

EVM User's Guide: TPS7N59EVM-184

TPS7N59EVM-184 Evaluation Module

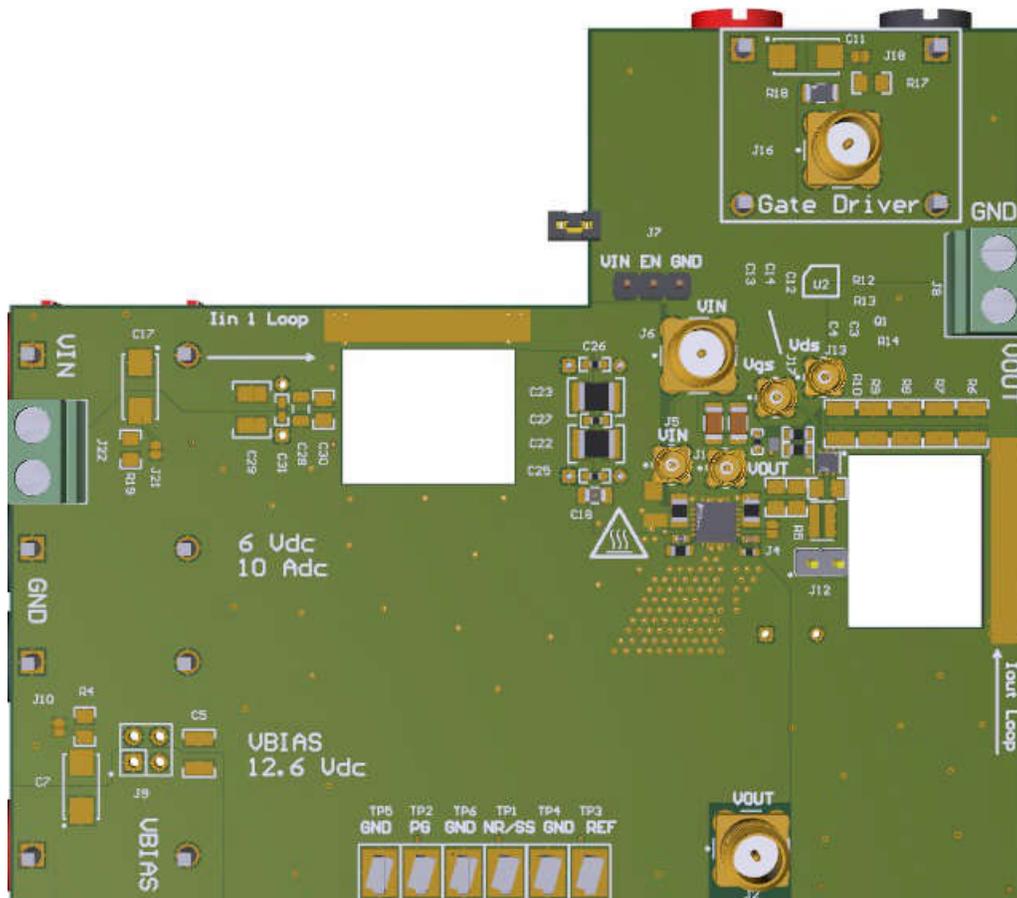


Description

The TPS7N59EVM-184 evaluation module (EVM) is a reference design for engineering demonstration and evaluation of the TPS7N59, an ultra-low noise, ultra-high PSRR, 10A capable, RF low-dropout (LDO) linear regulator. Included in this user's guide are setup and operating instructions, thermal and layout guidelines, a printed circuit board (PCB) layout, a schematic diagram, and a bill of materials (BOM).

Features

- Embedded high speed load transient circuit included with the evaluation module.



TPS7N59EVM-184 Evaluation Module

1 Evaluation Module Overview

1.1 Introduction

This user's guide describes the operational use of the TPS7N59EVM-184 evaluation module (EVM) as a reference design for engineering demonstration and evaluation of the TPS7N5901RTWR, an ultra-low noise, high current, ultra-high PSRR, RF low-dropout (LDO) linear regulator. Included in this user's guide are setup and operating instructions, thermal and layout guidelines, a printed circuit board (PCB) layout, a schematic diagram, and a bill of materials (BOM).

Throughout this document the terms *demonstration kit*, *evaluation board*, and *evaluation module* are synonymous with the TPS7N59EVM-184.

Texas Instruments' TPS7N59EVM-184 helps design engineers evaluate the operation and performance of the TPS7N5901RTWR linear regulator for possible end-user circuit applications. This particular EVM configuration contains a single high-accuracy, small size, adjustable linear regulator for a wide range of applications. The regulator is capable of delivering up to 10A to the load with low V_{IN} to V_{OUT} dropout voltage. For stability, use a minimum capacitor of 22 μ F at the output.

[Related Documentation](#) lists the related documentation available through the Texas Instrument web site at www.ti.com.

Table 1-1. Related Documentation

Device	Literature Number
TPS7N5901RTWR	SBVS470

1.2 Kit Contents

This evaluation module includes the following kit components:

- An evaluation module for the TPS7N59 high performance LDO.

1.3 Specification

The adjustable TPS7N59EVM-184 can accept an input voltage between 0.7V to 6.0V and provide an output voltage between 0.5V to 5.2V. The TPS7N59 is a 10A LDO (150mV dropout (typical) at 10A) with ultra-low output voltage noise (2.5 μ VRMS), high accuracy (1% (max) accuracy over line, load, and temperature), and high Power-supply rejection ratio (– 84dB at 1kHz, – 64dB at 10kHz, – 49dB at 100kHz, and – 30dB at 1MHz). The TPS7N59 also provides adjustable soft-start inrush control and an open-drain power-good (PG) signal. The small 24-pin WQFN package (4mm × 4mm) has excellent thermal resistance for high power operation. The $R_{\theta JA}$ for the TPS7N59EVM-184 is 14.3°C/W.

1.4 Device Information

1.4.1 TPS7N59

The TPS7N59 is a low-noise (2.5 μ V_{RMS}), ultra-low dropout linear regulator (LDO) capable of sourcing 10A with only 150mV of dropout, independently of the output voltage. The device output voltage is adjustable from 0.5V to 5.2V using a single external resistor. The combination of low noise, high PSRR (-30dB at 1MHz), and high output current capability makes the TPS7N59 designed for powering noise-sensitive components (such as RF amplifiers, radar sensors, SERDES and analog chipsets) found in radar power, communication, and imaging applications.

Digital loads [such as application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), and digital signal processors (DSPs)] requiring low-input, low-output (LILLO) voltage operation also benefit from the exceptional accuracy (1% over load, line, and temperature), remote sensing, excellent transient performance, and softstart capabilities to provide good system performance. The versatility, performance, and small footprint design makes this LDO an excellent choice for high-current analog loads such as analog-to-digital converters (ADCs), digital-to-analog converters (DACs), and imaging sensors as well as digital loads such as serializer/deserializers (SerDes), FPGAs, and DSPs.

1.4.2 LMG1020 Low Side Driver

The LMG1020 device is a single, low-side driver designed for driving GaN FETs and logic-level MOSFETs in high-speed applications including LiDAR, time-of-flight, facial recognition, and any power converters involving low side drivers. The design simplicity of the LMG1020 enables extremely fast propagation delays of 2.5 nanoseconds and minimum pulse width of 1 nanosecond. The drive strength is independently adjustable for the pull-up and pull-down edges by connecting external resistors between the gate and OUTH and OUTL, respectively.

The driver features undervoltage lockout (UVLO) and over-temperature protection (OTP) in the event of overload or fault conditions.

0.8mm \times 1.2mm WCSP package of LMG1020 minimizes gate loop inductance and maximizes power density in high-frequency application.

2 Hardware

2.1 EVM Setup

This section describes how to properly connect and set up the TPS7N59EVM-184, including the jumpers and connectors on the EVM board.

2.1.1 LDO Input/Output Connector Descriptions

2.1.1.1 VIN and GND

VIN and GND are the connection terminals for the input supply. The VIN terminal is the positive connection, and the GND terminal is the negative (that is, ground) connection.

2.1.1.2 BIAS and GND

BIAS and GND are the connection terminals for the bias supply. The BIAS terminal is the positive connection, and the GND terminal is the negative (that is, ground) connection.

2.1.1.3 VOUT and GND

VOUT and GND are the connection terminals for the output load. The VOUT terminal is the positive connection, and the GND terminal is the negative (that is, ground) connection.

2.1.1.4 EN

EN is a 3-pin header used to enable or disable the TPS7N59.

The center pin of the 3-pin header is tied to the TPS7N59 EN input. When the 2-pin shunt is placed across the top two pins of the header, VIN is shorted to EN, and the TPS7N59 is enabled. When the 2-pin shunt is placed across the bottom two pins of the header, GND is shorted to EN, and the TPS7N59 is disabled.

When driving the EN terminal with an off-board supply or signal generator, the applied voltage must be kept between 0V and 6V.

2.1.2 Optional Load Transient Input/Output Connector Descriptions

2.1.2.1 VDD and GND

VDD and GND are the connection terminals for the input supply of the load transient circuit. The VDD terminal is the positive connection, and the GND terminal is the negative (that is, ground) connection.

2.1.2.2 J12

J12 is an optional connection for the user to make measurements or apply small loads to the output of the LDO.

2.1.2.3 J14

J14 is an optional connection to insert a damping circuit across the load transient MOSFET drain to source voltage.

2.1.2.4 J16

J16 is the connection for the function generator to drive the gate driver device. J16 is terminated by the 50Ω resistor, R18.

2.1.2.5 J13

J13 is a high-frequency Kelvin connection that allows accurate measurements of the load transient MOSFET drain to source voltage.

2.1.2.6 J17

J17 is a high-frequency Kelvin connection that allows accurate measurements of the load transient MOSFET gate to source voltage.

2.1.3 TPS7N59 LDO Operation

The TPS7N59EVM-184 evaluation module contains the TPS7N59 LDO with input, bias, and output capacitors installed. These components provide the minimum required solution size, as illustrated by the white boxes in the

hardware image. Additional pads are available to test the LDO with additional input, bias, and output capacitors beyond what is already installed on the EVM. The TPS7N59 LDO can be enabled or disabled by using the J7 3-pin header.

1. Place a 2-pin shunt across the header to tie VIN to EN to enable the device.
2. Place a 2-pin shunt across the header to tie GND to EN to disable the device.

TPS7N59EVM-184 Turn On shows the result of the TPS7N59EVM-184 during turn on.

1. Channel 1 (blue trace) is the input voltage (VIN).
2. Channel 2 (red trace) is the output voltage (VOUT).
3. Channel 3 (orange trace) is the output current (IOUT).
4. Channel 4 (green trace) is the enable voltage.

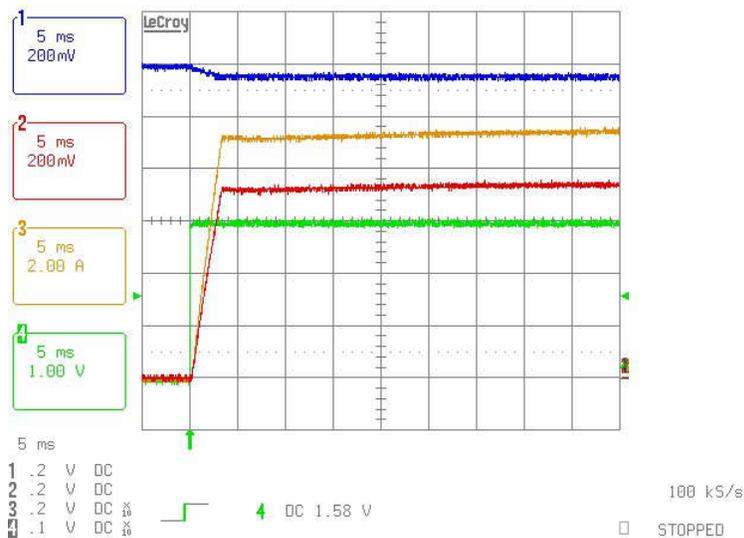


Figure 2-1. TPS7N59EVM-184 Turn On

If desired, a current probe can be inserted in the EVM as shown in [TPS7N59EVM-184 With Current Probes Attached](#) to measure the input and output current. The slots are sized to fit most current probes, such as the LeCroy™ AP015 or CP031 current probes.



Figure 2-2. TPS7N59EVM-184 With Current Probes Attached

J8 can be used to place a DC load that flows through the current sense path on the output of the LDO. In cases where very fast transient tests are performed, ringing can be observed on VIN or VOUT as a result of the parasitic inductance within the PCB of the EVM. A strip of wire placed on the exposed copper in the current path can reduce this ringing. Select the correct size of additional wire to fill the volume of the current probe. For most current probes, a 10 AWG wire can be used.

WARNING

The sensors of some current probes are tied to GND and cannot come into contact with energized conductors. See the user manual of your current probe for details. If your current probe has this limitation, use a thin strip of electrical or Kapton® tape to isolate the current sense path from the current probe.

Optional Kelvin sense points are provided using the SMA connectors J6 (VIN) and J2 (VOUT), and the MMCX connectors J5 (VIN) and J1 (VOUT).

2.1.4 Optional Load Transient Circuit Operation

The TPS7N59EVM-184 evaluation module contains an optional high-performance load transient circuit to allow efficient testing of the TPS7N59 LDO load transient performance. To use the optional load transient circuit, install the correct components in accordance with the application. Modify the input and output capacitance connected to the TPS7N59 LDO to match the expected operating conditions. Determine the desired peak current to test, and modify the parallel resistor combination of R6, R7, R8, R9, and R10 as shown:

$$I_{PEAK} = \frac{V_{OUT}}{R6 \parallel R7 \parallel R8 \parallel R9 \parallel R10} \quad (1)$$

The slew rate of the load step can be adjusted by C10, R11, R12, and R13. Typically, only R12 and R13 are adjusted to set the slew rate and C10 and R11 are left unpopulated.

After the EVM is modified (if needed), connect a power supply to banana connectors J15 (VDD) and J19 (GND) with a 5V DC supply and a 1A DC current limit. The TPS7N59 transient response is very fast and the output voltage recovers in well under 1ms after the initial load transient. Therefore, use a load transient pulse duration limit of 1ms to prevent excessive heating of the pulsed resistors (R6, R7, R8, R9, and R10). Configure a function generator for the 50Ω output, in a 0V DC to 5V DC square pulse. If necessary, burst mode can be configured in the function generator for repetitive, low duty cycle, load transient testing.

2.1.5 Inputs/Outputs Connectors and Jumper Descriptions

2.1.5.1 J20, J22 – IN

Input power-supply voltage connector with ground connection.

2.1.5.2 J8 – OUT

Regulated output voltage with ground connection.

2.1.5.3 TP1 – REF

Reference voltage sense test point.

2.1.5.4 TP2 – PG

Power-good sense connection.

2.1.5.5 TP3 – NR/SS

NR/SS sense pin test-point connection.

2.1.5.6 TP4, TP5, TP6 – GND

Ground pin test-point connection.

2.1.6 Soldering Guidelines

To avoid damaging the device, use a hot-air system for any solder rework to modify the EVM for the purpose of repair or other application reasons.

2.1.7 Equipment Connections

Connect the equipment in the following steps:

1. Set the input power supply up to 6V and turn the power supply off.
2. Set the bias power supply up to 12V and turn the power supply off.
3. Connect the input power supply to the J20 or J22 V_{IN} connector on the EVM.
4. Connect the bias power supply to the J3V_{BIAS} connector on the EVM.
5. Turn on the V_{IN} and V_{BIAS} power supplies.
6. Connect a 0A to 10A load between OUT and GND.

3 Hardware Design Files

3.1 Schematic

Figure 3-1 through Figure 3-3 show the schematic for this EVM.

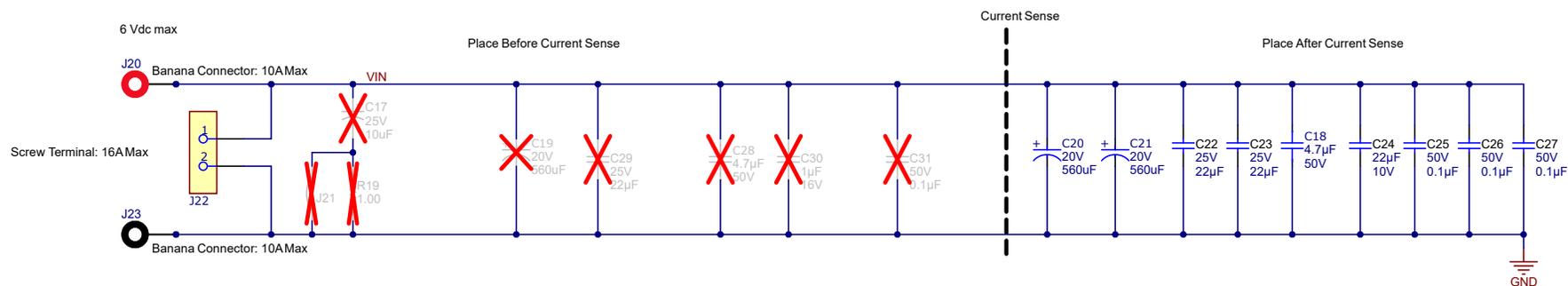


Figure 3-1. TPS7N59EVM-184 Vin Schematic

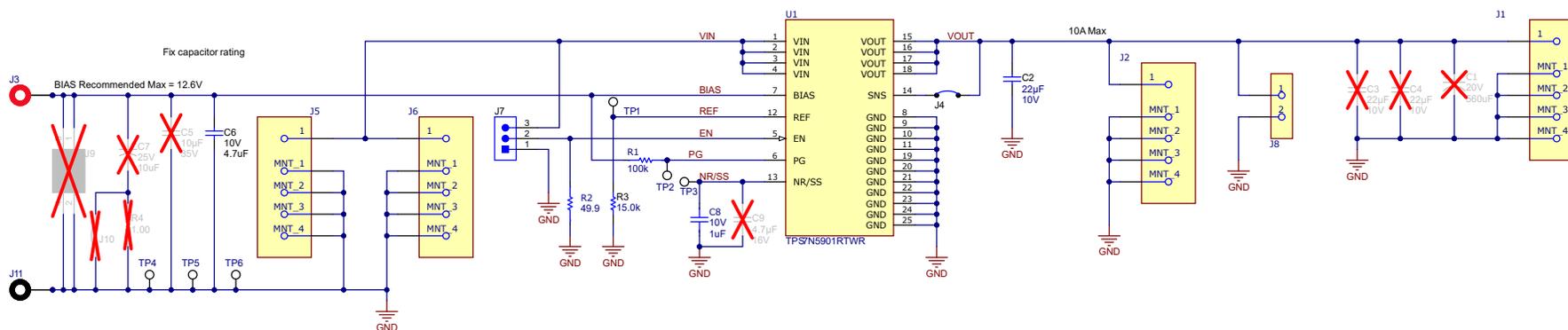


Figure 3-2. TPS7N59EVM-184 LDO Schematic

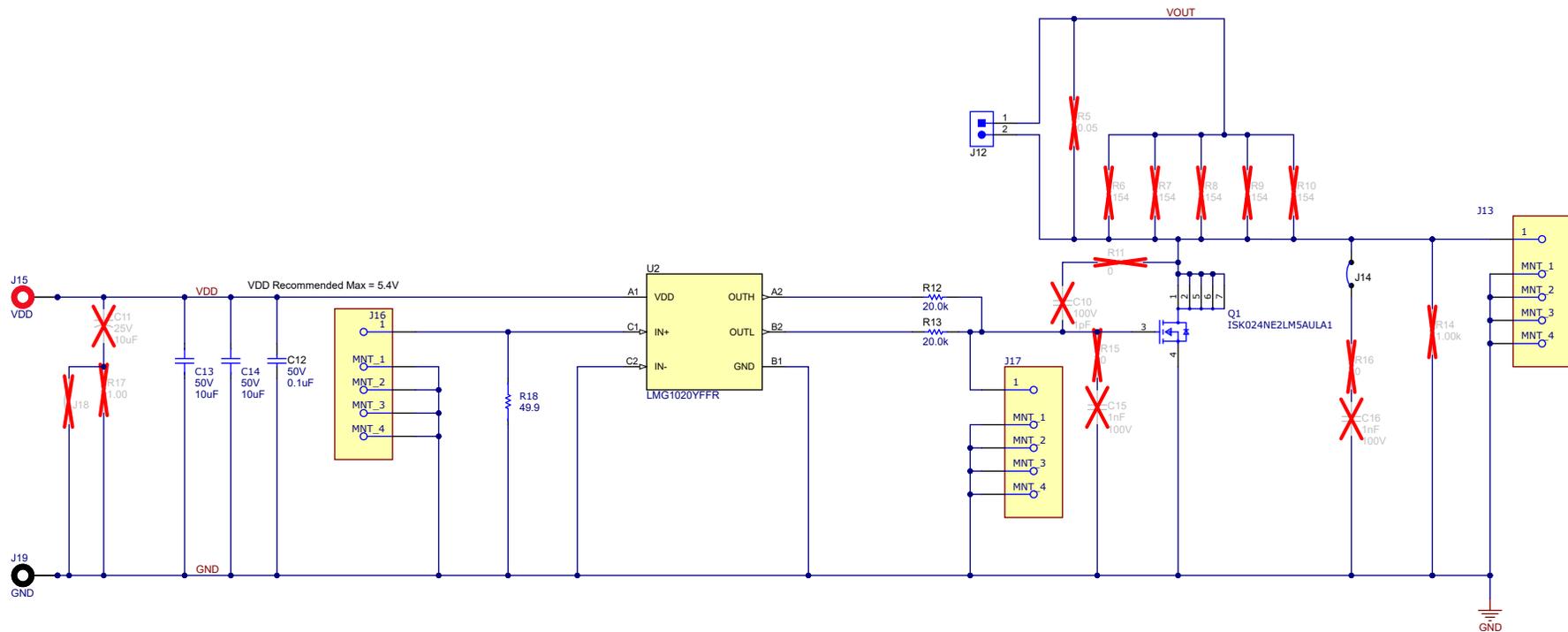


Figure 3-3. TPS7N59EVM-184 Load Transient Circuit Schematic

3.2 PCB Layout

Figure 3-4 to Figure 3-13 illustrate the PCB layout for this EVM.

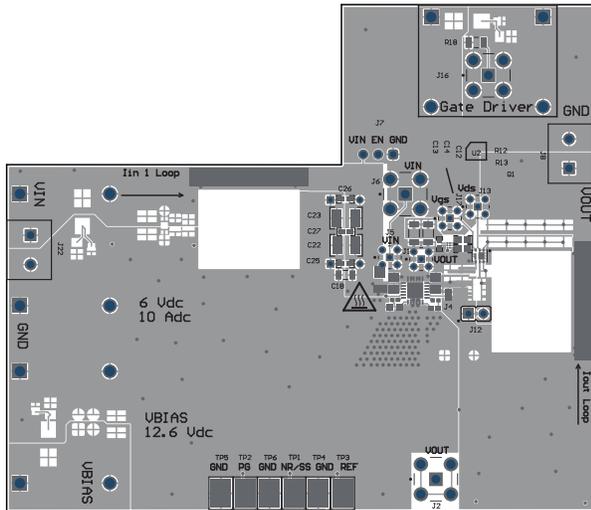


Figure 3-4. Top Assembly Layer

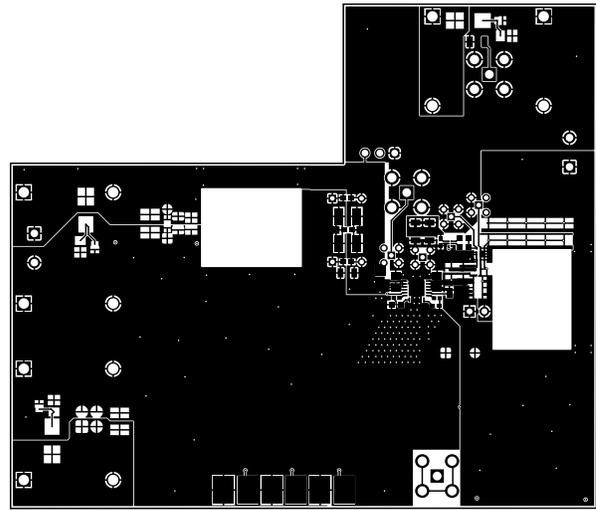


Figure 3-5. Top Layer Routing

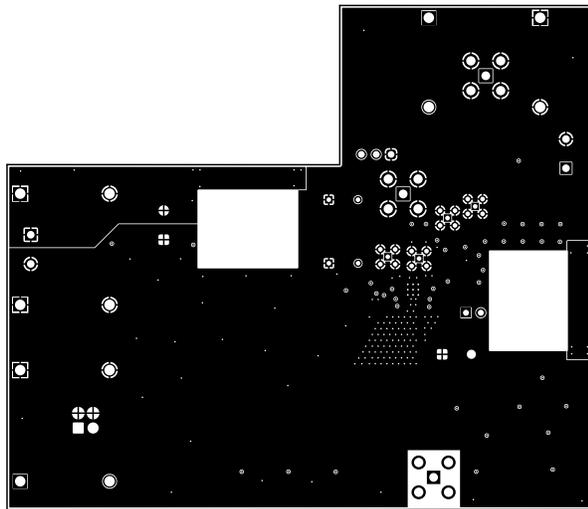


Figure 3-6. First Middle Layer

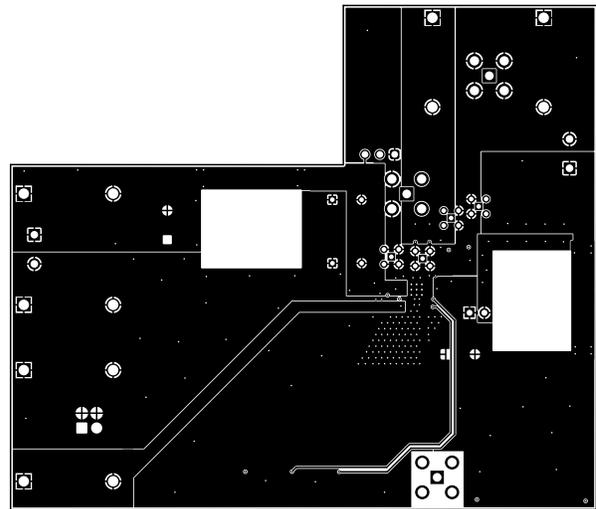


Figure 3-7. Second Middle Layer

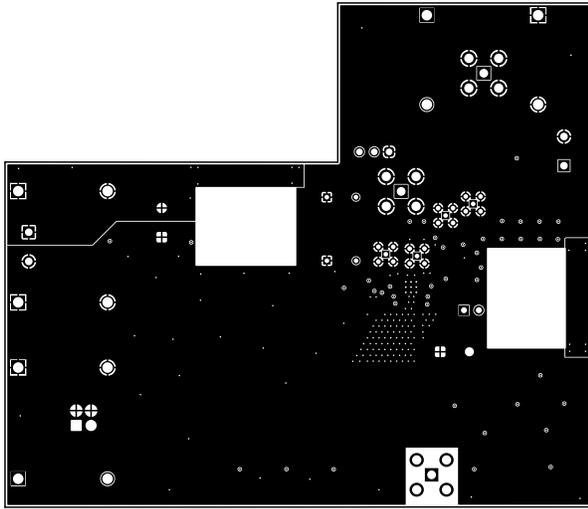


Figure 3-8. Third Middle Layer

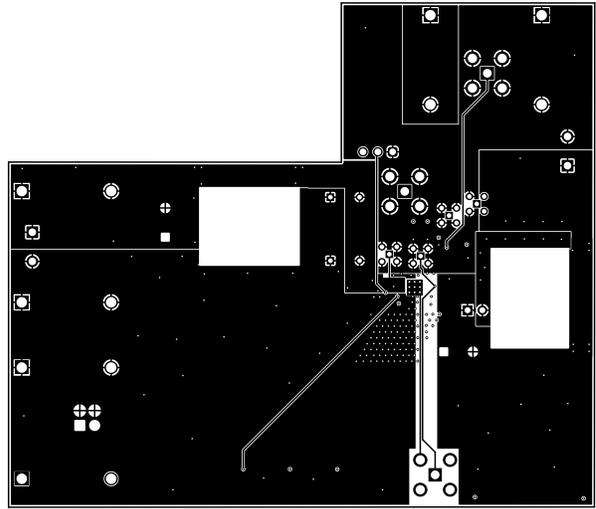


Figure 3-9. Fourth Middle Layer

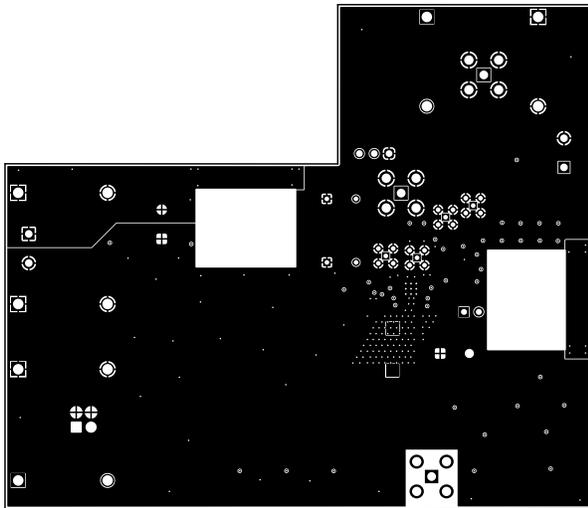


Figure 3-10. Fifth Middle Layer

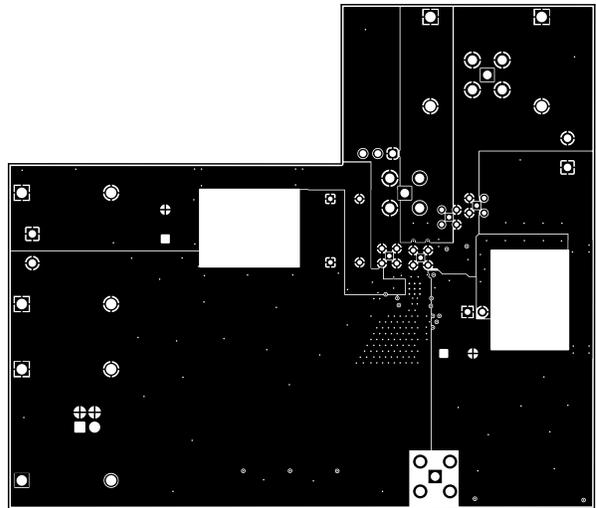


Figure 3-11. Sixth Middle Layer

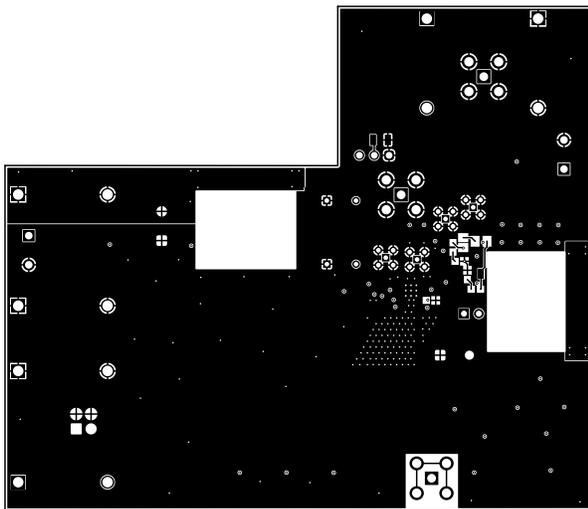


Figure 3-12. Bottom Layer Routing

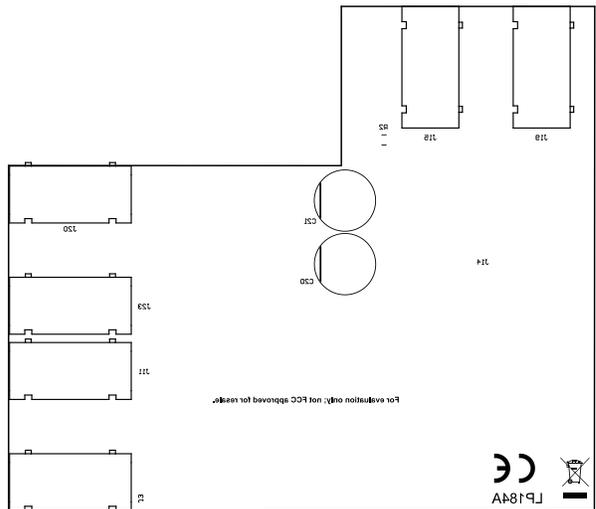


Figure 3-13. Bottom Assembly Layer

3.3 Bill of Materials (BOM)

Table 3-1 shows the bill of materials (BOM) for this EVM.

Table 3-1. TPS7N59EVM-184 BOM ⁽¹⁾ ⁽²⁾ ⁽³⁾ ⁽⁴⁾

DESCRIPTION	DESIGNATOR	PARTNUMBER	QUANTITY	MANUFACTURER	PACKAGEREFERENCE	VALUE	ALTERNATE MANUFACTURER	ALTERNATE PARTNUMBER
Printed Circuit Board	!PCB1	LP184	1	Any				
CAP, CERM, 22uF, 10V, +/- 20%, X7R, 0805	C2, C24	GRM21BZ71A226ME15L	2	MuRata	0805	22uF		
CAP, CERM, 4.7uF, 10V, +/- 10%, X5R, 0603	C6	C0603C475K8PAC TU	1	Kemet	0603	4.7uF		
1µF ±10% 10V Ceramic Capacitor X7R 0402 (1005 Metric)	C8	GMC04X7R105K10NT	1	Cal-Chip Electronics	0402	1µF		
CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0402	C12	C1005X7R1H104K050BB	1	TDK	0402	0.1uF		
10 µF ±10% 50V Ceramic Capacitor X7R 1206 (3216 Metric)	C13, C14	GMC31X7R106K50NT	2	Cal-Chip Electronics	1206	10µF		
Cap Ceramic 4.7uF 50V X7R 10% Pad SMD 0805 +125°C Automotive T/R	C18	CGA4J1X7R1H475K125AC	1	TDK Corporation	0805	4.7µF		
Cap Aluminum Polymer 560uF 20VDC 20% (10X 13mm) Radial 5mm 0.012 Ohm 1700mA 1000h 125C	C20, C21	20SEF560M	2	Panasonic	RADIAL	560µF		
CAP, CERM, 22 µF, 25V,+/- 10%, X7R, 1210	C22, C23	CL32B226KAJNFNE	2	Samsung Electro-Mechanics	1210	22uF		
CAP, CERM, 0.1 µF, 50V,+/- 20%, X7R, 0402	C25, C26, C27	UMK105B7104MVFR	3	Taiyo Yuden	0402	0.1uF		
MMCX Connector Jack, Female Socket 50Ohm Through Hole Solder	J1, J5, J13, J17	RF12-07H-T-00-50G	4	Adam Tech	CONN_MMCX			
SMA Connector Jack, Female Socket 50Ohm Through Hole Solder	J2, J6, J16	RF2-04A-T-00-50G	3	Adam Tech	CONN_RF_7MM00_7MM00			
Standard Banana Jack, insulated, 10A, red	J3, J15, J20	571-0500	3	DEM Manufacturing	571-0500			
Jumper, SMT	J4, J14	JMP-36-30X40SMT	2	Any	shorting jumper, SMT			
Header, 2.54mm, 3x1, Gold, TH	J7	61300311121	1	Würth Elektronik	Header, 2.54mm, 3x1, TH			
TERM BLK 2POS SIDE ENTRY 5MM PCB	J8, J22	691137710002	2	Würth Elektronik	HDR2			
Standard Banana Jack, insulated, 10A, black	J11, J19, J23	571-0100	3	DEM Manufacturing	571-0100			
Header, 100mil, 2x1, Gold, TH	J12	PBC02SAAN	1	Sullins Connector Solutions	Sullins 100mil, 1x2, 230 mil above insulator			
40V optiMOS Power Transistor, Surface Mount 6-PQFN Dual (2x2)	Q1	ISK024NE2LM5AULA1	1	Infineon	VSON6			
100 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Thick Film	R1	CRCW0402100KF KEDC	1	Vishay	0402	100k		
RES Thick Film, 49.9Ω, 1%, 0.75W, 100ppm/°C, 1206	R2, R18	CRCW120649R9F KEAHP	2	Vishay Dale	1206	49.9		
RES, 15.0k, 1%, 0.063W, 0402	R3	RC0402FR-0715K L	1	Yageo America	0402	15.0k		
RES, 20.0k, 1%, 0.1W, 0603	R12, R13	RC0603FR-0720K L	2	Yageo	0603	20.0k		

Table 3-1. TPS7N59EVM-184 BOM (1) (2) (3) (4) (continued)

DESCRIPTION	DESIGNATOR	PARTNUMBER	QUANTITY	MANUFACTURER	PACKAGEREFERENCE	VALUE	ALTERNATE MANUFACTURER	ALTERNATE PARTNUMBER
Shunt, 100mil, Gold plated, Black	SH-J1	SNT-100-BK-G	1	Samtec	Shunt	1x2	3M	969102-0000-DA
Test Point, Compact, SMT	TP1, TP2, TP3, TP4, TP5, TP6	5016	6	Keystone	Testpoint_Keystone_Compact			
TPS7N5901RTWR	U1	TPS7N5901RTWR	1	Texas Instruments	WQFN-24			
5V, 7A/5A Low Side GaN Driver With 60MHz/1ns Speed, YFF0006AEAE (DSBGA-6)	U2	LMG1020YFFR	1	Texas Instruments	YFF0006AEAE		Texas Instruments	LMG1020YFFT
Cap Aluminum Polymer 560uF 20VDC 20% (10X 13mm) Radial 5mm 0.012 Ohm 1700mA 1000h 125C	C1, C19	20SEF560M	0	Panasonic	RADIAL	560µF		
CAP, CERM, 22uF, 10V, +/- 20%, X7R, 0805	C3, C4	GRM21BZ71A226ME15L	0	MuRata	0805	22uF		
CAP, CERM, 10 µF, 35V,+/- 10%, X7R, 1210	C5	GRM32ER7YA106KA12K	0	MuRata	1210	10uF		
CAP, TA, 10uF, 25V, +/- 20%, 0.5ohm, SMD	C7, C11, C17	TPSC106M025R0500	0	AVX	6032-28	10uF		
CAP, CERM, 4.7uF, 16V,+/- 10%, X7R, 0603	C9	GRM188Z71C475KE21D	0	MuRata	0603	4.7uF		
CAP, CERM, 1pF, 100V, +/- 5%, C0G/NP0, 0805	C10	GQM2195C2A1R0CB01D	0	MuRata	0805	1pF		
CAP, CERM, 1000pF, 100V, +/- 5%, X7R, 0603	C15, C16	06031C102JAT2A	0	AVX	0603	1000pF		
Cap Ceramic 4.7uF 50V X7R 10% Pad SMD 0805 +125°C Automotive T/R	C28	CGA4J1X7R1H475K125AC	0	TDK Corporation	0805	4.7µF		
CAP, CERM, 22 µF, 25V,+/- 10%, X7R, 1210	C29	CL32B226KAJNFNE	0	Samsung Electro-Mechanics	1210	22uF		
CAP, CERM, 1 µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 0805	C30	C0805C105K4RACAUTO	0	Kemet	0805	1uF		
CAP, CERM, 0.1 µF, 50V,+/- 20%, X7R, 0402	C31	UMK105B7104MVFRR	0	Taiyo Yuden	0402	0.1uF		
Header, 100mil, 2x2, Gold, TH	J9	TSW-102-07G-D	0	Samtec	2x2 Header			
Jumper, SMT	J10, J18, J21	JMP-36-30X40SMT	0	Any	shorting jumper, SMT			
RES, 1.00, 1%, 0.333W, AEC-Q200 Grade 1, 0805	R4, R17, R19	ERJ-6BQF1R0V	0	Panasonic	0805	1.00		
RES, 0.05, 1%, 1W, AEC-Q200 Grade 0, 0612	R5	ERJ-B2CFR05V	0	Panasonic	0612	0.05		
RES, 154, 1%, 0.5W, 1210	R6, R7, R8, R9, R10	RC1210FR-07154RL	0	Yageo	1210	154		
RES, 0, 5%, 0.125W, AEC-Q200 Grade 0, 0805	R11	ERJ-6GEY0R00V	0	Panasonic	0805	0		
RES, 1.00k, 1%, 0.125W, AEC-Q200 Grade 0, 0805	R14	ERJ-6ENF1001V	0	Panasonic	0805	1.00k		
RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603	R15, R16	RMCF0603ZT0R00	0	Stackpole Electronics Inc	0603	0		

- (1) This assembly is ESD sensitive; observe ESD precautions.
- (2) This assembly must be clean and free from flux and all contaminants. Use of no-clean flux is not acceptable.
- (3) This assembly must comply with workmanship standards IPC-A-610 Class 2.
- (4) Unless otherwise noted in the *Alternate Part Number* or *Alternate Manufacturer* columns, all parts can be substituted with equivalents.

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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

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/lstds/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。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。技術適合証明を受けていないものご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。 <https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html>

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.

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- 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, INDEMNITY 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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