



---

***48-V to 3.3-V RCD Forward with  
UCC35705 Voltage-Mode Control and  
Self-Driven Synchronous  
Rectification***

*User's Guide*

### EVM IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

**EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.**

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive.**

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.**

Please read the EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265

Copyright © 2003, Texas Instruments Incorporated

### **DYNAMIC WARNINGS AND RESTRICTIONS**

It is important to operate this EVM within the input voltage range of 0 V<sub>DC</sub> to 72 V<sub>DC</sub>.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 50°C. The EVM is designed to operate properly with certain components above 50°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265

Copyright © 2003, Texas Instruments Incorporated

# **48-V to 3.3-V RCD Forward with UCC35705 Voltage-Mode Control and Self-Driven Synchronous Rectification**

Peter James Miller

Power Supply Control Products

## Contents

|           |  |           |
|-----------|--|-----------|
| <b>1</b>  | <b>Introduction</b> .....                        | <b>5</b>  |
| <b>2</b>  | <b>Features</b> .....                            | <b>5</b>  |
| <b>3</b>  | <b>Description</b> .....                         | <b>5</b>  |
| <b>4</b>  | <b>Schematic</b> .....                           | <b>6</b>  |
| <b>5</b>  | <b>Test Set Up</b> .....                         | <b>7</b>  |
| <b>6</b>  | <b>Output Load (LOAD1)</b> .....                 | <b>7</b>  |
| <b>7</b>  | <b>V<sub>CC</sub> dc Bias Supply (VCC)</b> ..... | <b>7</b>  |
| <b>8</b>  | <b>dc Input Source (VIN)</b> .....               | <b>7</b>  |
| <b>9</b>  | <b>Fan</b> .....                                 | <b>8</b>  |
| <b>10</b> | <b>Power Up and Down Test Procedure</b> .....    | <b>8</b>  |
| <b>11</b> | <b>EVM Assembly Drawing and Layout</b> .....     | <b>9</b>  |
| <b>12</b> | <b>List of Materials</b> .....                   | <b>10</b> |

## List of Figures

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>UCC35705EVM Board Schematic</b> .....        | <b>6</b>  |
| <b>2</b> | <b>Recommended EVM Test Configuration</b> ..... | <b>7</b>  |
| <b>3</b> | <b>Topside Component Assembly</b> .....         | <b>9</b>  |
| <b>4</b> | <b>Top Layer – Signal Traces</b> .....          | <b>9</b>  |
| <b>5</b> | <b>Bottom Layer – Isolated Grounds</b> .....    | <b>10</b> |

## List Of Tables

|          |                                |           |
|----------|--------------------------------|-----------|
| <b>1</b> | <b>List of Materials</b> ..... | <b>10</b> |
|----------|--------------------------------|-----------|

## 1 Introduction

The UCC35705 voltage mode controller with voltage feed-forward provides the control of this telecom (36 V<sub>DC</sub> to 72 V<sub>DC</sub>) to 3.3-V<sub>DC</sub> converter with synchronous rectification. Capable of supplying 10 A of output current at 3.3 V<sub>DC</sub> with up to 85% efficiency, UCC35705EVM uses self-driven, high-speed, very low R<sub>DS(on)</sub> MOSFETs for improved efficiency and high-speed operation.

### **WARNING:**

**Failure to exercise proper safety precautions or misuse of the module may result in damage to the module and/or injury to the operator.**

## 2 Features

- Full range telecom input 36 V<sub>DC</sub> to 72 V<sub>DC</sub>
- 3.3 V<sub>DC</sub> at 10 A<sub>DC</sub> for 33-W output
- 1500-V isolation
- Business card sized 2.0" x 3.5" single component side board
- Optically isolated voltage mode control with voltage feed-forward
- 500-kHz high-speed oscillator frequency
- Peak 85% efficiency
- Peak-by-peak current limit protection
- Low input voltage protection
- RCD transformer reset clamp
- Externally programmable soft-start circuit

## 3 Description

UCC35705EVM uses the Texas Instruments UCC35705 high-speed, single-ended PWM with voltage feed-forward in a forward configuration with RCD reset clamp and synchronous rectifier output. This evaluation module highlights the high-speed capabilities of the UCC35705 PWM, operating at 500 kHz. The UCC35705 is designed to use an external switch driver, allowing the user to select a driver, based on the switching frequency and switching MOSFET. This also allows the UCC35705 and its sensitive feedback signals to be located in a lower noise environment further from the high current power devices without lengthening the high-current gate drive path. UCC35705EVM uses a single TPS2829 ±2-A driver in a 5-pin SOT–23 package to provide the high drive currents necessary for high-speed operation. Constantly improving MOSFET technology and higher-current MOSFET drivers such as the UCC27324 or UCC27322 would allow for even higher speed operation.

The self-driving synchronous rectification output stage of the converter dramatically improves efficiency by reducing the voltage drop through the rectifier stage without additional timing and driver circuitry by using the transformer's secondary to drive the gates of both synchronous devices.

## 4 Schematic

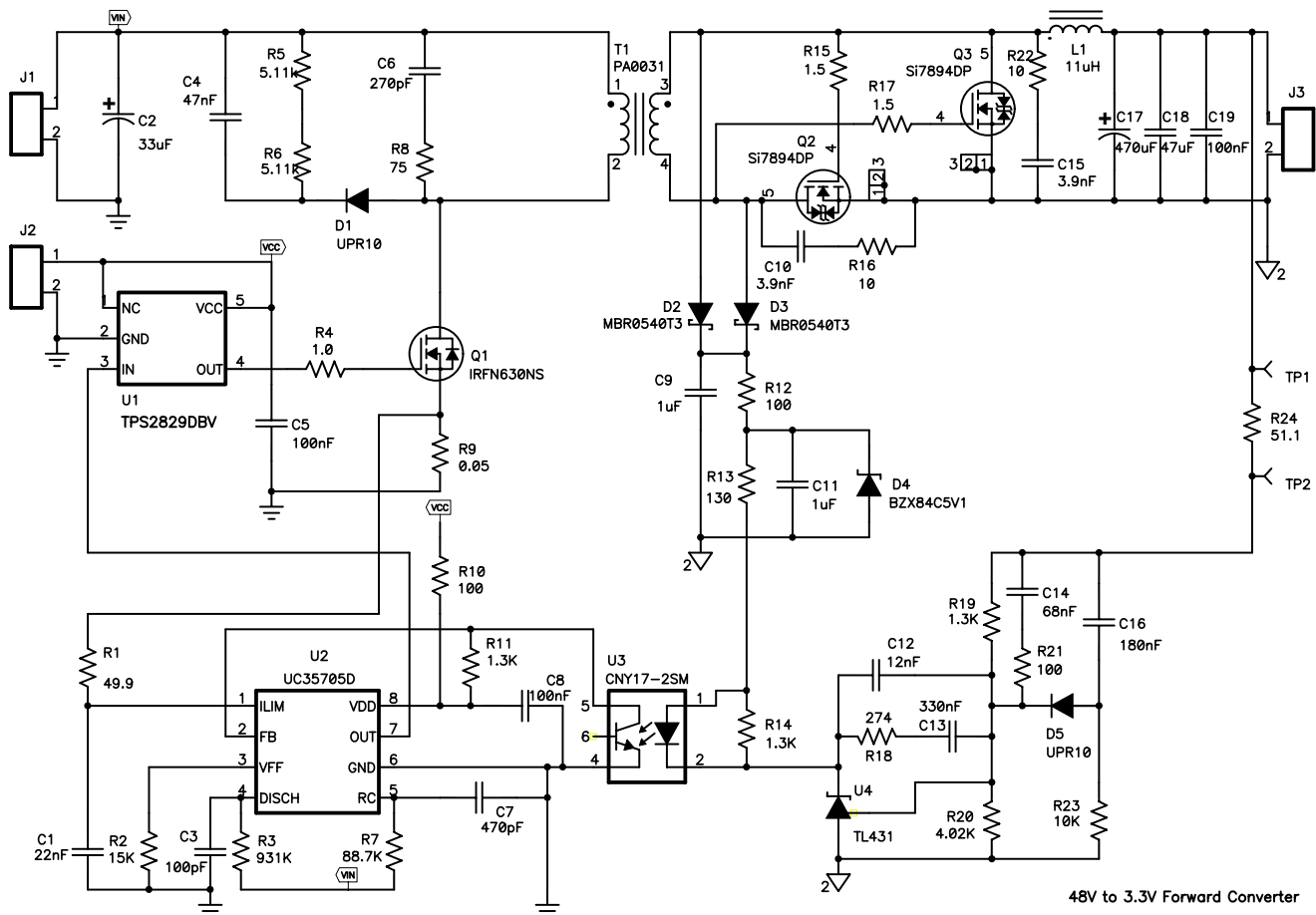
UCC35705EVM is built around the UCC35705 high speed voltage mode controller in a forward converter configuration. J1 provides the 48- $V_{DC}$  nominal, 36- $V_{DC}$  to 72- $V_{DC}$  supply to the power transformer (T1) and primary switch (Q1). The output stage uses synchronous rectifiers (Q2 and Q3) to rectify the transformer voltage, which is then smoothed by the output filter made from the output inductor (L1) and output capacitors (C17, C18 and C19).

The UCC35705 is configured with a unity gain buffer feedback pin designed to use a secondary side compensation network and optoisolator (U3).

The secondary side compensation network is a type three network with two zeros to cancel the voltage mode control double pole from the output L/C tank filter and two high-frequency poles to increase the control bandwidth and improve the supplies transient response. The feedback network uses a TL431 adjustable shunt regulator (U4) for low cost and high noise immunity while the soft-start network (C16, R23 and D5) forces the feedback network to come up slowly and minimizes overshoot during powerup.

A secondary dc input (J2) provides a  $V_{CC}$  bias voltage for the UCC35705 PWM (U2) and the TPS2829 MOSFET driver (U1). UCC35705EVM does not have self-biasing circuitry and will not operate without this secondary dc input.

UCC35705EVM is designed with a 50- $\Omega$  feedback resistor (R24) and two test points (TP1 and TP2) to allow for non-invasive analysis of the converters loop response with a network analyzer.



**Figure 1. UCC35705EVM Board Schematic**

## 5 Test Set Up

Testing and evaluation of UCC35705EVM requires two dc voltage supplies ( $V_{IN}$  and  $V_{CC}$ ) and an output load (LOAD1) as shown in Figure 2. Note that the primary side ground J1 and J2 is isolated from the secondary side ground (J3) and J3 has the opposite polarity of J1 and J2. Loop test points TP1 ( $V_{OUT}$ ) and TP2 (Feedback) are connected by a 50- $\Omega$  resistor and allow the user to connect a network analyzer for loop response evaluation.

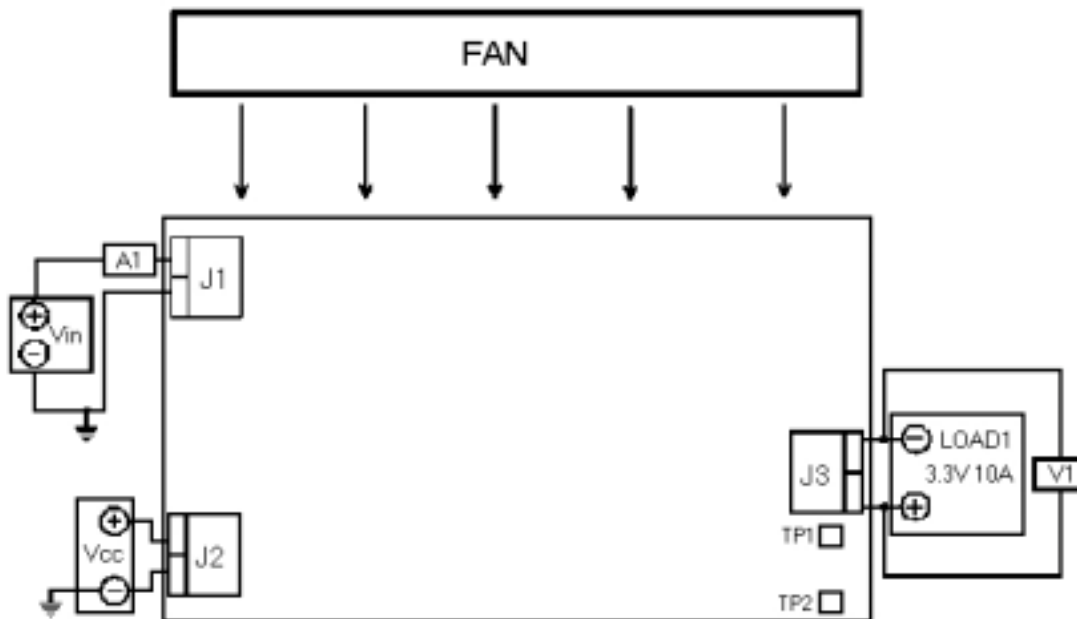


Figure 2. Recommended EVM Test Configuration

## 6 Output Load (LOAD1)

For the output load to  $V_{OUT}$ , a programmable electronic load set to constant current mode and capable of sinking up to 10  $A_{DC}$  is used. UCC35705EVM uses isolated grounds between input and output.  $V_{IN}$  and  $V_{CC}$  (J1 and J2) are referenced to the primary side, electrically isolated from  $V_{OUT}$  (J3), which is secondary side referenced.

The dc voltage meter V1 is connected directly to the output terminals (J3) to minimize voltage error from drops between the output terminals (J3) and output load (LOAD1)

## 7 $V_{CC}$ dc Bias Supply ( $V_{CC}$ )

UCC35705EVM is not designed with self-biasing circuitry and requires an external bias supply to provide power to the PWM and driver circuitry.  $V_{CC}$  is a variable dc voltage source capable of supplying between 0  $V_{DC}$  and 12  $V_{DC}$  at no less than 300 mA.  $V_{CC}$  is connected to J2 as shown in Figure 2.

## 8 dc Input Source ( $V_{IN}$ )

The input voltage source is a variable dc source capable of supplying between 0  $V_{DC}$  and 72  $V_{DC}$  at no less than 1.5  $A_{DC}$ , and connected to the input terminals (J1) as shown in Figure 2. For fault protection to the EVM, it is good common practice to current limit the source to no more than 2  $A_{DC}$ . A dc ammeter (A1) inserted between the input source ( $V_{IN}$ ) and input terminals (J1) ensures accurate input current readings.

## 9 Fan

Components in the UCC35705EVM reach temperatures exceeding 60°C during operation. Because UCC35705EVM is not enclosed to facilitate probing and circuit evaluation, it is recommended that a small fan capable of at least 20 cfm is placed near the module, blowing across the evaluation board to reduce component surface temperature and the risk of operator injury.

## 10 Power Up and Down Test Procedure

The following procedure is recommended for powering up and shutting down the EVM. Whenever the EVM is running the fan should be turned on. For safety reasons the EVM should never be left running unattended.

1. Working at an ESD workstation, make sure that any wrist straps, boot straps or mats are connected referencing the user to earth ground before power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.
2. Set  $V_{CC}$  supply to 0 V and connect  $V_{CC}$  to J1 as shown in Figure 2.
3. Prior to connecting the dc input source,  $V_{IN}$ , set it to 0 V. It is advisable to also limit the source current from  $V_{IN}$  to 1 A maximum. Connect the ammeter A1 (0-A to 1-A range) between VIN and J2 as shown in Figure 9. Make sure  $V_{IN}$  is initially set to 0 V.
4. Connect LOAD1 and the voltmeter, V1 to J1 as shown in Figure 2. Set LOAD1 to constant current mode to sink 0 A<sub>DC</sub> before  $V_{IN}$  and  $V_{CC}$  are applied.
5. Increase  $V_{CC}$  from 0 V to 12 V<sub>DC</sub> and then set to 10.5 V<sub>DC</sub>. Even with  $V_{CC}$  applied, the control and switching circuitry should not generate an output. The voltage feed forward function of the UCC35705 inhibits any output.
6. Increase  $V_{IN}$  from 0 V to 48 V<sub>DC</sub>, while monitoring the output voltage on V1. V1 should not start to rise before 30 V<sub>DC</sub> and should be in regulation (3.3 V) by 36 V<sub>DC</sub>.
7. Vary LOAD1 anywhere between 0 A to 10 A<sub>DC</sub>, making sure to turn on the fan blowing air directly on the EVM when running the EVM with a load.
8. Vary the input voltage between 36 V<sub>DC</sub> and 72 V<sub>DC</sub>.
9. Set the electronic load to 0 A then shut off.
10. Set VIN to 0 V then shut off.
11. Set  $V_{CC}$  to 0 V then shut off.

### WARNING:

**The voltage at the switch node between T1, Q1, D1 and R8 and the reset node C4, R6 and D1 can exceed 75 V and pose a shock hazard during operation. Use proper precautions when working around this switch node.**



## 11 EVM Assembly Drawing and Layout

Figure 3, shows the top-side component placement for the EVM, as well as pin numbers and component polarity where necessary. A two-sided PCB was designed using the top layer for signal traces and a bottom layer split ground plane. The PCB dimensions are 3.5" x 2.0" with a design goal of maintaining all components on one side of a business card sized PCB. All components are standard OTS surface mount components and placed on the top-side of the PCB only. The copper etch, shown looking through the top of the PCB, for both top and bottom layers are also included in Figure 4 and Figure 5.

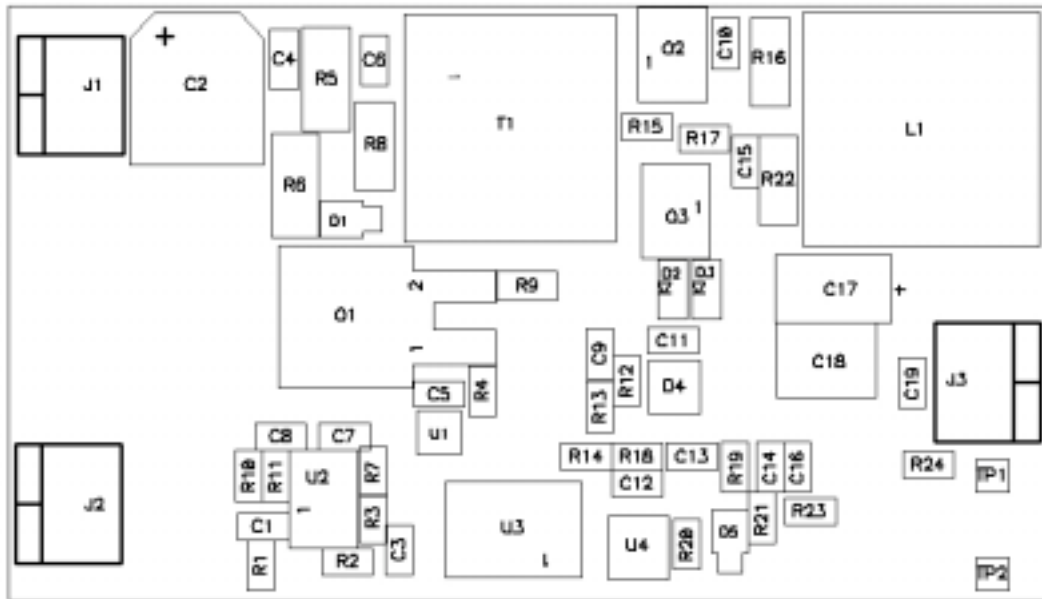


Figure 3. Topside Component Assembly

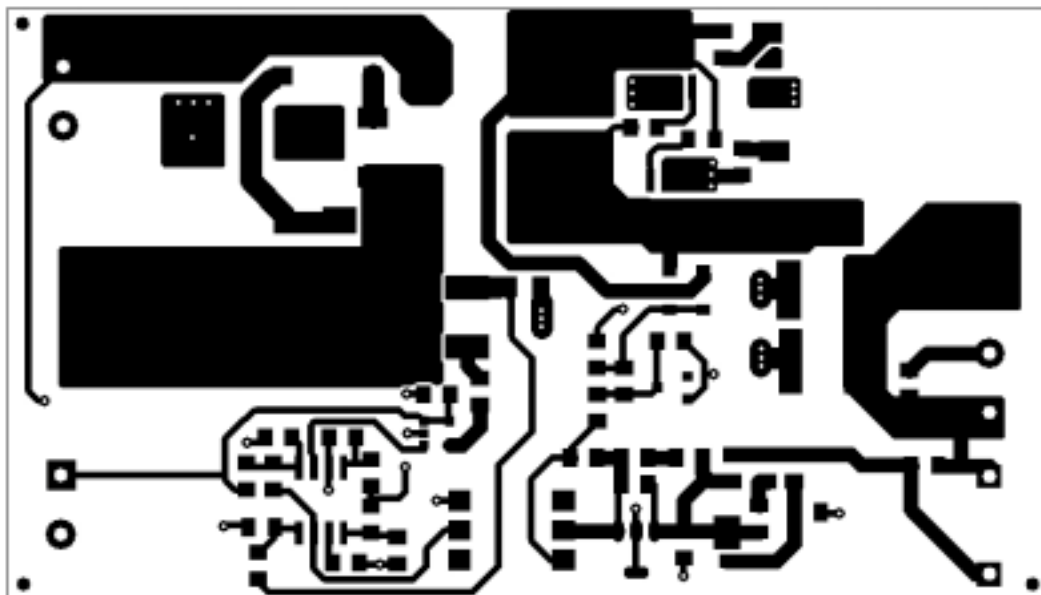


Figure 4. Top Layer – Signal Traces

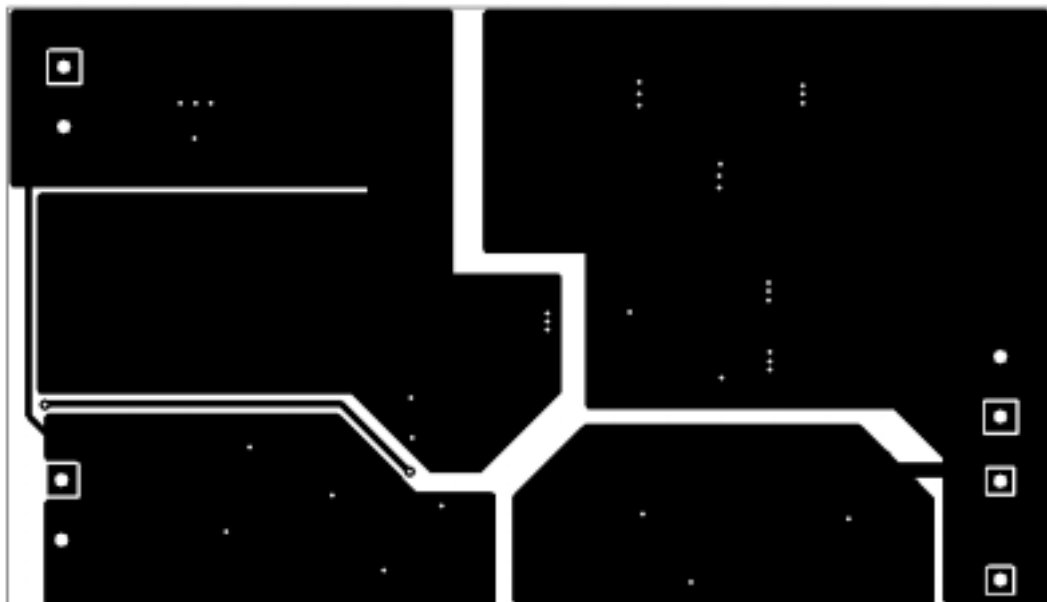


Figure 5. Bottom Layer – Isolated Grounds

## 12 List Of Materials

Table 1 below lists the EVM components as configured corresponding to the schematic shown in Figure 1. Part types and manufacturers can be modified according to specific application requirements.

Table 1. List of Materials

|           | Reference   | Qty | Description                          | Manufacturer | Part Number      |
|-----------|-------------|-----|--------------------------------------|--------------|------------------|
| Capacitor | C1          | 1   | Ceramic, X7R, 22 nF, 50 V, 10%       | Vishay       | VJ0805Y223KXAAB  |
|           | C2          | 1   | Aluminum, 33 $\mu$ F, 100 V, 20%     | Panasonic    | ECEV2AA330P      |
|           | C3          | 1   | Ceramic, NPO, 100 pF, 50 V, 5%       | Vishay       | VJ0805A101JXAAT  |
|           | C4          | 1   | Ceramic, X7R, 47 nF, 100 V, 10%      | Vishay       | VJ1206Y473KXBAT  |
|           | C5, C8, C19 | 3   | Ceramic, X7R, 100 nF, 50 V, 10%      | Vishay       | VJ0805Y104KXAAT  |
|           | C6          | 1   | Ceramic, NPO, 270 pF, 100 V, 5%      | Vishay       | VJ0805A271JXBAT  |
|           | C7          | 1   | Ceramic, NPO, 470 pF, 50 V, 5%       | Vishay       | VJ0805A471JXAAT  |
|           | C9, C11     | 2   | Ceramic, X5R, 1.0 $\mu$ F, 16 V, 20% | TDK          | C2012X7R1C105M   |
|           | C10, C15    | 2   | Ceramic, X7R, 3.9 nF, 50 V, 10%      | Vishay       | VJ0805Y392KXAAT  |
|           | C12         | 1   | Ceramic, X7R, 12 nF, 50 V, 10%       | Vishay       | VJ0805Y123KXAAB  |
|           | C13         | 1   | Ceramic, X7R, 330 nF, 25 V, 10%      | Vishay       | VJ0805Y334KXXAT  |
|           | C14         | 1   | Ceramic, X7R, 68 nF, 50 V, 10%       | Vishay       | VJ0805Y683KXAAB  |
|           | C16         | 1   | Ceramic, X7R, 180 nF, 25 V, 10%      | Vishay       | VJ0805Y184KXXAT  |
|           | C17         | 1   | Tantalum, 470 $\mu$ F, 6.3 V, 20%    | AVX          | TPSD477M006R0100 |
|           | C18         | 1   | Ceramic, X5R, 47 $\mu$ F, 16 V, 20%  | TDK          | C5750X5R1C476M   |

|                | Reference     | Qty                                     | Description                                   | Manufacturer            | Part Number           |
|----------------|---------------|---|---|-------------------------|-----------------------|
| Diode          | D1, D5        | 2                                       | 100 V, 2.5 A                                  | Microsemi               | UPR10                 |
|                | D2, D3        | 2                                       | Schottky, 40 V, 0.5 A                         | On Semiconductor        | MBR0540T3             |
|                | D4            | 1                                       | Zener, 5.1 V, 0.25 A                          | Fairchild Semiconductor | BZX84C5V1             |
| Terminal Block | J1, J2, J3    | 3                                       | 2-pin, 15 A                                   | OST                     | ED500/2DS             |
| Inductor       | L1            | 1                                       | 11 $\mu$ H, 10 A, SMD Planar                  | Payton                  | 90004                 |
| Transistor     | Q1            | 1                                       | NCH-FET, 9.3 A, 200 V                         | IR                      | IRF630NS              |
|                | Q2, Q3        | 2                                       | NCH-FET, 25 A, 30 V                           | Vishay                  | Si7894DP              |
| Resistor       | R1            | 1                                       | Thick Film, 49.9 $\Omega$ , 0.125 W, 1%       | Vishay                  | CRCW080549R9F100RT6   |
|                | R2            | 1                                       | Thick Film, 15 k $\Omega$ , 0.125 W, 1%       | Vishay                  | CRCW08051502F100RT6   |
|                | R3            | 1                                       | Thick Film, 931 k $\Omega$ , 0.125 W, 1%      | Vishay                  | CRCW08059313F100RT6   |
|                | R4            | 1                                       | Thick Film, 1.0 $\Omega$ , 0.125 W, 1%        | Vishay                  | CRCW08051R00F100RT6   |
|                | R5, R6        | 2                                       | Thick Film, 5.11 k $\Omega$ , 1 W, 1%         | Vishay                  | CRCW25125111F100RT6   |
|                | R7            | 1                                       | Thick Film, 88.7 k $\Omega$ , 0.125 W, 1%     | Vishay                  | CRCW08058872F100RT6   |
|                | R8            | 1                                       | Thick Film, 75 $\Omega$ , 0.5 W, 1%           | Vishay                  | CRCW201075R0F100RT7   |
|                | R9            | 1                                       | Power Metal Strip, 0.05 $\Omega$ , 0.25 W, 1% | Vishay                  | WSL1206_0.05_1.0%_R86 |
|                | R10, R12, R21 | 3                                       | Thick Film, 100 $\Omega$ , 0.125 W, 1%        | Vishay                  | CRCW08051000F100RT6   |
|                | R11, R14, R19 | 3                                       | Thick Film, 1.3 k $\Omega$ , 0.125 W, 1%      | Vishay                  | CRCW08051301F100RT6   |
|                | R13           | 1                                       | Thick Film, 130 $\Omega$ , 0.125 W, 1%        | Vishay                  | CRCW08051300F100RT6   |
|                | R15, R17      | 2                                       | Thick Film, 1.5 $\Omega$ , 0.125 W, 1%        | Vishay                  | CRCW08051R50F100RT6   |
|                | R16, R22      | 2                                       | Thick Film, 10 $\Omega$ , 0.5 W, 1%           | Vishay                  | CRCW201010R0F100RT7   |
|                | R18           | 1                                       | Thick Film, 274 $\Omega$ , 0.125 W, 1%        | Vishay                  | CRCW08052740F100RT6   |
|                | R20           | 1                                       | Thick Film, 4.02 k $\Omega$ , 0.125 W, 1%     | Vishay                  | CRCW08054021F100RT6   |
|                | R23           | 1                                       | Thick Film, 10 k $\Omega$ , 0.125 W, 1%       | Vishay                  | CRCW08051002F100RT6   |
| R24            | 1             | Thick Film, 51.1 $\Omega$ , 0.125 W, 1% | Vishay  | CRCW080551R1F100RT6     |                       |
| Transformer    | T1            | 1                                       | Planar, 25 W, 12:2                            | Pulse                   | PA0031                |
| IC             | U1            | 1                                       | Single 2-A MOSFET driver                      | Texas Instruments       | TPS2829DBV            |
|                | U2            | 1                                       | High-speed voltage mode PWM                   | Texas Instruments       | UCC35705D             |
|                | U3            | 1                                       | Optocoupler                                   | Isocom                  | CNY17-2SM             |
|                | U4            | 1                                       | Adjustable precision shunt regulator          | Texas Instruments       | TL431CPKR             |

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

### Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265