TPS40345EVM-353 Evaluation Module

The TPS40345EVM-353 evaluation module (EVM) is a synchronous buck converter providing a fixed 1.2-V output at up to 20 A from a 12-V input bus. The EVM is designed to start-up from a single supply, which means no additional bias voltage is required for start-up. The module uses the TPS40345 high-performance, mid-input voltage synchronous buck controller and TI's NexFET™ high performance MOSFETs.

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Trademarks

NexFET is a trademark of Texas Instruments.
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1 Description

The TPS40345EVM-353 is designed to use a regulated 12 V (8 V – 14 V) bus voltage to provide a regulated 1.2-V output at up to 20 A of load current. The TPS40345EVM-353 is designed to demonstrate the TPS40345 controller and TI NexFETs in a typical 12-V bus to low-voltage application while providing a number of non-invasive test points to evaluate the performance of the TPS40345 and TI NexFETs in a given application.

1.1 Applications

- High-current, low-voltage FPGA or microcontroller core supplies
- High-current point of load modules
- Telecommunications equipment
- Computer peripherals

1.2 Features

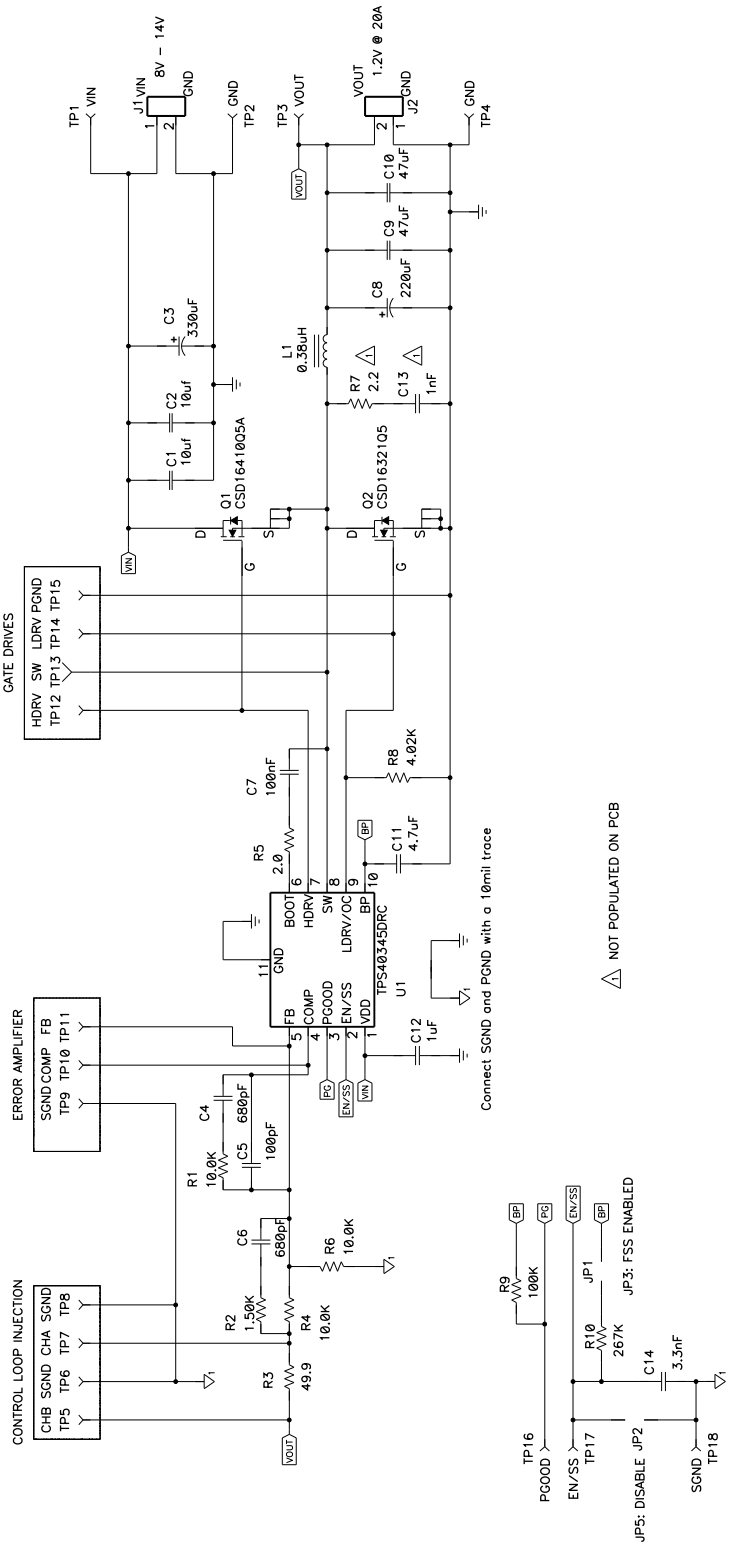
- 8-V to 14-V input voltage rating
- 1.2-V ± 2% output voltage rating
- 20-A steady state load current
- 600-kHz switching frequency
- Simple access to IC features including power good, enable, soft start, and error amplifier
- Convenient test points for simple, non-invasive measurements of converter performance

2 TPS40345EVM-353 Electrical Performance Specifications

Table 1. TPS40345EVM-353 Electrical and Performance Specifications

PARAMETER		NOTES AND CONDITIONS	MIN	TYP	MAX	UNIT
INPUTS CHARACTERISTICS						
V_{IN}	Input voltage		8	12	14	V
I_{IN}	Input current	V_{IN} = Nom, I_{OUT} = Max		2.3	2.5	A
	No load input current	V_{IN} = Nom, I_{OUT} = 0A		40	50	mA
V_{IN_UVLO}	Input UVLO	I_{OUT} = 10 A		3.0		V
OUTPUTS CHARACTERISTICS						
V_{OUT1}	Output voltage 1	V_{IN} = 12 V, I_{OUT} = 20 A	1.17	1.2	1.23	V
	Line regulation	V_{IN} = 8 V to 14 V			0.5%	
	Load regulation	I_{OUT} = 0 A to 20 A			0.5%	
V_{OUT_ripple}	Output voltage ripple	V_{IN} = 12 V, I_{OUT} = 20 A			24	mVpp
I_{OUT1}	Output current 1	V_{IN} = 8 V to 14 V	0		20	A
SYSTEMS CHARACTERISTICS						
f_{SW}	Switching frequency		540	600	660	kHz
ηpk	Peak efficiency	V_{IN} = 12 V		88%		
η	Full load efficiency	V_{IN} = 12 V, I_{OUT} = 20 A		86%		

3 TPS40345EVM-353 Schematic



For reference only, See Table 3 for specific values

Figure 1. TPS40345EVM-353 Schematic

4 Connector and Test Point Descriptions

4.1 Enable Jumper (JP2)

The TPS40345EVM-353 is designed with a Disable Jumper (JP2) using a 0.1-inch spacing header and shunt. Installing a shunt in the JP2 position connects the EN/SS pin to GND, discharges the soft-start capacitor, and disables the TPS40304 controller. This forces the output into a high-impedance state (approximately 20kΩ to GND).

4.2 Frequency Spread Spectrum – FSS Jumper (JP1)

The TPS40345EVM-353 is designed with a frequency spread spectrum (FSS) enable jumper (JP1) using a 0.1" spacing header and shunt. Installing a shunt in the JP1 position connects the EN/SS pin to BP via a 267-kΩ resistor (R10) to enable frequency spread spectrum.

FSS modulates the switching frequency to ±10% of the nominal value at 30 kHz to reduce EMI at the switching frequency and its harmonics, however there may be a 30-kHz component to the output ripple (see Figure 10).

The TPS40345EVM-353 does not dynamically monitor the JP1 status for programming FSS. The TPS40345EVM-353 must be disabled via JP2 or powered down by reducing VIN to less than 3 V to remove or install JP1.

4.3 Test Point Descriptions

Table 2. Test Point Descriptions

TEST POINT	LABEL	USE	SECTION
TP1	VIN	Measurement test point for input voltage	4.3.1
TP2	GND	Ground test point for input voltage	4.3.1
TP3	VOUT	Measurement test point for output voltage	4.3.1
TP4	GND	Ground test point for output voltage	4.3.2
TP5	CHB	Measurement test point for channel B of loop response	4.3.3
TP6	SGND	Ground test point for channel B of loop response	4.3.3
TP7	CHA	Measurement test point for channel A of loop response	4.3.3
TP8	SGND	Ground test point for channel A of loop response	4.3.3
TP9	SGND	Ground test point for error amplifier measurements	4.3.4
TP10	COMP	Measurement test point for error amplifier output voltage	4.3.4
TP11	FB	Measurement test point for error amplifier input voltage	4.3.4
TP12	HDRV	Measurement test point for high-side gate driver voltage	4.3.5
TP13	SW	Measurement test point for switching node voltage	4.3.5
TP14	LDRV	Measurement test point for low-side gate driver voltage	4.3.5
TP15	PGND	Ground test point for switch node and gate drive voltages	4.3.5
TP16	PGOOD	Measurement test point for power good	4.3.6
TP17	EN/SS	Measurement test point for enable / soft start	4.3.7
TP18	SGND	Ground test point for power good and enable / soft start	4.3.6 and 4.3.7

4.3.1 Input Voltage Monitoring (TP1 and TP2)

The TPS40345EVM-353 provides two test points for measuring the input voltage applied to the module. This allows the user to measure the actual input module voltage without losses from input cables and connectors. All input voltage measurements should be made between TP1 and TP2. To use TP1 and TP2, connect a voltmeter positive input to TP1 and input terminal to TP2.

4.3.2 Output Voltage Monitoring (TP3 and TP4)

The TPS40345EVM-353 provides two test points for measuring the output voltage generated by the module. This allows the user to measure the actual module output voltage without losses from input cables and connectors. All input voltage measurements should be made between TP3 and TP4. To use TP3 and TP4, connect a voltmeter positive input to TP3 and negative input to TP4.

4.3.3 Loop Response Testing (TP5, TP6, TP7, TP8, and R3)

The TPS40345EVM-353 provides four test points (2 signal and 2 ground) for measuring the control loop frequency response. This allows the user to measure the actual module loop response without modifying the evaluation board. A transformer isolated signal up to 30 mV can be injected between TP5 and TP7. The injected signal amplitude can be measured by the ac coupled amplitude at CHA (TP7) and the resulting output voltage deviation can be measured at CHB (TP5). See Figure 4 for additional detail.

4.3.4 Error Amplifier Voltage Monitoring (TP9, TP10, and TP11)

The TPS40345EVM-353 provides three test points for measuring the error amplifier input and output voltages. This allows the user to directly measure the feedback and control voltages of the TPS40304 controller. The control voltage (TP10) can also be used to measure the control to output or power-stage frequency response or output to control or error amplifier frequency response. See *Section 5.5* for additional details.

4.3.5 Switching Waveform Monitoring (TP12, TP13, TP14, and TP15)

The TPS40345EVM-353 provides three test points and a local power ground for measuring the switching waveforms of the module power stage. This allows the user to monitor actual switching waveforms during operation. TP13 is a 0.040-inch square pad of exposed PCB copper to minimize EMI radiation from the high transient voltages on the switch node. Switching waveform measurements should be made using power ground (TP15) as the ground reference for more accurate measurements.

4.3.6 Power-Good Voltage Monitoring (TP16 and TP18)

The TPS40345EVM-353 provides a test point and local ground for measuring the power good output voltage. A 100-kΩ resistor pullup to BP (R9) is included to allow the power-good signal to be monitored without requiring an external pull-up. For true open-drain operation with no pullup, remove R9. With R9 removed, TP16 can be connected to TP17 of another TPS40345EVM-353 to provide sequential start-up of the two TPS40345EVM-353 converters.

4.3.7 Enable and Soft-Start Voltage Monitoring (TP17 and TP18)

The TPS40345EVM-353 provides a test point and local ground for measuring the enable and soft-start voltage. TP17 and TP18 or JP2 can be used to provide an external enable signal. Due to the nature of the soft-start function, the external signal must be open-collector or open-drain without pullup.

5 Test Setup

5.1 Equipment

5.1.1 Voltage Source

V_{IN} — The input voltage source (V_{IN}) must be a 0-V to 15-V variable DC source capable of supplying 5 Adc.

5.1.2 Meters

A1: — Input current meter. 0 Adc – 5 Adc ammeter

V1: — Input voltage meter. 0 V – 15 V voltmeter

V2: — Output voltage meter. 0 V – 2 V voltmeter

5.1.3 Load

LOAD1: — Output load. Electronic load set for constant current or constant resistance capable of 0 Adc – 20 Adc at 1.2-Vdc.

5.1.4 Oscilloscope

For output voltage ripple: — Oscilloscope must be an analog or digital oscilloscope set for ac-coupled measurement with 20-MHz bandwidth limiting. Use 20 mV/division vertical resolution, 1-µs/division horizontal resolution.

For switching waveforms: — Oscilloscope shall be an analog or digital oscilloscope set for dc coupled measurement with 20-MHz bandwidth limiting. Use 2 V/division or 5V/division vertical resolution and 1-µs/division horizontal resolution.

5.1.5 Recommended Wire Gauge

VIN to J1: — The connection between the source voltage (V_{IN}) and J1 of TPS40345EVM-353 can carry as much as 3.5 Adc of current. The minimum recommended wire size is AWG #16 with the total length of wire less than 2 feet (1 foot input, 1 foot return).

J2 to LOAD1: — The connection between the source voltage (V_{IN}) and J1 of TPS40345EVM-353 can carry as much as 20 Adc of current. The minimum recommended wire size is AWG #12 with the total length of wire less than 2 feet (1 foot input, 1 foot return).

5.1.6 Other

FAN: — The TPS40345EVM-353 evaluation module includes components that can get hot to the touch when operating. Because this evaluation module is not enclosed to allow probing of circuit nodes, TI recommends a small fan capable of 200 lfm – 400 lfm to reduce component temperatures when operating.

5.2 Equipment Setup

Shown in Figure 2 is the basic test set up recommended to evaluate the TPS40345EVM-353. Note that although the return for J1 and JP2 are the same system ground, the connections should remain separate as shown in Figure 2.

5.2.1 Procedure

1. Working at an ESD workstation, make sure 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_{IN}, it is advisable to limit the source current from V_{IN} to 4 A, maximum. Make sure V_{IN} is initially set to 0 V and connected as shown in Figure 2.
3. Connect VIN to J1 as shown in Figure 2.

4. Connect ammeter A1 between VIN and J1 as shown in Figure 2.
5. Connect voltmeter V1 to TP1 and TP2 as shown in Figure 2.
6. Connect voltmeter V2 to TP3 and TP4 as shown in Figure 2.
7. Connect oscilloscope probes to desired test points per Table 2.
8. Place fan as shown in Figure 2 and turn on making sure to blow air directly across the evaluation module.

5.2.2 Diagram

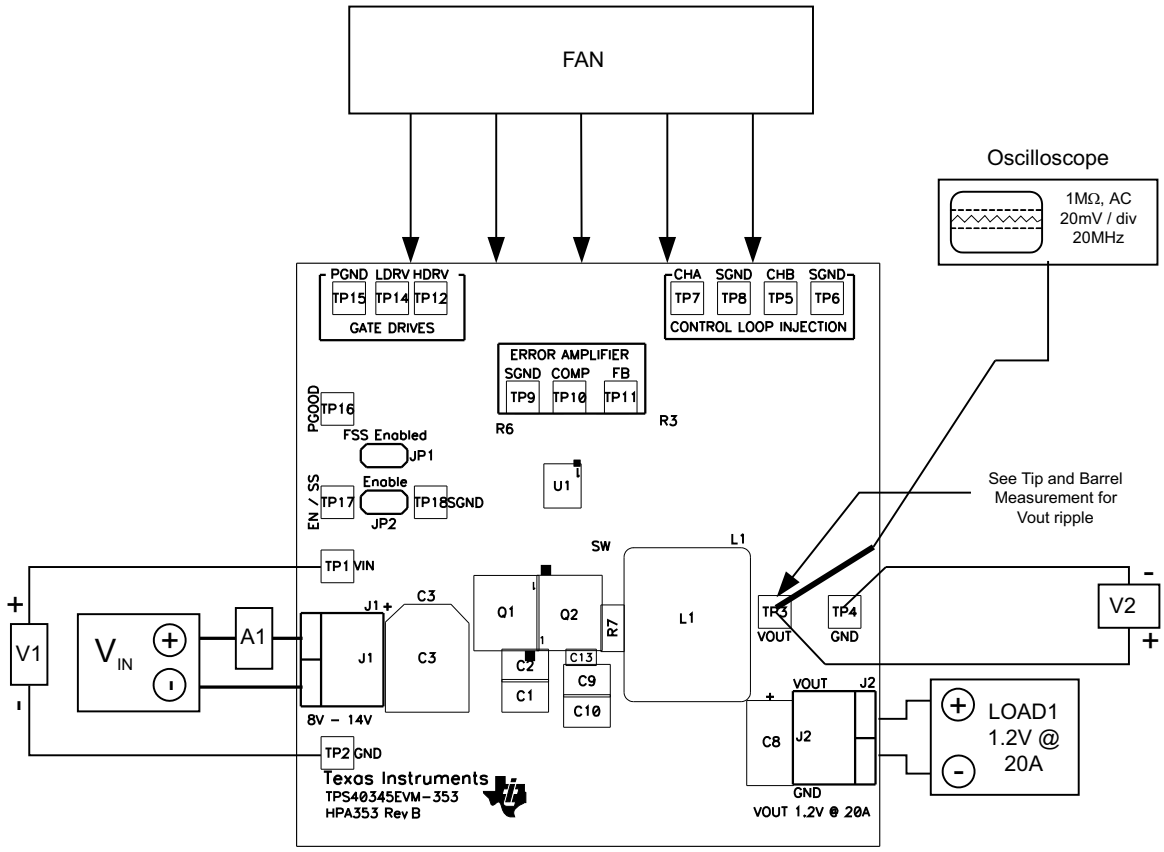


Figure 2. TPS40345EVM-353 Recommended Test Set-Up

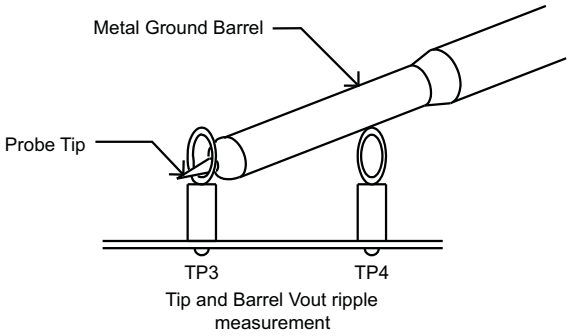


Figure 3. Output Ripple Measurement – Tip and Barrel using TP3 and TP4

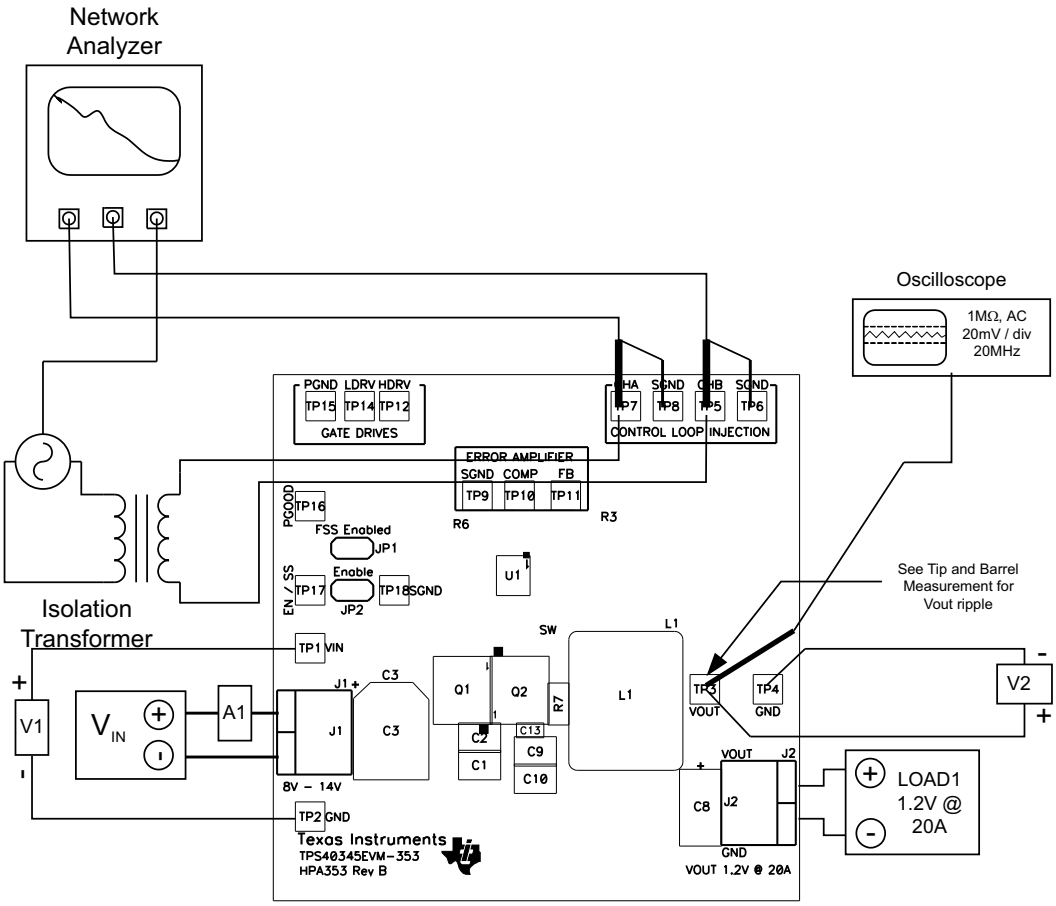


Figure 4. Control Loop Measurement Setup

5.3 Start-Up/Shutdown Procedure

1. Verify shunt position for JP1 for desired FSS status per _____(need correct reference).
2. Remove shunt from JP2 location if present.
3. Increase V_{IN} from 0 Vdc to 12 Vdc.
4. Vary LOAD1 from 0 Adc to 20 Adc.
5. Vary V_{IN} from 8 V to 14 V.
6. Decrease V_{IN} to 0 V.
7. Decrease LOAD1 to 0 A.

5.4 Output Ripple Voltage Measurement Procedure

1. Follow *Section 5.3* steps 1 – 5 to set V_{IN} and LOAD1 to the desired operating condition.
2. Connect oscilloscope probe with exposed metal barrel to TP3 and TP4 per Figure 3.
3. Set oscilloscope per oscilloscope for output voltage ripple measurement in *Section 5.1.4*.
4. Follow Section 5.3 steps 6 and 7 to power down.

5.5 Control Loop Gain and Phase Measurement Procedure

1. Follow Section 5.3 steps 1 – 5 to set V_{IN} and LOAD1 to the desired operating condition:
   a. If JP1 is installed (FSS enabled), loop response data about the modulation frequency (30 kHz) may be affected.
2. Connect a 1-kHz – 1-MHz isolation transformer to TP5 and TP7 as shown in Figure 4.

3. Connect input signal amplitude measurement probe (channel A) to TP7 as shown in Figure 4.
4. Connect output signal amplitude measurement probe (channel B) to TP5 as shown in Figure 4.
5. Connect ground lead of channel A and channel B to TP6 and TP8 as shown in Figure 4.
6. Inject 30 mV or less signal across R3 through isolation transformer.
7. Sweep frequency from 1 kHz to 1 MHz with 10-Hz or lower post filter.
8. Control loop gain can be measured by $20 \times \text{LOG}\left(\frac{\text{Channel B}}{\text{Channel A}}\right)$
9. Control loop phase can be measured by the phase difference between channel A and channel B.
10. Control to output response (power stage transfer function) can be measured by connecting channel A probe to TP10 (COMP) and channel B probe to TP5 (CHB).
11. Output to control response (compensated error amplifier transfer function) can be measured by connecting channel A probe to TP7 (CHA) and channel B probe to TP10 (COMP).
12. Follow Section 5.3 steps 6 and 7 to power down.

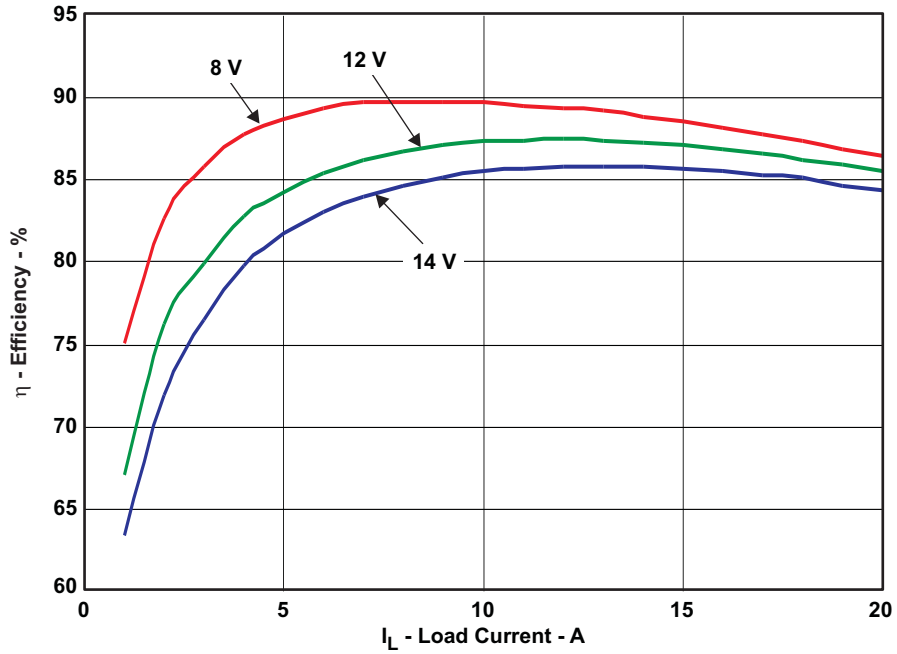
5.6 Equipment Shutdown

1. Shut down oscilloscope
2. Shut down LOAD1
3. Shut down V_{IN}
4. Shut down fan

6 TPS40345EVM-353 Test Data

Figure 5 through Figure 10 present typical performance curves for the TPS40345EVM-353. Since 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.

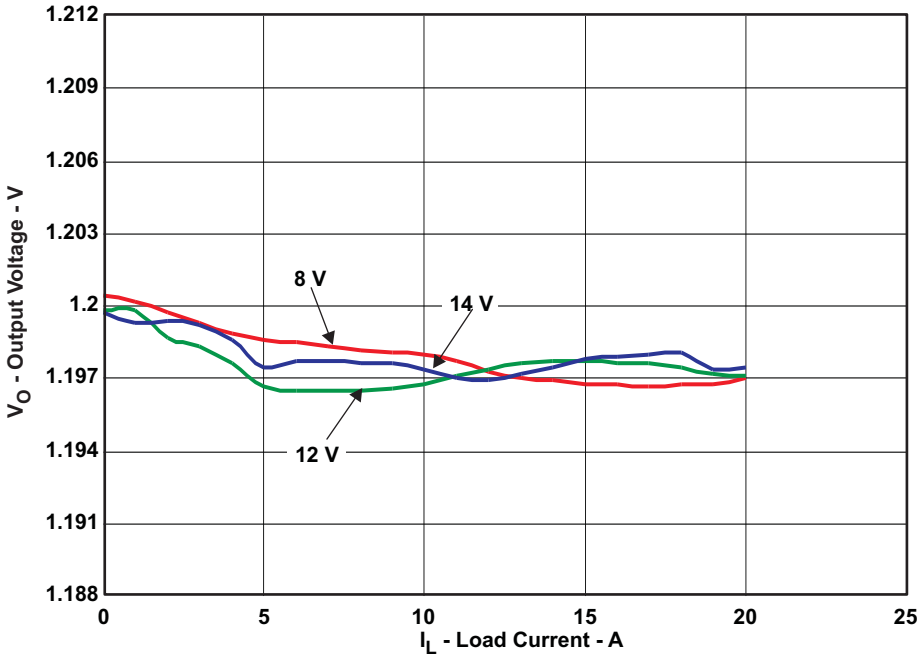
6.1 Efficiency



V_{IN} = 8.0V – 14V, V_{OUT} = 1.2V, I_{OUT} = 0A – 20A

Figure 5. TPS40345EVM-353 Efficiency vs Load Current

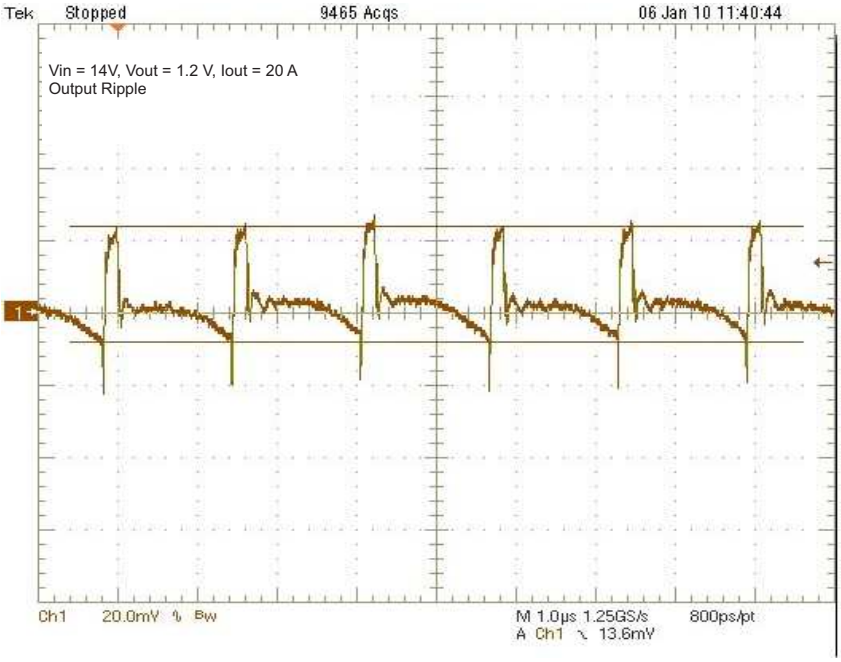
6.2 Line and Load Regulation



V_{IN} = 8.0V – 14V, V_{OUT} = 1.2V, I_{OUT} = 0A – 20A

Figure 6. TPS40345EVM-353 Output Voltage vs Load Current

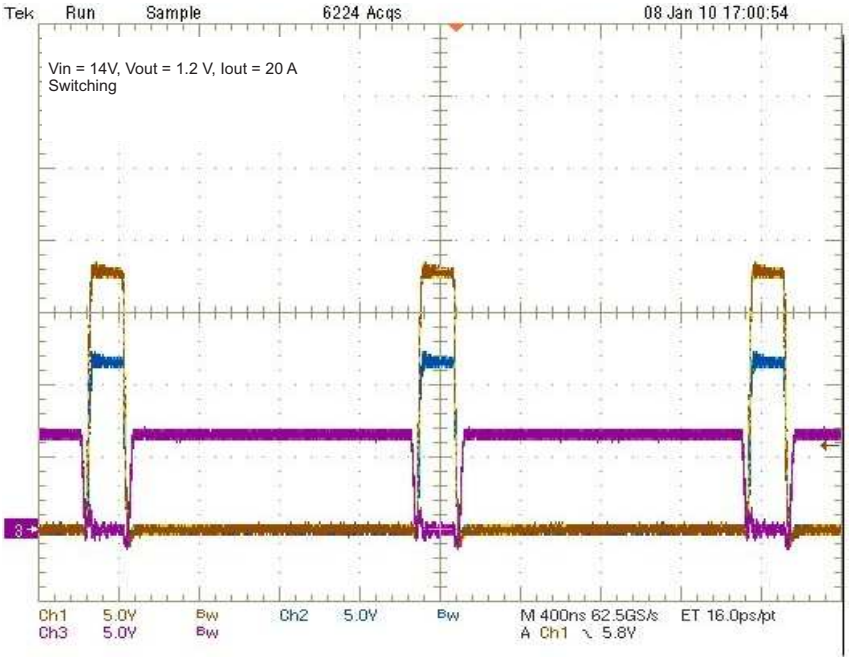
6.3 Output Voltage Ripple



V_{IN} = 14V, V_{OUT} = 1.2V, I_{OUT} = 20A

Figure 7. TPS40345EVM-353 Output Voltage Ripple

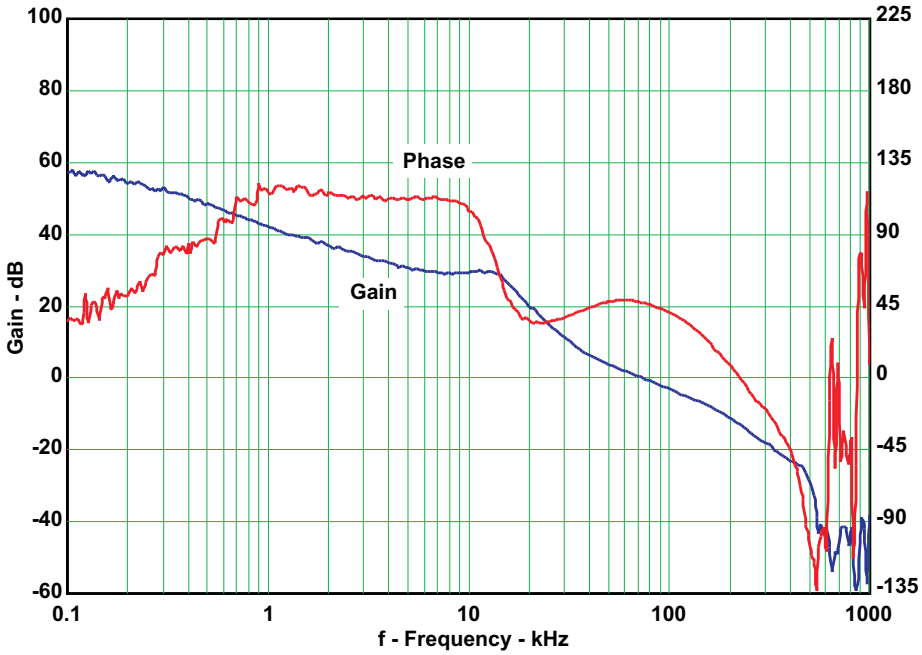
6.4 Switch Node



V_{IN} = 12V, V_{OUT} = 1.2V, I_{OUT} = 20 A
Ch1: TP12 (HDRV), Ch2:13 TP (SW), Ch3: TP14 (LDRV)

Figure 8. TPS40345EVM-353 Switching Waveforms

6.5 Control Loop Bode Diagram



V_{IN} = 14V, V_{OUT} = 1.2V, I_{OUT} = 20A, Bandwidth: 73kHz, Phase Margin: 47°

Figure 9. TPS40345EVM-353 Gain and Phase vs Frequency

6.6 Additional Waveforms

6.6.1 Output Ripple With Frequency Spread Spectrum (FSS) Enabled

FSS varies the output switching frequency. This change in switching frequency can produce a small change in the output voltage at the modulation frequency. Figure 10 shows the approximately 10-mV modulation of the output voltage generated when FSS is enabled.

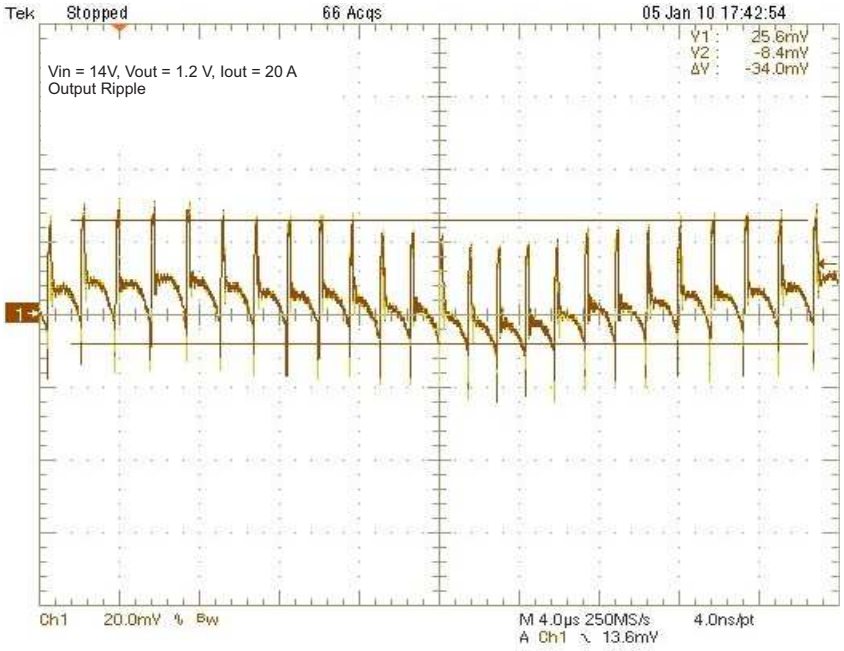


Figure 10. TPS40345EVM-353 Output Ripple With FSS Enabled

7 TPS40345EVM-353 Assembly Drawings and Layout

The following figures (Figure 11 through Figure 16) show the design of the TPS40345EVM-353 printed circuit board. The EVM has been designed using a 4-layer, 2-oz. copper-clad circuit board 3-inch × 3-inch with all components on the top to allow the user to easily view, probe, and evaluate the **TPSxxxxx** control IC in a practical double-sided application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space constrained systems.

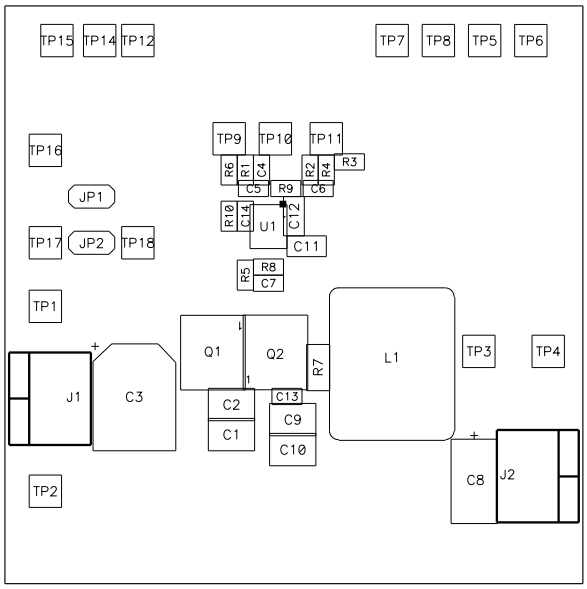


Figure 11. TPS40345EVM-353 Component Placement (Top View)

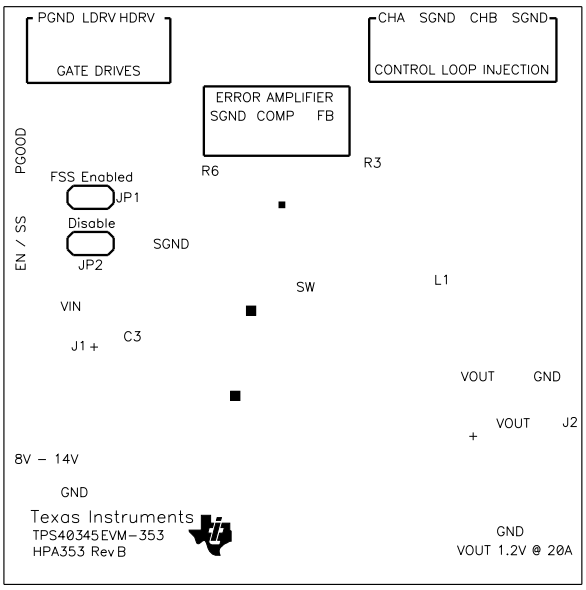


Figure 12. TPS40345EVM-353 Silk Screen (Top View)

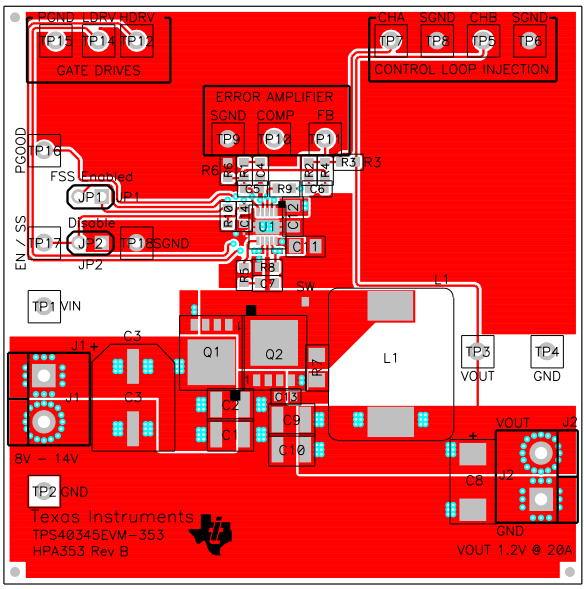


Figure 13. TPS40345EVM-353 Top Copper (Top View)

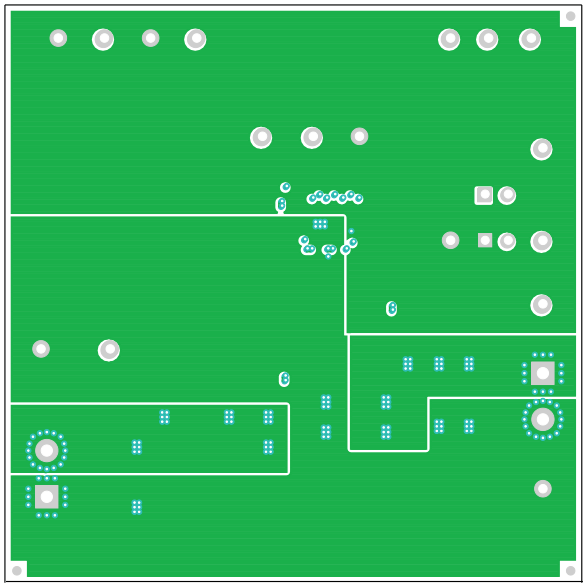


Figure 14. TPS40345EVM-353 Bottom Copper (Top View)

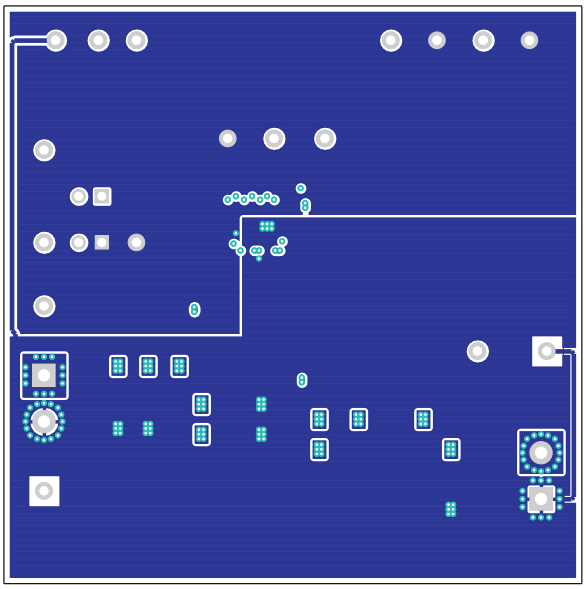


Figure 15. TPS40345EVM-353 Internal 1 (X-Ray Top View)

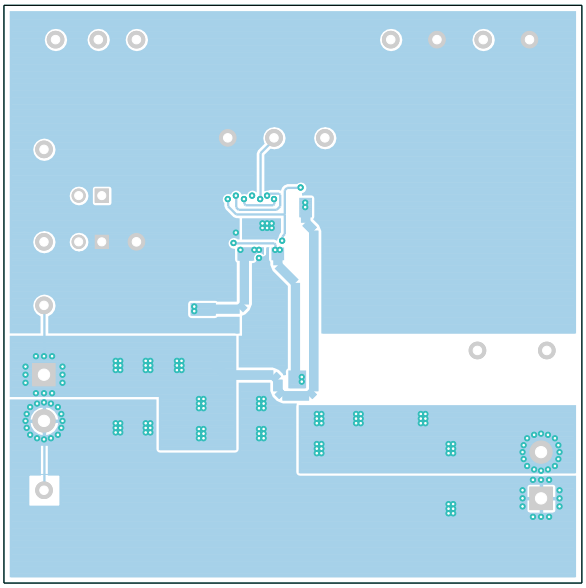


Figure 16. TPS40345EVM-353 Internal 2 (X-Ray Top View)

8 TPS40345EVM-353 Bill of Materials

Table 3. TPS40345EVM-353 Bill of Materials

QTY	RefDes	Value	Description	Size	Part Number	MFR
2	C1, C2	10µF	Capacitor, Ceramic, 25V, X7R, 10%	1210	Std	Std
1	C11	4.7µF	Capacitor, Ceramic, 10V, X7R, 20%	0805	Std	Std
1	C12	1µF	Capacitor, Ceramic, 25V, X7R, 20%	0805	Std	Std
0	C13	1nF	Capacitor, Ceramic, 25V, X5R, 20%	0603	Std	Std
1	C14	3.3nF	Capacitor, Ceramic, 16V, X7R, 20%	0603	Std	Std
1	C3	330µF	Capacitor, Aluminum, 25V, ±20%, 160mΩ	0.328 x 0.390 inch	EEEFK1E331P	Panasonic
2	C4, C6	680pF	Capacitor, Ceramic, 25V, COG, 10%	0603	Std	Std
1	C5	100pF	Capacitor, Ceramic, 25V, COG, 10%	0603	Std	Std
1	C7	100nF	Capacitor, Ceramic, 16V, X7R, 20%	0603	Std	Std
1	C8	220µF	Capacitor, POSCAP, 6.3V, 25mΩ, 105C, 20%	7343(D)	6TPE220M	Sanyo
2	C9, C10	47µF	Capacitor, Ceramic, 6.3V, X5R, 20%	1210	Std	Std
2	J1, J2	ED120/2DS	Terminal Block, 2-pin, 15A, 5.1mm	0.40 x 0.35 inch	ED120/2DS	OST
2	JP1, JP2	PEC02SAAN	Header, 2-pin, 100mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
1	L1	0.38µH	Inductor, SMT, 35A	0.512 x 0.571 inch	PG0077.401NLT	Pulse
1	Q1*	CSD16410Q5A	MOSFET, N-Chan, 25V, 59A, 9.6mΩ	QFN-8 POWER	CSD16410Q5A	TI
1	Q2*	CSD16321Q5	MOSFET, N-Chan, 25V, 31A	QFN-8 POWER	CSD16321Q5	TI
3	R1, R4, R6	10.0kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R10	267kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	1.50kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	49.9Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	2Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R7	2.2Ω	Resistor, Chip, 1/8W, 5%	1206	Std	Std
1	R8	4.02kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R9	100kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	TP1, TP3	5000	Test Point, Red, Thru Hole Color Keyed	0.100 x 0.100 inch	5000	Keystone
0	TP13	N/A	Test Point, SM, 2x3mm	0.118 x 0.079 inch		
6	TP2, TP4, TP6, TP8, TP15, TP18	5001	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
9	TP5, TP7, TP9–TP12, TP14, TP16, TP17	5002	Test Point, White, Thru Hole Color Keyed	0.100 x 0.100 inch	5002	Keystone
1	U1*	TPS40345DRC	IC, 3V – 20V sync. Buck controller/Enable Light Load/Fq Spread Spectrum	DRC10	TPS40345DRC	TI
2	–		Shunt, 100-mil, Black	0.1	929950-00	3M
1	–		PCB, 2.5 In x 2.5 In x 0.062 In		HPA353	Any

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.

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EVM Warnings and Restrictions

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

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 . The EVM is designed to operate properly with certain components above 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

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

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西新宿三井ビル

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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