

High Efficiency 14A Synchronous Buck Converter with Eco-Mode™

The TPS53319EVM-136 is designed to use a regulated 12V bus to produce a regulated 1.5V output at up to 14A of load current. The TPS53319EVM-136 is designed to demonstrate the TPS53319 in a typical low voltage application while providing a number of test points to evaluate the performance of the TPS53319.

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1 Introduction

The TPS53319EVM-136 evaluation module (EVM) uses the TPS53319. The TPS53319 is a D-CAP™ mode, 14A synchronous Buck converter with integrated MOSFETs. It provides a fixed 1.5V output at up to 14A from a 12V input bus.

1.1 Typical Applications

- Server/Storage
- Workstations and Desktops
- Telecommunication Infrastructure

1.2 Features

The TPS53319EVM-136 features:

- 14A DC Steady State Output Current
- Support pre-bias output voltage start-up
- J3 for selectable switching frequency setting
- J4 for selectable soft start time
- J5 for auto-skip and forced CCM selection
- J6 for enable function
- Convenient test points for probing critical waveforms

2 Electrical Performance Specifications

Table 1. TPS53319EVM-136 Electrical Performance Specifications⁽¹⁾

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS					
Voltage range	V _{IN}	8	12	20	V
Maximum input current	V _{IN} = 8V, I _o = 14 A	2.874			A
No load input current	V _{in} =20V, I _o =0A with auto skip mode	0.7			mA
OUTPUT CHARACTERISTICS					
Output voltage V _{OUT}		1.5			V
Output voltage regulation	Line regulation(V _{in} =8V-20V)	0.1%			
	Load regulation(V _{in} =12V, I _o =0A-14A) Auto-skip	1%			
Output voltage ripple	V _{in} =12V, I _o =14A	15			mVpp
Output load current		0		14	A
Output over current		16			A
SYSTEMS CHARACTERISTICS					
Switching frequency		500			kHz
Peak efficiency	V _{in} =12V, 1.5V/8A	91.68%			
Full load efficiency	V _{in} =12V, 1.5V/14A	90.04%			
Operating temperature		25			°C

⁽¹⁾ **Note:** Jumpers set to default locations, See section 6 of this user's guide

3 Schematic

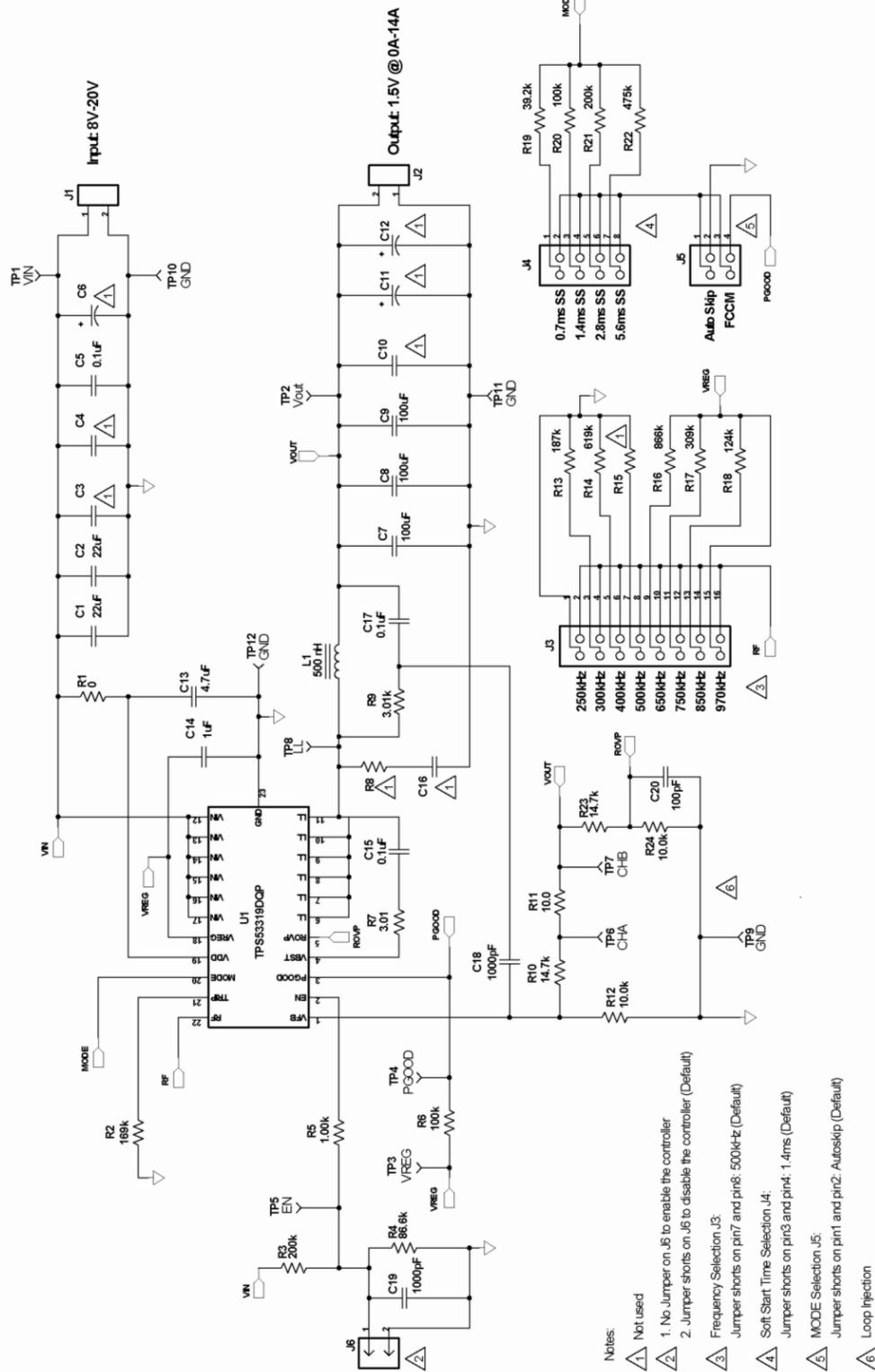


Figure 1. TPS53319EVM-136 Schematic

4 Test Setup

4.1 Test Equipment

Voltage Source:

The input voltage source V_{in} should be a 0-20V variable DC source capable of supplying 10A_{dc}. Connect V_{in} to J1 as shown in [Figure 3](#).

Multimeters:

V1: V_{in} at TP1 (V_{in}) and TP10 (GND). V2: V_{out} at TP2 (V_{out}) and TP11 (GND). A1: V_{in} input current

Output Load:

The output load should be an electronic constant resistance mode load capable of 0-16A_{dc} at 1.5V.

Oscilloscope:

A digital or analog oscilloscope can be used to measure the output ripple. The oscilloscope should be set for 1M Ω impedance, 20MHz Bandwidth, AC coupling, 2 μ s/division horizontal resolution, 20mV/division vertical resolution. Test points TP2 and TP11 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP2 and holding the ground barrel on TP11 as shown in [Figure 2](#). Using a leaded ground connection may induce additional noise due to the large ground loop.

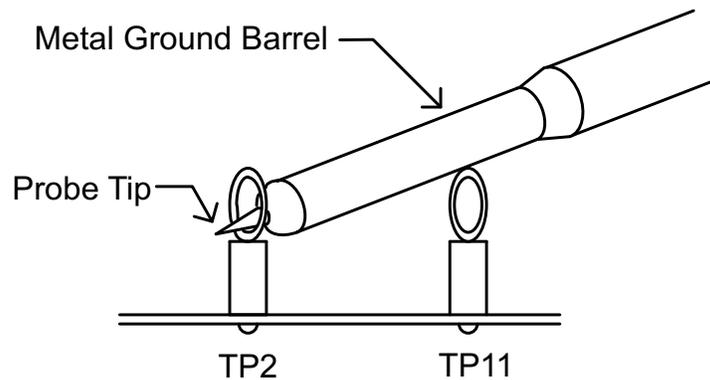


Figure 2. Tip and Barrel Measurement for V_{out} Ripple

Recommended Wire Gauge:

1. V_{IN} to J1(12V input):
The recommended wire size is AWG #16 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
2. J2 to LOAD:
The minimum recommended wire size is AWG #14, with the total length of wire less than 4 feet (2 feet output, 2 feet return)

4.2 Recommended Test Setup

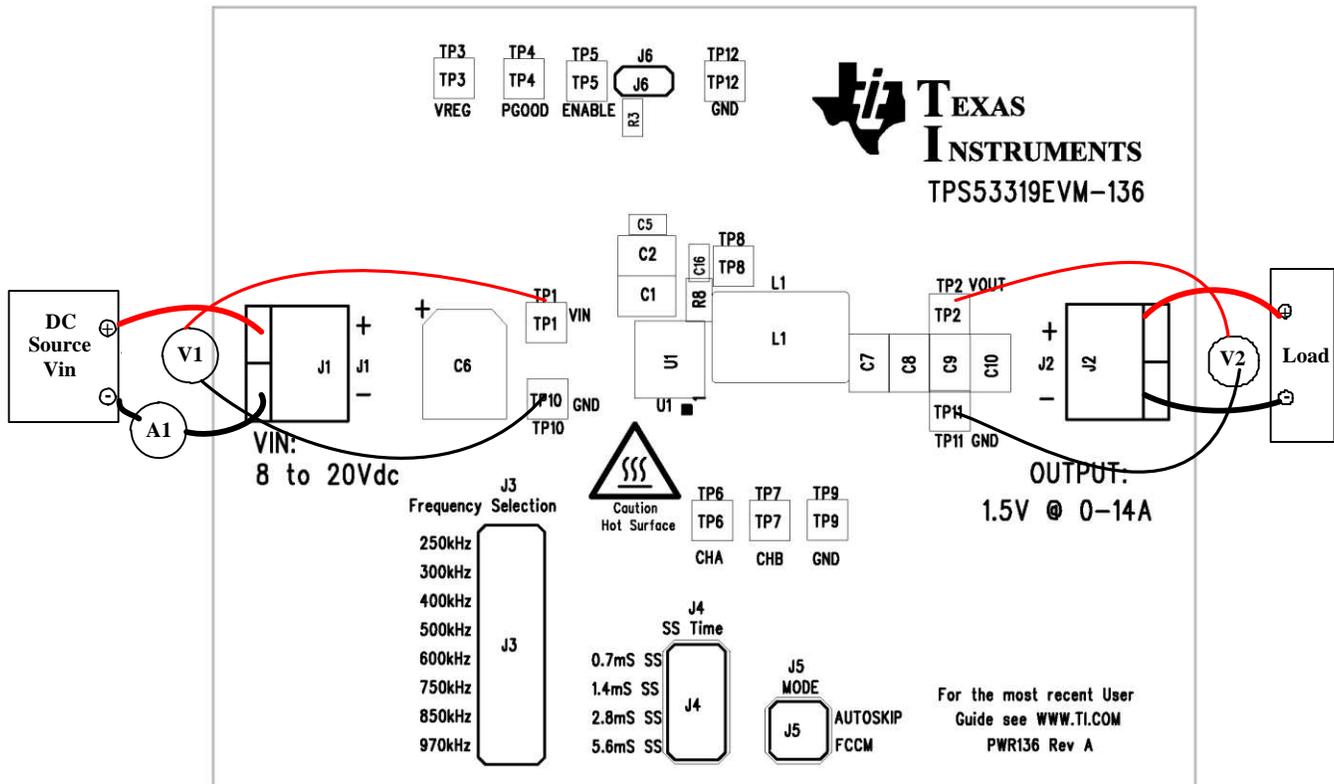


Figure 3. TPS53319EVM-136 Recommended Test Set Up

Figure 3 is the recommended test set up to evaluate the TPS53319EVM-136. 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.

Input Connections:

1. Prior to connecting the DC input source V_{in} , it is advisable to limit the source current from V_{in} to 10A maximum. Make sure V_{in} is initially set to 0V and connected as shown in Figure 3.
2. Connect a voltmeter V1 at TP1(V_{in}) and TP10(GND) to measure the input voltage.
3. Connect a current meter A1 to measure the input current.

Output Connections

1. Connect Load to J2 and set Load to constant resistance mode to sink 0Adc before V_{in} is applied.
2. Connect a voltmeter V2 at TP2 (V_{out}) and TP11 (GND) to measure the output voltage.

5 Configurations

All Jumper selections should be made prior to applying power to the EVM. User can configure this EVM per following configurations.

5.1 Switching Frequency Selection

The switching frequency can be set by J3.

Default setting: 500kHz

Table 2. Switching Frequency Selection

Jumper set to	Resistor (RF) Connections(Ω)	Switching Frequency(kHz)
Top(1-2 pin shorted)	0	250
2 nd (3-4 pin shorted)	187k	300
3 rd (5-6 pin shorted)	619k	400
4th(7-8 pin shorted)	Open	500
5 th (9-10 pin shorted)	866k	600
6 th (11-12 pin shorted)	309k	750
7 th (13-14 pin shorted)	124k	850
Bottom(15-16 pin shorted)	0	970

5.2 Soft Start Selection

The soft start time can be set by J4.

Default setting: 1.4ms

Table 3. Soft Start Time Selection

Jumper set to	R _{MODE} Connections(Ω)	Soft Start Time(ms)
Top(1-2 pin shorted)	39.2k	0.7
2nd (3-4 pin shorted)	100k	1.4
3 rd (5-6 pin shorted)	200k	2.8
Bottom(7-8 pin shorted)	475k	5.6

5.3 Mode Selection

The MODE can be set by J5.

Default setting: Auto Skip

Table 4. MODE Selection

Jumper set to	MODE Selection
Top(1-2 pin shorted)	Auto Skip
Bottom(3-4 pin shorted)	Forced CCM

5.4 Enable Selection

The controller can be enabled and disabled by J6.

Default setting: Jumper shorts on J6 to disable the controller

Table 5. Enable Selection

Jumper set to	Enable Selection
Jumper shorts on J6	Disable the controller
No Jumper shorts on J6	Enable the controller

6 Test Procedure

6.1 Line/Load Regulation and Efficiency Measurement Procedure

1. Set up EVM as described in [Section 4](#) and [Figure 3](#).
2. Ensure Load is set to constant resistance mode and to sink 0Adc
3. Ensure all jumpers configuration settings per section 5.
4. Ensure the jumper provided in the EVM shorts on J6 before Vin is applied.
5. Increase Vin from 0V to 12V. Using V1 to measure input voltage.
6. Remove the jumper on J6 to enable the controller.
7. Use V2 to measure Vout voltage.
8. Vary Load from 0-14Adc, Vout should be remain in load regulation.
9. Vary Vin from 8V to 20V, Vout should remain in line regulation.
10. Put the jumper on J6 to disable the controller.
11. Decrease Load to 0A
12. Decrease Vin to 0V.

6.2 Control Loop Gain and Phase Measurement Procedure

TPS53319EVM-136 contains a 10 Ω series resistor in the feedback loop for loop response analysis.

1. Set up EVM as described in [Section 4](#) and [Figure 3](#).
2. Connect isolation transformer to test points marked TP6 and TP7.
3. Connect input signal amplitude measurement probe (channel A) to TP6. Connect output signal amplitude measurement probe (channel B) to TP7.
4. Connect ground lead of channel A and channel B to TP9.
5. Inject around 20mV or less signal through the isolation transformer.
6. Sweep the frequency from 100Hz to 1MHz with 10Hz or lower post filter. The control loop gain and phase margin can be measured.
7. Disconnect isolation transformer from bode plot test points before making other measurements (Signal injection into feedback may interfere with accuracy of other measurements).

6.3 List of Test Points

Table 6. The Functions of Each Test Points

Test Points	Name	Description
TP1	VIN	Controller input
TP2	Vout	Output Voltage
TP3	VREG	5V LDO output
TP4	PGOOD	Power Good
TP5	EN	Enable
TP6	CHA	Input A for loop injection
TP7	CHB	Input B for loop injection
TP8	LL	Switching node
TP9	GND	Ground
TP10	GND	Ground
TP11	GND	Ground
TP12	GND	Ground

6.4 Equipment Shutdown

1. Shut down Load
2. Shut down Vin

7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 18 present typical performance curves for TPS53319EVM-136.

7.1 Efficiency

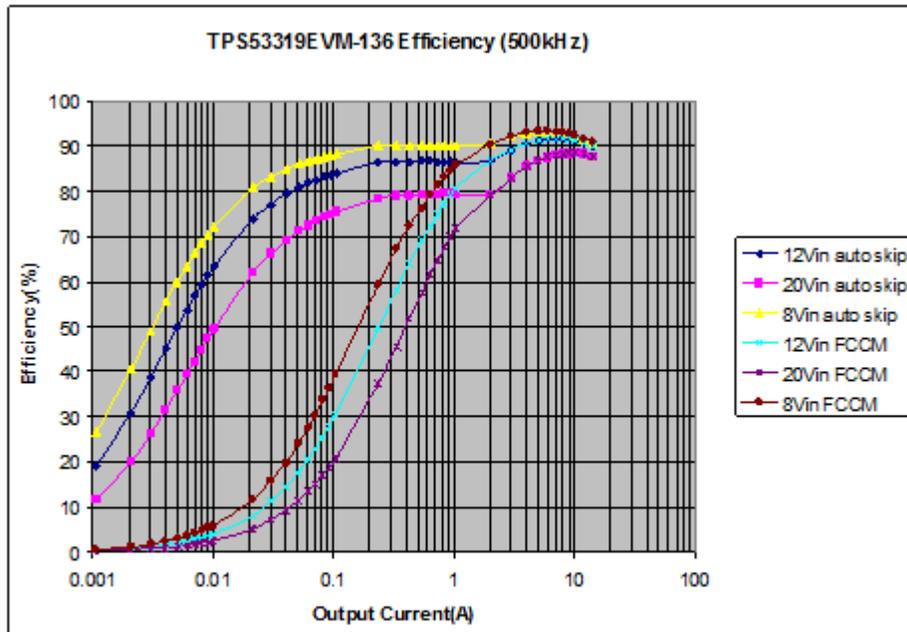


Figure 4. Efficiency

7.2 Load Regulation

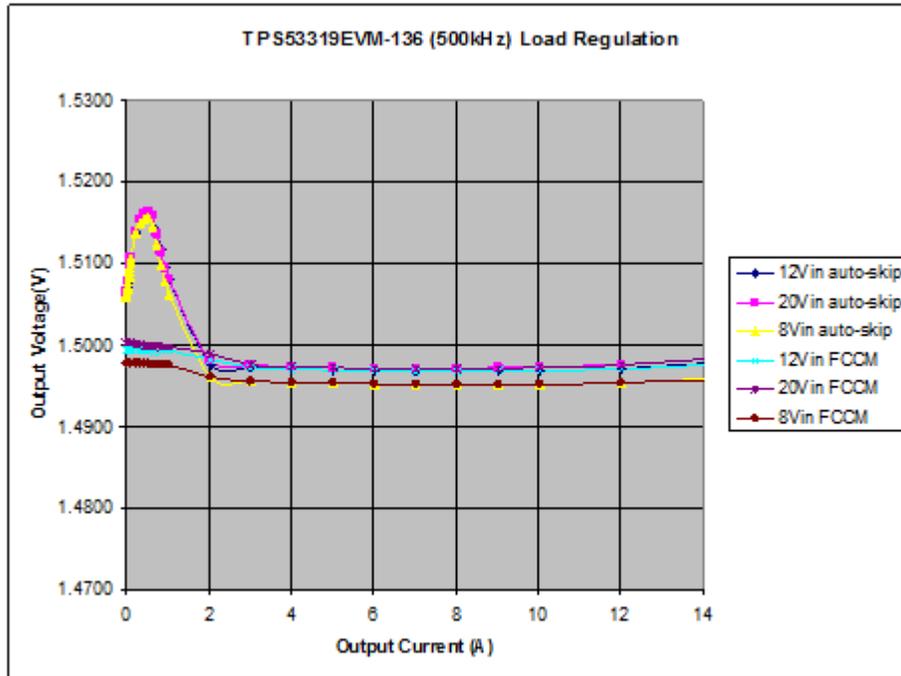


Figure 5. Load Regulation

7.3 Line Regulation

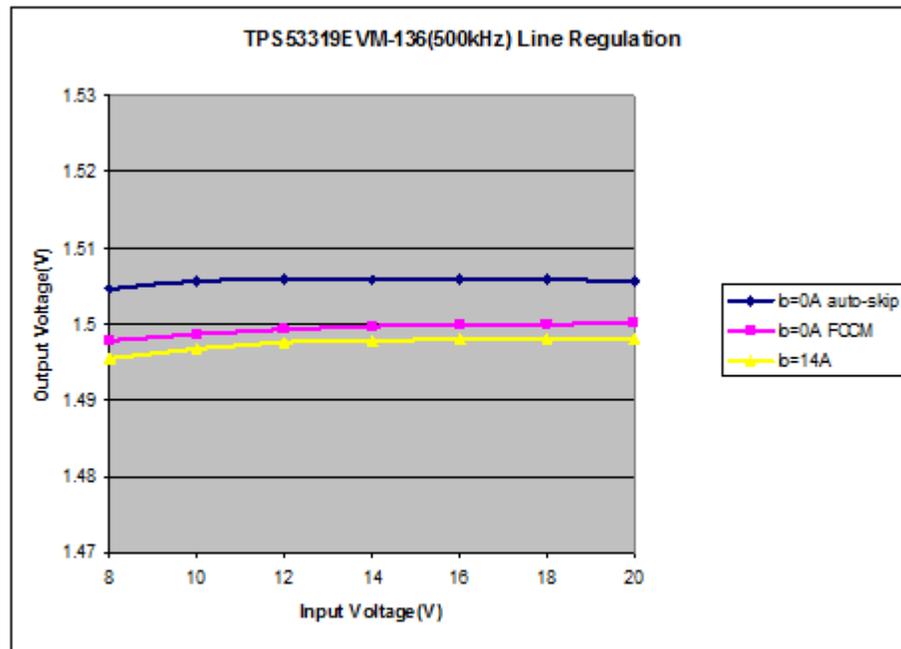


Figure 6. Line Regulation

7.4 Enable Turn on/ Turn off

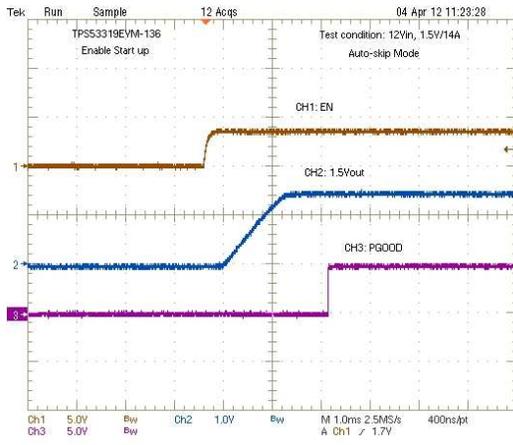


Figure 7. Enable Turn on

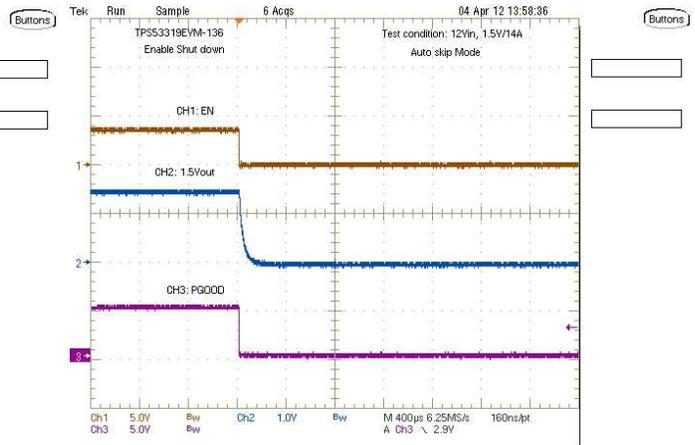


Figure 8. Enable Turn off

7.5 Output Ripple

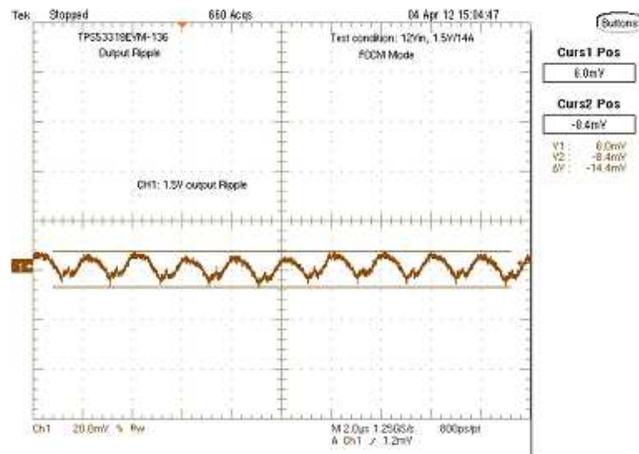


Figure 9. Output Ripple

7.6 Switching Node

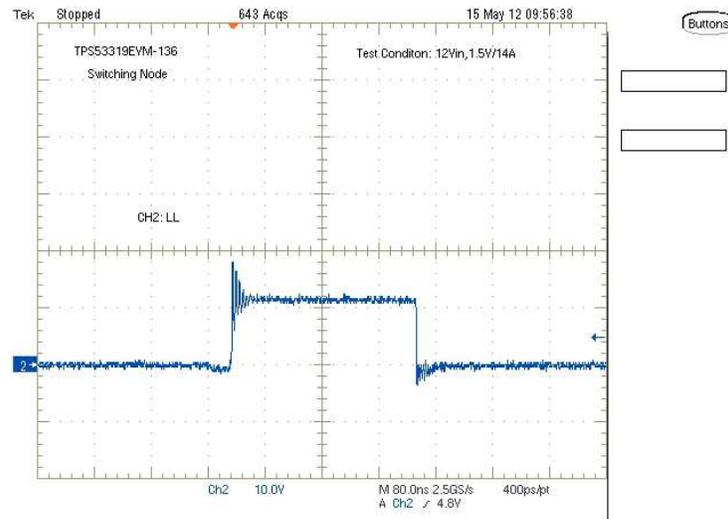


Figure 10. Switching Node

7.7 Output Transient with Auto-skip mode

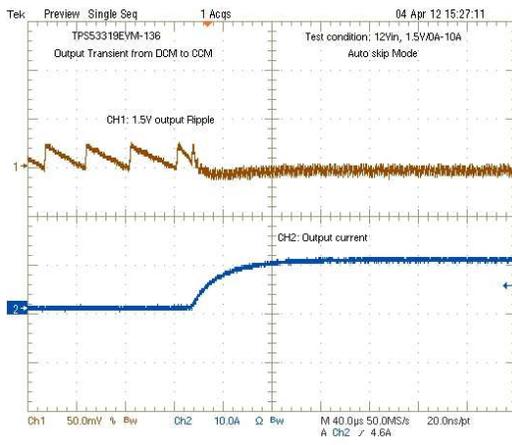


Figure 11. Output Transient from DCM to CCM

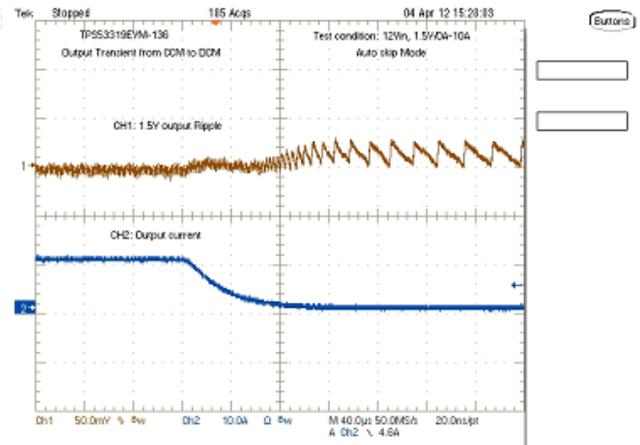


Figure 12. Output Transient from CCM to DCM

7.8 Output Transient with FCCM mode

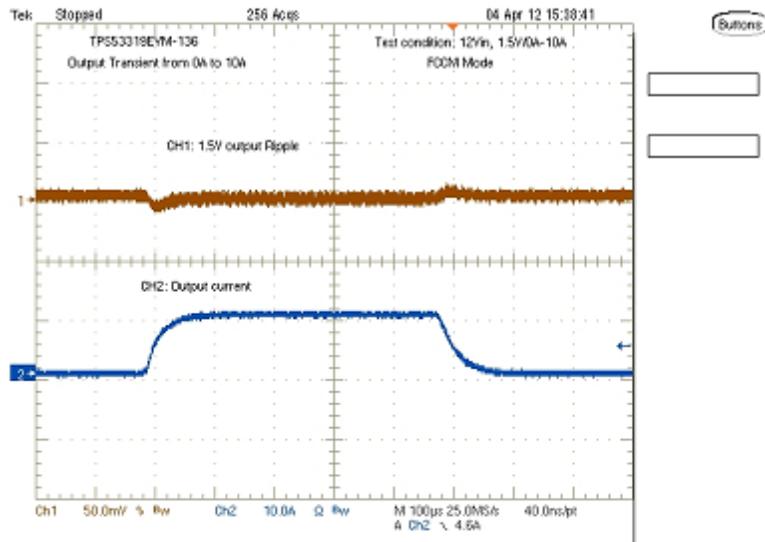


Figure 13. Output Transient with FCCM mode

7.9 Output 0.75V Pre-bias Turn on

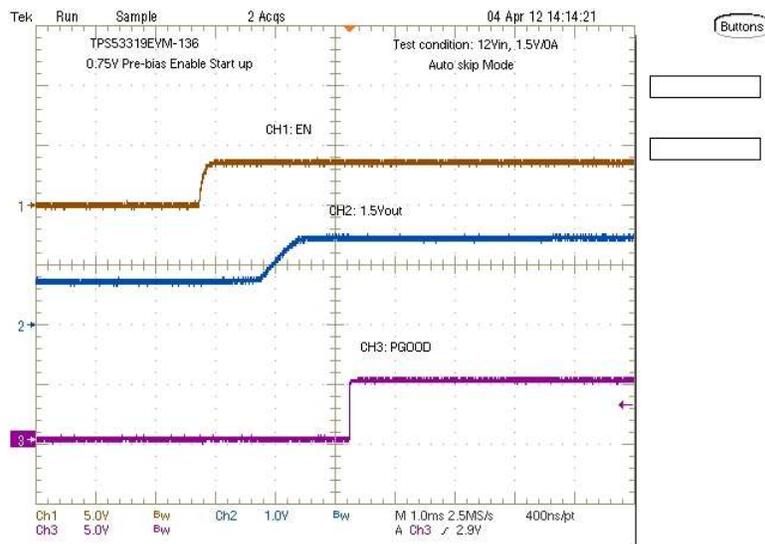


Figure 14. Output 0.75V Pre-bias Turn on

7.10 Output Over Current and Short Circuit Protection

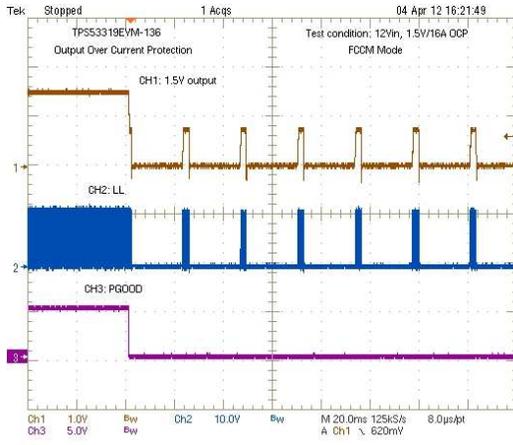


Figure 15. Output Over Current Protection

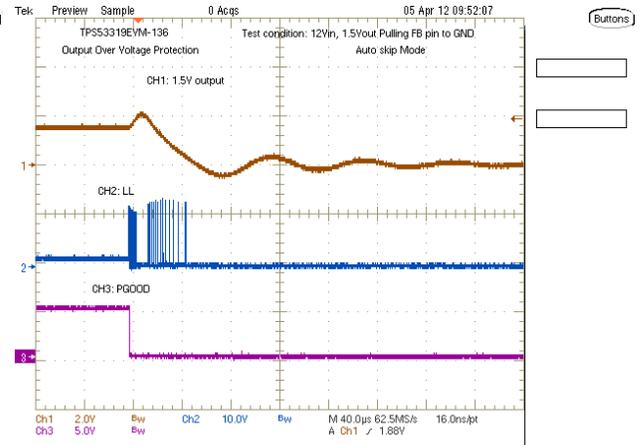


Figure 16. Output Over Voltage Protection

7.11 Bode plot

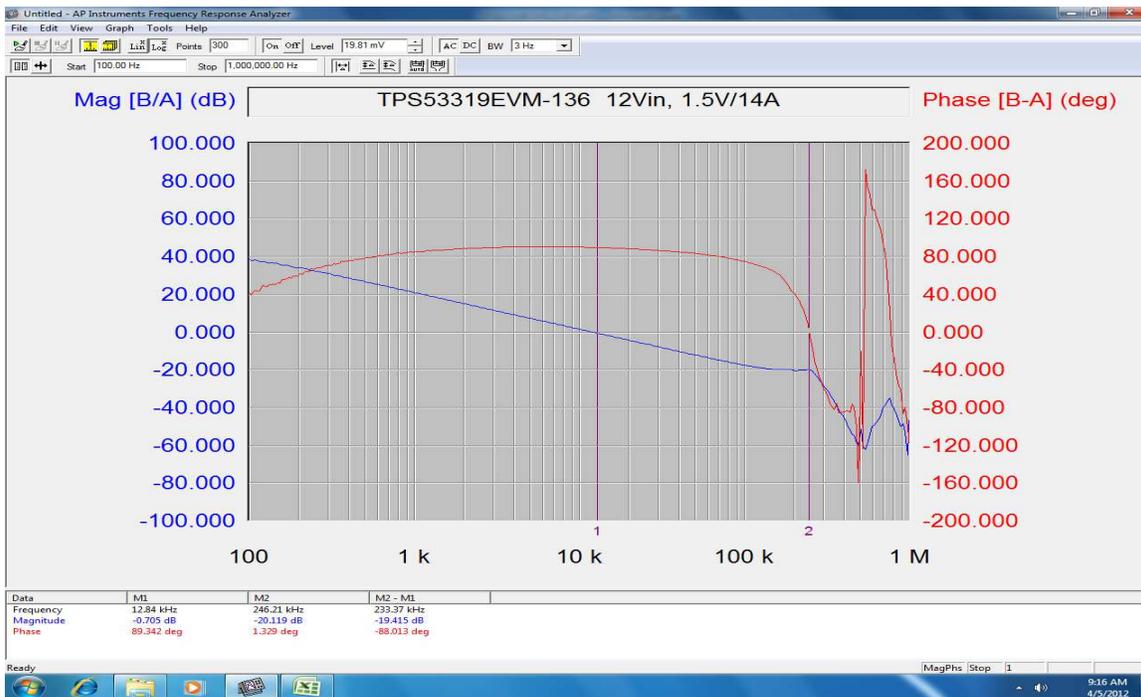


Figure 17. Bode plot at 12Vin, 1.5V/14A

7.12 Thermal Image

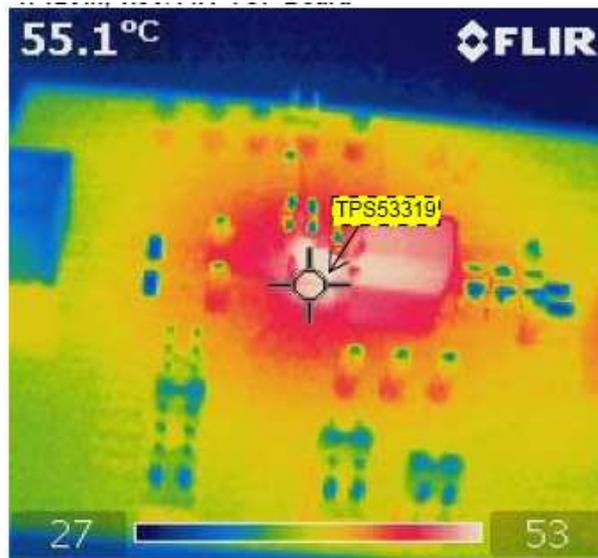


Figure 18. Top Board at 12Vin, 1.5V/14A, 25deg.C amb. without airflow

8 EVM Assembly Drawing and PCB Layout

The following figures (Figure 19 through Figure 26) show the design of the TPS53319EVM-136 printed circuit board. The EVM has been designed using a 6 Layer, 2 oz copper circuit board.

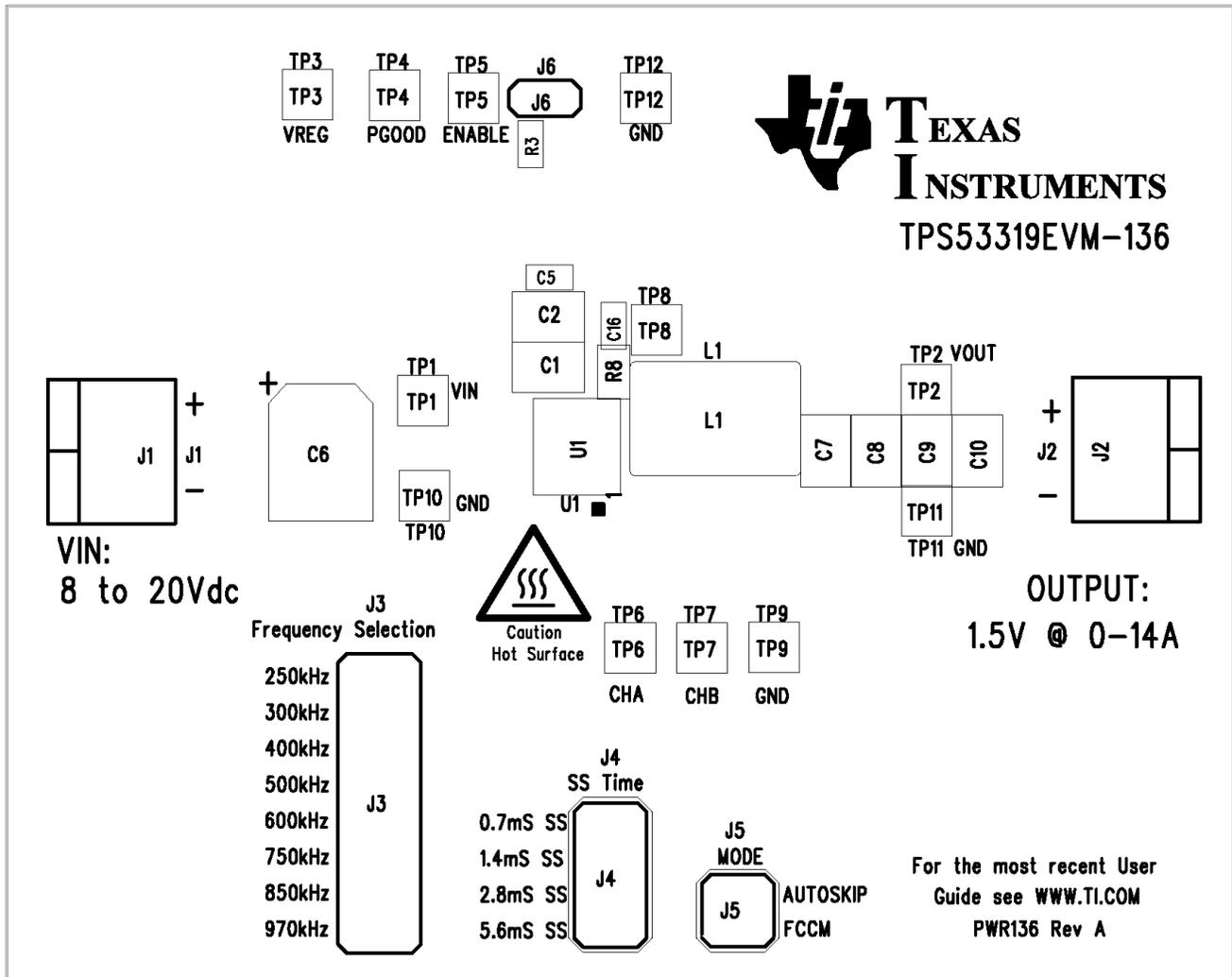


Figure 19. TPS53319EVM-136 Top Layer Assembly Drawing

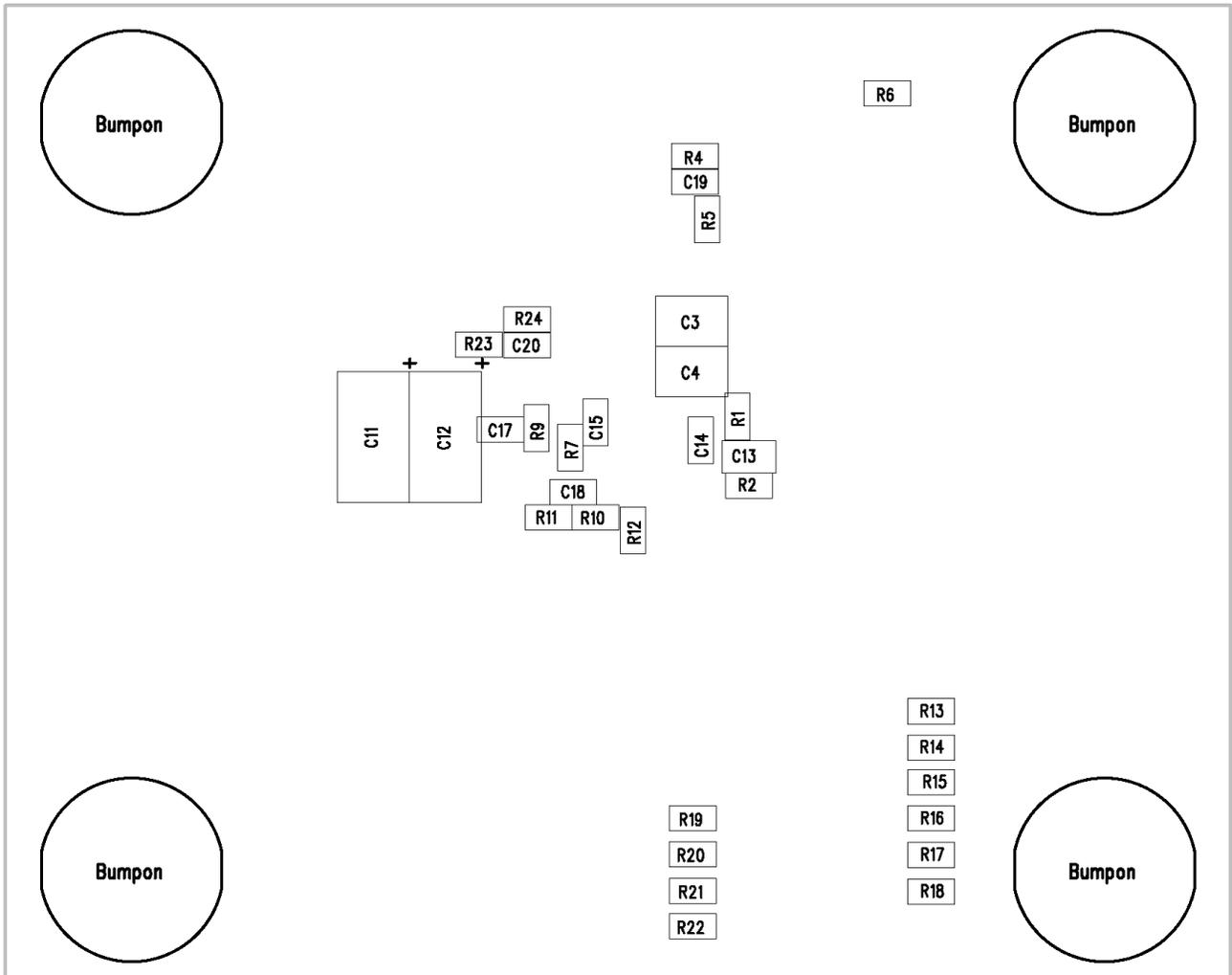


Figure 20. TPS53319EVM-136 Bottom Assembly Drawing

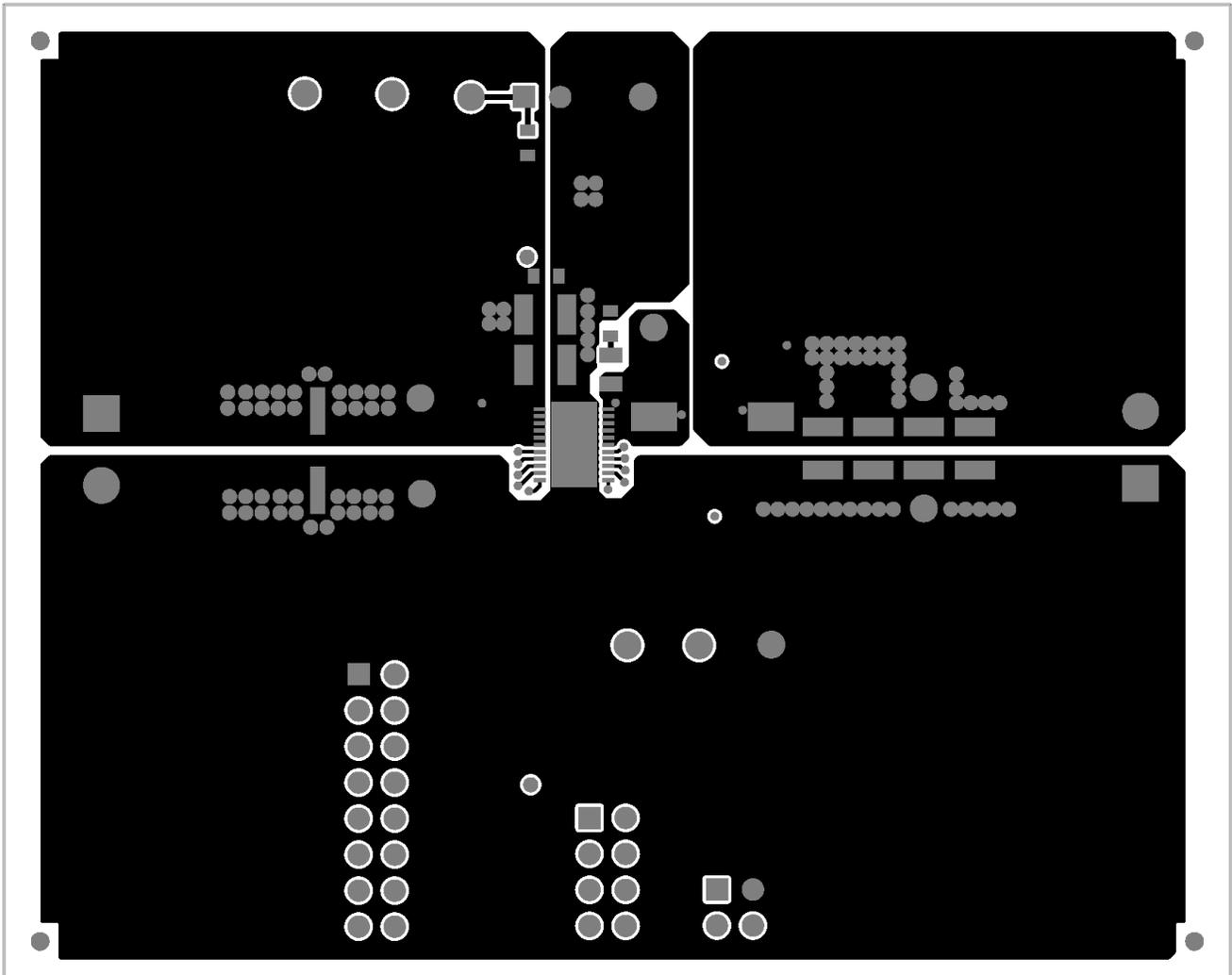


Figure 21. TPS53319EVM-136 Top Copper

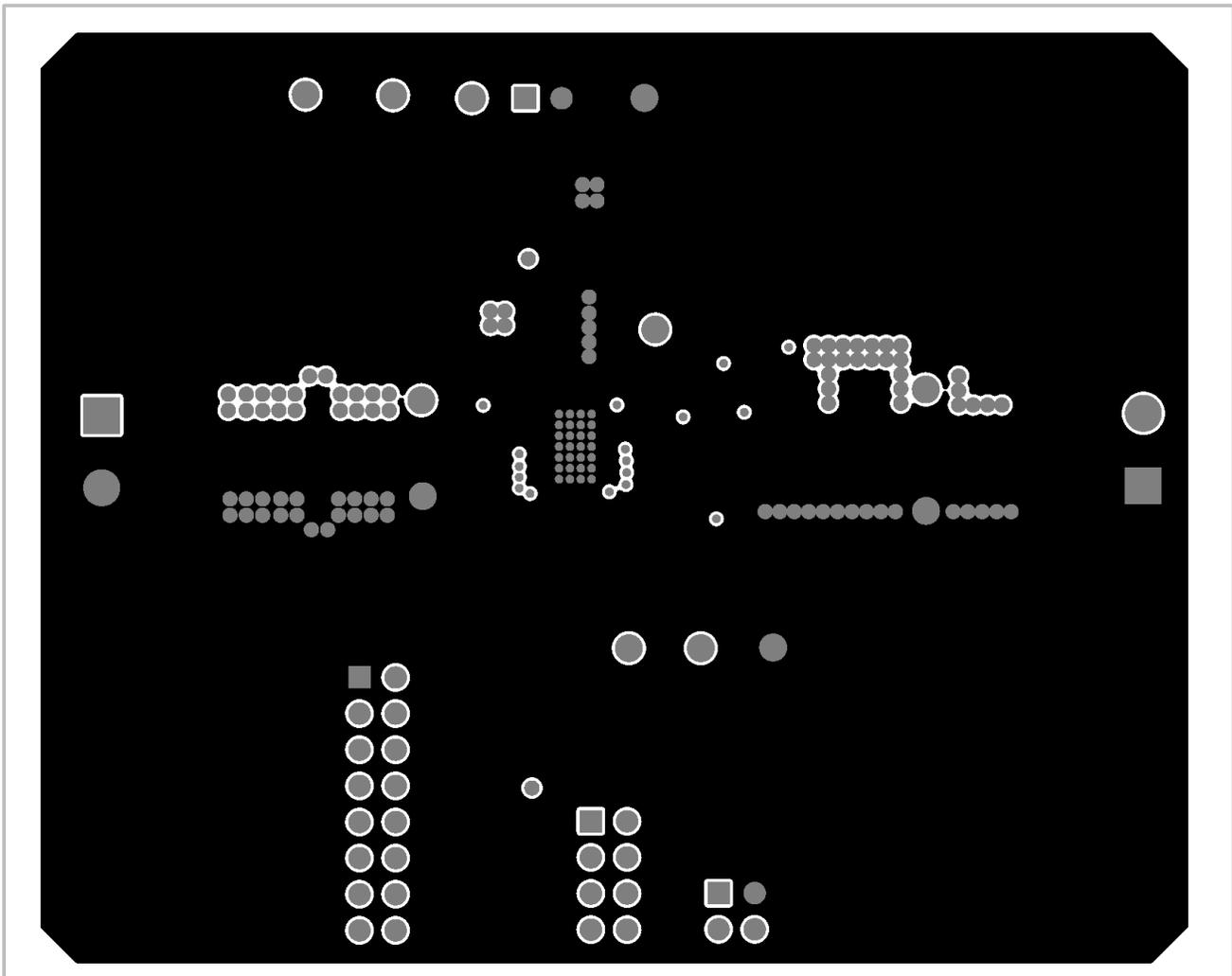


Figure 22. TPS53319EVM-136 Layer 2 Copper

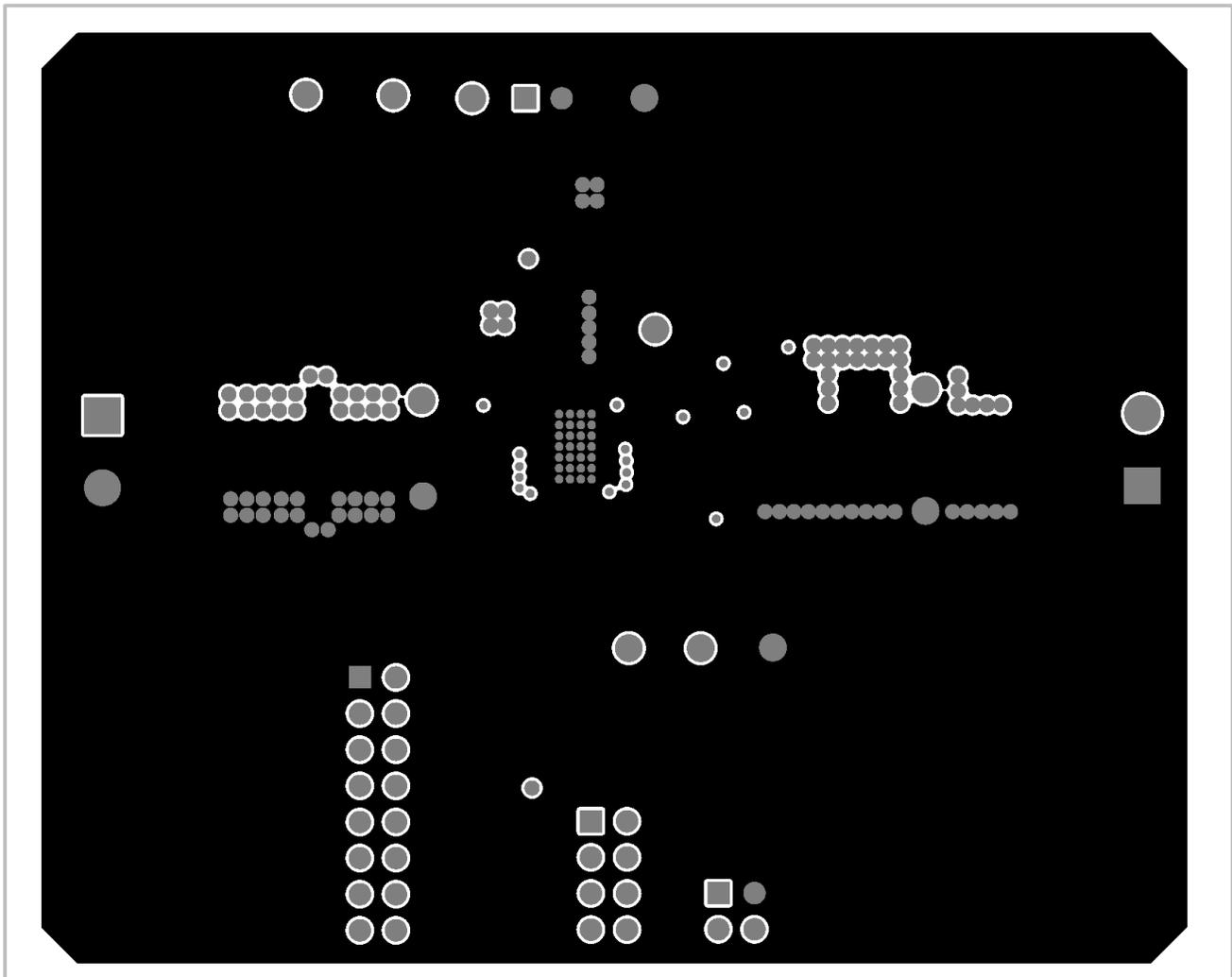


Figure 23. TPS53319EVM-136 Layer 3 Copper

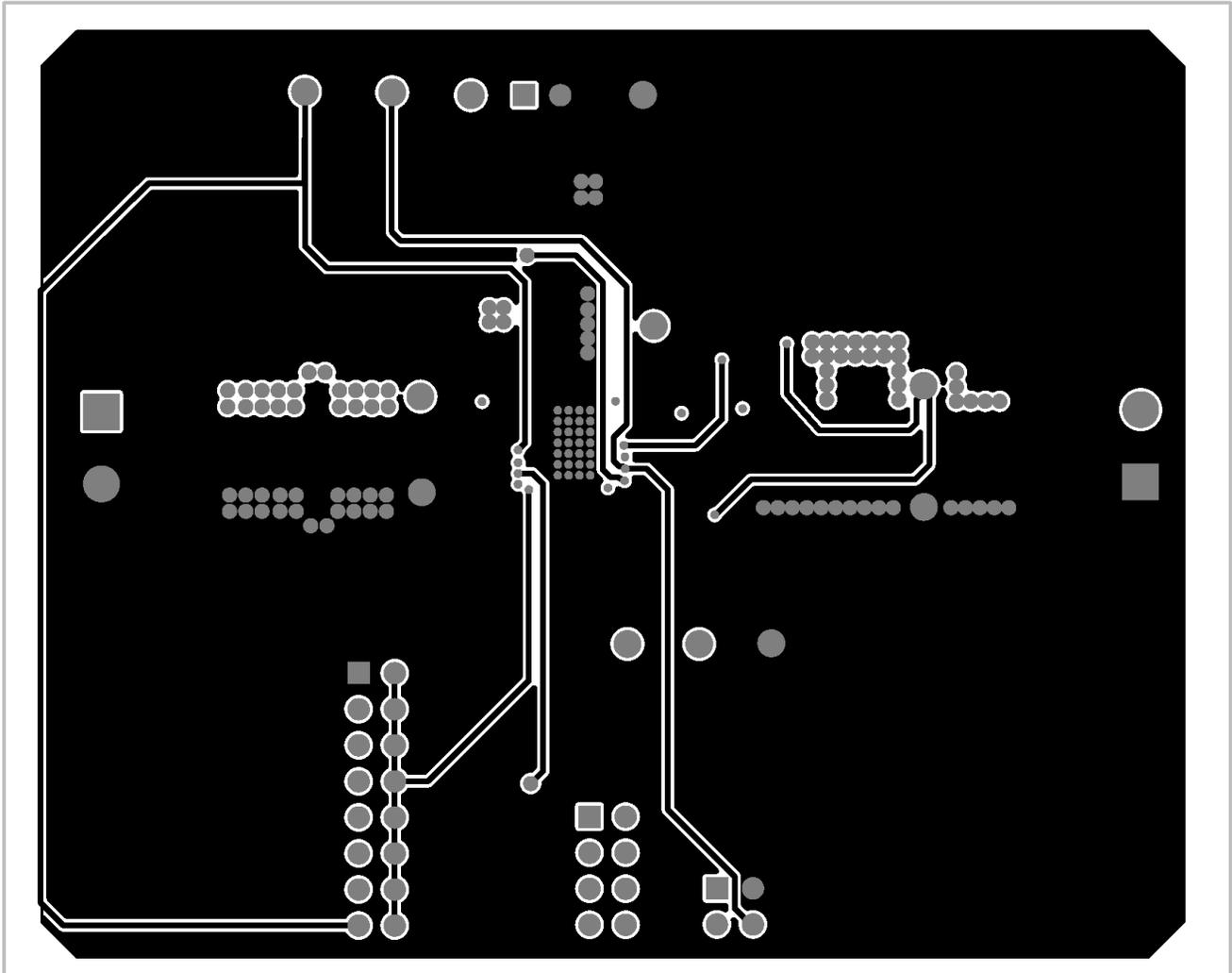


Figure 24. TPS53319EVM-136 Layer 4 Copper

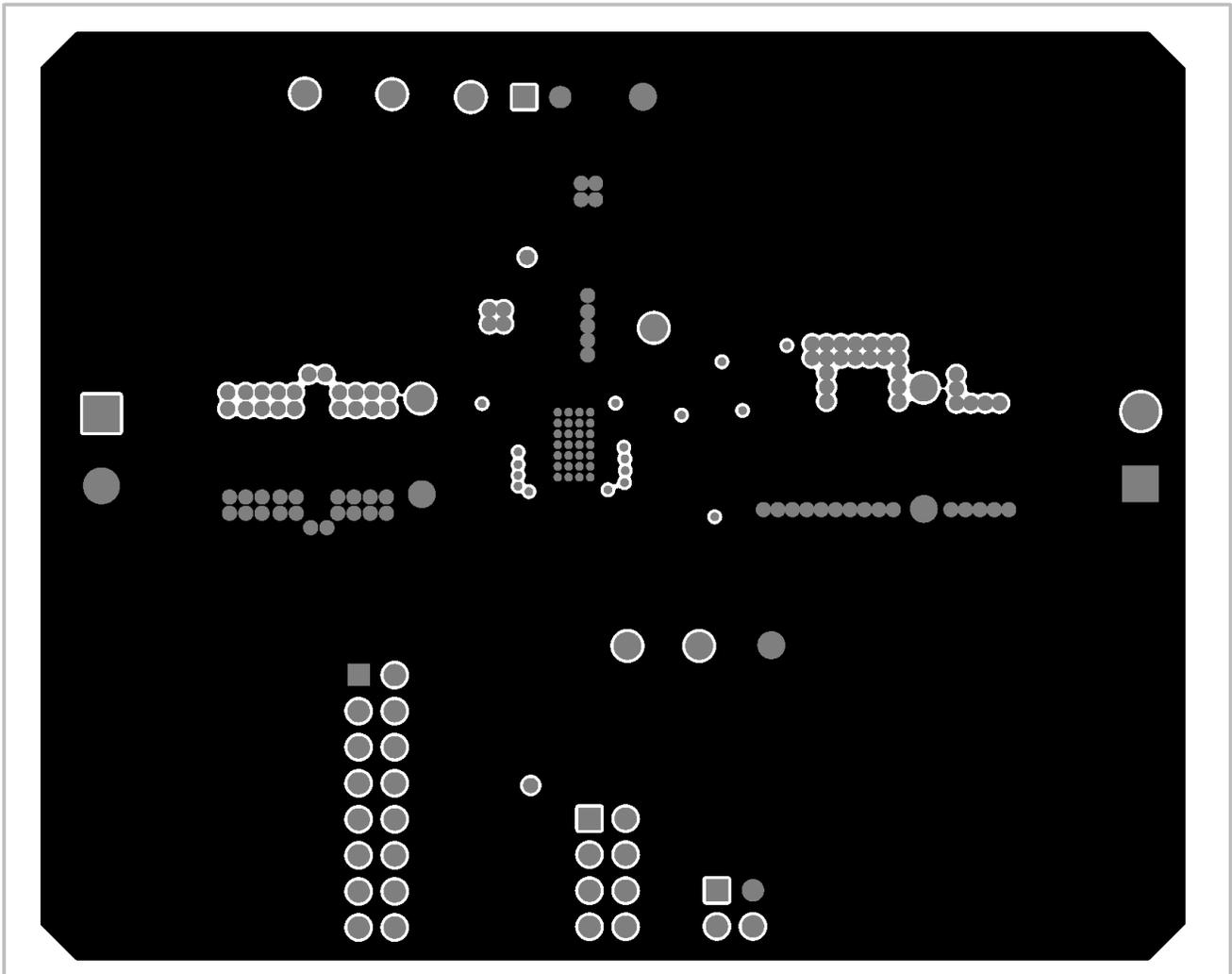


Figure 25. TPS53319EVM-136 Layer 5 Copper

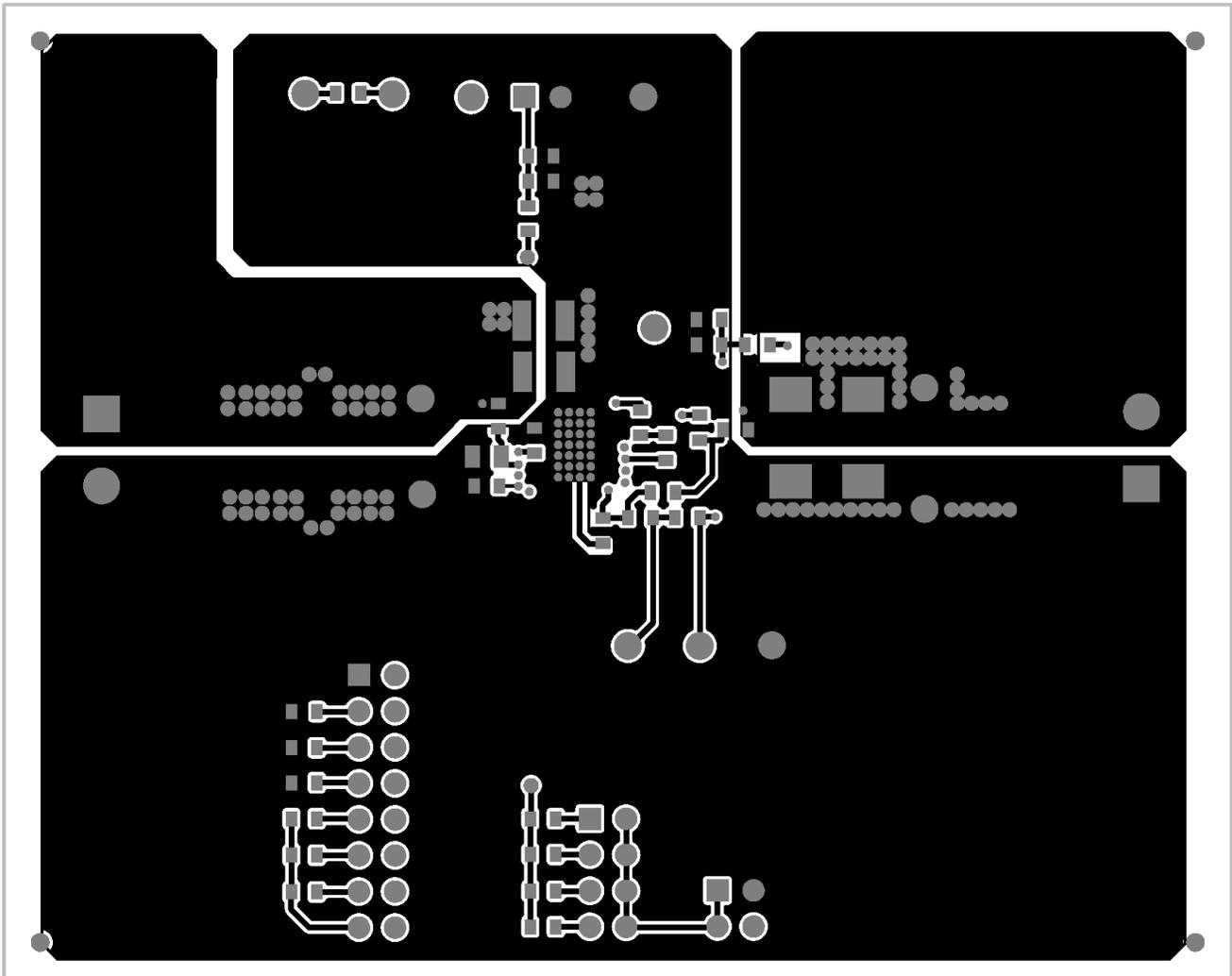


Figure 26. TPS53319EVM-136 Bottom Layer Copper

9 Bill of Materials

Table 7 list the EVM components according to the schematic shown in Figure 1.

Table 7. Components List

QTY.	RefDes	Description	MFR	Part Number
2	C1, C2	Capacitor, Ceramic, 22uF, 25V, X5R, 20%, 1210	STD	STD
3	C7, C8, C9	Capacitor, Ceramic, 100uF, 6.3V, X5R, 20%, 1210	STD	STD
1	C13	Capacitor, Ceramic, 4.7uF, 25V, X5R, 20%, 0805	STD	STD
1	C14	Capacitor, Ceramic, 1uF, 50V, X7R, 10%, 0603	STD	STD
2	C18, C19	Capacitor, Ceramic, 1000pF, 50V, X7R, 10%, 0603	STD	STD
3	C5, C15, C17	Capacitor, Ceramic, 0.1uF, 50V, X7R, 10%, 0603	STD	STD
1	C20	Capacitor, Ceramic, 100pF, 50V, X7R, 10%, 0603	STD	STD
1	L1	Inductor, SMT, 500nH+/-15%, 17A, DCR: 0.29mohms+/-10%, 7x11mm	Delta	HCB1175-501TI
1	R1	Resistor, Chip, 0, 1/16W, 1%, 0603	STD	STD
1	R7	Resistor, Chip, 3.01, 1/16W, 1%, 0603	STD	STD
2	R10, R23	Resistor, Chip, 14.7k, 1/16W, 1%, 0603	STD	STD
1	R11	Resistor, Chip, 10, 1/16W, 1%, 0603	STD	STD
1	R13	Resistor, Chip, 187k, 1/16W, 1%, 0603	STD	STD
1	R14	Resistor, Chip, 619k, 1/16W, 1%, 0603	STD	STD
1	R16	Resistor, Chip, 866k, 1/16W, 1%, 0603	STD	STD
1	R17	Resistor, Chip, 309k, 1/16W, 1%, 0603	STD	STD
1	R18	Resistor, Chip, 124k, 1/16W, 1%, 0603	STD	STD
1	R19	Resistor, Chip, 39.2k, 1/16W, 1%, 0603	STD	STD
1	R2	Resistor, Chip, 169k, 1/16W, 1%, 0603	STD	STD
1	R22	Resistor, Chip, 475k, 1/16W, 1%, 0603	STD	STD
2	R3, R21	Resistor, Chip, 200k, 1/16W, 5%, 0603	STD	STD
1	R4	Resistor, Chip, 86.6k, 1/16W, 1%, 0603	STD	STD
1	R5	Resistor, Chip, 1.00k, 1/16W, 1%, 0603	STD	STD
2	R6, R20	Resistor, Chip, 100k, 1/16W, 1%, 0603	STD	STD
1	R9	Resistor, Chip, 3.01k, 1/16W, 1%, 0603	STD	STD
2	R12, R24	Resistor, Chip, 10.0k, 1/16W, 1%, 0603	STD	STD
1	U1	IC, 14A Synchronous Buck converter with integrated MOSFETs,DQP-22	TI	TPS53319DQP

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

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.

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 LIMITED 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. 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.

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 visit www.ti.com/esh or contact TI.

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REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module 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 or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment 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.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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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。

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. 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 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible 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, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

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.

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 LIMITED 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. 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.

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 visit www.ti.com/esh or contact TI.

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. 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.

REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module 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 or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment 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.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

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Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

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3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

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Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. 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 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible 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, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

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