Texas Instruments

Off-Line Low-Voltage Power Supply Evaluation Module UCC3889EVM-001 for TMS320C24xt DSPs

User's Guide

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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.

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1 Introduction

The SLUP146A evaluation module (EVM) is a dual-output, non-isolated, off-line power supply, highlighting the UCC3889 and TPS77401. It is capable of generating a primary regulated, user-selectable 3.3-Vdc or 5-Vdc output voltage at a load current up to 120 mA, as well as a secondary, quasi-regulated, 15-Vdc output providing up to 35 mA of load current. This EVM operates from either a universal ac input voltage of 85 V_{RMS} to 265 V_{RMS}, or a dc input of 100 Vdc to 400 Vdc. The actual power and control circuitry footprint requires just over 2 square inches on a three-layer single-sided printed circuit board, and is less than 0.5 inches high. The following user's guide provides the schematic, component list, assembly drawing, artwork and test set up necessary to fully evaluate the functionality of the UCC3889.

1.1 Features

- Compact size, low profile (2" $\times$ 1" $\times$ 0.5")
- Transformerless off-line applications
- Single-output, low-side control
- Wide input range
- Short circuit protection
- Low-input line protection
- Single- or dual-output configuration
- Standard, OTS, SMD, low-cost components

1.2 Applications

- TMS320C24*x* DSPs
- Low-voltage, low-current bias supply

1.3 Description

This evaluation module highlights the benefits of using the UCC3889 off-line power supply controller to implement control of a non-isolated, cascaded, flyback, power supply operating in the discontinuous current mode. The UCC3889 was originally intended for use as on off-line, low-power, low-voltage, regulated housekeeping or bias supply capable of converting 400 V to 12 V with no transformer and low internal device losses. Due to fixed internal biasing resistors, the lowest voltage that the UCC3889 can regulate down to is 5.4 Vdc. However, using the TPS77401 low dropout regulator (LDO), the 5.4-V output can easily be post-regulated to achieve even lower output voltages with very little additional circuitry. This EVM includes a feedback divider network, local to the TPS77401, which comes preset to regulate the output to 5 Vdc. The user can also select a 3.3-V output simply by removing an installed jumper.

As explained in this user's guide, the EVM configuration can easily be modified to accommodate specific low-voltage, low-current power supply applications. Details of operation regarding the UCC3889 as well as the cascaded flyback topology are fully explained in the Application Report, *Elegantly Simple Off–Line Bias Supply for Very Low Power Applications*[1].

2 Schematic

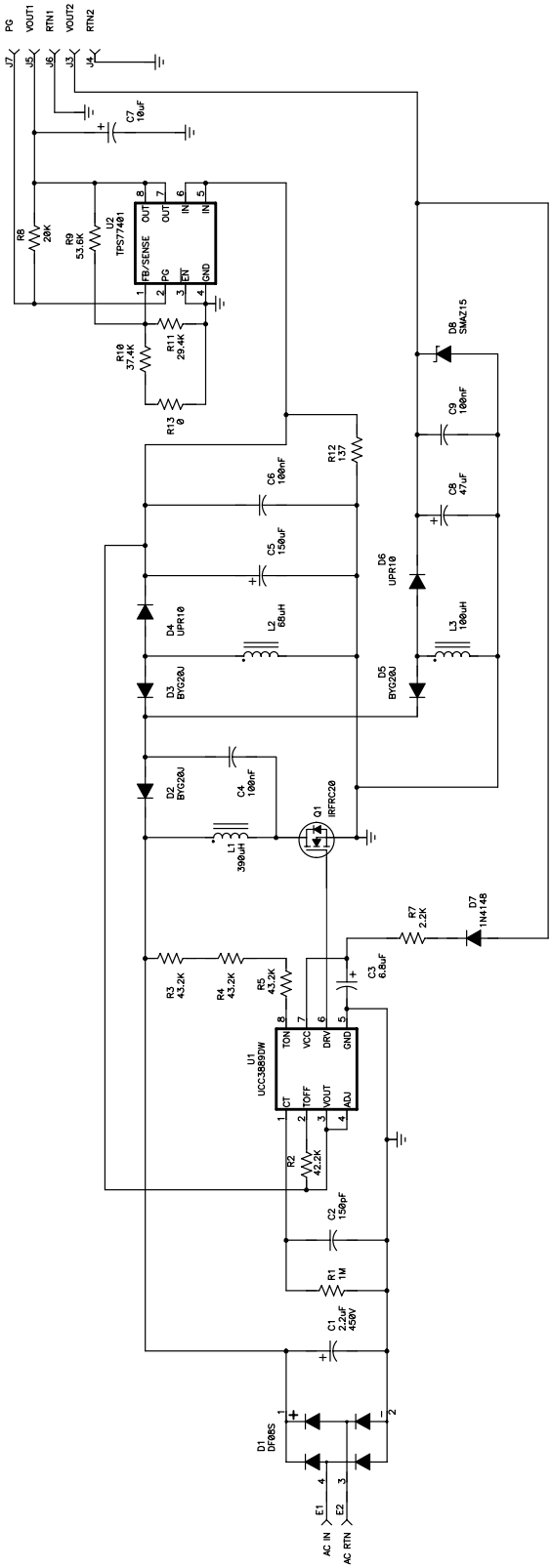
A schematic of the SLUP146A board is shown in Figure 1. Input terminals E1 and E2 are the ac-input voltage source connectors, sized to receive standard banana plugs. Pins J4 and J5 are the output and return for the 5-V output, while pins J6 and J7 are the output and return for the 15-V output. Since there are no isolated grounds, the output returns, J5 and J7, are the same and can be referenced interchangeably.

Control of the cascaded flyback topology is greatly simplified using the UCC3889 to control a single switch shared by both flyback stages. Notice that there is no direct current sensing of any leg within the supply, yet the UCC3889 still offers inherent short-circuit current protection. This is achieved because the off-time, t_{OFF}, is inversely proportional to the output voltage. As the output load is increased, the output voltage drops slightly. As V_{OUT} approaches zero, due to increased load current during the short-circuit fault, t_{OFF} approaches infinity. Similarly, the on-time, t_{ON}, is inversely proportional to the input line voltage, allowing for a minimum low-line input condition to be set. Varying the on-time and off-time simultaneously implies a variable frequency control technique. For the UCC3889, the range of variable switching frequencies is established by proper selection of R1, R2, R3, R4, R5, and C2. The details of selecting these components are highlighted in the product data sheet as well as *Elegantly Simple Off–Line Bias Supply for Very Low Power Applications*[1].

Because of the UCC3889's fixed internal error amplifier biasing resistors, the lowest output voltage that the controller can regulate to is approximately 5.4 V. This output voltage can be selected by shorting pins 3 and 4 of U1 together as shown Figure 1. The 5.4-V output voltage is then fed back to U1, as well as used for the input to the post regulator, U2.

Post regulation is accomplished using a 250 mA, TPS77401 LDO regulator. The TPS77401 comes in a variety of fixed low voltage outputs, but a 1.5-V to 5.5-V adjustable version was selected for the SLUP146A. The TPS77401 is well suited for low-voltage, low-current, DSP motor drive applications offering either a 220-ms power-up RESET delay, or a power good (PG) terminal. Either can be used to feed a power-on reset (POR) or a low-voltage indicator signal directly to a DSP, ASIC or microprocessor. The EVM is delivered with jumper R13 installed, which configures the output of the LDO to regulate to 5 V. As an additional output option, removing R13 will allow the LDO to regulate to 3.3 V.

The 15-V output is produced using a flyback stage placed in parallel with VOUT1. One disadvantge to this approach is that the output of U1 responds to the load demand of VOUT1, not VOUT2. When VOUT1 is lightly loaded (< 25 mA), VOUT2 may not have enough duty cycle to maintain 15-V regulation. To achieve better light-load regulation, a preload, R12, was added to VOUT1. Conversely, when VOUT1 is fully loaded, VOUT2 rises in response to a longer duty cycle. D8 clamps VOUT2 to 15 V. The intent of VOUT2 is for powering a MOSFET driver found in a typical DSP motor control application, where tight regulation is not required. When including VOUT2 in a design, actual inductance, t_{ON} and t_{OFF} values have to be modified from calculated results, to achieve regulation good enough for powering a driver. For applications where a MOSFET driver bias voltage may already be available, VOUT2 can be eliminated, with R12 also removed, resulting in a slight efficiency increase. The component calculations for VOUT1 are then straight forward as described in *Elegantly Simple Off–Line Bias Supply for Very Low Power Applications*[1].



UDP–01001

Figure 1. UCC3889EVM–001 Evaluation Module

3 Test Setup

Figure 2 shows the basic test set-up needed to evaluate the SLUP146A, when measuring both VOUT1 and VOUT2.

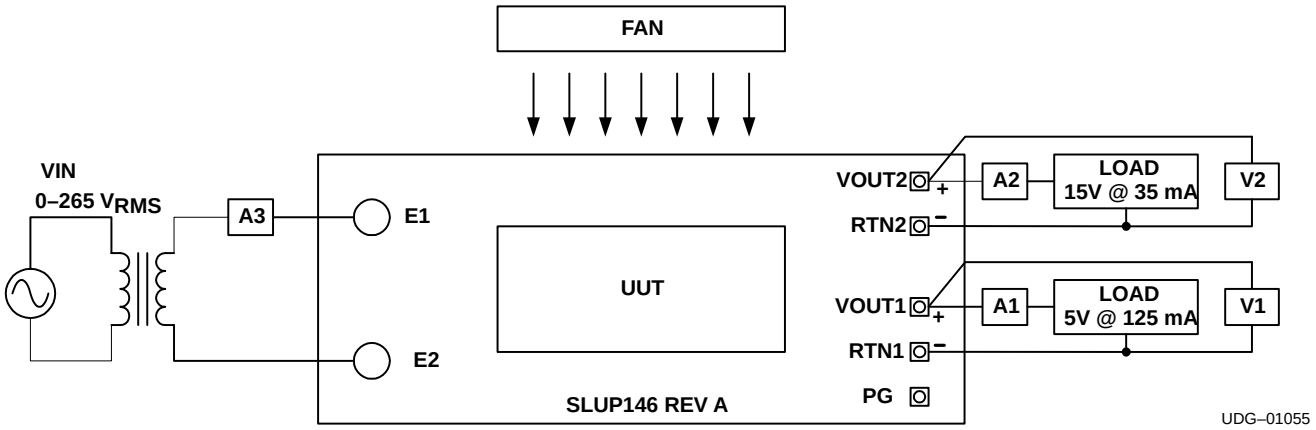


Figure 2. Dual Ouput EVM Test Configuration

3.1 Output Loads

For the output loads to VOUT2 and VOUT1, load resistors, a decade box or an electronic load can be used. If the load does not contain an integrated DVM (ie. non-electronic load) ammeters, A1 and A2 should be connected in series with the passive load as shown. Since the output power of the evaulation module is so low, RTN1 and RTN2 could be connected together; however, it is good practice to connect each return to its designated pin as shown above. Make sure that the load for VOUT2 is limited to less than 0.5 W, and the load for VOUT1 is limited to less than 0.6 W. By removing jumper R13, the evaulation module can also be evaluated with VOUT1 set to 3.3 V.

3.2 Input Source

The input voltage should be an isolated ac source capable of supplying between 85 V_{RMS} and 265 V_{RMS} and connected to E1 and E2 as shown in Figure 2. For operator safety, the ac source should be current limited to 100 mA_{RMS} . Caution should also be exercised when probing the evaulation module with high potential voltage applied. The SLUP146A can also run from a distributed dc bus voltage between 100 Vdc and 400 Vdc. For testing the evaulation module in this type of application, simply apply the positive and negative inputs of a dc power supply to either E1 or E2. Since E1 and E2 are connected to a bridge rectifier, it will not matter to which side the positive dc terminal is connected. However, as is the case using the ac source, the dc supply should be current limited to 100 mA, and caution observed when probing the board with high potential voltage applied. Starting from zero, slowly increase the input voltage, while monitoring VOUT1 and VOUT2, until both outputs appear in regulation.

3.3 Fan

Most power converters include components that can get hot to the touch when approaching temperatures of 60°C. Because this evaulation module is not enclosed to allow probing of circuit nodes, a small fan capable of 20–30 cubic feet per minute (CFM) is recommended to reduce component temperatures when operating at full output load or applied input voltage greater than 150 V_{RMS}.

3.4 Single EVM Output Only

As previously mentioned, the evaulation module can also be operated to provide a single output only. This is useful for applications that either do not require the 15-V output or may already have it available from another source.

Referring to the schematic in Figure 1, remove D5, disabling VOUT2, and remove R13, the preload to VOUT1. Since the bias voltage to U1 was supplied by bootstrapping VOUT2 to VCC, an external lab dc bias supply will now be required to keep U1 up and running. Using the test setup shown in Figure 3, the bias voltage, V_{BIAS}, to U1 can now be applied directly to the VOUT2 output pins. With the external bias supply initially set to 0 V, slowly increase the voltage to 10 Vdc. The bias current to U1 will still be limited through R7 of Figure 1. For single output applications where no bias voltage is available, VCC can be powered directly off-line or from a distributed dc bus voltage, however the bias current into pin 7 of U1 must be limited to less than 5 mA max under all input line variations.

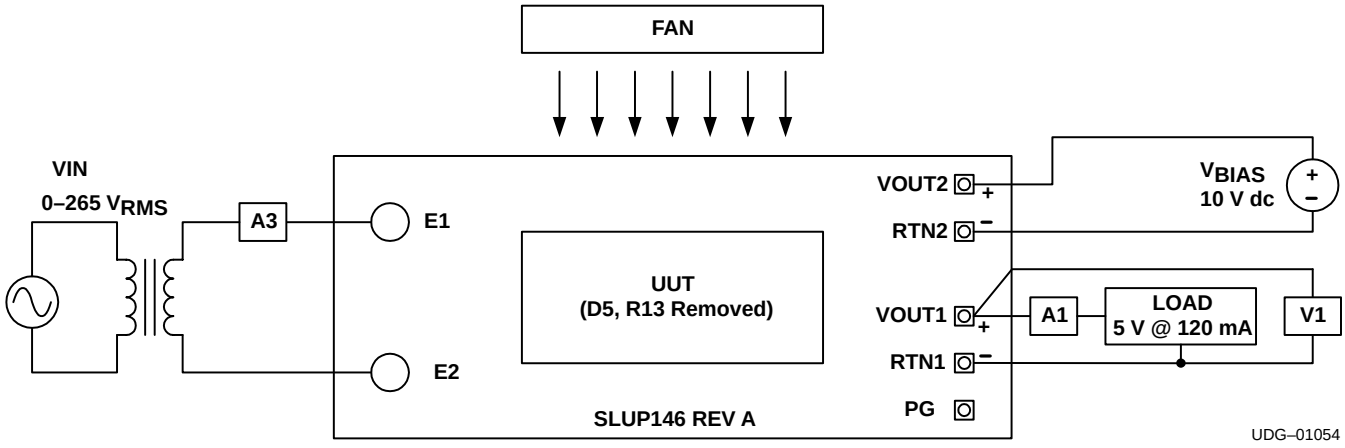


Figure 3. Single Ouput EVM Test Configuration

Once U1 is up and running, follow the same power up and loading procedure as the previous test case for the dual output configuration.

4 EVM Assembly Drawing and Layout

Figure 4 shows the top side component placement for the evaluation modlue, as well as pin numbers and component polarity where necessary. A four layer printed circuit board uses the top and bottom layers for signal traces and a center split-plane ground layer. The copper etch of each layer is also shown in Figures 5 through 8.

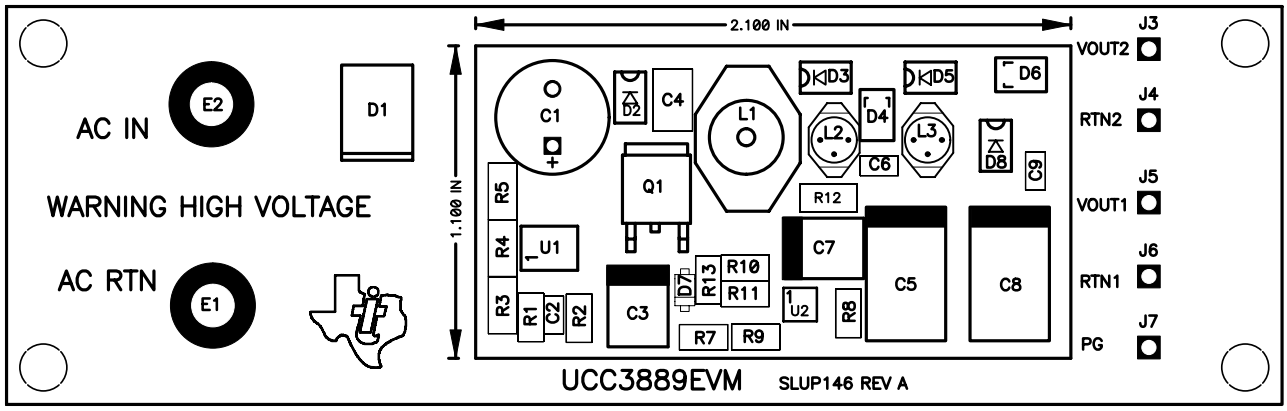


Figure 4. Top Side Component Assembly

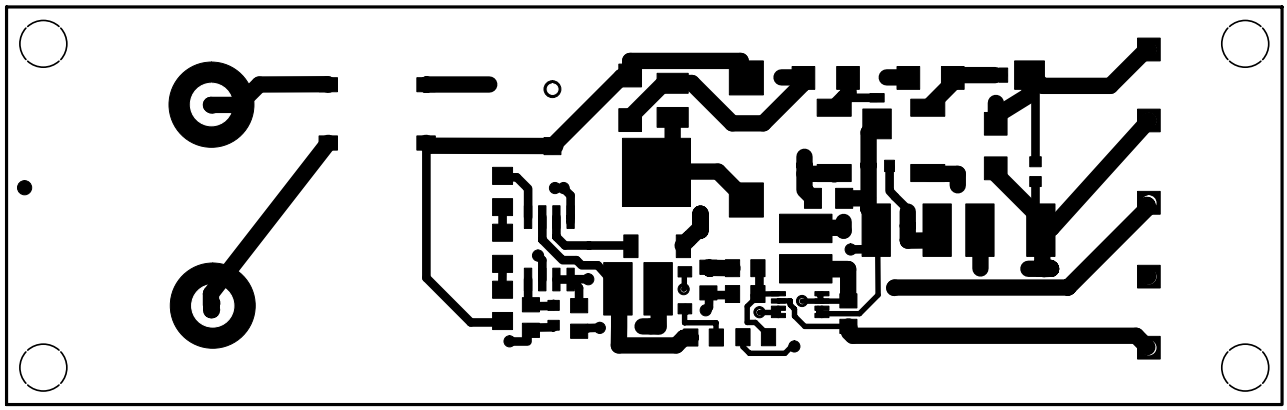


Figure 5. Layer 1 Signal Trace Layer

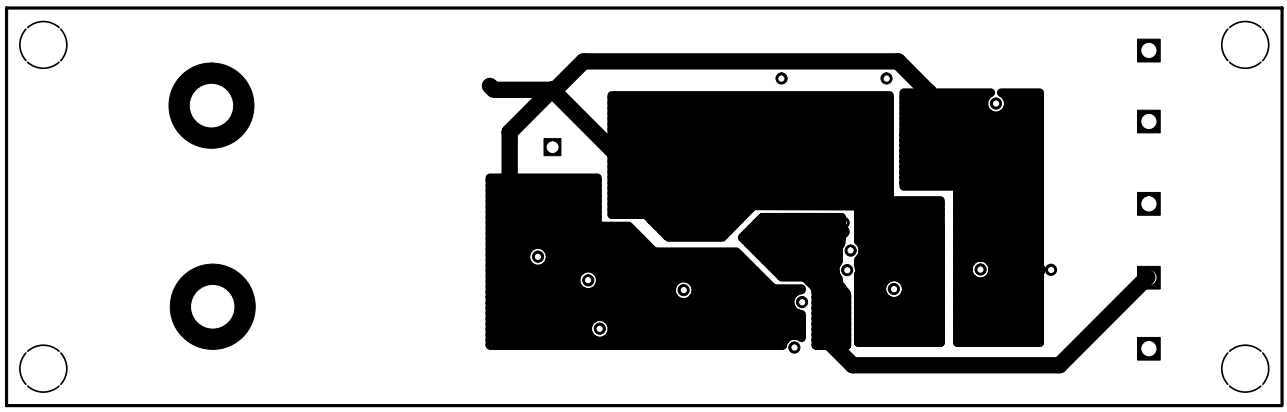


Figure 6. Layer 2 Split-Plane Ground

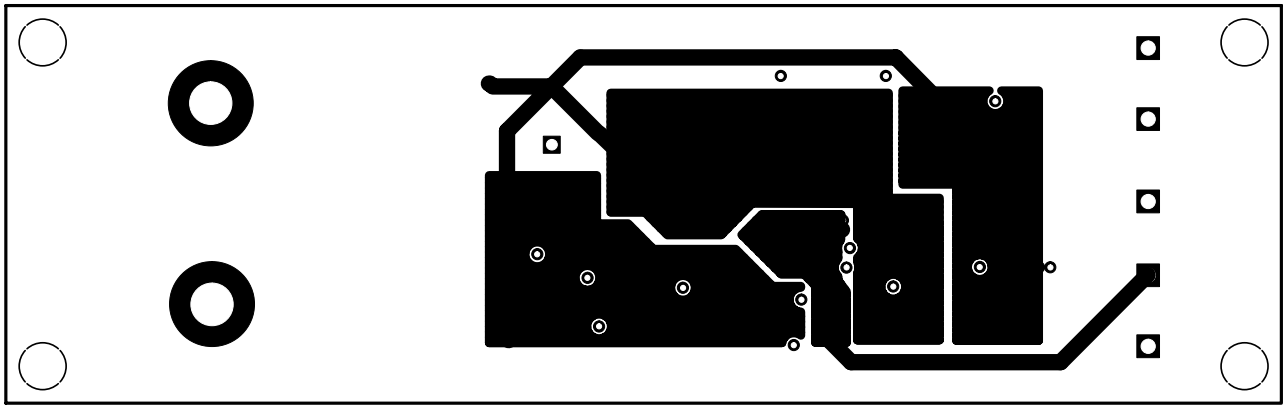


Figure 7. Layer 3 Split-Plane Ground

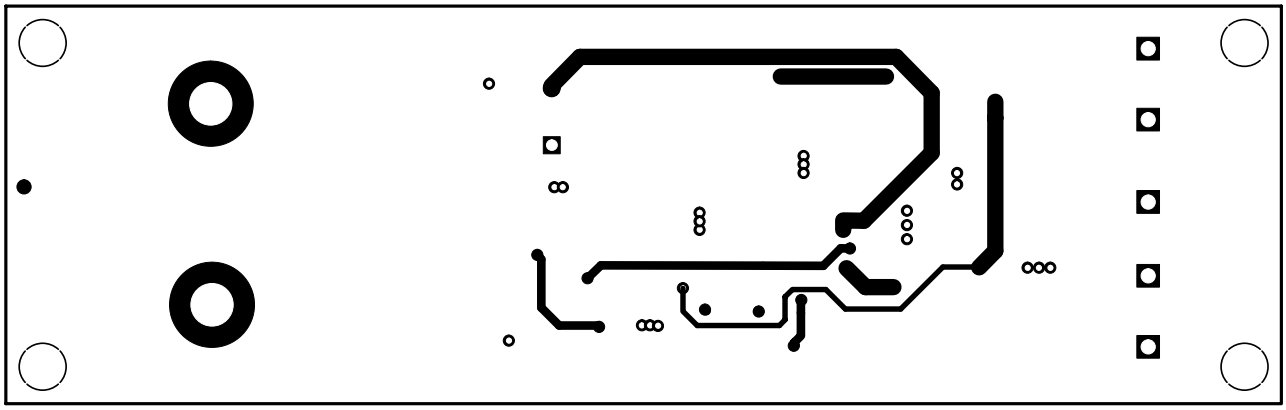


Figure 8. Layer 4 Signal Trace Layer

5 List of Materials

Table 1. List of Materials

REFERENCE DESIGNATOR	QTY	PART NUMBER	DESCRIPTION	MANUF	PKG
N/A	1	SLUP146A	UCC3889 EVM Printed circuit board	N/A	N/A
C1	1	ECA–2WHG2R2	Capacitor, aluminum, 2.2 μF, 450 V, 20%	Panasonic	ECA
C2	1	ECUV1H151JCV	Capacitor, ceramic, NPO, 150 pF, 50 V, 5%	Panasonic	0603
C3	1	16SN6R8M	Capacitor, OSCON, 6.8 μF, 16 V, 20%	Sanyo	SMA
C4	1	VJ1210Y393KXEAT	Capacitor, ceramic, X7R, 39 nF, 500 V, 10%	Vishay	1210
C5	1	6SN150N	Capacitor, OSCON, 150 μF, 6.3 V, 20%	Sanyo	SMD
C6, C9	2	ECJIVB1C104KM	Capacitor, ceramic, X7R, 100 nF, 16 V, 20%	Panasonic	0603
C1	1	ECA–2WHG2R2	Capacitor, aluminum, 2.2 μF, 450 V, 20%	Panasonic	ECA
C7	1	10SN10M	Capacitor, OSCON, 10 μF, 10 V, 20%	Sanyo	SMA
C8	1	20SN47M	Capacitor, OSCON, 47 μF, 20 V, 20%	Sanyo	SMD
D1	1	DF08S	Diode, bridge rectifier, 800 V, 1 A	General Semi	DFS
D2, D3, D5	3	BYG20J	Diode, fast recovery, 600 V, 1 A	Vishay	SMA
D4, D6	2	UPR10	Diode UF, 100 V, 2.5 A	Microsemi	Power-mite
D7	1	1N4148W	Diode, switching, 100 V, 300 mA	Diodes Inc	SOD–123
D8	1	SMAZ15	Diode, Zener, 15 V, 1 W	Diodes Inc	SMA
J3, J4, J5, J6, J7	5	3104–2	0.5 inch printed circuit test point pin	Mill–Max	N/A
L1	1	Z9199–A	Inductor, 390 μH, 0.6 A	Coilcraft	D03316
L2	1	DO1608C–683	Inductor, 68 μH, 0.4 A	Coilcraft	DO1608C
L3	1	DO1608C–104	Inductor, 100 μH, 0.3 A	Coilcraft	DO1608C
Q1	1	IRFRC20	Transistor, NCH–FET, 2 A, 600 V	Int'l Rectifier	D–Pak
R1	1	ERJ6ENF1004V	Resistor, metal film, 1 M, 0.1 W, 1%	Panasonic	0805
R2	1	ERJ6ENF4222V	Resistor, metal film, 42.2 kΩ, 0.1W, 1%	Panasonic	0805
R3, R4, R5	3	ERJ8ENF4322V	Resistor, metal film, 43.2 kΩ, 0.125W, 1%	Panasonic	1206
R6, R13	2	ERJ6GEY0R00V	Resistor, metal film, 0 kΩ, jumper	Panasonic	0805
R7	1	ERJ6ENF2201V	Resistor, metal film, 2.2 kΩ, 0.1W, 1%	Panasonic	0805
R8	1	ERJ6ENF2002V	Resistor, metal film, 20 kΩ, 0.1W, 1%	Panasonic	0805
R9	1	ERJ6ENF5362V	Resistor, metal film, 53.6 kΩ, 0.1W, 1%	Panasonic	0805
R10	1	ERJ6ENF3742V	Resistor, metal film, 37.4 kΩ, 0.1W, 1%	Panasonic	0805
R11	1	ERJ6ENF2942V	Resistor, metal film, 29.4 kΩ, 0.1W, 1%	Panasonic	0805
R12	1	ERJ8ENF1370V	Resistor, metal film, 137 kΩ, 0.125W, 1%	Panasonic	1206
S1, S2, S3, S4	4	CBP75–C	0.75 inch, nylon stand–off	Panduit	N/A
U1	1	UCC3889DW	Integrated circuit, off–line controller	Texas Instruments	SO–8
U2	1	TPS77401DGK	Integrated circuit, LDO, 250 mA	Texas Instruments	MSOP

6 References

Andreycak, William. *Elegantly Simple Off–Line Bias Supply for Very Low Power Applications*, Application Report Texas Instruments Literature No. SLUA116.

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