

TPS23525EVM-815 Evaluation Module

This user's guide describes the TPS23525 evaluation module (TPS23525EVM-815). TPS23525EVM-815 contains evaluation and reference circuitry for the TPS23525, which is a low-side hot swap and dual ORing controller targeted at telecom applications.

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1 Introduction

The TPS23525 EVM provides a jump-start to anyone designing a redundant feed –48-V system. The EVM 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. Additionally, the EVM includes circuitry that supports auxiliary bulk capacitors. This “auxiliary bulk capacitor” approach is useful when designing for large hold-up times (example: 10 ms) making the hot-swap design more manageable by reducing the initial charge on the capacitor.

1.1 Features

This EVM has the following features:

- Inrush current control
- Hot-swap output short-circuit protection
- Reverse current protection
- Dual supply ORing
- Reverse hookup protection

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 TPS23525 electrical and performance specifications at 25°C.

Table 1. TPS23525 Electrical and Performance Specifications at 25°C

Characteristic	TPS23525EVM-PWR815
Input voltage Range (Recommended)	38 V to 60 V
Input Voltage Range (Abs Max)	0 V to 150 V
Load Power	400 W
Load Output Cap	660 μ F
Current Limit (Normal)	12.5 A
Current Limit (High FET VDS)	1.5 A
Typical Inrush Current	0.4 A
Hot-swap FET VDS when current transitions from high to low	20.2 V
Time Out (VDS,HS < 10 V)	2.25 ms
Time Out (10 V < VDS,HS < 20 V)	1.12 ms
Time Out (VDS,HS > 20 V)	0.23 ms
Undervoltage Threshold (Rising)	36.6 V
Undervoltage Threshold (Falling)	34.6 V
Overvoltage Threshold (Rising)	64.4 V
Overvoltage Threshold (Falling)	61.4 V

2 Schematic

Figure 1 illustrates the EVM schematic.

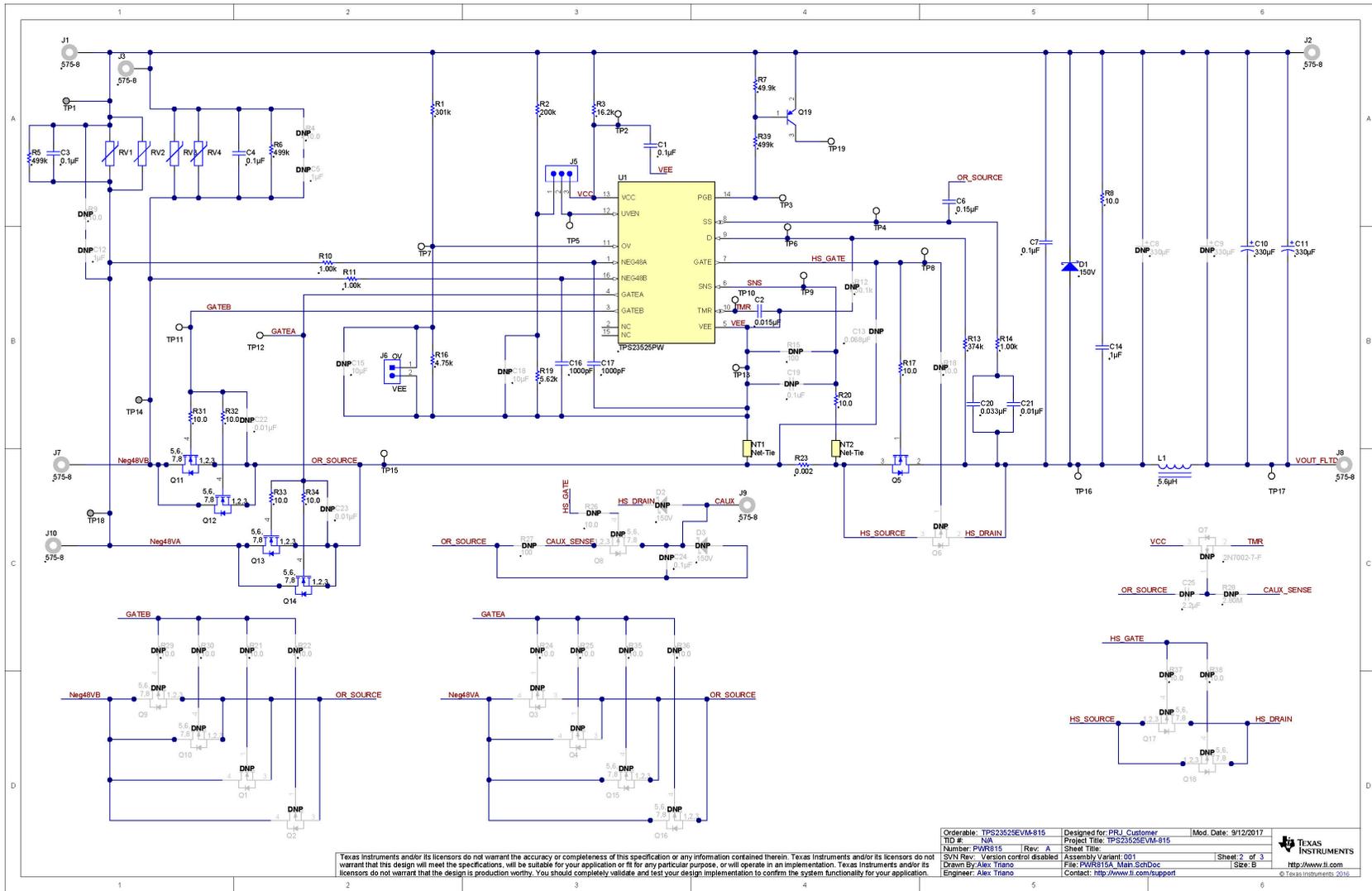


Figure 1. TPS23525EVM-815 Schematic

3 General Configuration and Description

3.1 Physical Access

Table 2 lists the TPS23525EVM 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, J2, J3	RTN	Power bus input - Tie the high-side of power-supply inputs and outputs here
J7	Neg48V_B	Power bus input - Tie the low-side of power-supply B input here
J8	Vout_FLTD	Output bus - Apply the low-side load here (if applicable)
J9	CAUX	Connect to auxiliary bulk capacitor (if applicable)
J10	Neg48V_A	Power bus input - Tie the low-side of power-supply A input here

Table 3. Test Points

Connector	Label	Description
TP1	RTN	High-side power-supply input and high-side output load voltage
TP2	VCC	Clamped voltage supply
TP3	PGB	Power Good Bar
TP4	SS	Soft-start pin voltage
TP5	UVEN	UV pin voltage
TP6	D	D pin voltage
TP7	OV	OV pin voltage
TP8	GATE	Gate drive output voltage for hot-swap FET
TP9	SNS	Sense pin test point
TP10	TMR	Timer capacitor voltage
TP11	GATEB	Gate drive output voltage for Gate B ORing FET
TP12	GATEA	Gate drive output voltage for Gate A ORing FET
TP13, TP15	VEE	IC ground - Place voltage probe ground at this pin
TP14	Neg48VB	Low-side input for power-supply B
TP16	HS_DRAIN	Drain voltage of the hot-swap FET
TP17	VOUT_FLTD	Low-side output for load
TP18	Neg48VA	Low-side input for power-supply A
TP19	-	Open-drain output for power good signal. Attach to downstream EN pin.

Table 4. Jumper Descriptions

Connector	Description
J5	Jump pins 1-2 to enable UV (default), or jump pins 2-3 to tie UV to VCC (disable)
J6	Leave open to enable OV (default), or jump pins 1-2 to tie OV to GND (disable)

3.2 Equipment Setup

Use the following equipment list and setup steps to work with the EVM:

- 2x power supplies capable of $\geq 60\text{ V}$ and $\geq 15\text{ A}$ (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 J5
- Leave pins 1-2 on J6 open
- Connect the positive voltage lead from the power-supply A to J1 (RTN). Connect the ground lead from the power-supply A to J10 (Neg48V_A).
- Connect the positive voltage lead from the power-supply B to J3 (RTN). Connect the ground lead from the power-supply B to J7 (Neg48V_B).
- Make sure all voltmeter or oscilloscope GNDs are tied to VEE
- Turn the power supplies on

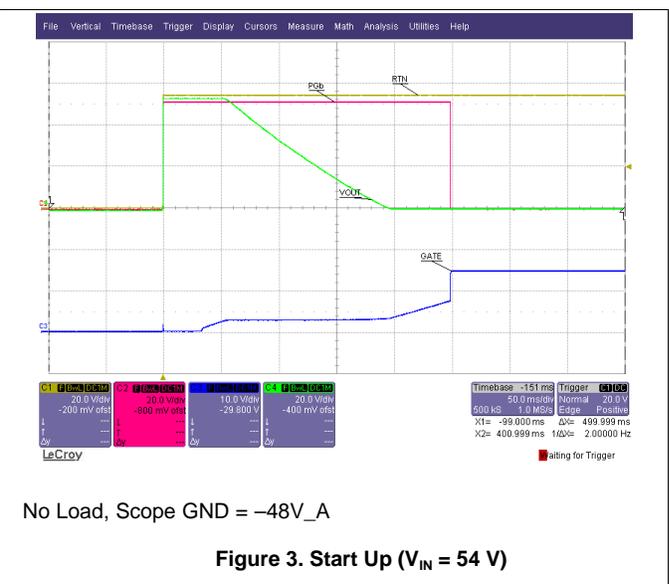
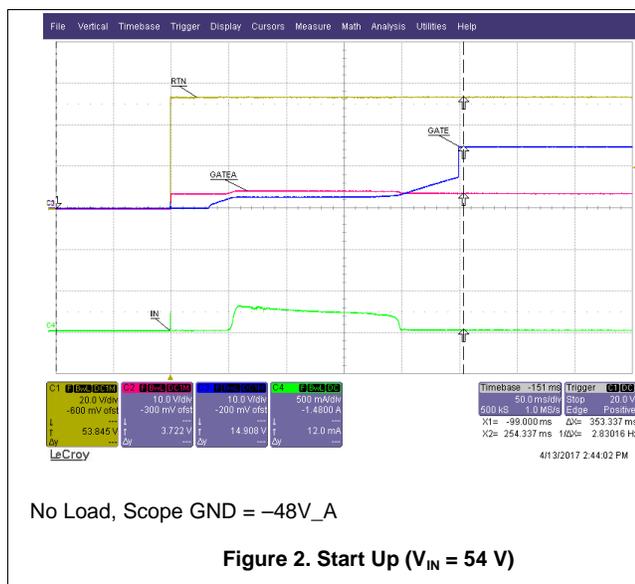
3.3 Scope Considerations

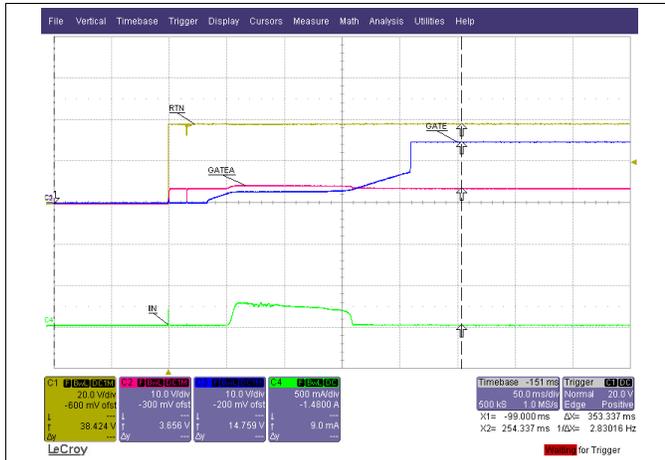
Observe the following scope considerations:

- Most scopes have a 10-M Ω resistance between scope GND and probe.
- If scope GND is tied to RTN and a probe is placed on TMR, that creates approximately 5 μA of pullup current which can overpower the pull down of the TMR pin and result in an undesired time out.

4 Test Results

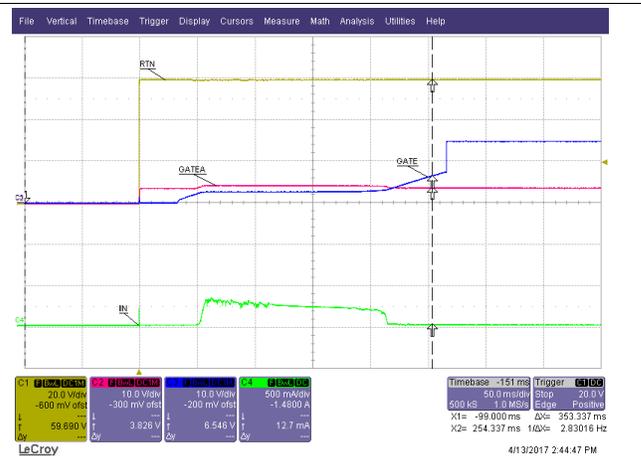
This section provides typical performance waveforms for the TPS23525EVM-815 board. Actual performance data is affected by measurement techniques and environmental variables; therefore, these curves are presented for reference and may differ from actual results obtained. All curves are based on $V_{IN} = 48\text{ V}$, unless stated otherwise.





No Load, Scope GND = -48V_A

Figure 4. Start Up ($V_{IN} = 38\text{ V}$)



No Load, Scope GND = -48V_A

Figure 5. Start Up ($V_{IN} = 60\text{ V}$)



$V_{IN,A} = 54\text{ V}$, $V_{IN,B} = 54\text{ V}$, No Load, Scope GND = RTN

Figure 6. Hot Plug Channel A and B Together



$V_{IN,A} = 54.5\text{ V}$, $V_{IN,B} = 54\text{ V}$, No Load, Scope GND = RTN

Figure 7. Hot Plug Channel A and B Together



$V_{IN,A} = 54\text{ V}$; $V_{IN,B} = 38\text{ V}$, Scope GND = RTN, Iload = 5 A

Figure 8. Hot Plug A After B



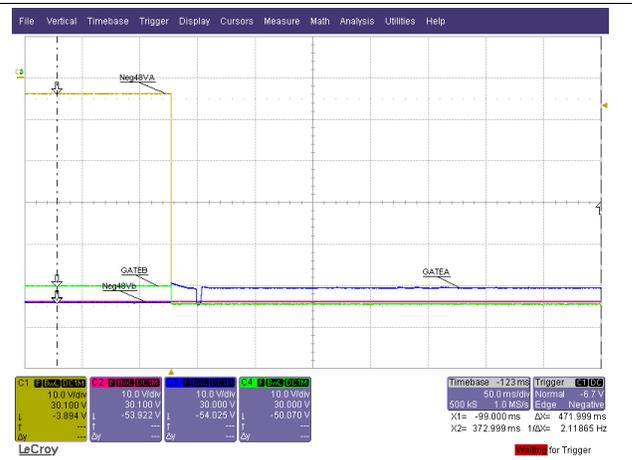
$V_{IN,A} = 54\text{ V}$; $V_{IN,B} = 38\text{ V}$, Scope GND = RTN, Iload = 5 A

Figure 9. Hot Plug A After B



$V_{IN,A} = 54\text{ V}$; $V_{IN,B} = 38\text{ V}$, Scope GND = RTN, Iload = 5 A

Figure 10. Hot Plug A After B



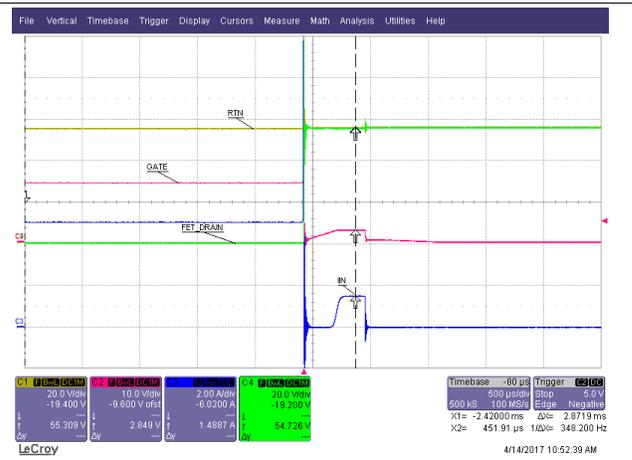
$V_{IN,A} = 54.5\text{ V}$; $V_{IN,B} = 54\text{ V}$, Scope GND = RTN, No Load

Figure 11. Hot Plug A After B



Scope GND = -48V_B, No Load, After Inductor

Figure 12. Output Hot Short ($V_{IN,B} = 54\text{ V}$)



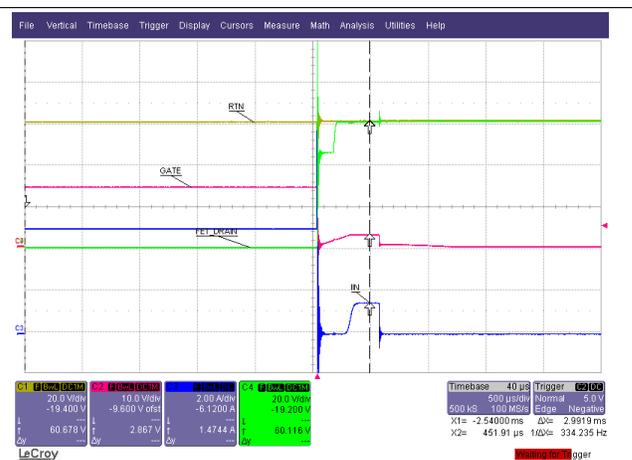
Scope GND = -48V_B, 5-A Load, After Inductor

Figure 13. Output Hot Short ($V_{IN,B} = 54\text{ V}$)



Scope GND = -48V_B, 5A Load, Zoomed in

Figure 14. Output Hot Short ($V_{IN,B} = 54\text{ V}$)



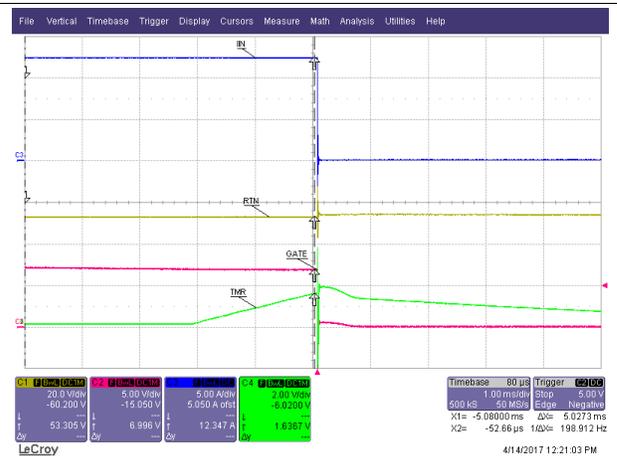
Scope GND = -48V_B, 5-A Load

Figure 15. Output Hot Short ($V_{IN,B} = 60\text{ V}$)



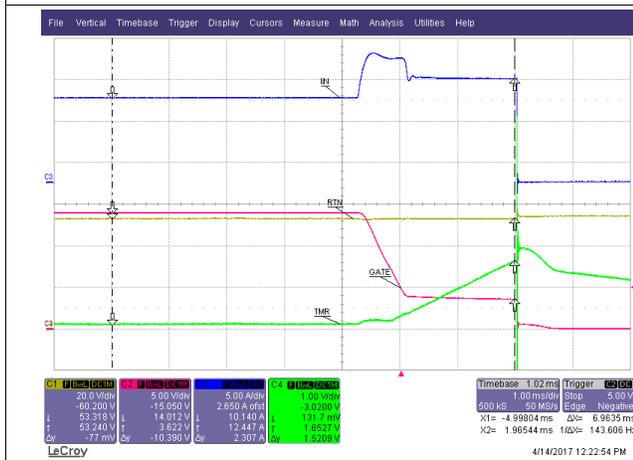
Scope GND = -48V_B, 5-A Load, Zoomed In

Figure 16. Output Hot Short ($V_{INB} = 60\text{ V}$)



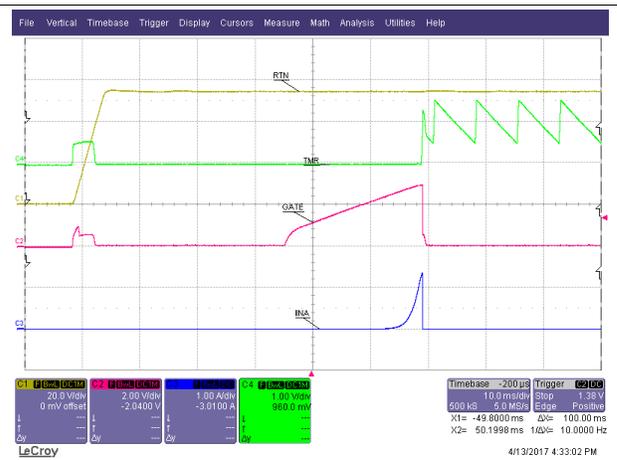
Scope GND = -48V_A

Figure 17. Gradual Overcurrent ($V_{INA} = 54\text{ V}$)



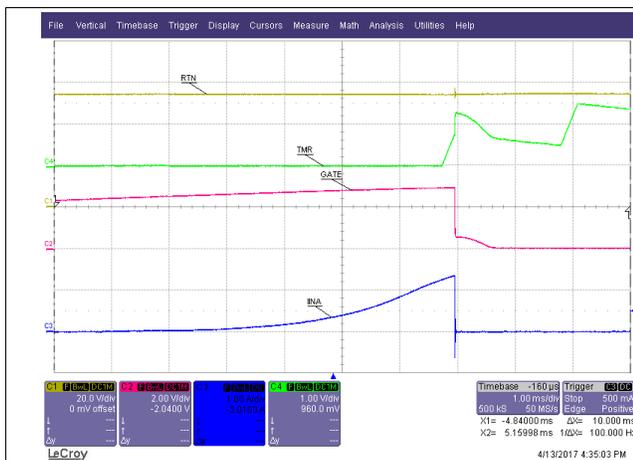
Scope GND = -48V_A

Figure 18. Load Step Overcurrent



Scope Gnd = -48V_A, $V_{IN} = 54\text{ V}$

Figure 19. Start Into Short



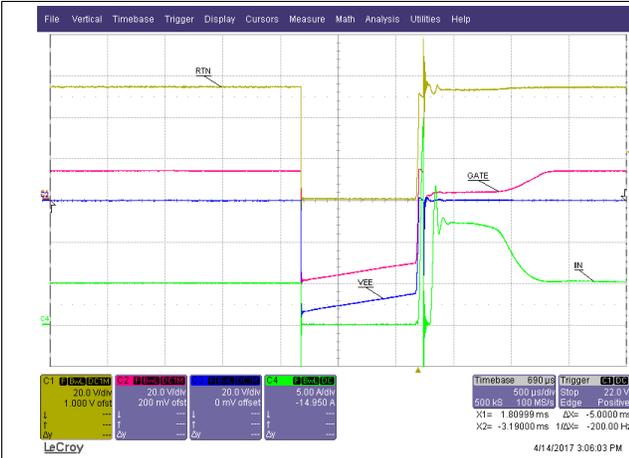
Scope Gnd = -48V_A, $V_{IN} = 54\text{ V}$

Figure 20. Start Into Short



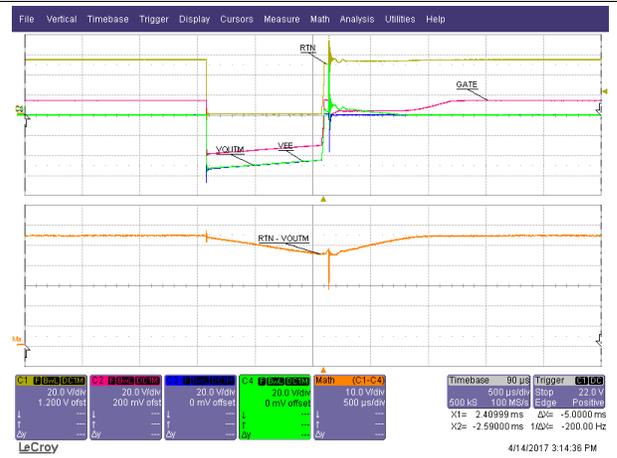
Scope Gnd = -48V_A, $V_{IN} = 54\text{ V}$

Figure 21. Apply Short and Remove Short



Scope GND = -48V_A, Iload = 5 A

Figure 22. 1-ms Brown Out



Scope GND = -48V_A, Iload = 5 A

Figure 23. 1-ms Brown Out



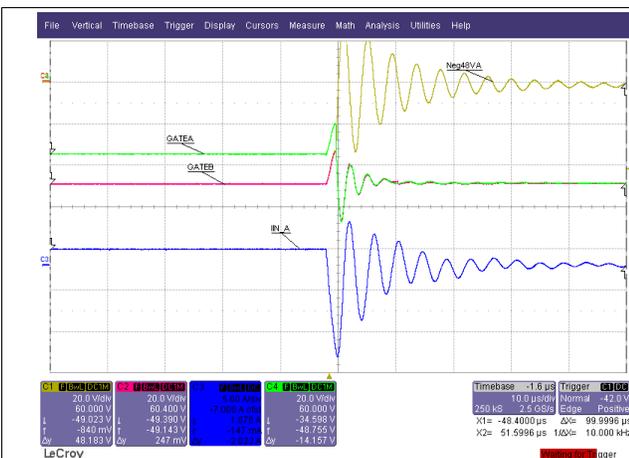
$V_{INB} = 53\text{ V}$, Iload = 5 A, Scope GND = RTN

Figure 24. Supply Switch Over (Raise V_{IN})



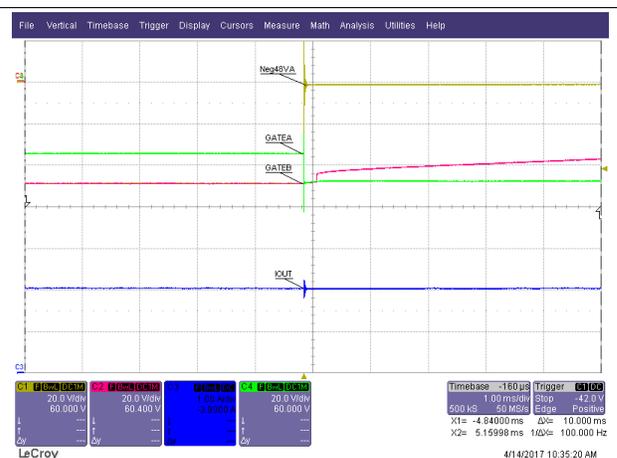
$V_{INB} = 53\text{ V}$ (Raise V_{IN}), Scope GND = RTN, Iload = 5 A

Figure 25. Supply Switch Over (Zoomed in)



$V_{INA} = 54.5\text{ V}$; $V_{INB} = 54\text{ V}$, Iload = 5 A, Scope GND = RTN

Figure 26. V_{IN} A Short



$V_{INA} = 54.5\text{ V}$; $V_{INB} = 54\text{ V}$, Iload = 5 A, Scope GND = RTN

Figure 27. V_{IN} A Short



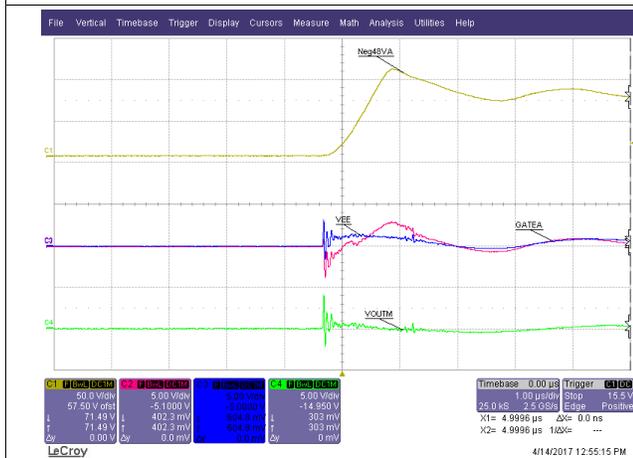
$V_{IN A} = 54.5 V$; $V_{IN B} = 54 V$, $I_{load} = 5 A$, Scope GND = RTN

Figure 28. Unplug $V_{IN A}$



$V_{IN B} = 60 V$

Figure 29. Plug in $V_{IN A}$ Backwards



$V_{IN B}$ Floating

Figure 30. Plug in $V_{IN A}$ Backwards



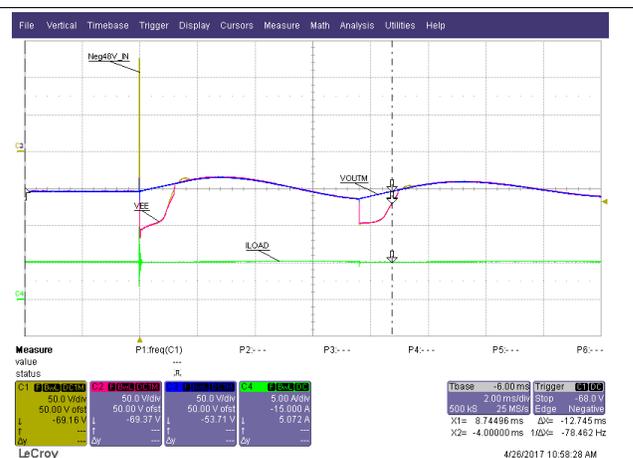
Scope GND = -48V_A, No Load

Figure 31. Undervoltage and Overvoltage (Rising)



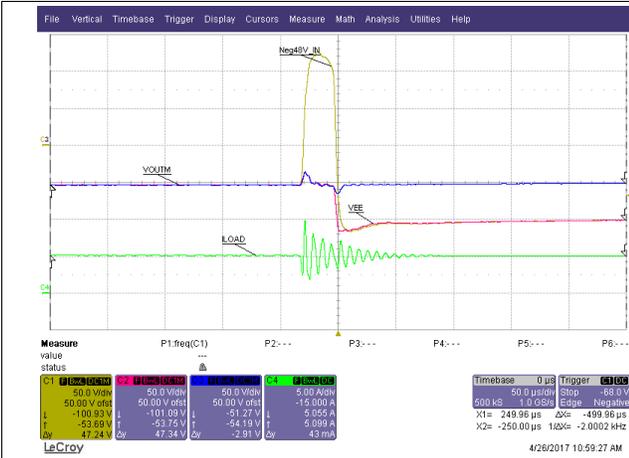
Scope GND = -48V_A, No Load

Figure 32. Undervoltage and Overvoltage (Falling)



Scope GND = RTN, 5-A Load, Per IEC61000-4-5

Figure 33. -2-kV (2 Ω) Lightning Surge



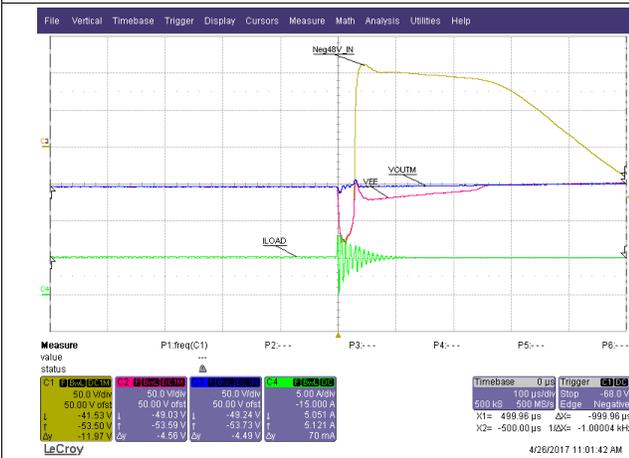
Scope GND = RTN, 5-A Load, Per IEC61000-4-5

Figure 34. -2-kV (2 Ω) Lightning Surge (Zoomed in)



Scope GND = RTN, 5-A Load, Per IEC61000-4-5

Figure 35. 2-kV (2 Ω) Lightning Surge (Zoomed in)



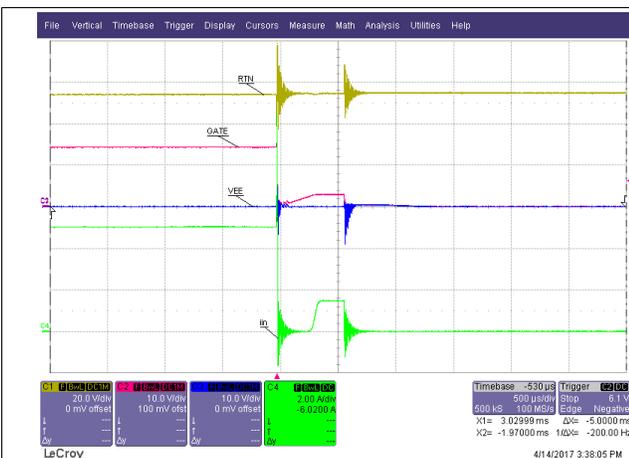
Scope GND = RTN, 5-A Load, Per IEC61000-4-5

Figure 36. 2-kV (2 Ω) Lightning Surge (Zoomed in)



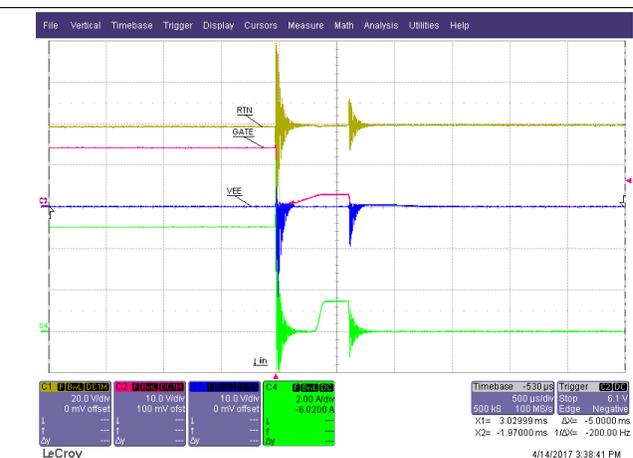
L1 = 20 μH, Scope GND = -48V_A

Figure 37. Start-Up (V_{IN} = 54 V)



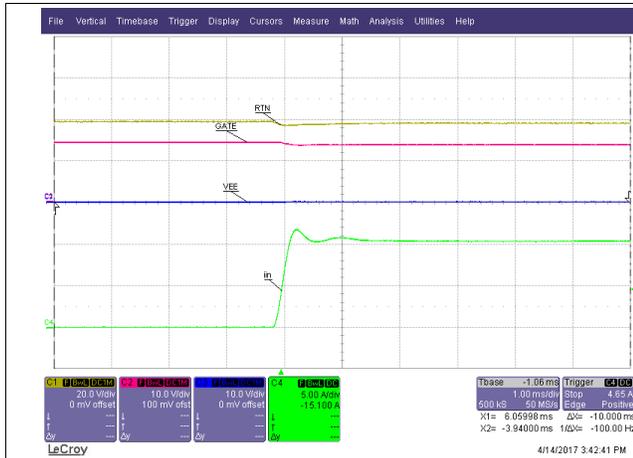
L1 = 20 μH, Scope GND = -48V_A

Figure 38. Hot Short (V_{IN} = 54 V)



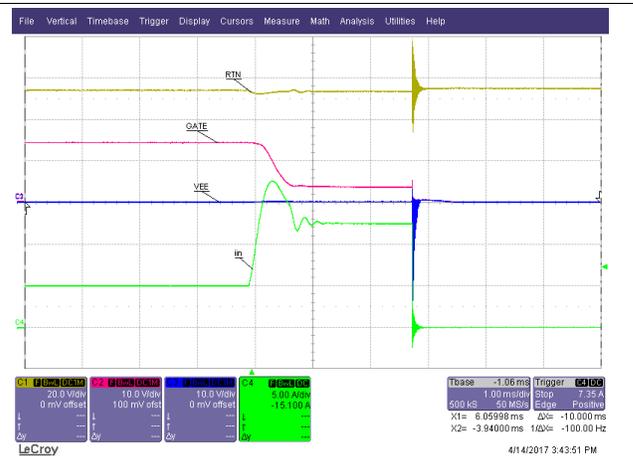
L1 = 20 μH, Scope GND = -48V_A

Figure 39. Hot Short (V_{IN} = 38 V)



L1 = 20 μ H, Scope GND = -48V_A,

Figure 40. Load Step (0 A–11 A)



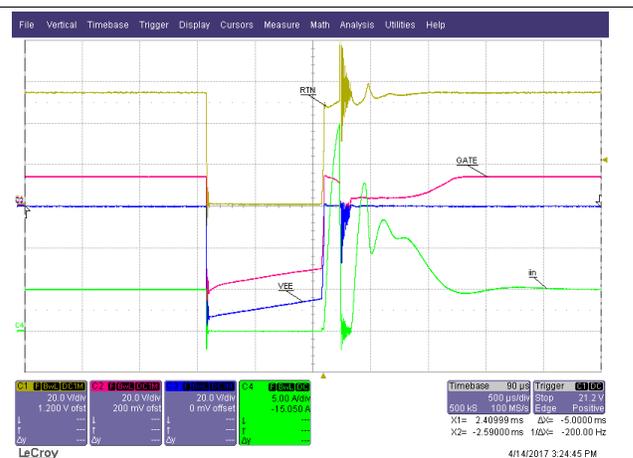
L1 = 20 μ H, Scope GND = -48V_A

Figure 41. Load Step Into Overcurrent



L1 = 20 μ H, Scope GND = -48V_A

Figure 42. Start Into Short



L1 = 20 μ H, Scope GND = -48V_A

Figure 43. 1-ms Brown Out

5 Bill of Material

Table 5 lists the EVM BOM.

Table 5. TPS23525EVM-815 Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		PWR815	Any
C1, C7	2	0.1uF	CAP, CERM, 0.1 μ F, 100 V, \pm 10%, X7R, 1206	1206	C3216X7R2A104K160AA	TDK
C2	1	0.015uF	CAP, CERM, 0.015 μ F, 100 V, \pm 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R2A153K080AA	TDK
C3, C4	2	0.1uF	CAP, CERM, 0.1 μ F, 250 V, \pm 10%, X7R, 1206	1206	GRM31CR72E104KW03L	Murata
C6	1	0.15uF	CAP, CERM, 0.15 μ F, 50 V, \pm 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H154K080AB	TDK
C10, C11	2	330uF	CAP, AL, 330 μ F, 100 V, \pm 20%, 0.153 ohm, SMD	SMT Radial K16	EEV-FK2A331M	Panasonic
C14	1	1uF	CAP, CERM, 1 μ F, 100 V, \pm 20%, X7R, 1206	1206	C3216X7R2A105M160AA	TDK
C16, C17	2	1000pF	CAP, CERM, 1000 pF, 250 V, \pm 10%, X7R, 0805	0805	GRM21AR72E102KW01D	Murata
C20	1	0.033uF	CAP, CERM, 0.033 μ F, 100 V, \pm 10%, X7R, 0805	0805	GRM21BR72A333KA01L	Murata
C21	1	0.01uF	CAP, CERM, 0.01 μ F, 100 V, \pm 1%, COG/NP0, 0805	0805	C0805C103F1GAC TU	Kemet
D1	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, J3, J7, J8, J9, J10	7		Standard Banana Jack, Uninsulated, 8.9mm	Keystone575-8	575-8	Keystone
J5	1		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
J6	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
L1	1	5.6uH	Inductor, Shielded Drum Core, Mn-Zn, 5.6 μ H, 25 A, 0.00274 ohm, SMD	18.3x8.9x18.2mm	7443557560	Würth Elektronik
Q5	1	100V	MOSFET, N-CH, 100 V, 197 A, TO-263-2	KTT0002A	CSD19535KTT	Texas Instruments
Q11, Q12, Q13, Q14	4	200V	MOSFET, N-CH, 200 V, 36 A, PG-TDSON-8	PG-TDSON-8	BSC320N20NS3 G	Infineon Technologies
Q19	1	150 V	Transistor, PNP, 150 V, 0.5 A, SOT-23	SOT-23	MMBT5401LT1G	ON Semiconductor
R1	1	301k	RES, 301 k, 1%, 0.125 W, 0805	0805	CRCW0805301KF KEA	Vishay-Dale
R2	1	200k	RES, 200 k, 1%, 0.125 W, 0805	0805	CRCW0805200KF KEA	Vishay-Dale
R3	1	16.2k	RES, 16.2 k, 1%, 0.75 W, AEC-Q200 Grade 0, 2010	2010	CRCW201016K2F KEF	Vishay-Dale
R5, R6	2	499k	RES, 499 k, 1%, 0.25 W, 1206	1206	CRCW1206499KF KEA	Vishay-Dale
R7	1	49.9k	RES, 49.9 k, 1%, 0.1 W, 0603	0603	CRCW060349K9F KEA	Vishay-Dale
R8	1	10.0	RES, 10.0, 1%, 0.25 W, 1206	1206	CRCW120610R0F KEA	Vishay-Dale
R10, R11	2	1.00k	RES, 1.00 k, 1%, 0.125 W, 0805	0805	CRCW08051K00F KEA	Vishay-Dale
R13	1	374k	RES, 374 k, 1%, 0.1 W, 0603	0603	RC0603FR-07374KL	Yageo America
R14	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00F KEA	Vishay-Dale
R16	1	4.75k	RES, 4.75 k, 1%, 0.1 W, 0603	0603	CRCW06034K75F KEA	Vishay-Dale
R17, R31, R32, R33, R34	5	10.0	RES, 10.0 ohm, 1%, 0.1W, 0603	0603	CRCW060310R0F KEA	Vishay-Dale

Table 5. TPS23525EVM-815 Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
R19	1	5.62k	RES, 5.62 k, 1%, 0.1 W, 0603	0603	CRCW06035K62F KEA	Vishay-Dale
R20	1	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	CRCW060310R0F KEA	Vishay-Dale
R23	1	0.002	RES, 0.002, 1%, 1 W, 2512	2512	ERJ-M1WTF2M0U	Panasonic
R39	1	499k	RES, 499 k, 1%, 0.125 W, 0805	0805	CRCW0805499KF KEA	Vishay-Dale
RV1, RV2, RV3, RV4	4		Ceramic transient voltage suppressor, 2220_250		B72540T6500S162	TDK
TP1, TP14, TP18	3		Terminal, Turret, TH, Double	Keystone1573-2	1573-2	Keystone
TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP15, TP16, TP17, TP19	16		Test Point, Miniature, SMT	Testpoint_Keyston e_Miniature	5015	Keystone
U1	1		TPS2352x Family, PW0016A	PW0016A	TPS23525PW	Texas Instruments
C5, C12	0	1uF	CAP, CERM, 1 μ F, 200 V, \pm 10%, X7R, 2225	2225	VJ2225Y105KBCA T4X	Vishay-Vitramon
C8, C9	0	330uF	CAP, AL, 330 μ F, 100 V, \pm 20%, 0.153 ohm, SMD	SMT Radial K16	EEV-FK2A331M	Panasonic
C13	0	0.068uF	CAP, CERM, 0.068 μ F, 50 V, \pm 10%, X7R, 0603	0603	GRM188R71H683 KA93D	Murata
C15, C18	0	10uF	CAP, CERM, 10 μ F, 10 V, \pm 20%, X5R, 0603	0603	C1608X5R1A106M 080AC	TDK
C19	0	0.1uF	CAP, CERM, 0.1uF, 16V, \pm 5%, X7R, 0603	0603	0603YC104JAT2A	AVX
C22, C23	0	0.01uF	CAP, CERM, 0.01 μ F, 25 V, \pm 10%, X7R, 0603	0603	GRM188R71E103 KA01D	Murata
C24	0	0.1uF	CAP, CERM, 0.1 μ F, 250 V, \pm 10%, X7T, 0805	0805	C2012X7T2E104K 125AA	TDK
C25	0	2.2uF	CAP, CERM, 2.2 μ F, 16 V, \pm 10%, X5R, 0603	0603	GRM188R61C225 KE15D	Murata
D2, D3	0	150V	Diode, Schottky, 150 V, 1 A, SMA	SMA	STPS1150A	STMicroelectronics
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
Q1, Q2, Q3, Q4	0	200V	MOSFET, N-CH, 200 V, 62 A, DDPAK	DDPAK	IRFS4227PBF	International Rectifier
Q6	0	100V	MOSFET, N-CH, 100 V, 200 A, TO-263- 2	KTT0002A	CSD19536KTT	Texas Instruments
Q7	0	60V	MOSFET, N-CH, 60 V, 0.17 A, SOT-23	SOT-23	2N7002-7-F	Diodes Inc.
Q8, Q9, Q10, Q15, Q16	0	200V	MOSFET, N-CH, 200 V, 36 A, PG- TDSON-8	PG-TDSON-8	BSC320N20NS3 G	Infineon Technologies
Q17, Q18	0	100V	MOSFET, N-CH, 100 V, 17 A, SON 5x6mm	SON 5x6mm	CSD19532Q5B	Texas Instruments
R4, R9	0	10.0	RES, 10.0, 1%, 0.25 W, 1206	1206	CRCW120610R0F KEA	Vishay-Dale
R12	0	30.1k	RES, 30.1 k, 1%, 0.1 W, 0603	0603	CRCW060330K1F KEA	Vishay-Dale
R15	0	100	RES, 100, 1%, 0.1 W, 0603	0603	CRCW0603100RF KEA	Vishay-Dale
R18, R21, R22, R24, R25, R26, R29, R30, R35, R36, R37, R38	0	10.0	RES, 10.0 ohm, 1%, 0.1W, 0603	0603	CRCW060310R0F KEA	Vishay-Dale
R27	0	100	RES, 100, 1%, 1 W, AEC-Q200 Grade 0, 2512	2512	CRCW2512100RF KEG	Vishay-Dale
R28	0	2.80Meg	RES, 2.80 M, 1%, 0.1 W, 0603	0603	CRCW06032M80F KEA	Vishay-Dale

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 semiconductor products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
 - 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.
2. *Limited Warranty and Related Remedies/Disclaimers:*
 - 2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
 - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.
3. *Regulatory Notices:*
 - 3.1 *United States*
 - 3.1.1 *Notice applicable to EVMs not FCC-Approved:*

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 Canada

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/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。
http://www.tij.co.jp/lstds/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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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。

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3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

6. *Disclaimers:*

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

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

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

8. *Limitations on Damages and Liability:*

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

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, 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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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
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