# 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.

**Contents**



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## Trademarks

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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 µF |
| 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.

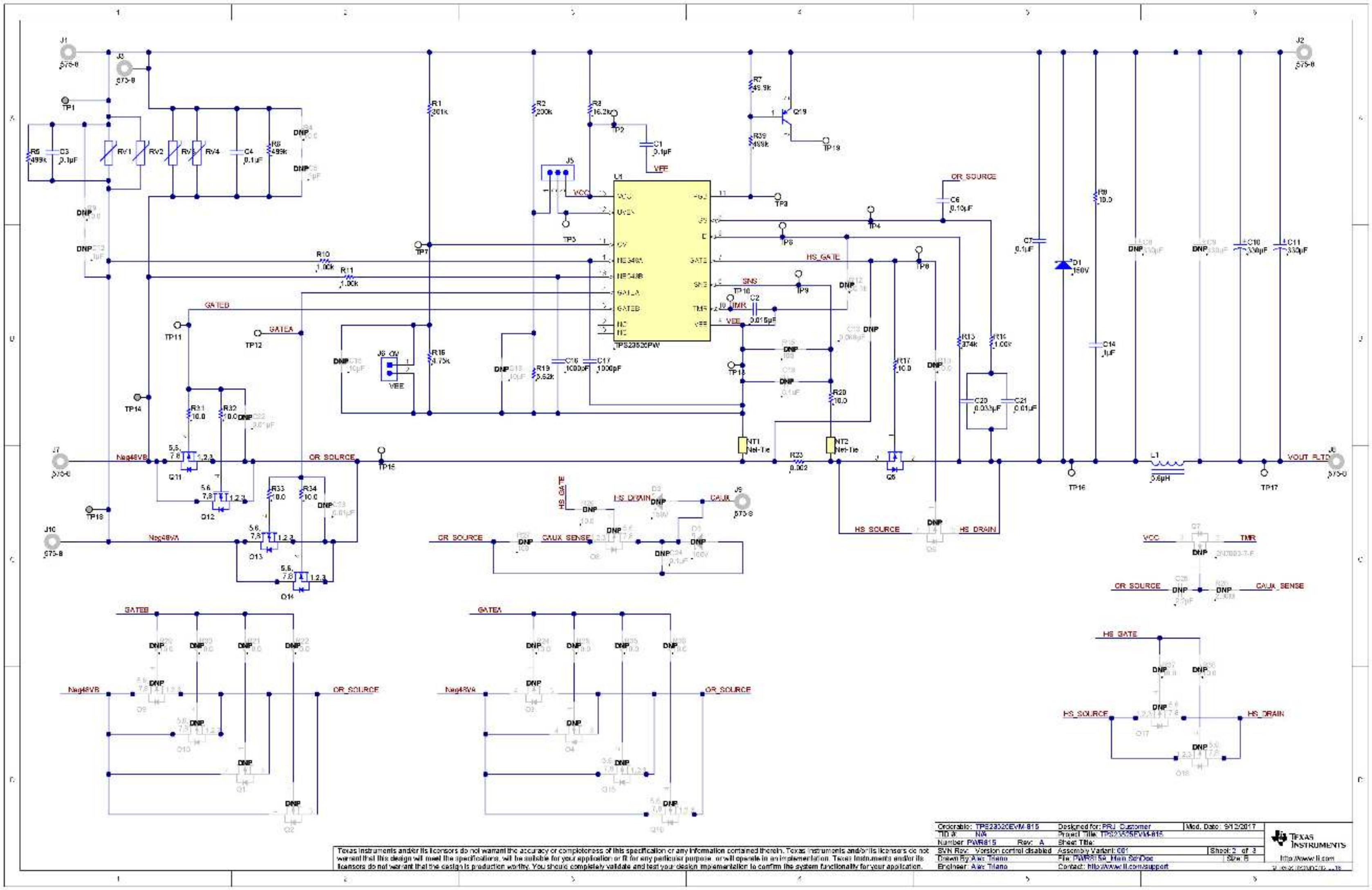



**Figure 1. TPS23525EVM-815 Schematic**

# 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:

- 2× power supplies capable of ≥ 60 V and ≥ 15 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

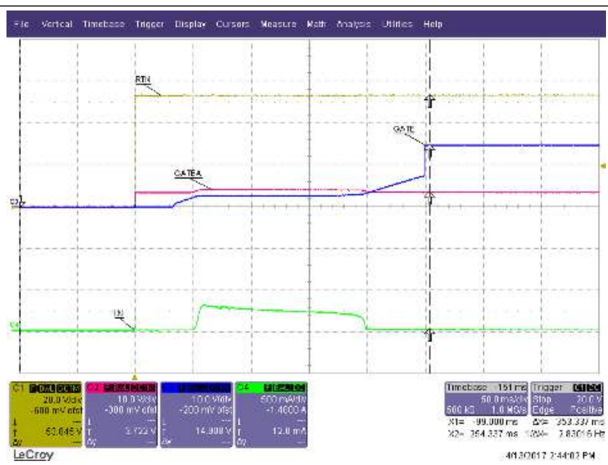
### 3.3 Scope Considerations

Observe the following scope considerations:

- Most scopes have a 10-MΩ 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 V, unless stated otherwise.

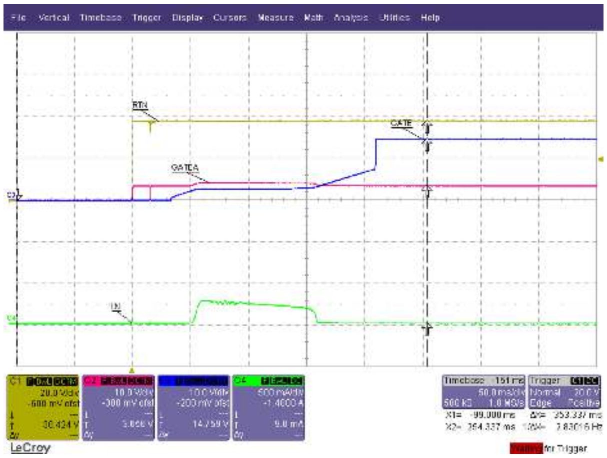



No Load, Scope GND = –48V_A

**Figure 2. Start Up ($V_{IN}$ = 54 V)**

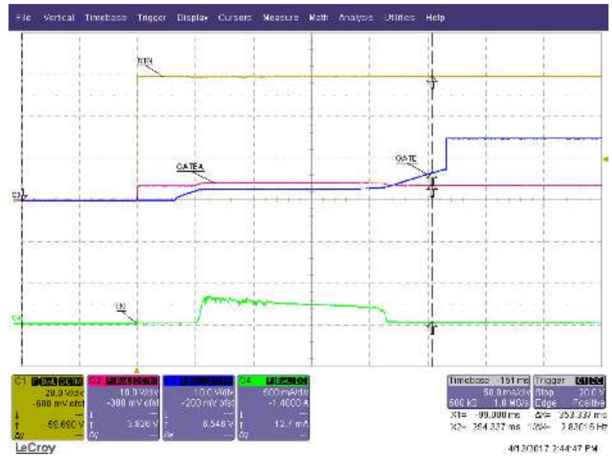

No Load, Scope GND = –48V_A

**Figure 3. Start Up ($V_{IN}$ = 54 V)**



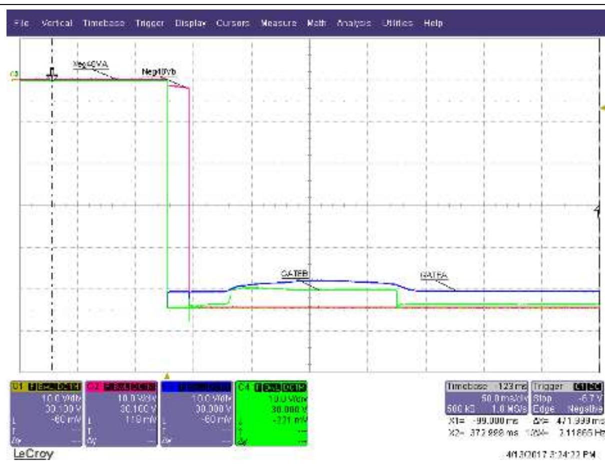

No Load, Scope GND = –48V_A

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




No Load, Scope GND = –48V_A

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

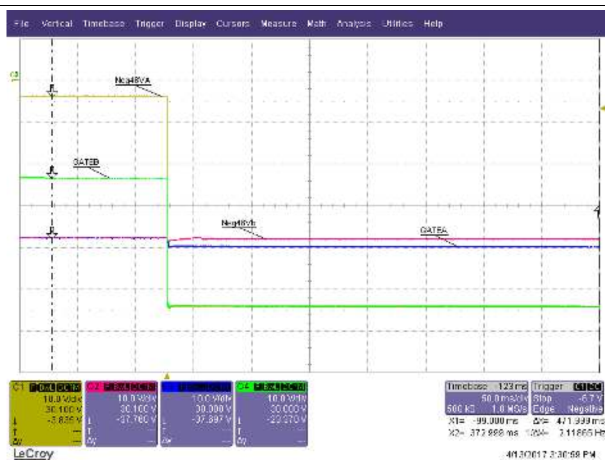



$V_{IN}A$ = 54 V, $V_{IN}B$ = 54 V, No Load, Scope GND = RTN

**Figure 6. Hot Plug Channel A and B Together**

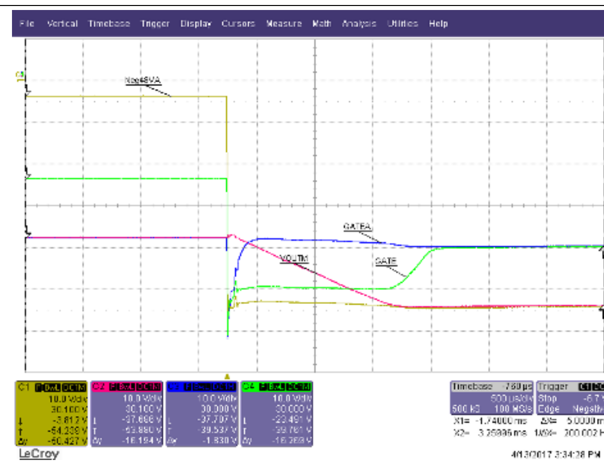

$V_{IN}A$ = 54.5 V, $V_{IN}B$ = 54 V, No Load, Scope GND = RTN

**Figure 7. Hot Plug Channel A and B Together**



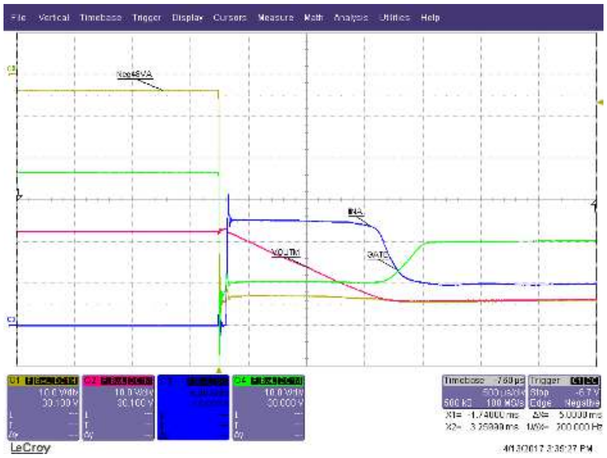

$V_{IN}A$ = 54 V; $V_{IN}B$ = 38 V, Scope GND = RTN, Iload = 5 A

**Figure 8. Hot Plug A After B**



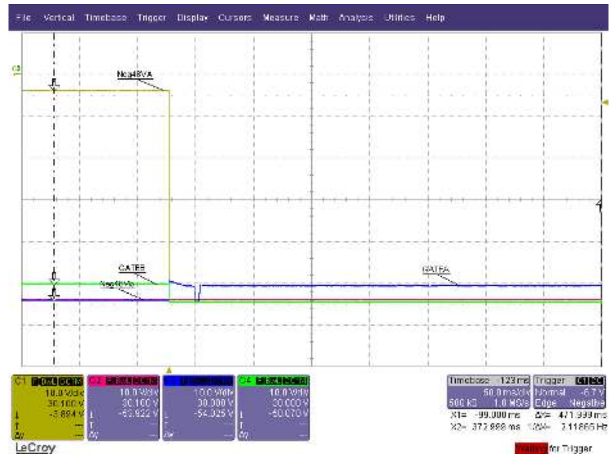

$V_{IN}A$ = 54 V; $V_{IN}B$ = 38 V, Scope GND = RTN, Iload = 5 A

**Figure 9. Hot Plug A After B**



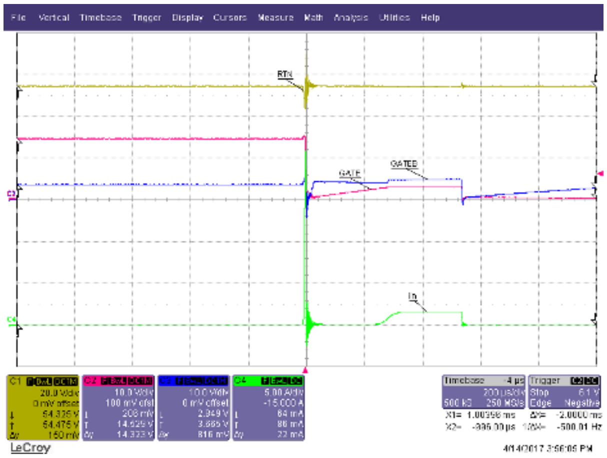

$V_{IN}A$ = 54 V; $V_{IN}B$ = 38 V, Scope GND = RTN, Iload = 5 A

**Figure 10. Hot Plug A After B**



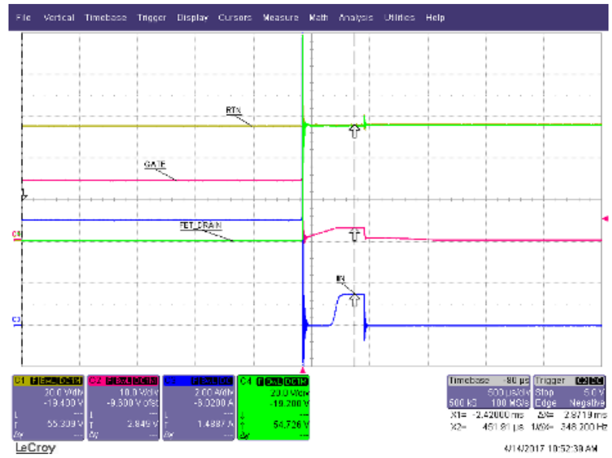

$V_{IN}A$ = 54.5 V; $V_{IN}B$ = 54 V, Scope GND = RTN, No Load

**Figure 11. Hot Plug A After B**



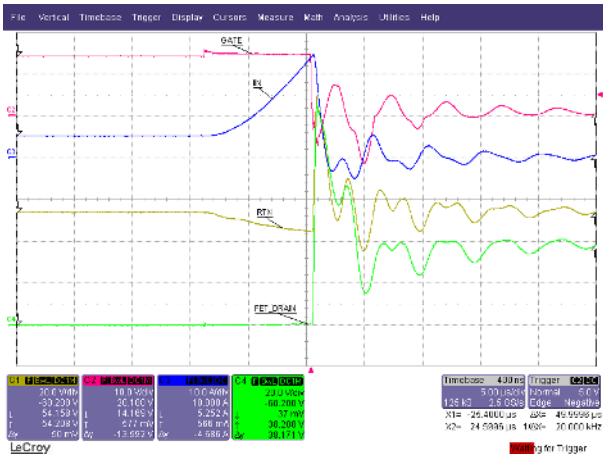

Scope GND = –48V_B, No Load, After Inductor

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



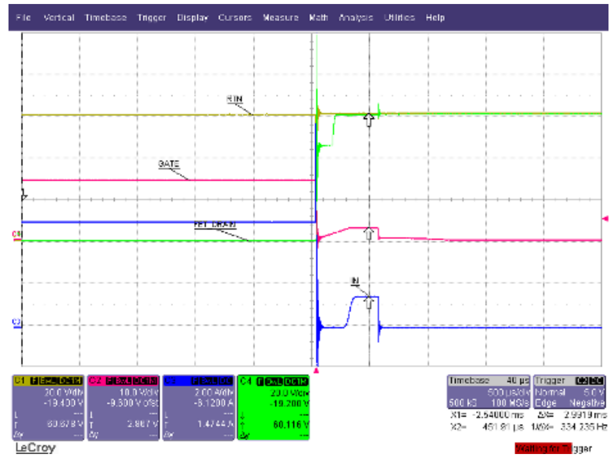

Scope GND = –48V_B, 5-A Load, After Inductor

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



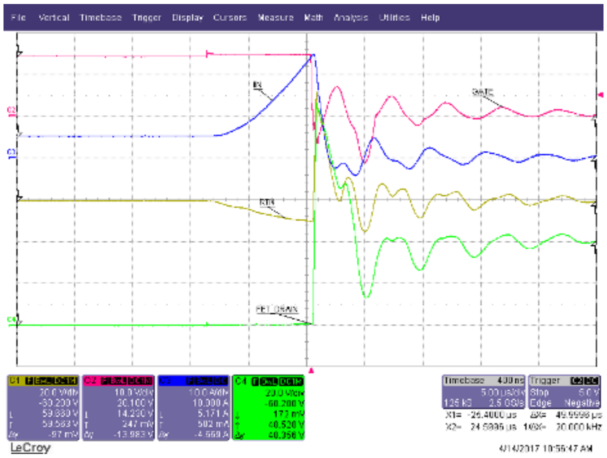

Scope GND = –48V_B, 5A Load, Zoomed in

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



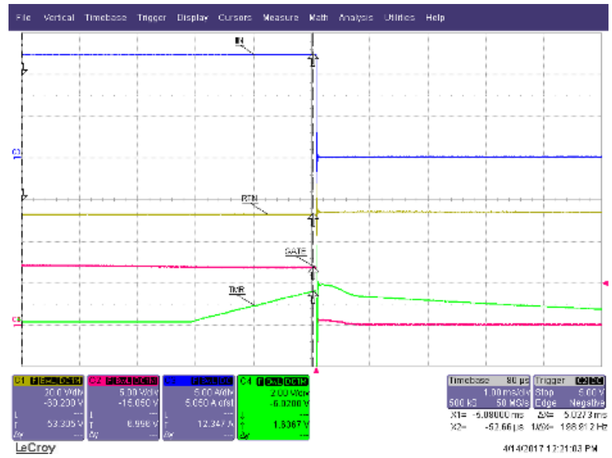

Scope GND = –48V_B, 5-A Load

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



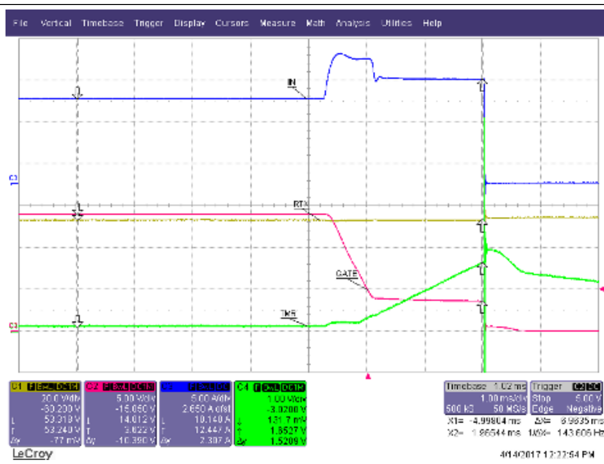

Scope GND = –48V_B, 5-A Load, Zoomed In

**Figure 16. Output Hot Short ($V_{IN}$B = 60 V)**




Scope GND = –48V_A

**Figure 17. Gradual Overcurrent ($V_{IN}$A = 54 V)**

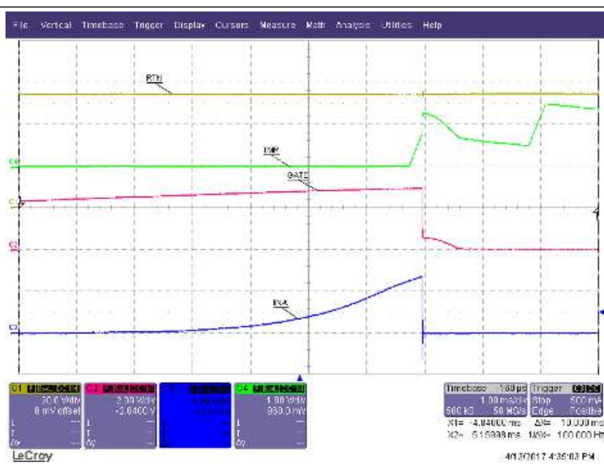



Scope GND = –48V_A

**Figure 18. Load Step Overcurrent**

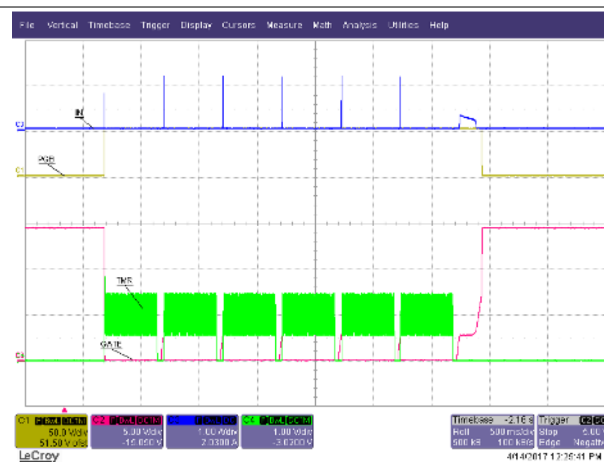

Scope Gnd = –48V_A, $V_{IN}$ = 54 V

**Figure 19. Start Into Short**



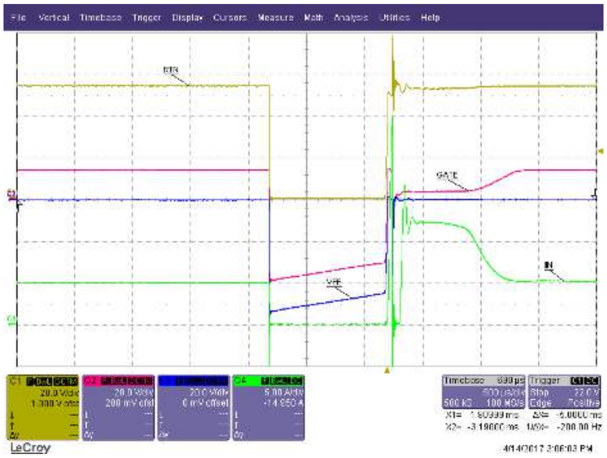

Scope Gnd = –48V_A, $V_{IN}$ = 54 V

**Figure 20. Start Into Short**



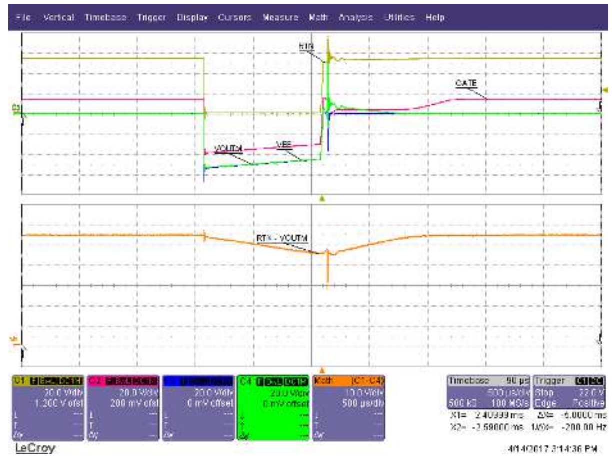

Scope Gnd = –48V_A, $V_{IN}$ = 54 V

**Figure 21. Apply Short and Remove Short**



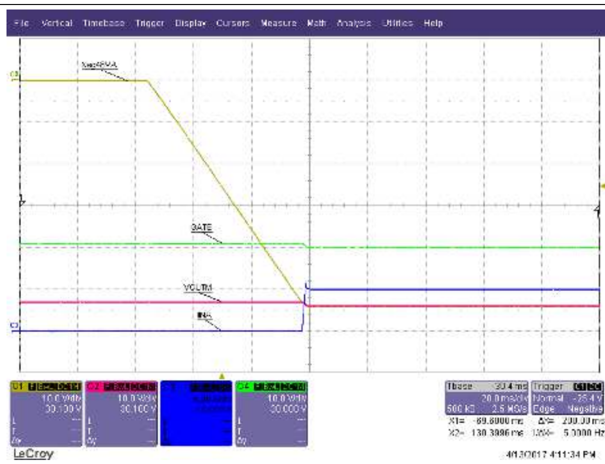
Scope GND = –48V_A, Iload = 5 A

**Figure 22. 1-ms Brown Out**



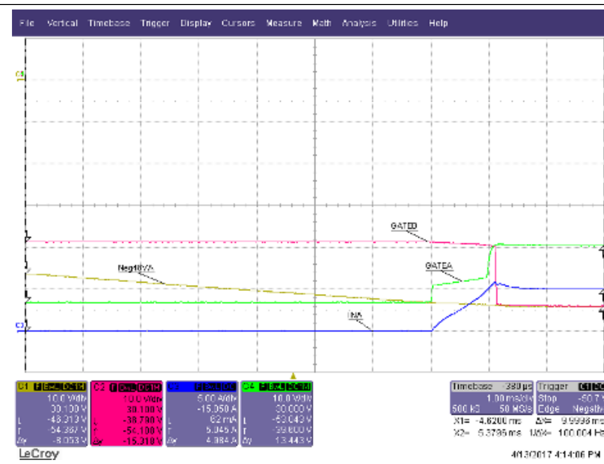
Scope GND = –48V_A, Iload = 5 A

**Figure 23. 1-ms Brown Out**



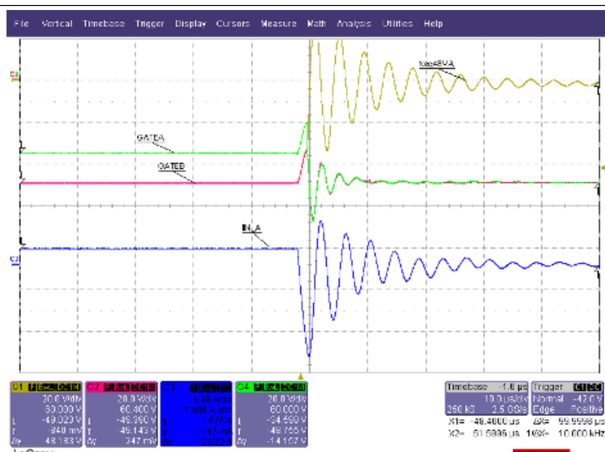
$V_{IN}$B = 53 V, Iload = 5 A, Scope GND = RTN

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



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

**Figure 25. Supply Switch Over (Zoomed in)**

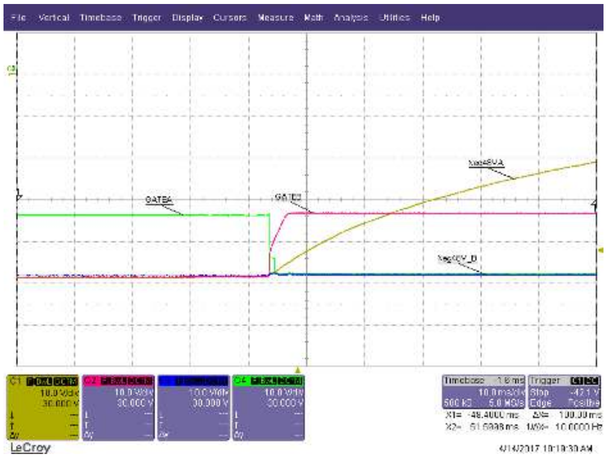


$V_{IN}$A = 54.5 V; $V_{IN}$B = 54 V, Iload = 5 A, Scope GND = RTN

**Figure 26. $V_{IN}$A Short**

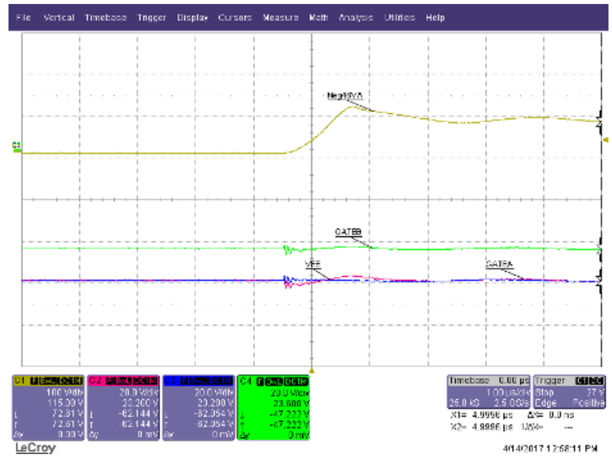
$V_{IN}$A = 54.5 V; $V_{IN}$B = 54 V, Iload = 5 A, Scope GND = RTN

**Figure 27. $V_{IN}$A Short**



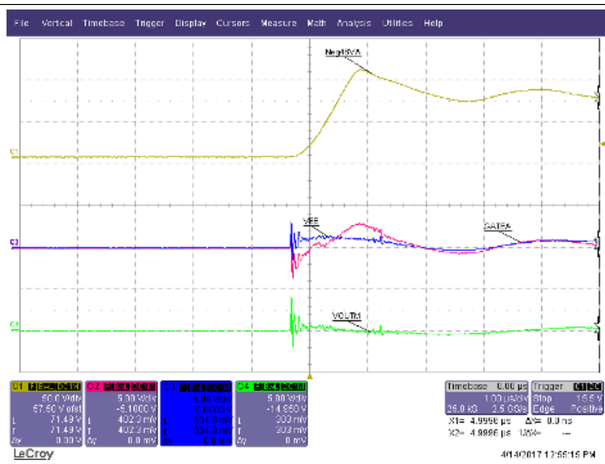
$V_{IN}A$ = 54.5 V; $V_{IN}B$ = 54 V, Iload = 5 A, Scope GND = RTN

**Figure 28. Unplug $V_{IN}$ A**



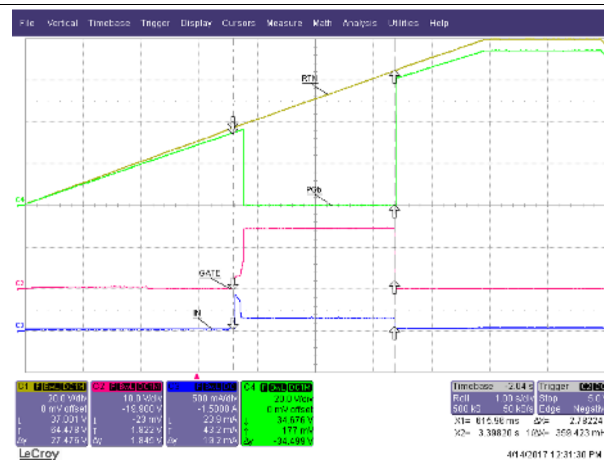
$V_{IN}B$ = 60 V

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



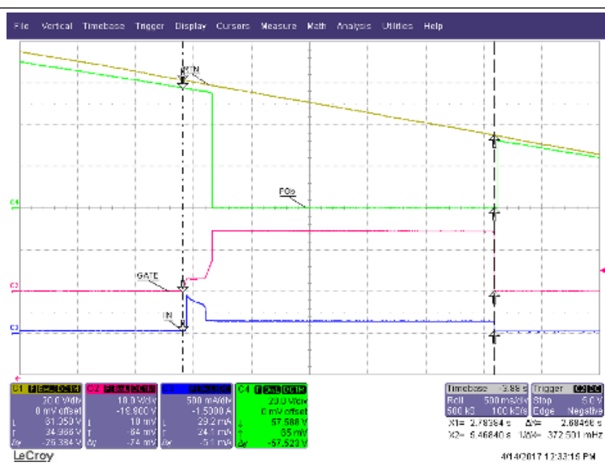
$V_{IN}B$ Floating

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



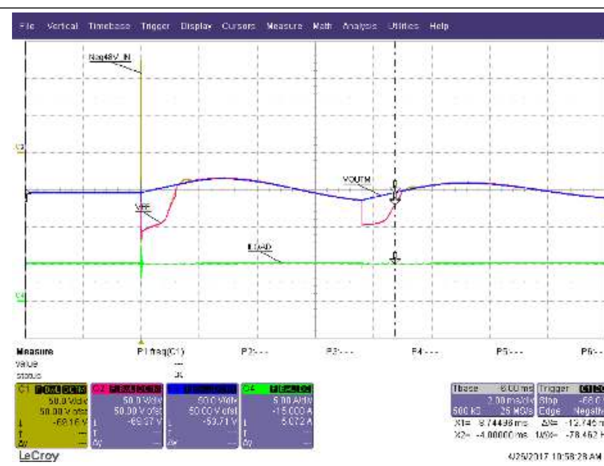
Scope GND = –48V_A, No Load

**Figure 31. Undervoltage and Overvoltage (Rising)**



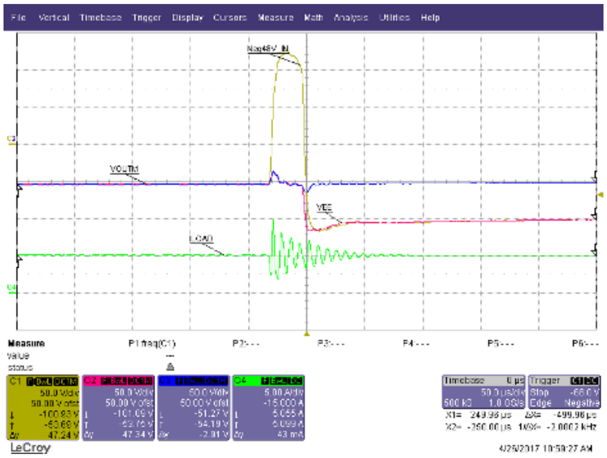
Scope GND = –48V_A, No Load

**Figure 32. Undervoltage and Overvoltage (Falling)**



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

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

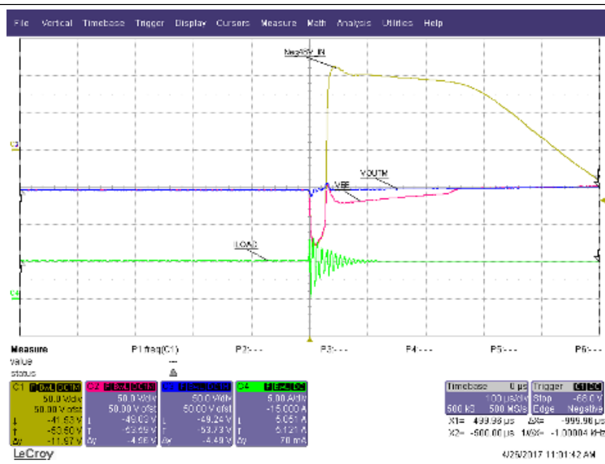



Scope GND = RTN, 5-A Load, Per IEC61000-4-5

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

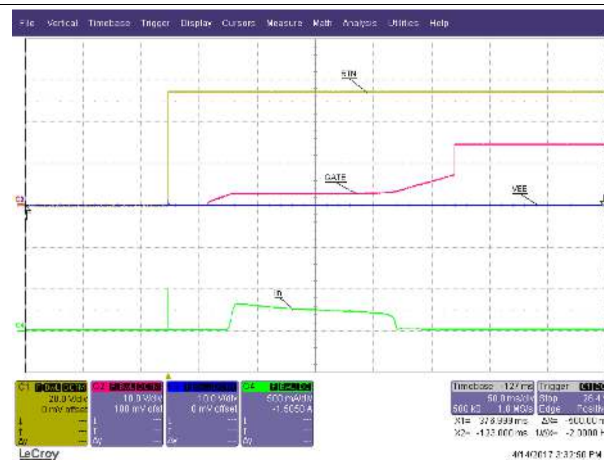

Scope GND = RTN, 5-A Load, Per IEC61000-4-5

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



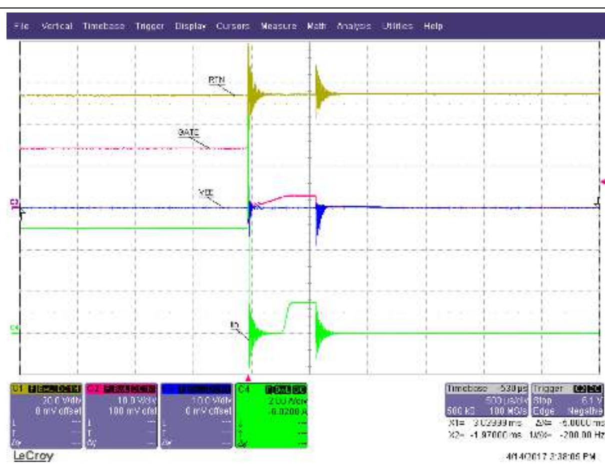

Scope GND = RTN, 5-A Load, Per IEC61000-4-5

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



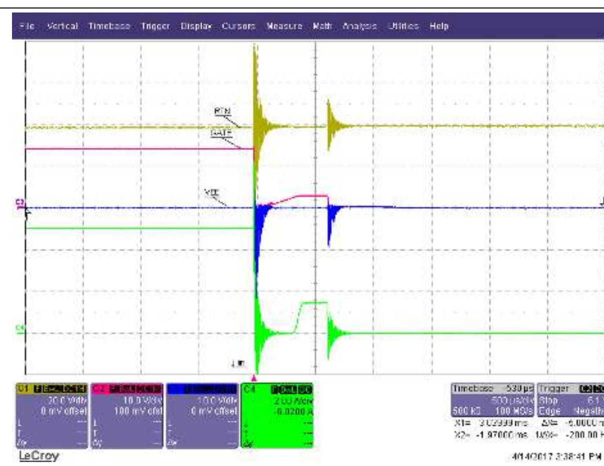

L1 = 20 µH, Scope GND = –48V_A

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



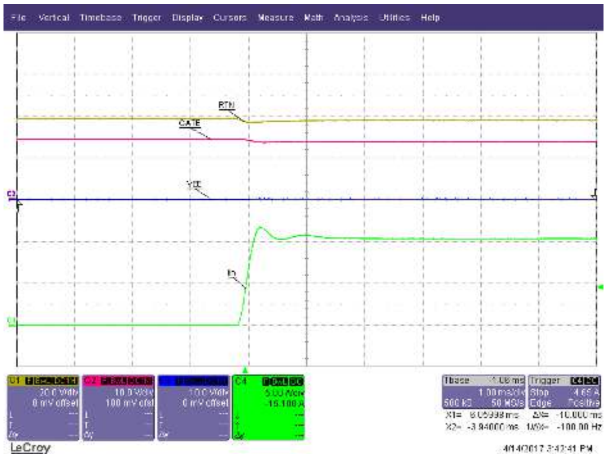

L1 = 20 µH, Scope GND = –48V_A

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



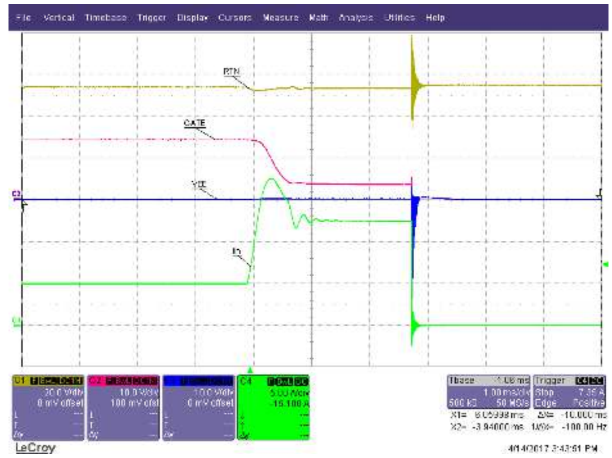

L1 = 20 µH, Scope GND = –48V_A

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



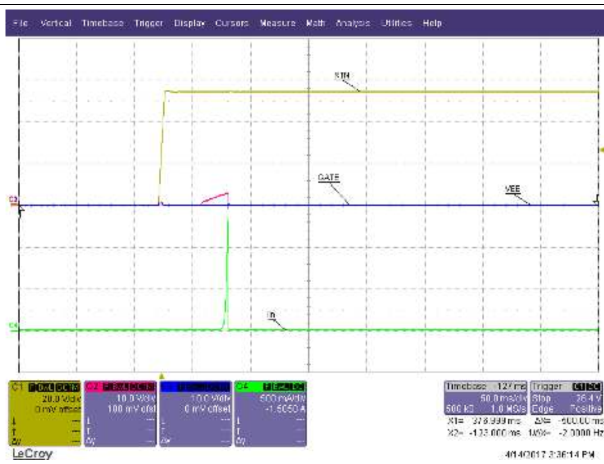

L1 = 20 µH, Scope GND = –48V_A,

**Figure 40. Load Step (0 A–11 A)**



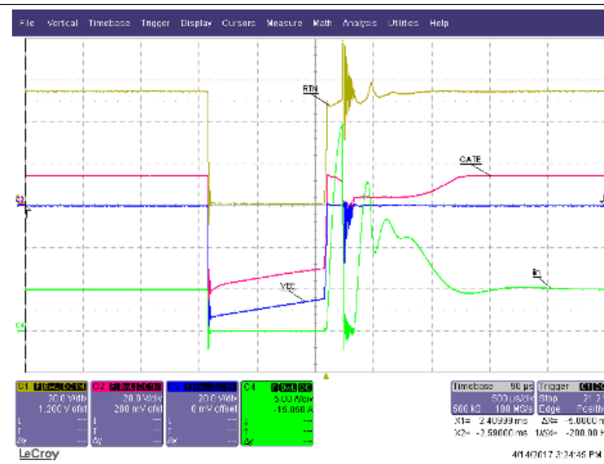

L1 = 20 µH, Scope GND = –48V_A

**Figure 41. Load Step Into Overcurrent**




L1 = 20 µH, Scope GND = –48V_A

**Figure 42. Start Into Short**




L1 = 20 µH, 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 µF, 100 V, ±10%, X7R, 1206 | 1206 | C3216X7R2A104K160AA | TDK |
| C2 | 1 | 0.015uF | CAP, CERM, 0.015 µF, 100 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 | CGA3E2X7R2A153K080AA | TDK |
| C3, C4 | 2 | 0.1uF | CAP, CERM, 0.1 µF, 250 V, ±10%, X7R, 1206 | 1206 | GRM31CR72E104KW03L | Murata |
| C6 | 1 | 0.15uF | CAP, CERM, 0.15 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 | CGA3E3X7R1H154K080AB | TDK |
| C10, C11 | 2 | 330uF | CAP, AL, 330 µF, 100 V, ±20%, 0.153 ohm, SMD | SMT Radial K16 | EEV-FK2A331M | Panasonic |
| C14 | 1 | 1uF | CAP, CERM, 1 µF, 100 V, ±20%, X7R, 1206 | 1206 | C3216X7R2A105M160AA | TDK |
| C16, C17 | 2 | 1000pF | CAP, CERM, 1000 pF, 250 V, ±10%, X7R, 0805 | 0805 | GRM21AR72E102KW01D | Murata |
| C20 | 1 | 0.033uF | CAP, CERM, 0.033 µF, 100 V, ±10%, X7R, 0805 | 0805 | GRM21BR72A333KA01L | Murata |
| C21 | 1 | 0.01uF | CAP, CERM, 0.01 µF, 100 V, ±1%, C0G/NP0, 0805 | 0805 | C0805C103F1GACTU | 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 µH, 25 A, 0.00274 ohm, SMD | 18.3x8.9x18.2mm | 7443557560 | Wurth 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 | CRCW0805301KFKEA | Vishay-Dale |
| R2 | 1 | 200k | RES, 200 k, 1%, 0.125 W, 0805 | 0805 | CRCW0805200KFKEA | Vishay-Dale |
| R3 | 1 | 16.2k | RES, 16.2 k, 1%, 0.75 W, AEC-Q200 Grade 0, 2010 | 2010 | CRCW201016K2FKEF | Vishay-Dale |
| R5, R6 | 2 | 499k | RES, 499 k, 1%, 0.25 W, 1206 | 1206 | CRCW1206499KFKEA | Vishay-Dale |
| R7 | 1 | 49.9k | RES, 49.9 k, 1%, 0.1 W, 0603 | 0603 | CRCW060349K9FKEA | Vishay-Dale |
| R8 | 1 | 10.0 | RES, 10.0, 1%, 0.25 W, 1206 | 1206 | CRCW120610R0FKEA | Vishay-Dale |
| R10, R11 | 2 | 1.00k | RES, 1.00 k, 1%, 0.125 W, 0805 | 0805 | CRCW08051K00FKEA | 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 | CRCW06031K00FKEA | Vishay-Dale |
| R16 | 1 | 4.75k | RES, 4.75 k, 1%, 0.1 W, 0603 | 0603 | CRCW06034K75FKEA | Vishay-Dale |
| R17, R31, R32, R33, R34 | 5 | 10.0 | RES, 10.0 ohm, 1%, 0.1W, 0603 | 0603 | CRCW060310R0FKEA | 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 | CRCW06035K62FKEA | Vishay-Dale |
| R20 | 1 | 10.0 | RES, 10.0, 1%, 0.1 W, 0603 | 0603 | CRCW060310R0FKEA | 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 | CRCW0805499KFKEA | 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_Keystone_Miniature | 5015 | Keystone |
| U1 | 1 | | TPS2352x Family, PW0016A | PW0016A | TPS23525PW | Texas Instruments |
| C5, C12 | 0 | 1uF | CAP, CERM, 1 µF, 200 V, ±10%, X7R, 2225 | 2225 | VJ2225Y105KBCAT4X | Vishay-Vitramon |
| C8, C9 | 0 | 330uF | CAP, AL, 330 µF, 100 V, ±20%, 0.153 ohm, SMD | SMT Radial K16 | EEV-FK2A331M | Panasonic |
| C13 | 0 | 0.068uF | CAP, CERM, 0.068 µF, 50 V, ±10%, X7R, 0603 | 0603 | GRM188R71H683KA93D | Murata |
| C15, C18 | 0 | 10uF | CAP, CERM, 10 µF, 10 V, ±20%, X5R, 0603 | 0603 | C1608X5R1A106M080AC | TDK |
| C19 | 0 | 0.1uF | CAP, CERM, 0.1uF, 16V, ±5%, X7R, 0603 | 0603 | 0603YC104JAT2A | AVX |
| C22, C23 | 0 | 0.01uF | CAP, CERM, 0.01 µF, 25 V, ±10%, X7R, 0603 | 0603 | GRM188R71E103KA01D | Murata |
| C24 | 0 | 0.1uF | CAP, CERM, 0.1 µF, 250 V, ±10%, X7T, 0805 | 0805 | C2012X7T2E104K125AA | TDK |
| C25 | 0 | 2.2uF | CAP, CERM, 2.2 µF, 16 V, ±10%, X5R, 0603 | 0603 | GRM188R61C225KE15D | 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 | CRCW120610R0FKEA | Vishay-Dale |
| R12 | 0 | 30.1k | RES, 30.1 k, 1%, 0.1 W, 0603 | 0603 | CRCW060330K1FKEA | Vishay-Dale |
| R15 | 0 | 100 | RES, 100, 1%, 0.1 W, 0603 | 0603 | CRCW0603100RFKEA | 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 | CRCW060310R0FKEA | Vishay-Dale |
| R27 | 0 | 100 | RES, 100, 1%, 1 W, AEC-Q200 Grade 0, 2512 | 2512 | CRCW2512100RFKEG | Vishay-Dale |
| R28 | 0 | 2.80Meg | RES, 2.80 M, 1%, 0.1 W, 0603 | 0603 | CRCW06032M80FKEA | 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 semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

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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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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