TEXAS INSTRUMENTS

User's Guide

SLVU260–December 2008

TPS61175EVM-326

This user's guide describes the characteristics, operation, and use of the TPS61175EVM-326 evaluation module (EVM). This EVM contains the Texas Instruments TPS61175 high-efficiency boost converter that is configured to provide a regulated 24-V output voltage from an input voltage ranging from 5.0 V to 12 V. This user's guide includes a schematic diagram, board layout, bill of materials and test data.

Contents

List of Figures

List of Tables

1 Introduction

This section contains background information for the TPS61175EVM-326 evaluation module.

1.1 Background

This TPS61175EVM-326 is designed to boost 5.0 V to 12.0 V input voltages to a 24-V output. The goal of the EVM is to facilitate evaluation of the TPS61175 power supply solution. The EVM uses the TPS61175 adjustable output boost converter, external schottky diode, input and output capacitors, inductor, and the appropriate feedback and compensation components to provide a regulated 24V.

1.2 Performance Specification Summary

Table 1 provides a summary of the TPS61175EVM-326 performance specifications. All specifications are given for an ambient temperature of 25°C.

Table 1. Performance Specification Summary for V_{IN} = 5.0 V

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input voltage			5		V
$I_{IN(AVG)}$	Average input current	I_O = 450 mA			2.6	A
f_{SW}	Switching frequency			750		kHz
OUTPUT CHARACTERISTICS						
V_O	Output voltage		23(1)	24	25(1)	V
	Line regulation	4.5 V < V_{IN} < 5.5 V at I_O = 400 mA			1%	$\Delta V_O/\Delta V_{IN}$
	Load regulation	V_{IN} = 5 V, 1 mA < I_O < 450 mA			1%	$\Delta V_O/\Delta I_O$
$\Delta V_{O(PP)}$	Output voltage ripple	I_O = 450 mA			75	mV_{PP}
I_O	Output current		1		450	mA
TRANSIENT RESPONSE						
ΔI_O	Load step			0.35		A
$\Delta I_O/\Delta T$	Load slew rate			9		A/µs
ΔV_O	V_O undershoot			1.1		V
t_S	Settling time			280		µs

(1) Minimum and maximum values include 1% resistor tolerance as well as IC feedback reference voltage tolerance.

Table 2. Performance Specification Summary for V_{IN} = 12.0V

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input Voltage			12		V
$I_{IN(AVG)}$	Average Input Current				2.6	A
f_{SW}	Switching Frequency			750		kHz
OUTPUT CHARACTERISTICS						
V_O	Output Voltage		23(1)	24	25(1)	V
	Line Regulation	11 V < V_{IN} < 13 V at I_O = 1.1 A			1%	$\Delta V_O/\Delta V_{IN}$
	Load Regulation	V_{IN} = 12 V, 1 mA < Io < 1.2 A			1%	$\Delta V_O/\Delta I_O$
$\Delta V_{O(PP)}$	Output Voltage Ripple	I_O = 1.2 A			250	mV_{PP}
I_O	Output Current		1		1.2	A
TRANSIENT RESPONSE						
ΔI_{TRAN}	Load Step			0.35		A
$\Delta_{IO}/\Delta T$	Load slew rate			9		A/µs
ΔV_{TRAN}	V_O undershoot			480		mV
t_S	Settling time			300		µs

(1) Minimum and maximum values include 1% resistor tolerance as well as IC feedback reference voltage tolerance.

1.3 Design Example

The following example illustrates the design process and component selection for a 12-V to 24-V non-synchronous boost regulator using the TPS61175 converter.

1. Determining the duty cycle.

$$D_{(MIN)} = \frac{V_{OUT} + V_D - V_{IN(MIN)}}{V_{OUT} + V_D} = \frac{24\text{ V} + 0.5\text{V} - 12\text{ V}}{24\text{ V} + 0.5\text{ V}} = 51\% \qquad (1)$$

2. Computing the maximum output current.

   Assuming η_{est} = 90% at V_{IN} = 12 V and RPL% =20%, datasheet equation 6 gives

$$I_{OUT(max)} = \frac{V_{IN} \times I_{LIM} \times (1 - RPL\%/2) \times \eta_{est}}{V_{OUT}} = \frac{12\ V \times 3A \times (1 - 20\%/2) \times 90\%}{24} = 1.2\ A \tag{2}$$

3. Selecting the inductor.

   The designer chose RPL% = 20% and f_{SW} = 750kHz and assumed η_{est} = 90% for use in datasheet equation 5.

$$L \geq \frac{\eta_{est} \times V_{IN}}{\left[f_{SW} \times \left(\frac{1}{V_{OUT} + V_D - V_{IN}} + \frac{1}{V_{IN}} \right) \right] \times RPL\%\ x\ P_{OUT}}$$

$$= \frac{90\% \times 12\ V}{750\ kHz \times \left(\frac{1}{24\ V + 0.5\ V - 12\ V} + \frac{1}{12\ V} \right) \times 20\% \times 1.2\ A \times 24\ V} = 15.3\ \mu H \rightarrow 22\ \mu H \tag{3}$$

4. Setting the output voltage.

   Selecting R2 = 16.2 kΩ gives

$$R1 = R2 \times \left(\frac{V_{OUT}}{1.229\ V} - 1 \right) = 16.2\ k\Omega \times \left(\frac{24}{1.229\ V} - 1 \right) = 300\ k\Omega \rightarrow 301 k\Omega \tag{4}$$

5. Setting the switching frequency

   Using datasheet Table 1 and Figure 13 as well as some bench testing results, the designer selected a 143kΩ resistor to set the 750kHz switching frequency.

6. Selecting the soft start capacitor

   The designer selected the datasheet recommended value of 0.047 µF.

7. Selecting the Schottky diode

   The designer selected a 40-V rated diode to accommodate user modifications of higher output voltages to the power supply. With 1.2A×0.45V = 540mW potential power dissipation and T_{Amax} = 25°C , the designer choose the SMA package diode, which will experience a rise in junction temperature to T_J = 25°C + 81°C/W×540mW = 69°C. In a real application, a larger packaged diode is recommended.

8. Selecting the output capacitance:

   The output capacitance needs to be the larger of

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times \Delta V_{RIP}} = \frac{(24\ V - 12\ V) \times 1.2\ A}{24\ V \times 750\ kHz \times 300\ mV} = 2.7\ \mu F \tag{5}$$

   to meet the ripple specification or

$$C_{OUT} = \frac{\Delta I_{TRAN}}{2 \times \pi \times f_{LOOP\text{-}BW} \times \Delta V_{TRAN}} = \frac{350\ mA}{2 \times \pi \times 10\ kHz \times 500\ mW} = 11\ \mu F \tag{6}$$

   to meet the transient specification. The designer selected 3 × 4.7µF, 50V capacitors to give close to 15µF of output capacitance.

9. Compensating the control loop.

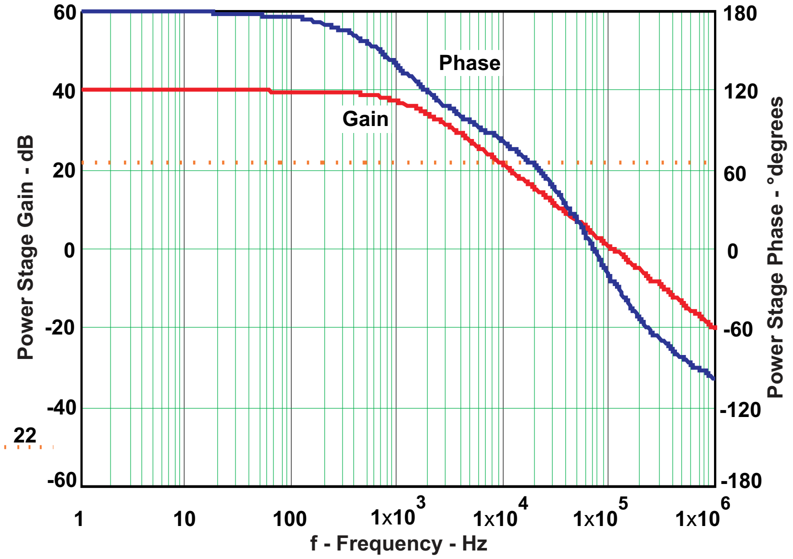
   Using MathCAD to plot data sheet equation 10 with

   R_{OUT} = 24V/1.2A = 20 Ω, R_{SENSE} = 40mΩ

$$f_P = \frac{2}{2\pi \times R_O \times C2} = \frac{2}{2\pi \times 20\ \Omega \times 3 \times 4.7\ \mu F} = 1.1\ kHz \tag{7}$$

$$f_{RHPZ} = \frac{R_O}{2\pi \times L} \times \left(\frac{Vin}{Vout} \right)^2 = \frac{20\ \Omega}{2\pi \times 22\ \mu H} \times \left(\frac{12}{24} \right)^2 = 36.2\ kHz \tag{8}$$

   and neglecting the ESR zero produce by the ceramic output capacitors gives



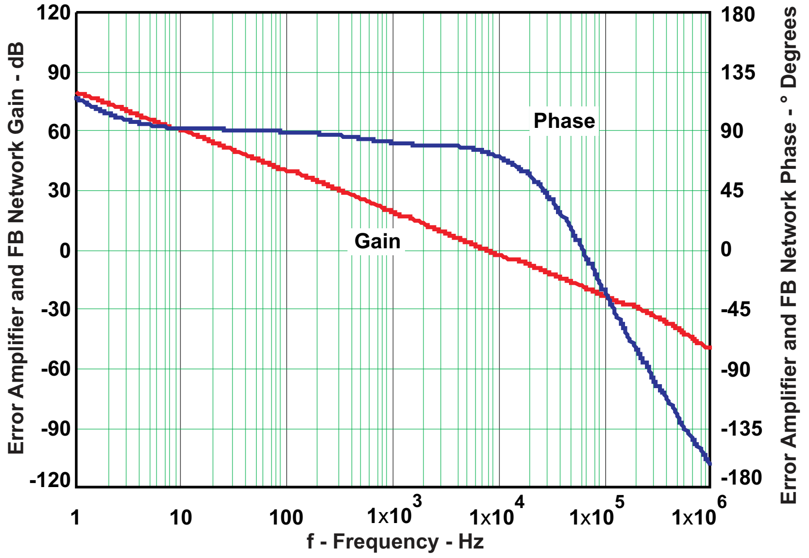
The designer chose f_C = 10kHz which means $K_{COMP}(f_C)$ = -22dB. With R1 = 16.2k and R2=301k G_{EAmax}= 440µmho, solving the equation on datasheet page 17 for R3 gives

$$R3 \cong \frac{10^{\frac{K_{COMP}(f_C)}{20dB}}}{G_{EA} \times \frac{R2}{R2+R1}} = \frac{10^{\frac{-22dB}{20dB}}}{340\ \mu\text{mho} \times \frac{16.2\ k\Omega}{301\ k\Omega + 16.2\ k\Omega}} = 4.57\ k\Omega \rightarrow 4.53\ k\Omega \tag{9}$$

Solving datasheet equation 20 for C4 and setting $f_Z \cong f_C/10$ = 1kHz gives

$$C4 \cong \frac{1}{2\pi \times R3 \times f_Z} = \frac{1}{2\pi \times 4.57\ k\Omega \times 1\ kHz} = 35\ nF \rightarrow 33\ nF \tag{10}$$

The designer used bench measurements to set R3 = 3.09kΩ in order to get closer to the desired 60 degrees phase margin. Using MathCAD to plot T(s) = $G_{PW}(s) \times H_{EA}(s)$ from the datasheet gives



1.4 Modifications

Because the primary goal of the EVM is to demonstrate the flexibility of the TPS61175 power supply solution, the selected capacitors and inductors are not optimized for either a 5-V or a 12-V to 24-V conversion.

The TPS61175 integrated circuit (IC) has a maximum input voltage of 18 V and can boost its input voltage up to 38 V. Changes to this EVM's recommended input and output voltage likely requires changing one or more of the following components: schottky diode, input or output capacitors, inductor, feedback resistors, or error amplifier compensation components. Consult the data sheet (link to datasheet **TBD**) and/or design tools for assistance in selecting these components for your application. Changing components could improve or degrade EVM performance.

2 Setup and Test Results

This section describes how to properly connect, set up, and use the TPS61175EVM-326.

2.1 Input/Output Connections

The connection points are described in the following paragraphs.

2.1.1 J1 - V_{IN}

This header is the positive connection to the input power supply used for lower (< 1A) input currents. Twist the leads to the input supply, and keep them as short as possible.

2.1.2 J2 - V_{OUT}

This header is the positive output for the device used for lower (< 1A) output currents. Connect the positive lead of the load and/or output multimeter to this point.

2.1.3 J3 - GND

This header is the return connection for the input power supply used for lower (< 1A) input currents.

2.1.4 J4 - GND

This header is the return connection for the load and/or output multimeter used for lower (< 1A) output currents.

2.1.5 J5 pin 1 - SYNC

This pin is available for the application of an external clock synchronization signal. Make sure that the frequency of the clock signal is within the range in Table 1. This pin cannot be left floating so use a shorting jumper to short the SYNC pin to GND if not used.

2.1.6 J5 pin 2 - GND

This pin is the return connection for the external synchronization signal.

2.1.7 J6 pin 1 - V_{IN}

This is the positive connection for the input power supply used for higher (> 1A) input currents.

2.1.8 J6 pin 2 - GND

This is the return connection to the input power supply used for higher (> 1A) input currents. Twist the leads to the input supply, and keep them as short as possible.

2.1.9 J7 pin 1 - GND

This is the return connection for the load used for higher (> 1A) output currents.

2.1.10 J7 pin 2 - V_{OUT}

This is the positive connection for the load used for higher (> 1A) output currents.

2.1.11 JP1 - ENABLE

Installing this jumper ties the enable pin to either the input voltage (on) or ground (off). If left unconnected, the enable pin's internal pull down resistor disables the IC.

2.1.12 TP1 - SW Node

Test point for the switch node of the boost converter.

2.1.13 TP2 - Loop Response

Test point for control loop response measurements.

2.1.14 TP3 - Comp Pin

Test point for the compensation network.

2.1.15 TP4 & TP5 - Output Ripple

Test points for measuring the output ripple voltage.

2.2 Test Results

The following section shows the test results of the TPS61175EVM-326.

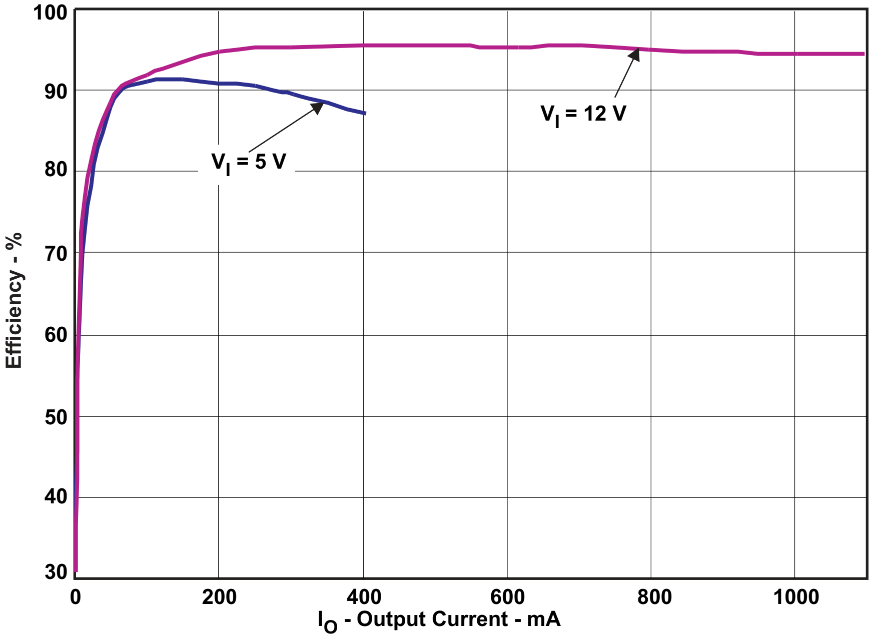


Figure 1. TPS61175EVM-326 Efficiency

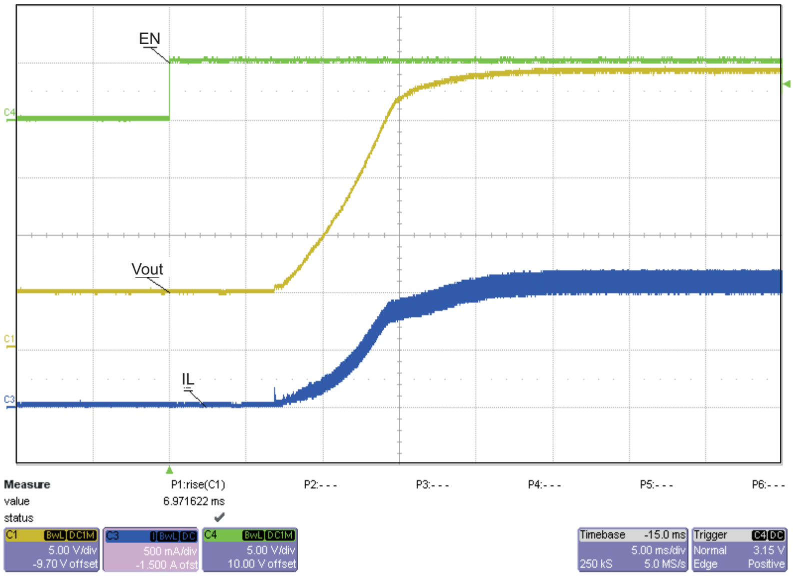


Figure 2. Start-Up With V_{IN} = 5V and I_{OUT} = 100 mA

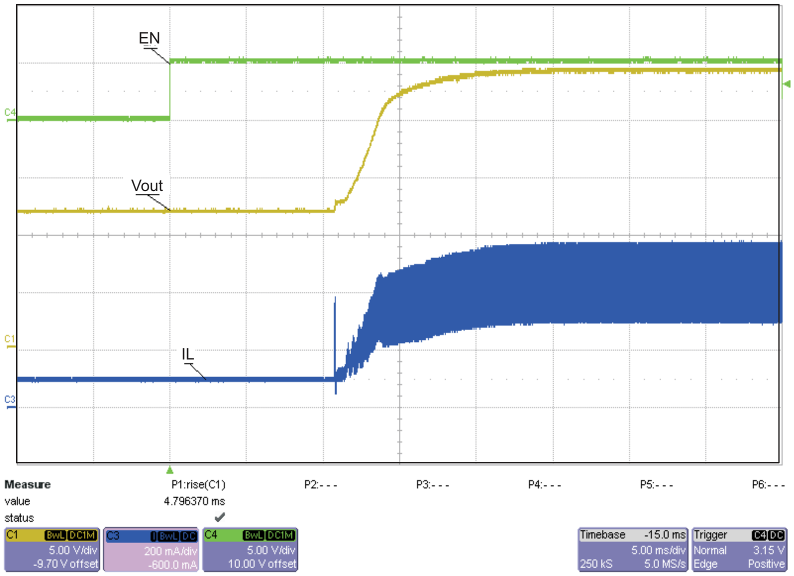


Figure 3. Start-Up With V_{IN} = 12V and I_{OUT} = 100 mA

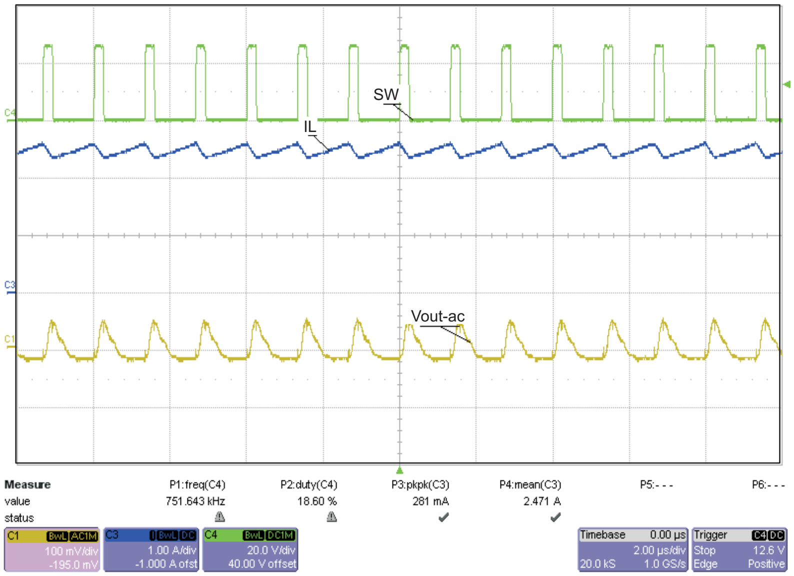


Figure 4. PWM Operation at 450 mA With V_{IN} = 5V

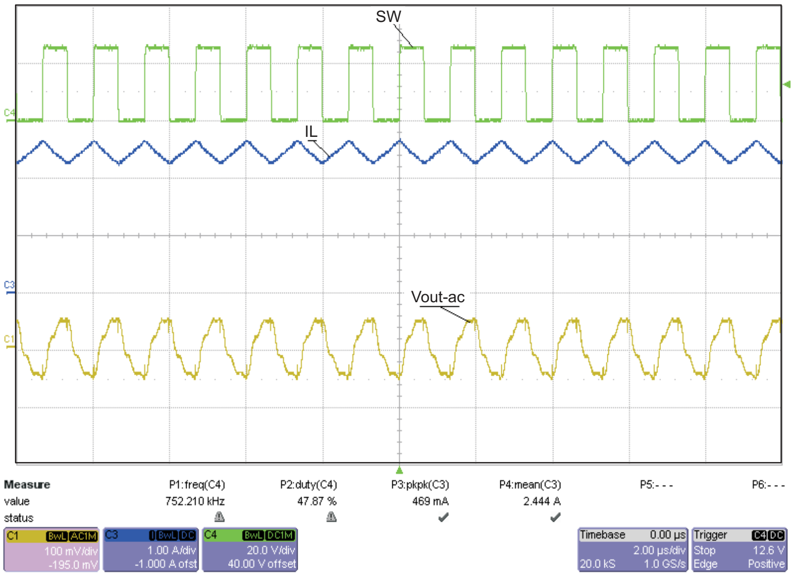


Figure 5. PWM Operation at 1.2 A With V_{IN} = 12V

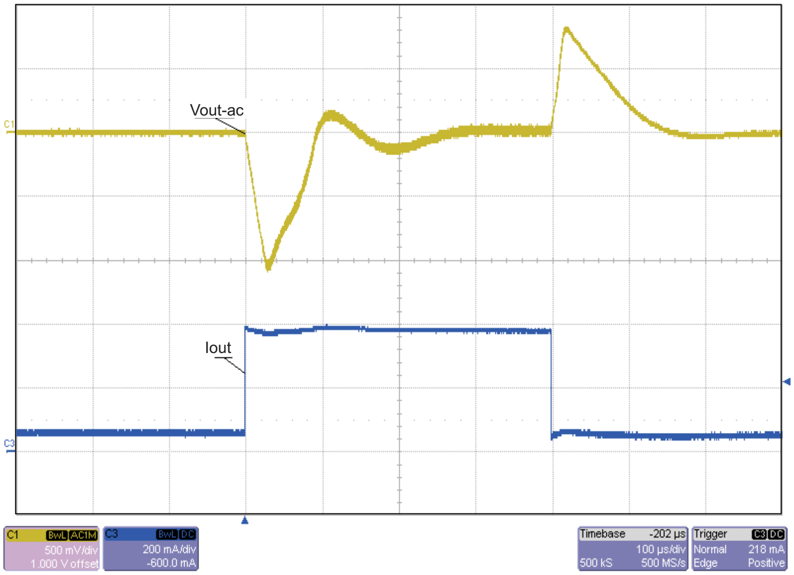


Figure 6. Load Transient Response From 45 mA to 400 mA With V_{IN} = 5V

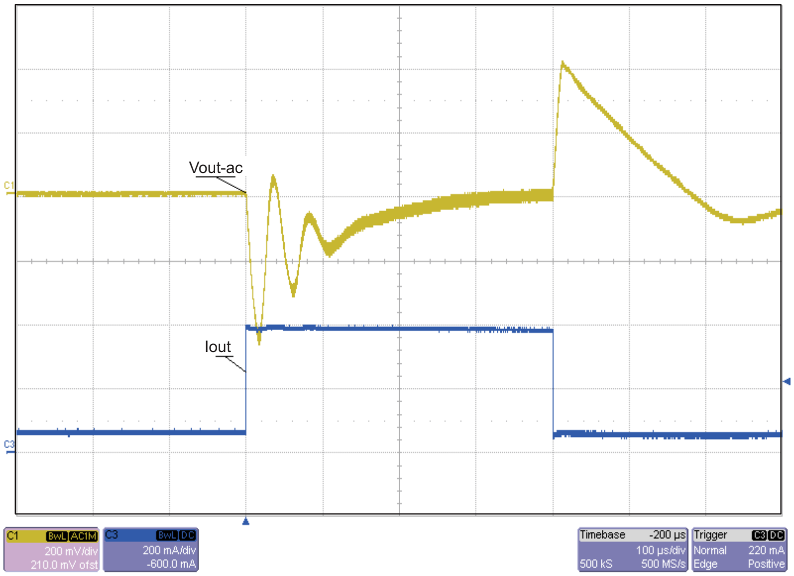


Figure 7. Load Transient Response From 45 mA to 400 mA With V_{IN} = 12V

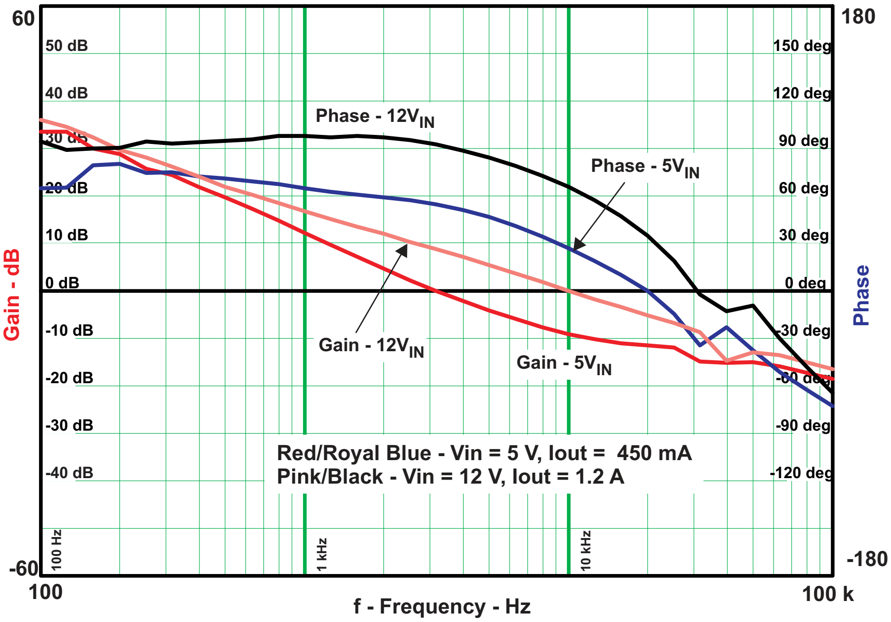


Figure 8. Loop Gain and Phase

3 Board Layout

This section provides the TPS61175EVM-326 board layout and illustrations.

3.1 Layout

Board layout is critical for all switch-mode power supplies. Figure 9 through Figure 13 show the board layout for the HPA326 printed-circuit board. The switching nodes with high-frequency noise are isolated from the noise-sensitive feedback circuitry. Careful attention has been given to the routing of high-frequency current loops. See the data sheet (**SLVS892**) for further layout recommendations.

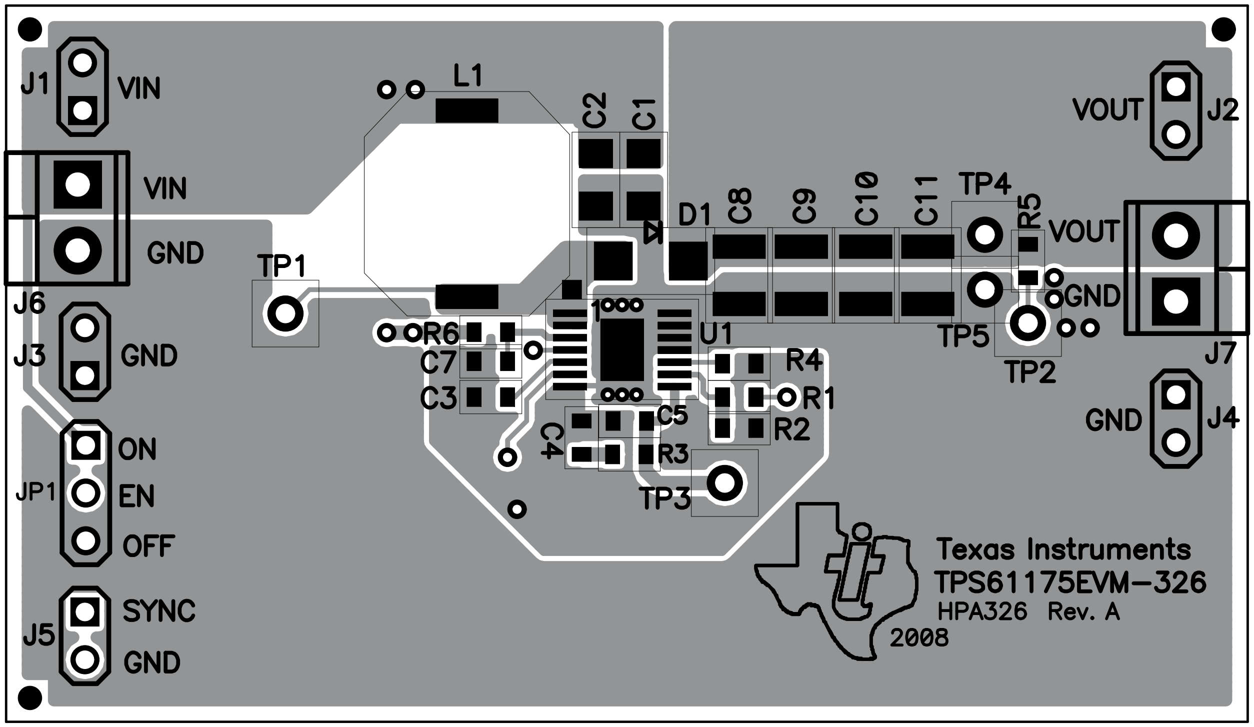


Figure 9. Top Assembly Layer

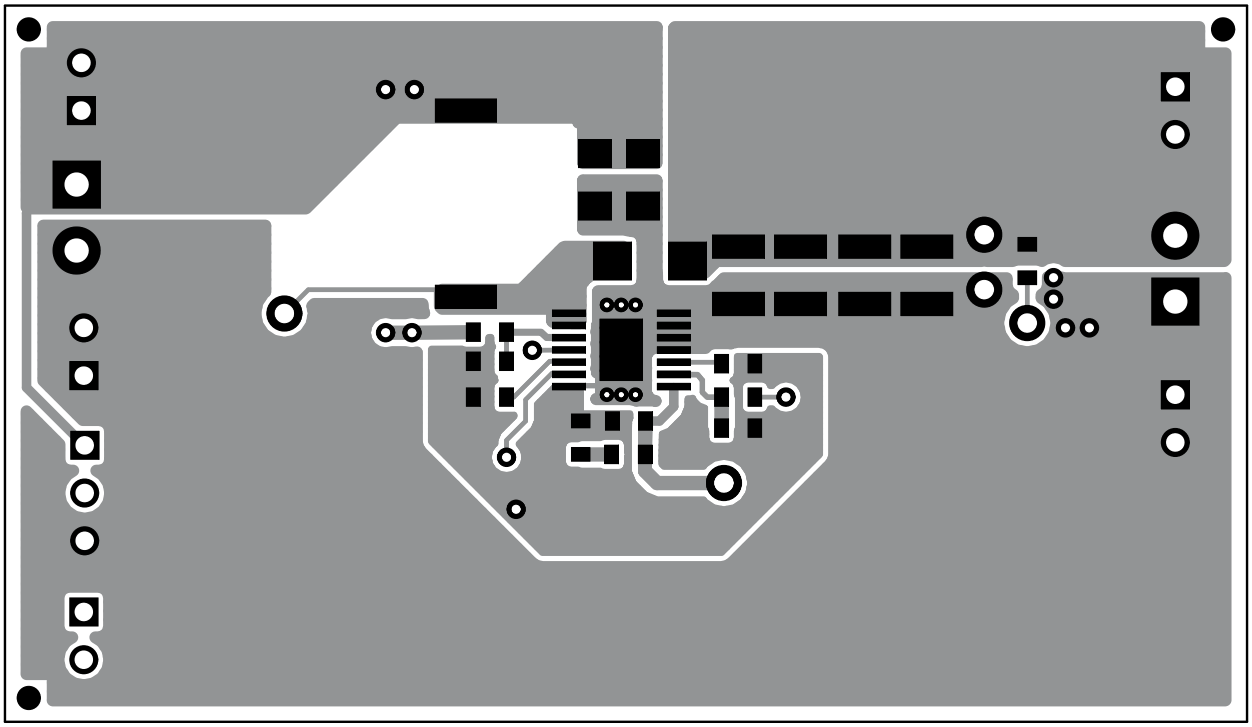


Figure 10. Top Layer Routing

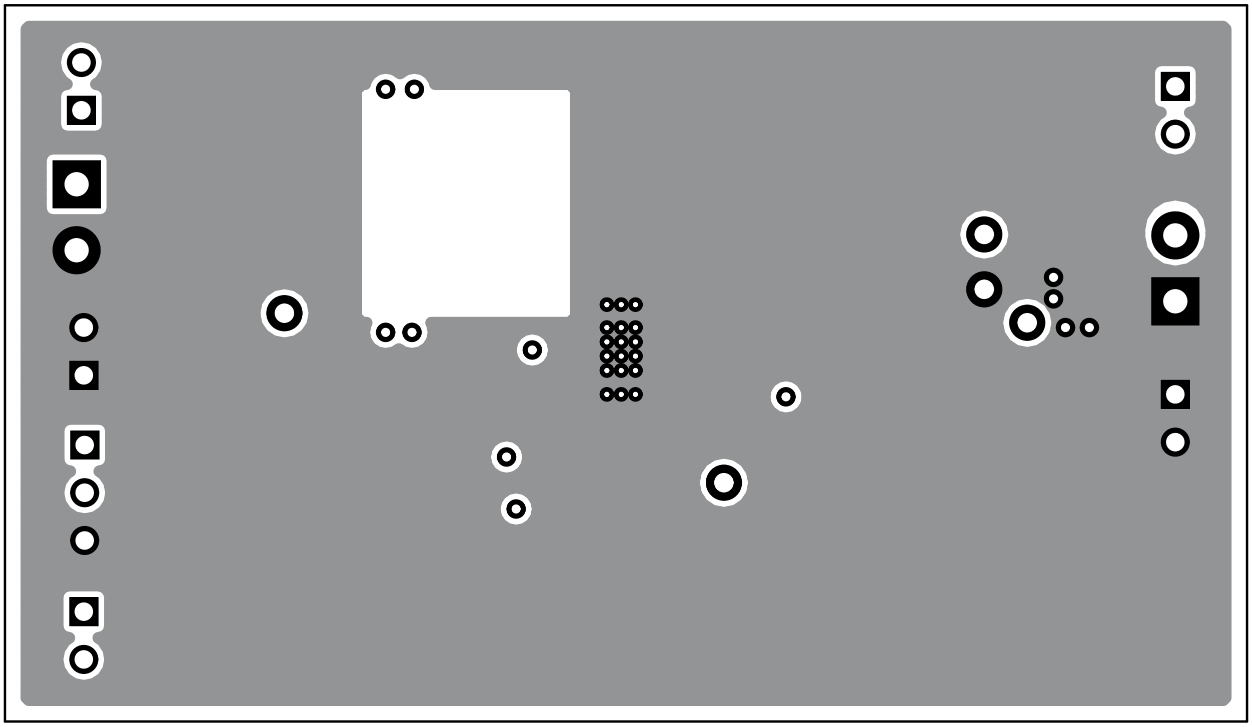


Figure 11. Internal Layer 1

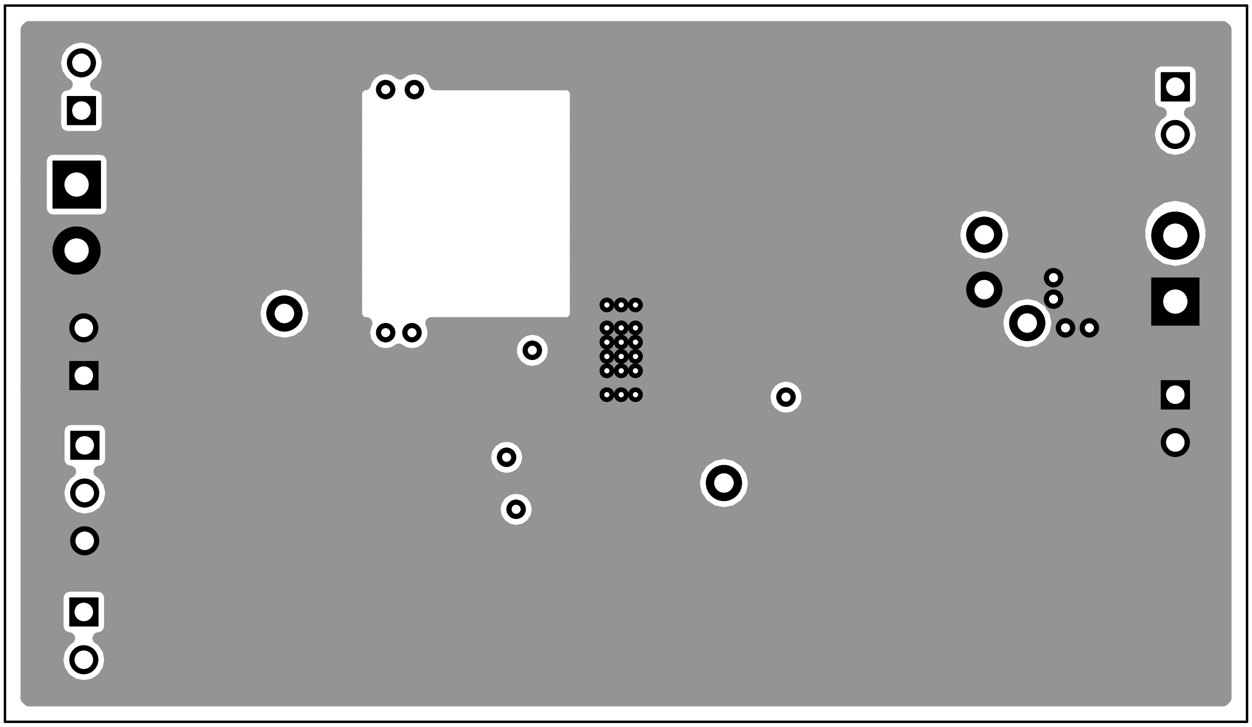


Figure 12. Internal Layer 2

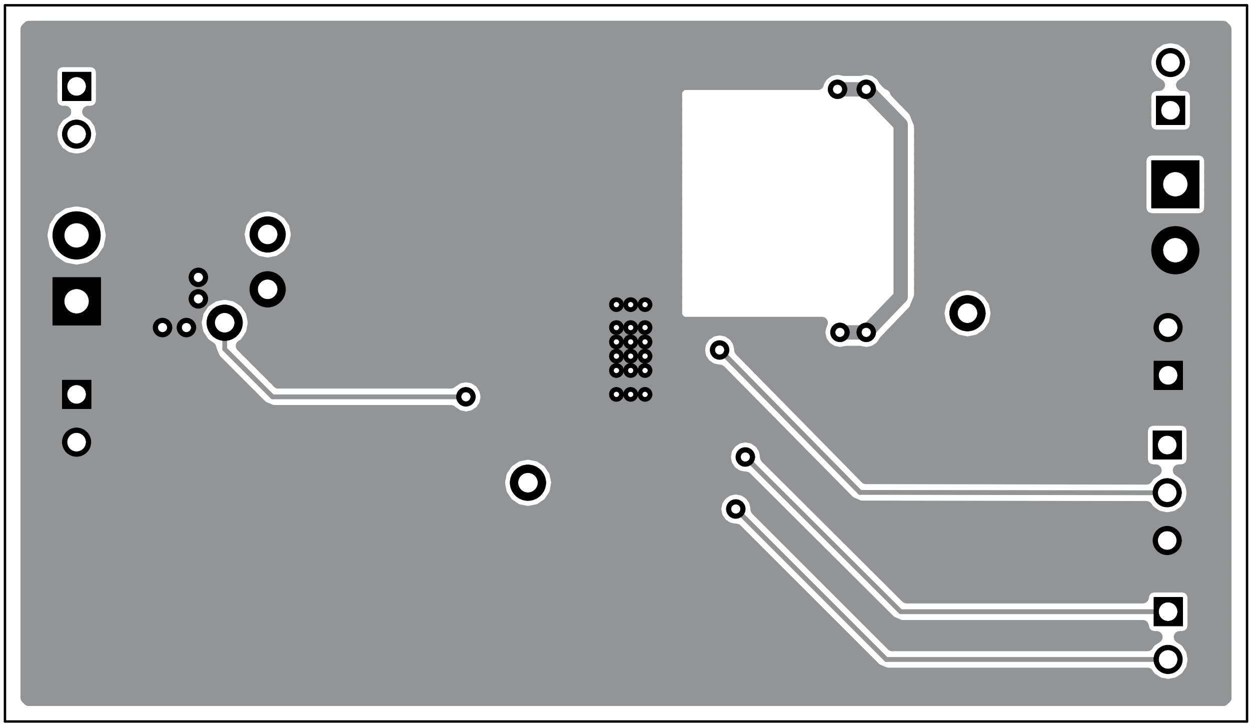


Figure 13. Bottom-Side Layer

4 Bill of Materials and Schematic

This section provides the TPS61175EVM-326 bill of materials and schematic.

4.1 Bill of Materials

Table 3. HPA326 Bill of Materials

RefDes	Value	Description	Size	Part Number	MFR
C1	10 µF	Capacitor, Ceramic, 25V, X5R, 20%	1206	STD	STD
C10	Open	Capacitor, Ceramic, 50V, X7R, 10%	1210	STD	STD
C2	Open	Capacitor, Ceramic, 25V, X5R, 20%	1206	STD	STD
C3	0.047 µF	Capacitor, Ceramic, 10V, X5R, 10%	0603	STD	STD
C4	33 nF	Capacitor, Ceramic, 10V, X5R, 10%	0603	STD	STD
C5	Open	Capacitor, Ceramic, 10V, X5R, 10%	0603	STD	STD
C7	0.1 µF	Capacitor, Ceramic, 25V, X5R, 20%	0603	STD	STD
C8, C9, C11	4.7 µF	Capacitor, Ceramic, 50V, X7R, 10%	1210	STD	STD
D1	MBRA340	Diode, Schottky, 3A, 40V	SMA	MBRA340	On Semi
J1– J5	PTC36SAAN	Header, Male 2-pin, 100mil spacing, (36-pin strip)	0.100 inch × 2	PTC36SAAN	Sullins
J6, J7	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 × 0.25 inch	ED555/2DS	OST
JP1	PTC36SAAN	Header, Male 3-pin, 100mil spacing, (36-pin strip)	0.100 inch × 3	PTC36SAAN	Sullins
L1	22 µH	Inductor, SMT, 2.9A, 47milliohm	0.402 sq inch	CDRH105RNP-220N	Sumida
R1	301k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R2	16.2k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R3	3.09k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R4	143k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R5	50	Resistor, Chip, 1/16W, 1%	0603	Std	Std
R6	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
TP1–TP4	5000	Test Point, Red, Thru Hole Color Keyed	0.100 × 0.100 inch	5000	Keystone
TP5	5001	Test Point, Black, Thru Hole Color Keyed	0.100 × 0.100 inch	5001	Keystone
U1	TPS61175PWP	IC, High Voltage/Current Boost Converter	HTSSOP-14	TPS61175PWP	TI
—		Shunt, 100-mil, Black	0.100	929950-00	3M
		PCB, 1.5" × 2.6" × 0.062"		HPA326	Any

4.2 Schematic

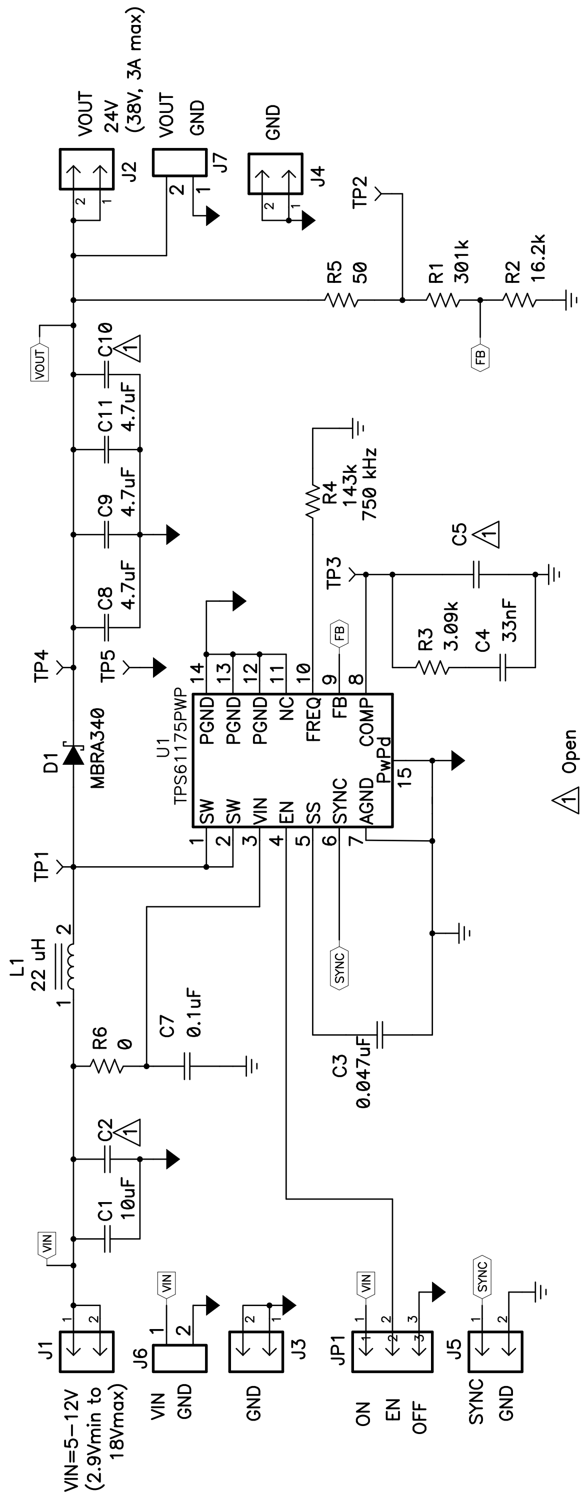


Figure 14. TPS61175EVM-326 Schematic

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 3 V to 18 V and the output voltage range of 38V.

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 125° C. The EVM is designed to operate properly with certain components above 85° 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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 TI 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. Information of third parties may be subject to additional restrictions.

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
Clocks and Timers	www.ti.com/clocks	Digital Control	www.ti.com/digitalcontrol
Interface	interface.ti.com	Medical	www.ti.com/medical
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
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265