Shut down oscilloscope.
2. Shut down LOAD1.
3. Shut down V_{5V_IN} .

4 TPS40222EVM Typical Performance Data and Characteristic Curves

[Figure 4](#) through [Figure 7](#) present typical performance curves for the TPS40222EVM-001. Because actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

4.1 Efficiency

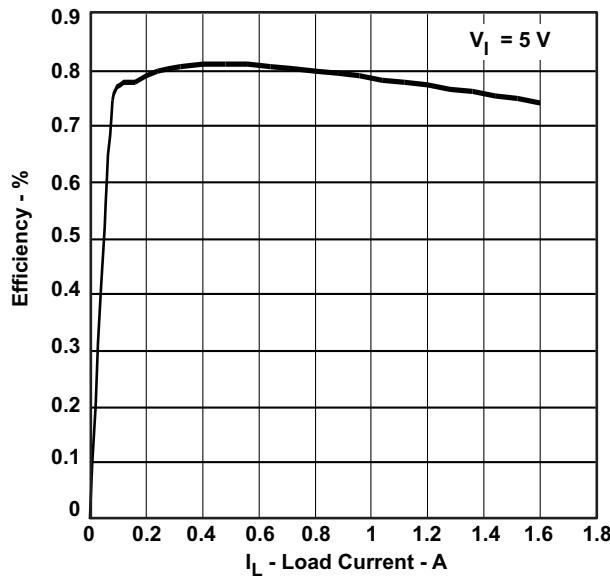


Figure 5. TPS40222EVM-001 Efficiency 1.4 V Out
 $(V_{5\text{V_IN}} = 4.5\text{--}8\text{ V}, V_{1\text{V4_OUT}} = 1.4\text{ V}, I_{1\text{V5_OUT}} = 0\text{--}1.6\text{ A})$

4.2 Line and Load Regulation

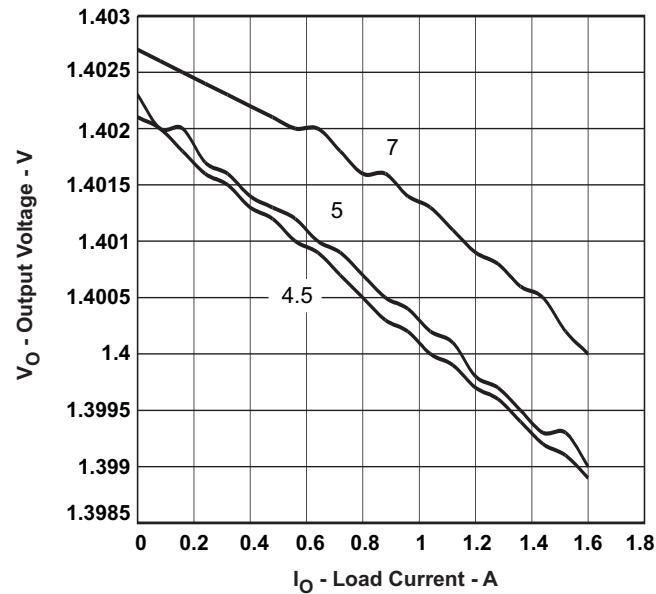


Figure 6. TPS40222EVM-001 Line and Load Regulation

4.3 Typical Ripple Voltage

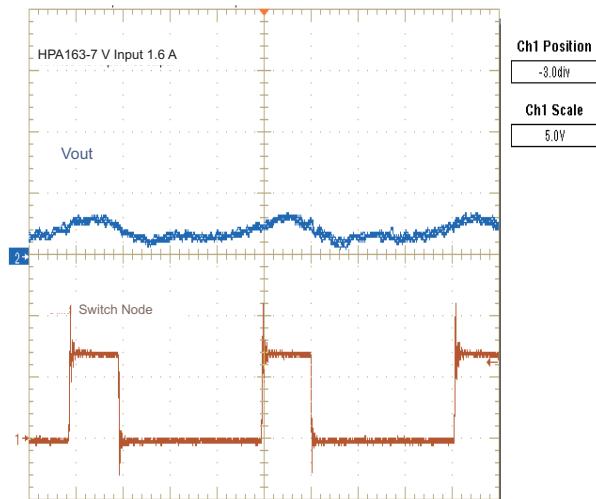


Figure 7. TPS40222EVM-001 Switch Node and Output Ripple at 1.6 A

5 EVM Assembly Drawings and Layout

The following figures (Figure 7 through Figure 11) show the design of the TPS40222EVM-001 printed-circuit board. The EVM has been designed using a 2-layer, 2-oz copper-clad circuit board 1.10 × 1.875 inch with all components on the top side to allow the user to easily view, probe, and evaluate the TPS40222 control IC in a practical application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space-constrained systems.

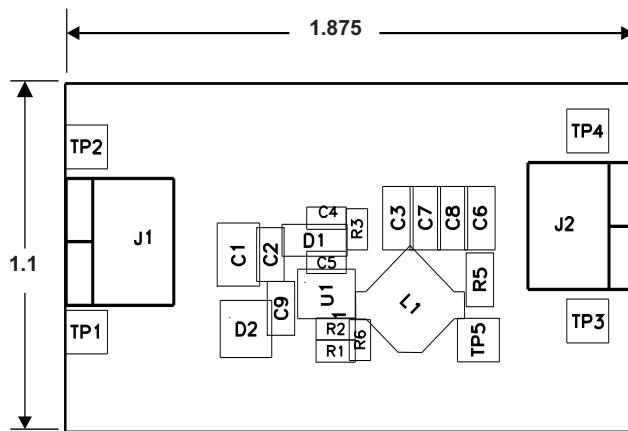


Figure 8. TPS40222EVM-001 Component Placement (Viewed From Top)

List of Materials

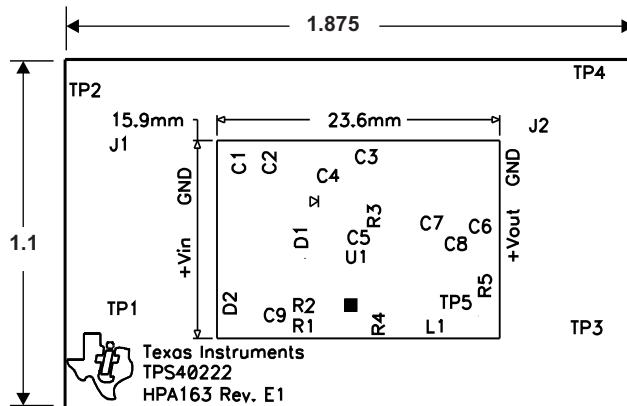


Figure 9. TPS40222EVM-001 Silkscreen (Viewed From Top)

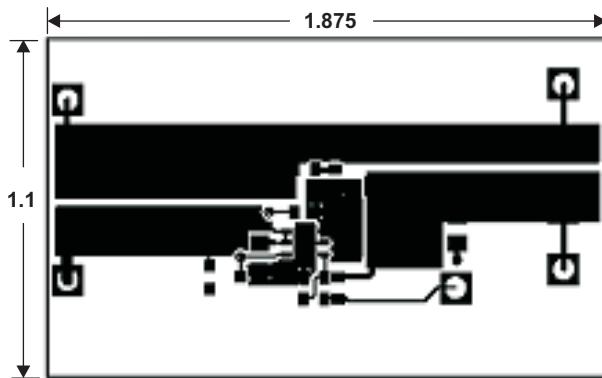


Figure 10. TPS40222EVM-001 Top Copper (Viewed From Top)

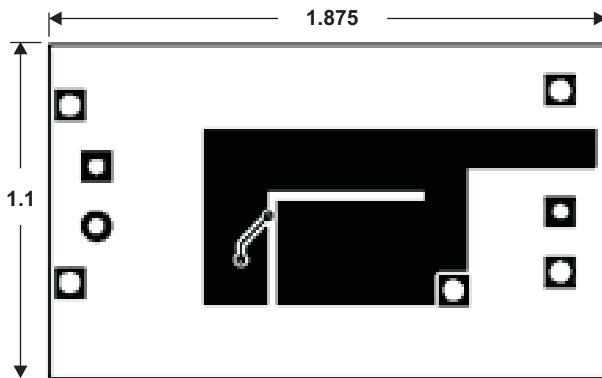


Figure 11. TPS40222EVM-001 Bottom Copper (X-Ray View From Top)

6 List of Materials

Table 3 lists the EVM components as configured according to the schematic shown in [Figure 1](#) and [Figure 2](#).

Table 2. TPS40222EVM-001 Bill of Materials⁽¹⁾⁽²⁾

Count	Reference Designator	Value	Description	Size	Part Number	MFR
1	C1	22 μ F	Capacitor, Ceramic, 22 μ F, 16V, [+80 -20%]	1210	ECJ4YF1C226Z	Panasonic
1	C2	0.1 μ F	Capacitor, Ceramic, 0.1 μ F, 50V, X7R, 20%	0805	Std	Panasonic
1	C3	2.2 μ F	Capacitor, Ceramic, 2.2 μ F, 16V, X5R, 20%	0805	ECJ2FB1C225M	Panasonic
1	C4	100pF	Capacitor, Ceramic, 100pF, 50-V, COG, 20%	0603	Std	Murata
1	C5	100nF	Capacitor, Ceramic, 16V, X7R	0603	Std	Murata
3	C6-C8	22 μ F/6.3V	Capacitor, Ceramic, 6.3V, 22 μ F, 20%	1206	ECJ3YB1C225M	Panasonic
1	C9	2.2 μ F	Capacitor, Ceramic, 16V, 2.2 μ F, 20%	1206	ECJ3YB1C225M	Panasonic
1	D1	RB081L-20	Diode, Schottky Barrier, 5A, 20V	SOD-106	RBO81L-20	Rohm
1	D2	BAT54	Diode, Schottky, 200mA, 30V	SOT23	BAT54	Vishay
2	J1, J2	ED1609-ND	Terminal Block, 2-pin, 15A, 5.1mm	0.40 x 0.35	ED1609	OST
1	L1	3.3 μ H	Inductor, SMT, 3.3 μ H, 1.9A, 32m Ω	0.236 x 0.236	ELL6PV3R3N	Panasonic
1	R1	10k Ω	Resistor, Chip, 10k Ω , 1/16W, 1%	0603	Std	Std
1	R2	13.3k Ω	Resistor, Chip, 13.3k Ω , 1/16W, 1%	0603	Std	Std
1	R3	10 Ω	Resistor, Chip, 10 Ω , 1/16W, 1%	0603	Std	Std
1	R4	51.1 Ω	Resistor, Chip, 51.1 Ω , 1/16W, 1%	0603	Std	Std
1	R5	120 Ω	Resistor, Chip, 120 Ω , 1/10W, 1%	0805	Std	Std
1	U1	TPS40222	IC, 6 pin Non-Synchronous Buck Converter	DRP-6	TPS40222DRP	TI
1	PCB		PCB, 1.875 in x 1.1 in x 62 in		HPA163A	Any

(1) These assemblies are ESD sensitive, ESD precautions shall be observed.

(2) These assemblies must be clean and free from flux and all contaminants

EVALUATION BOARD/KIT IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit 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. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

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 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.**

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. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

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.

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**.

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 contact the TI application engineer or visit www.ti.com/esh.

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.

FCC Warning

This evaluation board/kit 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 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments 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.

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0 V to 16 V and the output voltage range of 0 V to 6.3 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

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 49°C. The EVM is designed to operate properly with certain components above 40°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.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for 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, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
Low Power Wireless	www.ti.com/lpw	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2007, Texas Instruments Incorporated