TPS23521EVM-001 Evaluation Module

This user's guide describes the TPS23521 evaluation module (TPS23521EVM-001). The TPS23521EVM-001 contains evaluation and reference circuitry for the TPS23521, a low-side Hot Swap with Soft Start targeted at telecom applications.

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Trademarks

All trademarks are the property of their respective owners.

1 Introduction

The TPS23521 EVM is meant to give a jump start to anyone designing a –48-V system. It includes input clamping to support lightning surge (up to 2 kV), various FET placeholders to support various power levels, and an output inductor to mimic any EMI filter before the DC/DC converter.

1.1 Features

This EVM supports the following features:

- Inrush current control
- Hot swap output short circuit protection
- Dual hot swap gate drive
- Undervoltage and overvoltage protection
- Lightning surge support
- 1.2-kW design

1.2 Applications

This EVM is used in the following applications:

- Wireless infrastructure
- Telecom infrastructure
- –48-V interface

1.3 Electrical Specifications

Table 1 lists the EVM electrical specifications.

Table 1. TPS23521 Electrical and Performance Specifications at 25°C

Characteristic	TPS23521EVM-001
Input Voltage Range (Recommended)	36 V to 72 V
Load Power	1.2 kW
Load Output Capacitance	1.32 mF
Current Limit (Normal)	40 A
Current Limit (High FET V_{DS})	3 A
Circuit Breaker Trip (2× CL)	80 A
Typical Inrush Current	0.48 A
Hot Swap FET V_{DS} when current transitions from high to low	20.2 V
Time Out ($V_{DS,HS}$ < 10 V)	2.25 ms
Time Out (10 V < $V_{DS,HS}$ < 20 V)	1.12 ms
Time Out ($V_{DS,HS}$ > 20 V)	0.23 ms
Undervoltage Threshold (Rising)	34.9 V
Undervoltage Threshold (Falling)	32.9 V
Overvoltage Threshold (Rising)	75.9 V
Overvoltage Threshold (Falling)	73.9 V

2 Schematic

Figure 1 illustrates the EVM schematic.

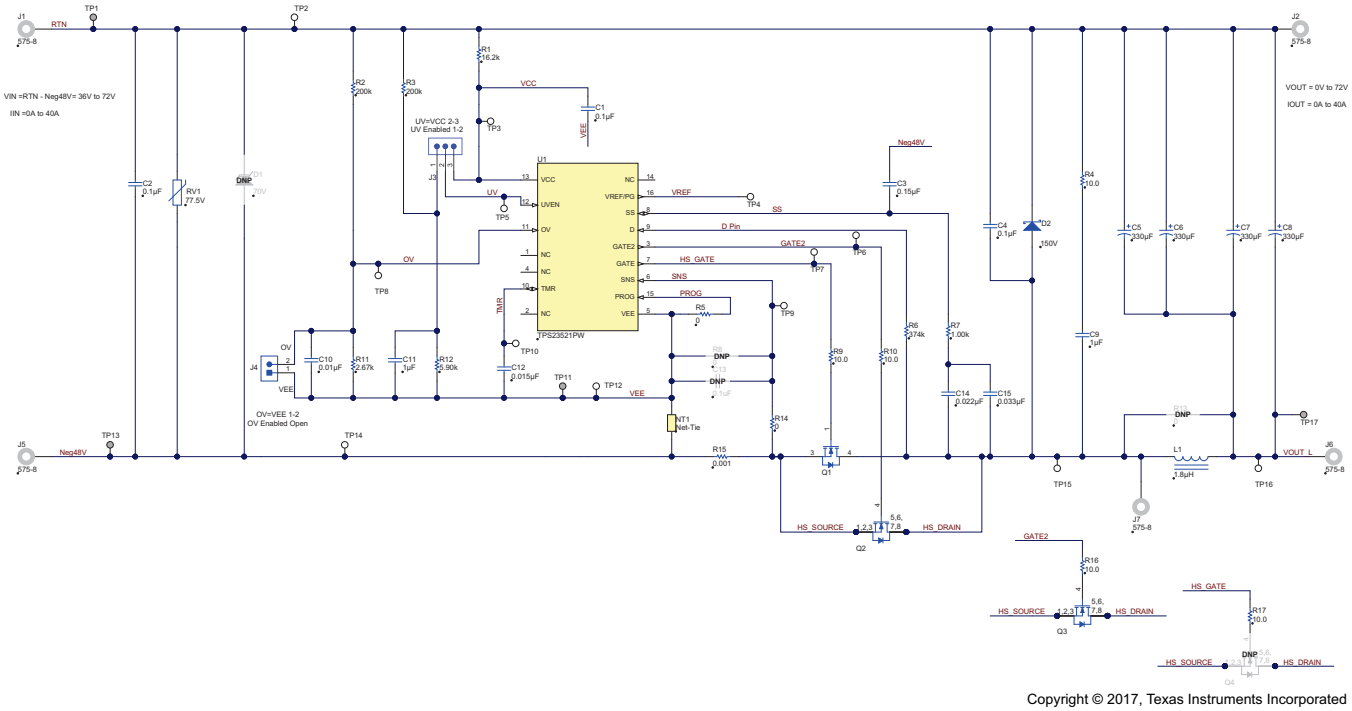

Figure 1. TPS23521EVM-001 Negative Hot Swap Controller Schematic

3 General Configuration and Description

3.1 Physical Access

Table 2 lists the TPS23521EVM connector and functionality, Table 3 describes the test point availability, and Table 4 describes the default jumper configuration.

Table 2. Connector Functionality

Connector	Label	Description
J1	RTN	Power bus input – Tie the high-side power supply input here.
J5	NEG_VIN	Power bus input – Tie the low-side power supply input here.
J2	RTN	Output bus – Apply the high-side load here (if applicable).
J6	VOUT	Output bus – Apply the low-side load here (if applicable).

Table 3. Test Points

Connector	Label	Description
TP1, TP2	RTN	High-side power supply input and high-side output load voltage
TP3	VCC	Clamped voltage supply
TP4	VREF/PG	5-V reference output
TP5	UV	UV pin voltage
TP6	GATE2	Gate drive output voltage for second Hot Swap FET
TP7	GATE	Gate drive output voltage for main Hot Swap FET
TP8	OV	OV pin voltage
TP9	SNS	Sense pin test point
TP10	TMR	Timer capacitor voltage
TP11, TP12	VEE	IC ground – Place voltage probe ground at this pin
TP13, TP14	NEG_VIN	Low-side power supply input
TP15	DRAIN	Drain voltage of the FET
TP16	VOUT	Low-side output load voltage

Table 4. Jumper Descriptions

Connector	Description
J3	Jump pins 1-2 to enable UV (default), or jump pins 2-3 to tie UV to VCC (disable)
J4	Leave open to enable OV (default), or jump pins 1-2 to tie OV to GND (disable)
J6, J7	Jump J6 and J7 to bypass the output inductor

3.2 Equipment Setup

The following equipment list and setup steps are provided to begin using the EVM:

- Power supplies capable of ≥ 72 V and ≥ 40 A (preferred)
- Resistive or electronic load – only turn on the load after the Hot Swap is up.
- Set the input power supply voltage to the desired operating input voltage.
- Turn the power supply off.
- Jump pins 1-2 on J3.
- Leave pins 1-2 on J4 open.
- Connect the positive voltage lead from the power supply to J1 (RTN). Connect the ground lead from the power supply to J5 (NEG_VIN).
- Make sure all voltmeter or oscilloscope GNDs are tied to VEE.
- Turn the power supply on.

4 Test Results

This section provides typical performance waveforms for the 1.2-kW Hot Swap TPS23521EVM-001 board. Scope GND was tied to VEE. Actual performance data is affected by measurement techniques and environmental variables; therefore, these curves are presented for reference and may differ from actual results obtained. All curves are based on V_{IN} = 48 V, unless stated otherwise.

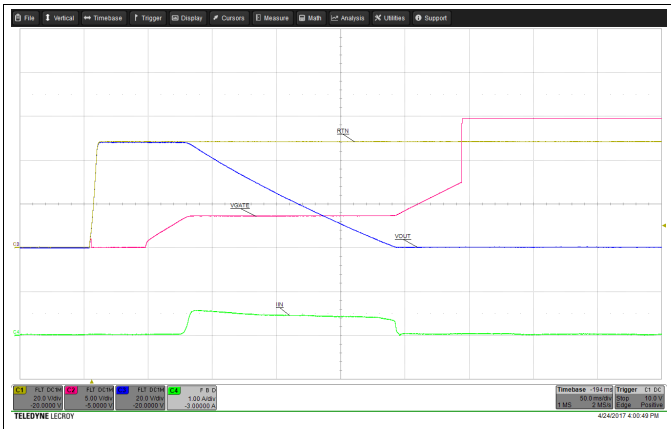

Figure 2. Start-up (V_{IN} = 48 V, C_{OUT} = 1.32 mF)

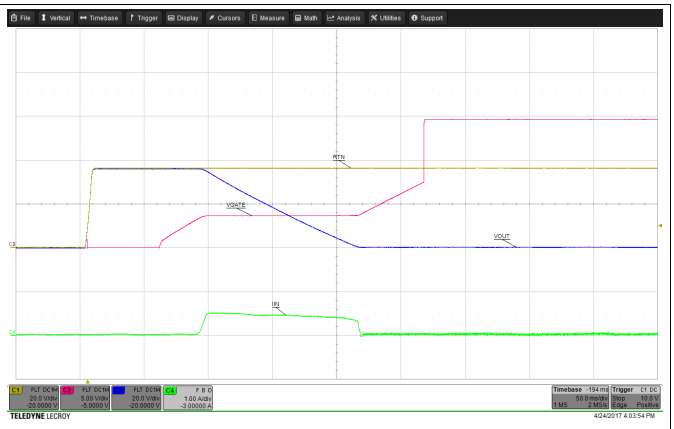

Figure 3. Start-up (V_{IN} = 36 V, C_{OUT} = 1.32 mF)

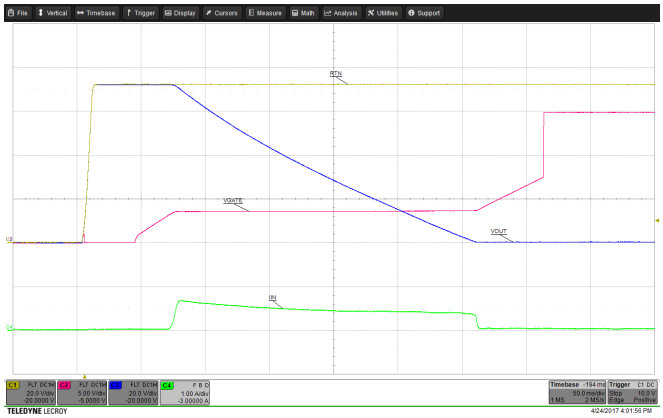

Figure 4. Start-up (V_{IN} = 72 V, C_{OUT} = 1.32 mF)

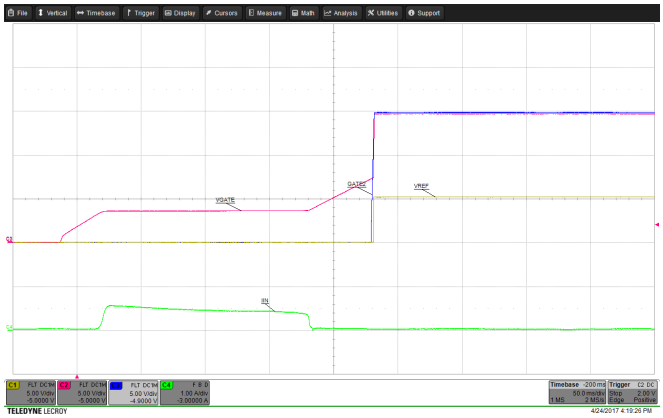

Figure 5. Start-up Showing VREF and GATE2

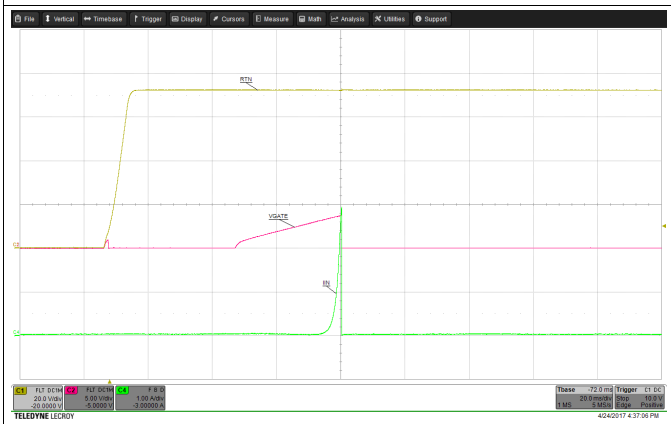

Figure 6. Start-into-Short (V_{IN} = 72 V)

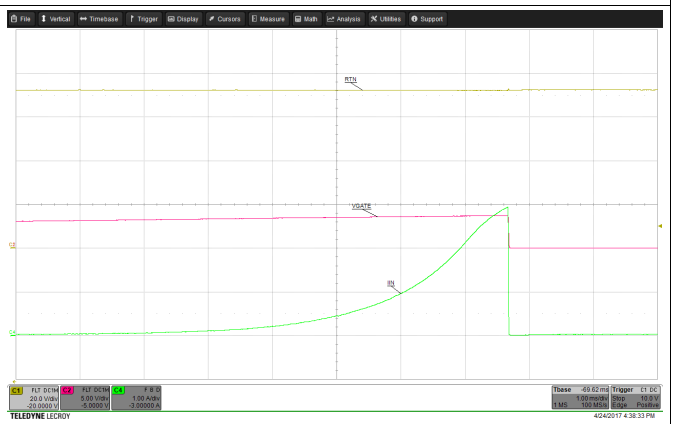

Figure 7. Start-into-Short Zoomed in (V_{IN} = 72 V)

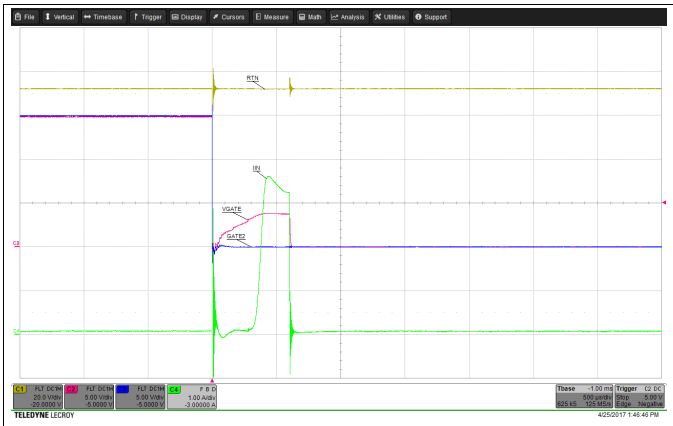

Figure 8. Hot-Short With No Load (V_{IN} = 72 V)

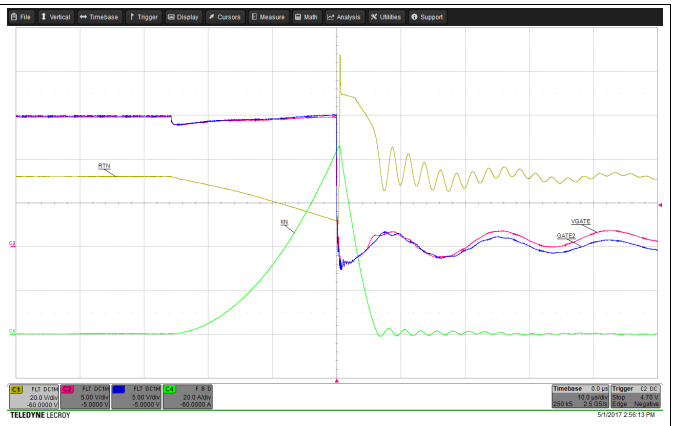

Figure 9. Hot-Short With no Load Zoomed In (V_{IN} = 72 V)

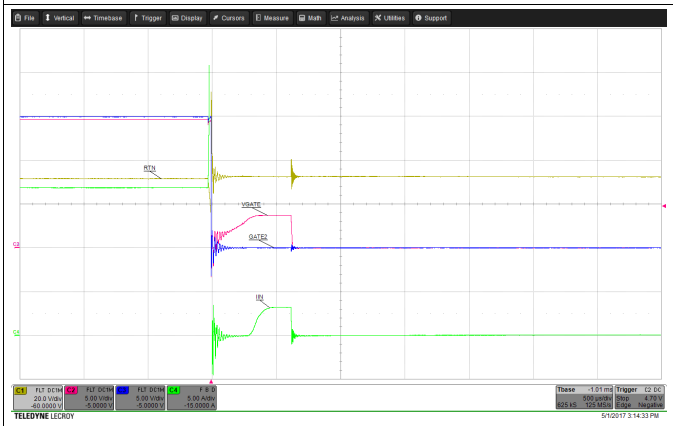

Figure 10. Hot-Short With 1.2-kW Load (V_{IN} = 72 V)

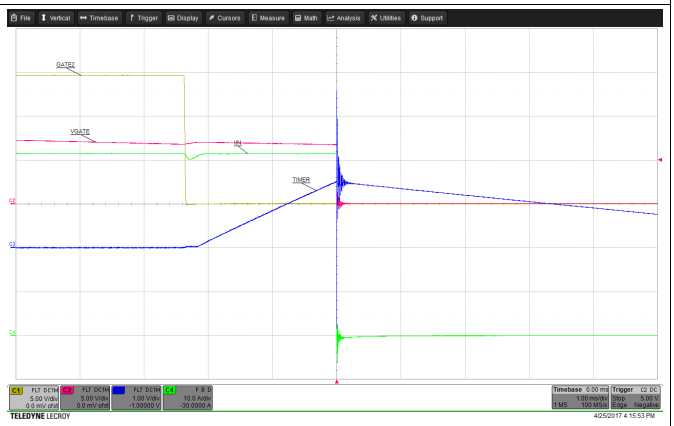

Figure 11. Gradual Overcurrent (V_{IN} = 36 V)

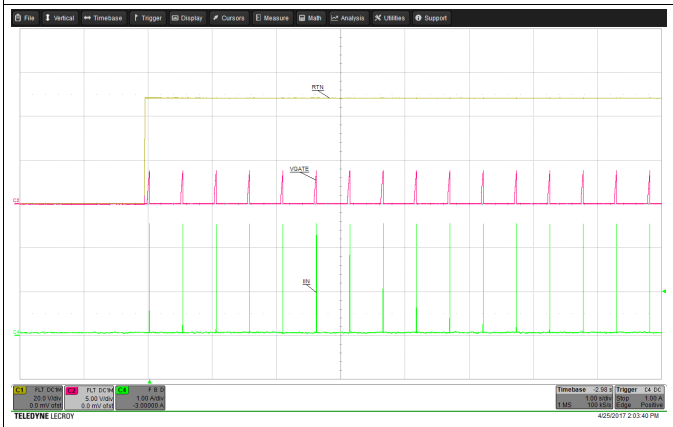

Figure 12. Retry Behavior

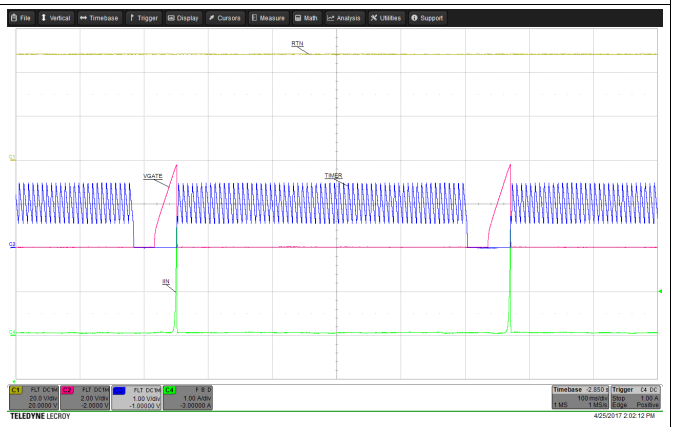

Figure 13. Retry Behavior Zoomed In

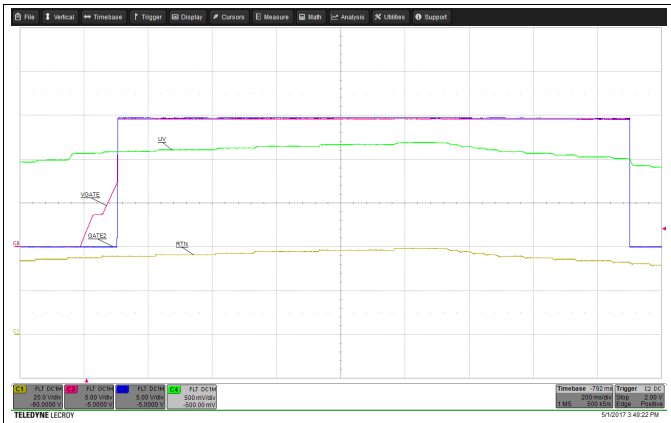

Figure 14. UV Rising and Falling Operation

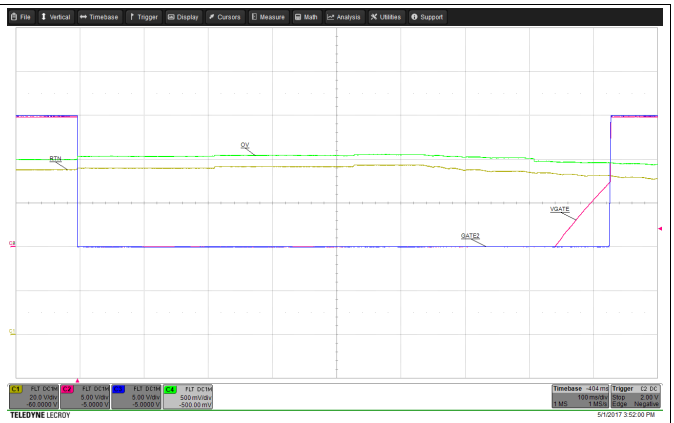

Figure 15. OV Rising and Falling Operation

5 Bill of Materials

Table 5 lists the EVM BOM.

Table 5. TPS23521EVM-001 Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		PSIL001	Any
C1	1	0.1uF	CAP, CERM, 0.1 µF, 50 V, ±5%, X7R, 0805	0805	08055C104JAT2A	AVX
C2	1	0.1uF	CAP, CERM, 0.1 µF, 250 V, ±10%, X7T, 0805	0805	C2012X7T2E104K125AA	TDK
C3	1	0.15uF	CAP, CERM, 0.15 µF, 25 V, ±10%, X7R, 0603	0603	C1608X7R1E154K080AA	TDK
C4	1	0.1uF	CAP, CERM, 0.1 µF, 100 V, ±10%, X7R, 0805	0805	C0805C104K1RACTU	Kemet
C5, C6, C7, C8	4	330uF	CAP, AL, 330 µF, 100 V, ±20%, 0.044 ohm, TH	D16xL25mm	100YXJ330MGC16X25	Rubycon
C9	1	1uF	CAP, CERM, 1 µF, 100 V, ±10%, X7R, 1206	1206	C3216X7R2A105K160AA	TDK
C10	1	0.01uF	CAP, CERM, 0.01 µF, 50 V, ±5%, X7R, 0603	0603	C0603C103J5RACTU	Kemet
C11	1	1uF	CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0603	0603	885012206076	Wurth Elektronik
C12	1	0.015uF	CAP, CERM, 0.015 µF, 25 V, ±10%, X7R, 0603	0603	GRM188R71E153KA01D	Murata
C14	1	0.022uF	CAP, CERM, 0.022 µF, 100 V, ±10%, X7R, 0805	0805	GRM21BR72A223KA01L	Murata
C15	1	0.033uF	CAP, CERM, 0.033 µF, 100 V, ±10%, X7R, 0805	0805	08051C333KAT2A	AVX
D2	1	150V	Diode, Schottky, 150 V, 1 A, SMA	SMA	STPS1150A	STMicroelectronics
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J2, J5, J6, J7	5		Standard Banana Jack, Uninsulated, 8.9mm	Keystone575-8	575-8	Keystone
J3	1		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
J4	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
L1	1	1.8uH	Inductor, Shielded, Composite, 1.8 µH, 43.8 A, 0.00161 ohm, SMD	15.2x8x16.2mm	XAL1580-182MEB	Coilcraft
Q1	1	100V	MOSFET, N-CH, 100 V, 120 A, DDPAK	DDPAK	PSMN4R8-100BSEJ	NXP Semiconductor
Q2, Q3	2	100V	MOSFET, N-CH, 100 V, 17 A, SON 5x6mm	SON 5x6mm	CSD19532Q5B	Texas Instruments
R1	1	16.2k	RES, 16.2 k, 1%, 0.75 W, AEC-Q200 Grade 0, 2010	2010	CRCW201016K2FKEF	Vishay-Dale
R2, R3	2	200k	RES, 200 k, 1%, 0.125 W, 0805	0805	CRCW0805200KFKEA	Vishay-Dale
R4	1	10.0	RES, 10.0, 1%, 0.25 W, 1206	1206	RC1206FR-0710RL	Yageo America
R5, R14	2	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R6	1	374k	RES, 374 k, 1%, 0.1 W, 0603	0603	RC0603FR-07374KL	Yageo America
R7	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R9, R10, R16, R17	4	10.0	RES, 10.0 ohm, 1%, 0.1W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
R11	1	2.67k	RES, 2.67 k, 0.1%, 0.1 W, 0603	0603	RG1608P-2671-B-T5	Susumu Co Ltd
R12	1	5.90k	RES, 5.90 k, 1%, 0.1 W, 0603	0603	CRCW06035K90FKEA	Vishay-Dale
R15	1	0.001	RES, 0.001, 1%, 3 W, AEC-Q200 Grade 0, 2512	2512	CRE2512-FZ-R001E-3	Bourns
RV1	1	77.5V	Ceramic transient voltage suppressor, 2220_250		B72540T6500S162	TDK
TP1, TP11, TP13, TP17	4		Terminal, Turret, TH, Double	Keystone1573-2	1573-2	Keystone
TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP12, TP14, TP15, TP16	13		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone

Table 5. TPS23521EVM-001 Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		–48-V Hot Swap Controller, PW0016A (TSSOP-16)	PW0016A	TPS23521PW	Texas Instruments
C13	0	0.1uF	CAP, CERM, 0.1uF, 16V, ±5%, X7R, 0603	0603	0603YC104JAT2A	AVX
D1	0	70V	Diode, TVS, Uni, 70 V, 113 Vc, SMC	SMC	5.0SMDJ70A	Littelfuse
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
Q4	0	100V	MOSFET, N-CH, 100 V, 17 A, SON 5x6mm	SON 5x6mm	CSD19532Q5B	Texas Instruments
R8	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R13	0	0	RES, 0, 5%, 1 W, AEC-Q200 Grade 0, 2512	2512	CRCW25120000Z0EG	Vishay-Dale

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

3 *Regulatory Notices:*

   3.1 *United States*

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

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

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

      CAUTION

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

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

      FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

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

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
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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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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.

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