TPS7N53EVM-138 Evaluation Module

Texas Instruments

Description

The TPS7N53EVM-138 is designed to help design engineers evaluate the operation and performance of the TPS7N53 linear regulator for possible use in a circuit application. This particular EVM configuration contains a single low-noise, high accuracy, linear regulator for a wide range of applications. The regulator is capable of delivering up to 3A to the load with low VIN to VOUT dropout voltage. A high performance load transient circuit is included to assist the user with high-speed load transient testing. Low inductive current loops are integrated into the board to assist the user with input and output current measurements.

Features

- Input voltage range: 1.1V to 2.2V
- Output voltage noise: $2.2\mu V_{RMS}$
- Low dropout: 95mV(typ) at 3A
- Adjustable output voltage range: 0.5V to 1.5V
- Adjustable soft-start inrush control
- Open-drain, power-good (PG) output
- Package: 3mm x 3mm, 16-pin WQFN

Applications

- Macro Remote Radio Units (RRU)
- Outdoor Backhaul Units
- Active Antenna System mMIMO (AAS)
- Ultrasound Scanners
- Lab and Field Instrumentation
- Sensor, Imaging, and Radar
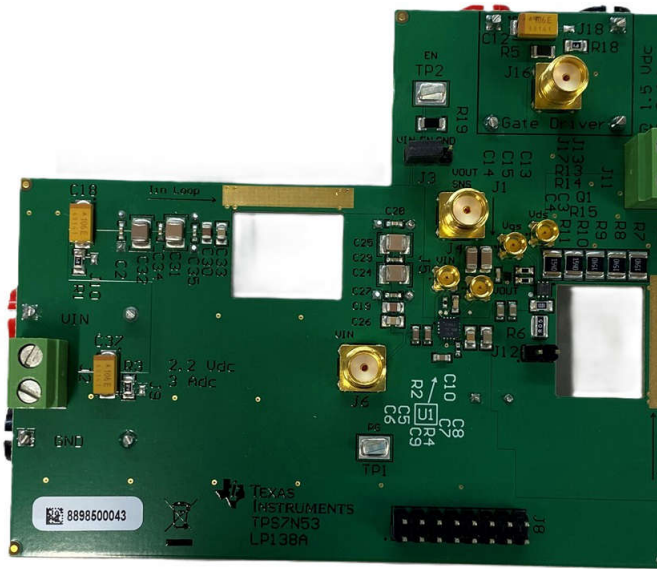
TPS7N53EVM-138 (Top View)
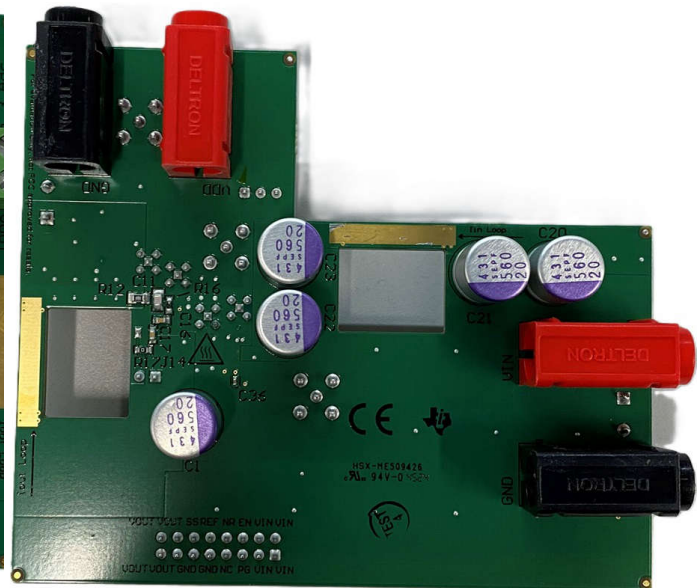
TPS7N53EVM-138 (Bottom View)

1 Evaluation Module Overview

1.1 Introduction

The TPS7N53EVM-138 evaluation module (EVM) is a linear regulator circuit that achieves low-noise (2.2μV$_{RMS}$), ultra-low-dropout (95mV typ), and high PSRR in a small footprint. The EVM has the capability to operate over an input voltage range of 1.1V to 2.2V, providing a regulated output of 0.5V to 1.5V, with the capability to source 3A. The output voltage has a 1.5% setpoint accuracy and is adjusted by modifying the reference resistor value, permitting the user to customize the output voltage as needed.

The TPS7N53 low dropout (LDO) regulator used in the EVM has the following features:

1. Input voltage range: 1.1V to 2.2V
2. 1.5% accuracy over line, load, and temperature
3. Low output voltage noise: 2.2μVRMS (100Hz to 100KHz)
4. Low dropout: 95mV (typ) at 3A
5. Adjustable output voltage range: 0.5V to 1.5V
6. Adjustable soft-start inrush control
7. Open-drain, power-good (PG) output
8. Package: 3mm x 3mm, 16-pin WQFN

1.2 Kit Contents

1. TPS7N53EVM Circuit Board
2. EVM Disclaimer Read Me
3. Prototype EVM Disclaimer Read Me

1.3 Specification

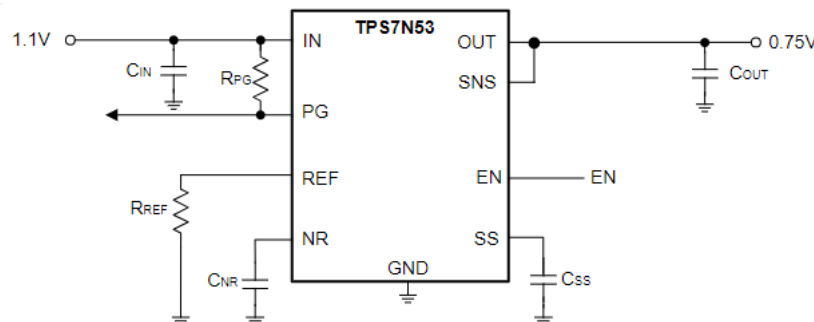Figure 1-1 shows a typical application schematic of the TPS7N53 low dropout (LDO) regulator.

Figure 1-1. Typical Application

1.4 Device Information

The TPS7N53 is a low-noise (2.2 μVRMS), ultra-low dropout linear regulator (LDO) capable of sourcing 3A with 95mV of dropout (typ). The device is able to operate over an adjustable output voltage from 0.5V to 1.5V with a single external resistor. The TPS7N53 LDO is available in a 16-pin WQFN package with 3mm × 3mm footprint. See the TPS7N53 3A, Low-Input Voltage, Low-Noise, High-Accuracy, Low-Dropout (LDO) Voltage Regulator Data Sheet for more information.

2 Hardware

2.1 Power Requirements

2.1.1 EVM Connections

Referencing the EVM connections described in *EVM Power Connections*, the recommended test setup to evaluate the TPS7N53 device is shown in *EVM Test Setup*. Working at an ESD-protected workstation, make sure that any wrist straps, boot straps, or mats are connected and referencing the user to earth ground before handling the EVM.
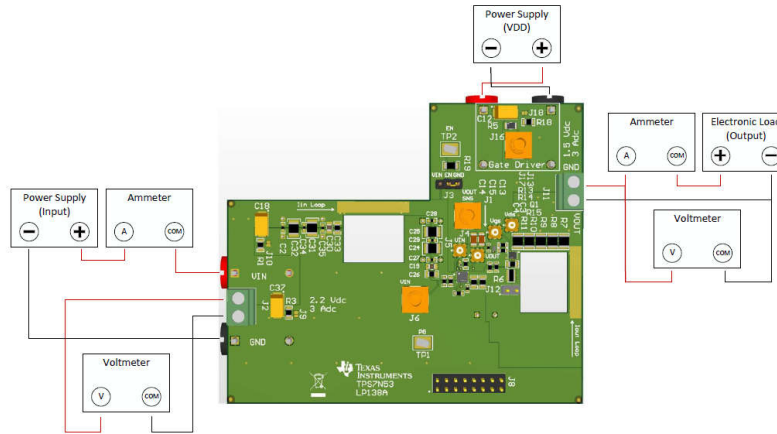

Figure 2-1. EVM Test Setup

CAUTION

Refer to the TPS7N53 data sheet for additional guidance pertaining to component selection and controller operation.

Table 2-1. EVM Power Connections

LABEL	DESCRIPTION
V_{IN}	Input voltage power connection.
V_{DD}	Load transient circuit power connection.

Table 2-2. EVM Signal Connections

LABEL	DESCRIPTION
PG	Open-drain, power-good indicator pin for the low-dropout regulator (LDO) output voltage.
SS	Soft-start connection.
EN	Enable connection.
V_{OUT}	Regulated output voltage.
REF	Reference connection.
NR	Noise-reduction connection.
GND	GND connection.

2.1.2 Test Equipment

Voltage Source: Use a power supply capable of supplying 0V to 2.2V and 4A. If necessary, use an additional power supply capable of supplying 0V to 5.0V and 500mA for the load transient circuit.

Multimeters:

- **Voltmeter 1:** Input voltage at V_{IN}.
- **Voltmeter 2:** Output voltage at V_{OUT} to GND.
- **Ammeter 1:** Input current. Set the ammeter to 1-second aperture time.
- **Ammeter 2:** Output current. Set the ammeter to 1-second aperture time.

Electronic Load: The load must be an electronic constant-resistance (CR) or constant-current (CC) mode load capable of 0A to 4A.

Oscilloscope: With the scope set to 20MHz bandwidth and AC coupling, measure the output voltage ripple directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the ground barrel of the probe through the ground lead to the negative terminal of the capacitor. TI does not recommend using a long-leaded ground connection because this can induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

Safety: Always use caution when touching any circuits that can be live or energized.

2.1.3 Recommended Test Setup

2.1.3.1 Input Connections

1. Prior to connecting the DC input source, set the current limit of the input supply to 4A maximum. Make sure the input source is initially set to 1.4V and connected to the V_{IN} connection point as shown in *EVM Test Setup*.
2. Additionally, if the load transient is to be used, set the current limit of the V_{DD} power supply to 500mA maximum. Make sure the V_{DD} source is initially set to 5.0V. **Under no circumstances can the V_{DD} voltage exceed 5.4V.**
3. Connect voltmeter 1 at V_{IN} connection point to measure the input voltage.
4. Connect ammeter 1 to measure the input current.

2.1.3.2 Output Connections

1. Connect electronic load to V_{OUT} connection. Set the load to constant-resistance mode or constant-current mode at 10mA after applying V_{IN} and V_{DD}.
2. Connect voltmeter 2 at V_{OUT} and GND connections to measure the output voltage.
3. Connect ammeter 2 to measure the output current.

2.1.4 Test Procedure

2.1.4.1 TPS7N53 LDO Operation

The TPS7N53 evaluation module contains a single TPS7N53 LDO with input, NR, SS, and output capacitors installed, as well as PG and REF resistors installed. These components provide an implementation example, as illustrated by *TPS7N53EVM-138 With Current Probes Attached*.

The TPS7N53 EVM is assembled for an output voltage of 0.75V. For other voltage options, resistor R4 can be modified as necessary. See the *Adjustable Operation* section in the TPS7N53 data sheet for guidance on selecting R4 for alternate values of VOUT.

The TPS7N53 LDO can be enabled or disabled by using the J3 jumper connection:

- Tie the center pin of the jumper to a voltage source greater than 0.68V and no greater than 6.0V to enable the device
- Tie the center pin of the jumper to a voltage source less than 0.64V to disable the device

If desired, then current probes can be inserted in the EVM as shown in Figure 2-2 to measure the input and output current. The slots were sized to fit most current probes, such as the LeCroy™ AP015 or CP031 current probes. The input and output current of the TPS7N53 LDO can be measured directly using the current probes.

Figure 2-2. TPS7N53EVM With Current Probes Attached

J11 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 occur on VIN or VOUT as a result of the PCB parasitic inductance. Placing a strip of wire on the exposed copper in the current path can reduce this ringing. 10 AWG wire can be used as needed. If ringing persists, then install damping networks by adding a series resistor and capacitor in parallel with V_{IN}. Locations where damping can be installed include C20 and R24, C18 and R1, and C37 and R3.

> **WARNING**
> Some current probe sensors can be tied to GND and must not 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 (V_{IN}) and J4 (V_{OUT}) and MMCX connectors J5 (V_{IN}) and J1 (V_{OUT}).

Optional Load Transient Circuit Operation

Note

: The load transient circuit comes pre-populated. R6 through R11 needs to be modified or removed. Similarly, R15 comes populated with a 1kΩ, this creates a DC load of 0.75mA. If a different DC load is required, then R15 can be removed and modified accordingly. J13 also offers the option to install a resistor across V_{OUT} and GND to also set a DC load across the LDO.

The TPS7N53 evaluation module contains an optional high-performance load transient circuit to allow efficient testing of the load transient performance of the TPS7N53 LDO. 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 TPS7N53 LDO to match the expected operating conditions. Determine the desired peak current to test, and modify the parallel resistor combination of R7, R8, R9, R10, and R11 as shown:

$$I_{Peak} = \frac{V_{OUT}}{R_6||R_7||R_8||R_9||R_{11}} \tag{1}$$

The slew rate of the load step can be adjusted by C11, R12, R13, and R14.

After the load transient circuit is modified as needed, connect a power supply to banana connectors J15 (V_{DD}) and J19 (GND) with a 5V DC supply and a 500mA DC current limit. Use a pulse-duration limit of 1ms to prevent excessive heating of the pulsed resistors (R7, R8, R9, R10, and R11). 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.

3 Implementation Results

3.1 Performance Data and Results

Table 3-1 lists the electrical characteristics.

Table 3-1. Electrical Performance Characteristics

Parameter	Test Conditions	MIN	TYP	MAX	Unit
Input voltage range, V_{IN}	Operating	1.1		2.2	V
Output voltage, V_{OUT} [1]		0.5		1.5	V
Output current, I_{OUT}		0		3	A
EN trip point rising (turn-on), $V_{IH(EN)}$	V_{IN} = 1.1V	0.62	0.65	0.68	V
EN trip point falling (turn-off), $V_{IL(EN)}$	V_{IN} = 1.1V	0.58	0.61	0.64	V
REF current pin, I_{REF}			150		µA
Output voltage accuracy, V_{OUT}	$0.5V \leq V_{OUT} \leq 1.5V$, $0A \leq I_{OUT} \leq 3A$, $1.1V \leq V_{IN} \leq 2.2V$	-1.5		1.5	%
Line regulation, $\Delta V_{OUT(\Delta VIN)}$	$1.1 \leq V_{IN} \leq 2.2V$ VOUT = 0.5V IOUT = 0A		-200		µV/V
Load regulation, $\Delta V_{OUT(\Delta IOUT)}$	V_{OUT} = 1.5V $0A \leq I_{OUT} \leq 3A$		-100		µV/A
Short circuit current limit, I_{SC}	R_{LOAD} = 10mΩ		1.1		A
Soft-start time, t_{SS}	C_{SS} = 10nF V_{OUT}=0.75V		0.7		ms
TPS7N53 junction temperature, T_J		−40		125	°C

(1)   The default output voltage of this EVM is 0.75V. Efficiency and other performance metrics can change based on operating input voltage, load currents, and other parameters.

Figure 3-1 through Figure 3-3 present typical performance curves for the TPS7N53EVM. Due to the actual performance data affected by measurement techniques and environmental variables, these curves are presented for reference and can differ from actual field measurements.
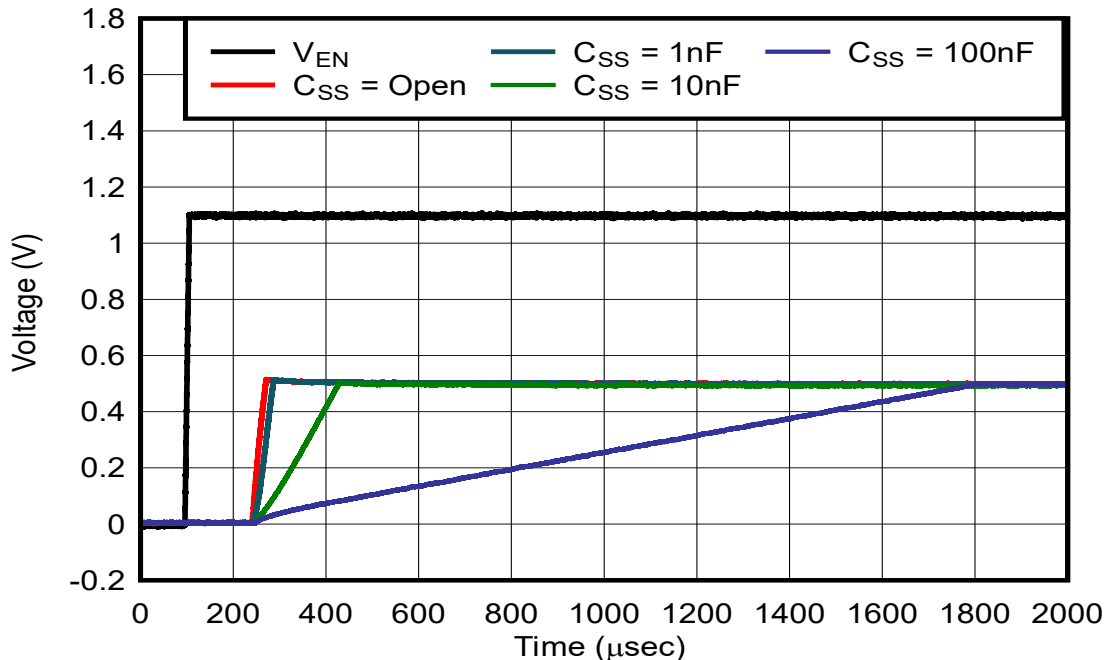
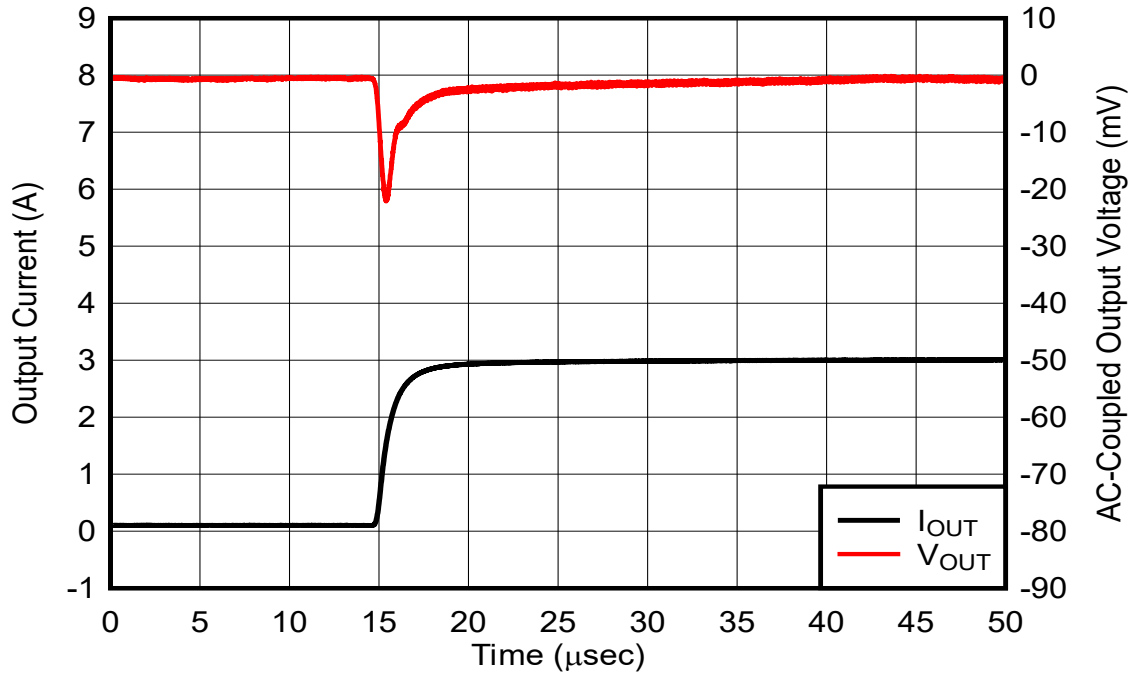

Figure 3-1. Start-Up Response
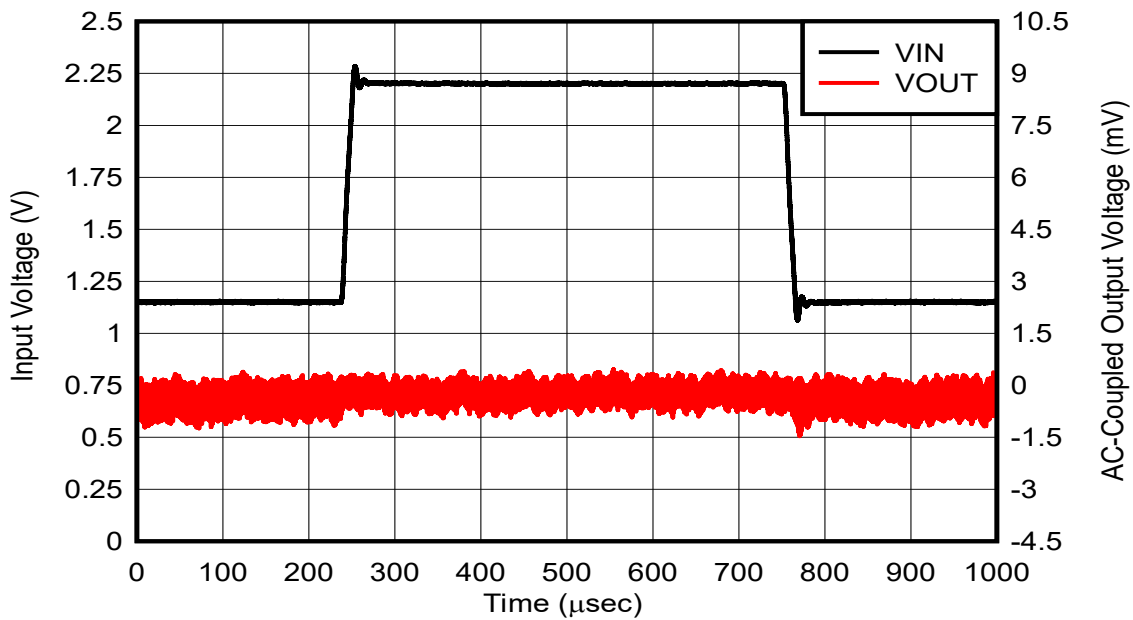
Figure 3-2. Load Transient Response

Figure 3-3. Line Transient Response

4 Hardware Design Files

4.1 Schematics

through show the EVM schematics.
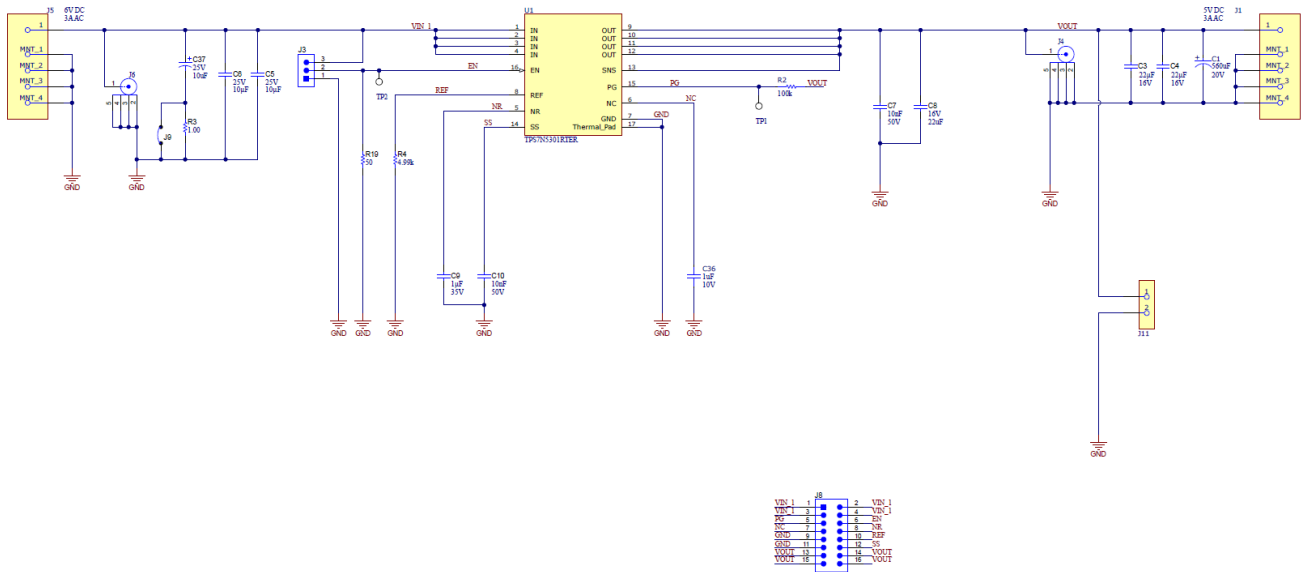
Figure 4-1. TPS7N53EVM Schematic

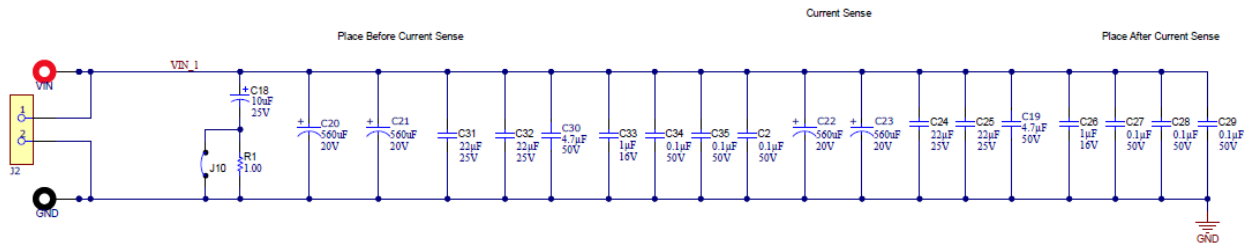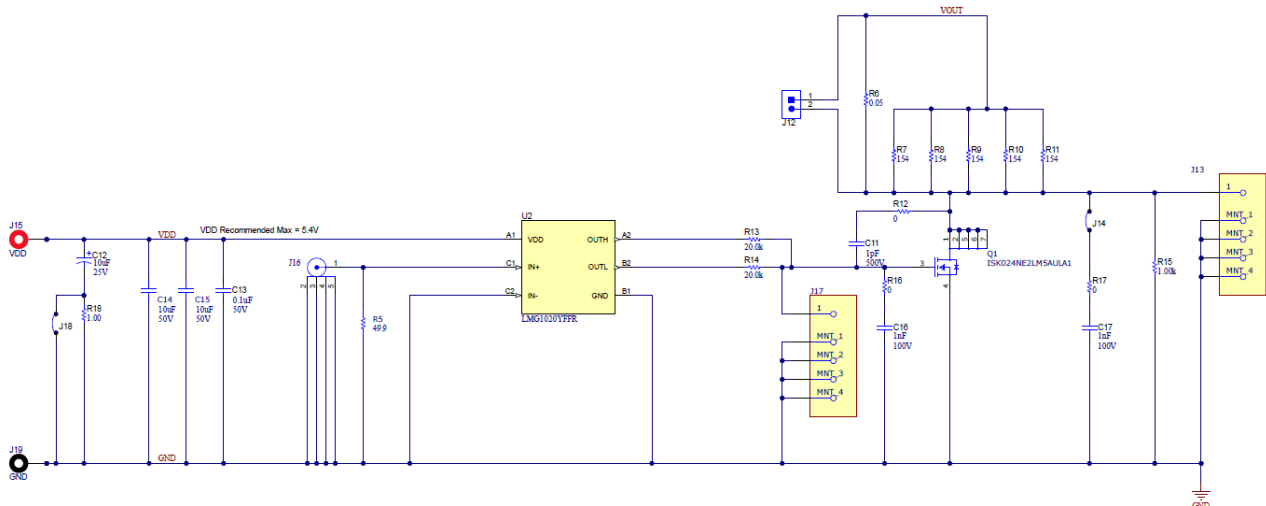**Figure 4-2. Input Capacitor Schematic**

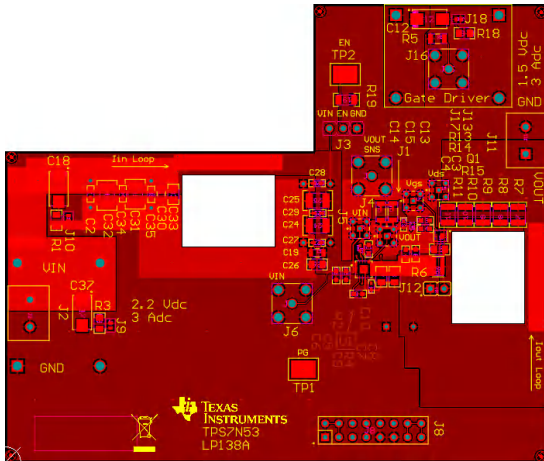**Figure 4-3. Load Transient Schematic**

4.2 PCB Layouts

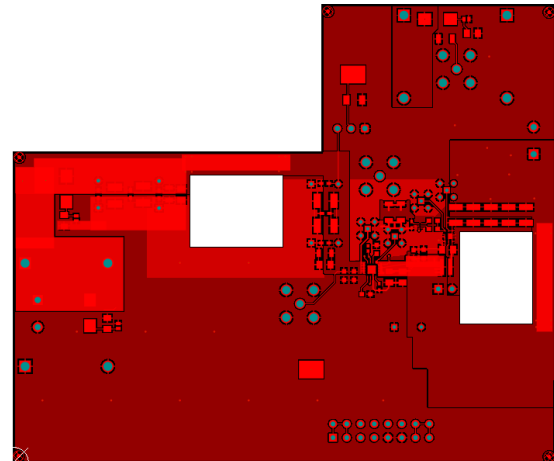

Figure 4-4. Top Assembly Layer and Silkscreen

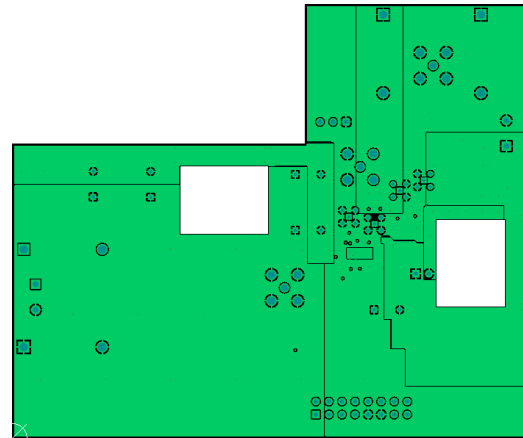**Figure 4-5. Top Layer Routing**
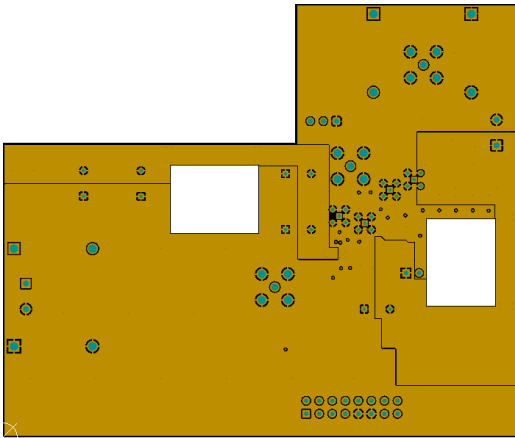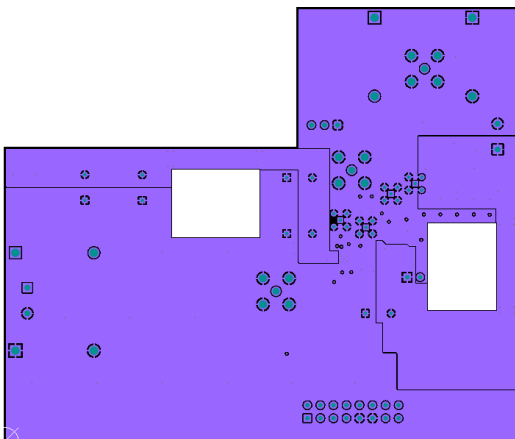

Figure 4-6. Layer 2

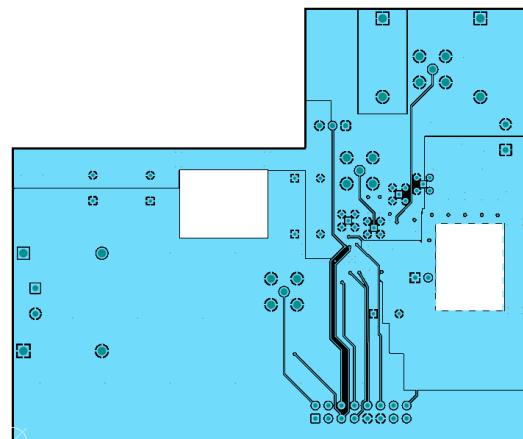**Figure 4-7. Layer 3**

Figure 4-8. Layer 4
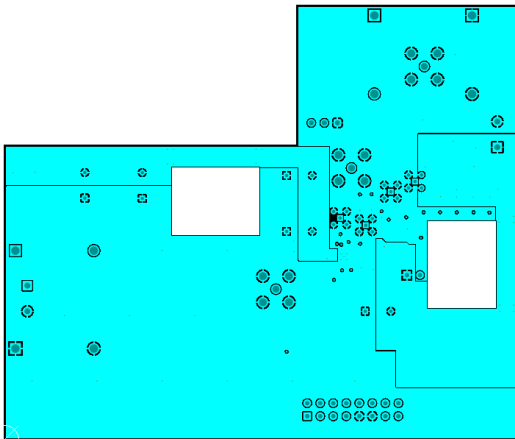

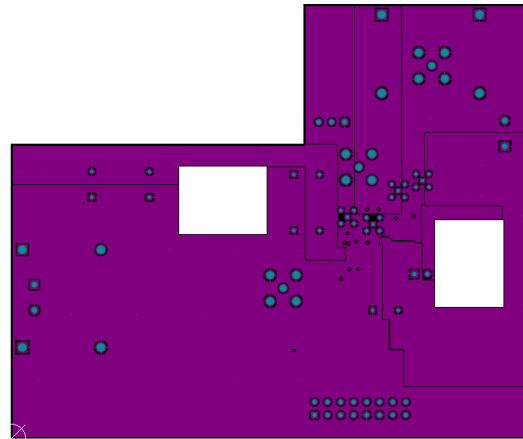**Figure 4-9. Layer 5**

Figure 4-10. Layer 6
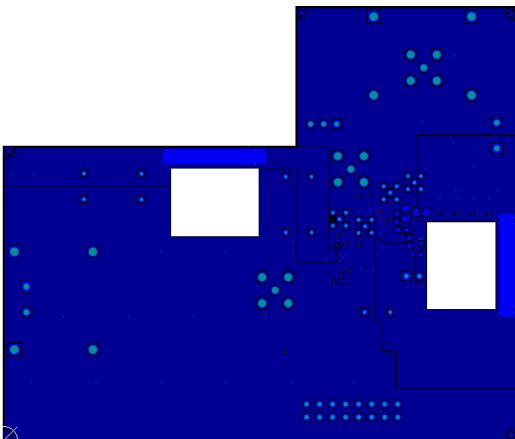

Figure 4-11. Layer 7
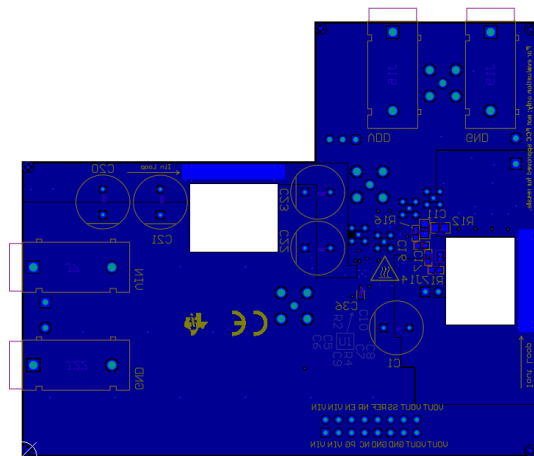

Figure 4-12. Bottom Layer Routing

Figure 4-13. Bottom Assembly Layer and Silkscreen

4.3 Bill of Materials (BOM)

Table 4-1. Bill of Materials

DESCRIPTION	REF DES	PART NUMBER	QTY	MFR
Printed Circuit Board	!PCB1	LP138	1	Any
Cap Aluminum Polymer 560uF 20VDC 20% (10 X 13mm) Radial 5mm 0.012 Ohm 1700mA 1000h 125C	C1, C20, C21, C22, C23	20SEF560M	5	Panasonic
CAP, CERM, 0.1µF, 50V,+/- 20%, X7R, 0402	C2, C27, C28, C29, C34, C35	UMK105B7104MV-FR	6	Taiyo Yuden
CAP, CERM, 22µF, 16V,+/- 20%, X5R, 0603	C3, C4	CL10A226MO7JZNC	2	Samsung
CAP, CERM, 10µF, 25V,+/- 10%, X5R, 0603	C5, C6	GRM188R61E106KA73D	2	MuRata
CAP, CERM, 0.01uF, 50V, +/- 10%, X7R, 0805	C7	C0805C103K5RACTU	1	Kemet
CAP, CERM, 22uF, 16V, +/- 20%, X5R, 0805	C8	C2012X5R1C226M125AC	1	TDK
CAP, CERM, 1µF, 35V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	C9	CGA3E1X7R1V105K080AE	1	TDK
CAP, CERM, 0.01uF, 50V, +/- 10%, X7R, 0603	C10	C0603X103K5RACTU	1	Kemet
CAP, CERM, 1pF, 500V, +/- 5%, C0G/NP0, 0805	C11	CBR08C109ACGAC	1	Kemet
CAP, TA, 10uF, 25V, +/- 20%, 0.5 ohm, SMD	C12, C18, C37	TPSC106M025R0500	3	AVX
CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0402	C13	C1005X7R1H104K050BB	1	TDK
10µF ±10% 50V Ceramic Capacitor X7R 1206 (3216 Metric)	C14, C15	GMC31X7R106K50NT	2	Cal-Chip Electronics
CAP, CERM, 1000pF, 100V, +/- 5%, X7R, 0603	C16, C17	06031C102JAT2A	2	AVX
Cap Ceramic 4.7uF 50V X7R 10% Pad SMD 0805 +125°C Automotive T/R	C19, C30	CGA4J1X7R1H475K125AC	2	TDK Corporation
CAP, CERM, 22µF, 25V,+/- 10%, X7R, 1210	C24, C25, C31, C32	CL32B226KAJNFNE	4	Samsung Electro-Mechanics
CAP, CERM, 1µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 0805	C26, C33	C0805C105K4RACAUTO	2	Kemet
1µF ±10% 10V Ceramic Capacitor X7R 0402 (1005 Metric)	C36	GMC04X7R105K10NT	1	Cal-Chip Electronics
MMCX Connector Jack, Female Socket 50Ohm Through Hole Solder	J1, J5, J13, J17	66012002111503	4	Wurth
TERM BLK 2POS SIDE ENTRY 5MM PCB	J2, J11	691137710002	2	Würth Elektronik
Header, 2.54mm, 3x1, Gold, TH	J3	61300311121	1	Wurth Elektronik
SMA Straight Jack, Gold, 50 Ohm, TH	J4, J6, J16	901-144-8RFX	3	Amphenol RF
Standard Banana Jack, insulated, 10A, red	J7, J15	571-0500	2	DEM Manufacturing
Header, 100mil, 8x2, Gold, TH	J8	TSW-108-07-G-D	1	Samtec
Jumper, SMT	J9, J10, J14, J18	JMP-36-30X40SMT	4	Any
Header, 100mil, 2x1, Gold, TH	J12	PBC02SAAN	1	Sullins Connector Solutions
Standard Banana Jack, insulated, 10A, black	J19, J22	571-0100	2	DEM Manufacturing
40V optiMOS Power Transistor, Surface Mount 6-PQFN Dual (2x2)	Q1	ISK024NE2LM5AULA1	1	Infineon
RES, 1.00, 1%, 0.333 W, AEC-Q200 Grade 1, 0805	R1, R3, R18	ERJ-6BQF1R0V	3	Panasonic
100 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Thick Film	R2	CRCW0402100KFKEDC	1	Vishay
RES, 4.99 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	R4	CRCW04024K99FKED	1	Vishay-Dale
RES Thick Film, 49.9Ω, 1%, 0.75W, 100ppm/°C, 1206	R5	CRCW120649R9FKEAHP	1	Vishay Dale
RES, 0.05, 1%, 1 W, AEC-Q200 Grade 0, 0612	R6	ERJ-B2CFR05V	1	Panasonic
RES, 154, 1%, 0.5 W, 1210	R7, R8, R9, R10, R11	RC1210FR-07154RL	5	Yageo
RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	R12	ERJ-6GEY0R00V	1	Panasonic
RES, 20.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	R13, R14	ERJ-3EKF2002V	2	Panasonic
RES, 1.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	R15	ERJ-6ENF1001V	1	Panasonic
RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	R16, R17	RMCF0603ZT0R00	2	Stackpole Electronics Inc
RES, 50, 2%, 11 W, 1206	R19	RCP1206W50R0GEB	1	Vishay-Dale

Table 4-1. Bill of Materials (continued)

DESCRIPTION	REF DES	PART NUMBER	QTY	MFR
Shunt, 100mil, Gold plated, Black	SH-J1	SNT-100-BK-G	1	Samtec
Test Point, Compact, SMT	TP1, TP2	5016	2	Keystone Electronics
Low-Input Voltage, Low-Noise, High-Accuracy, Low-Dropout (LDO) Voltage Regulator	U1	TPS7N5301RTER	1	Texas Instruments
5V, 7A/5A Low Side GaN Driver With 60MHz/1ns Speed, YFF0006AEAE (DSBGA-6)	U2	LMG1020YFFR	1	Texas Instruments

5 Compliance Information

5.1 Compliance and Certifications

•   TPS7N53EVM EU Declaration of Conformity (DoC) for Restricting the use of Hazardous Substances (RoHS)

6 Additional Information

6.1 Trademarks

LeCroy™ is a trademark of Teledyne LeCroy.

TI E2E™ is a trademark of Texas Instruments.

Kapton® is a registered trademark of DuPont.

All trademarks are the property of their respective owners.

7 Related Documentation

For development support see the following:

•   For TI's reference design library, visit TI reference designs
•   For TI's WEBENCH Design Environments, visit the WEBENCH® Design Center
•   For TI's customer question forum, visit TI E2E™ support forums

7.1 Supplemental Content

•   Texas Instruments, *TPS7N53 3A, Low-Input Voltage, Low-Noise, High Accuracy, Low-Dropout (LDO) Voltage Regulator*, data sheet.
•   Texas Instruments, *LMG1020 5V, 7A, 5A Low-Side GaN and MOSFET Driver For 1ns Pulse Width Applications*, data sheet.
•   IPC-2221B, Generic Standard on Printed Board Design.
•   Texas Instruments, *Linear Regulator Design Guide for LDOs*, application note
•   Texas Instruments, *Semiconductor and IC Package Thermal Metrics*, application note
•   Texas Instruments, *Using New Thermal Metrics*, application note
•   Texas Instruments, *LDO Basics: Thermals - How Hot is Your Application?*, technical article

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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.

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   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 DEGREDATION 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/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。

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２４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/lsds/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.

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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