AN-1724 LM5015 Isolated Two-Switch DC-DC Regulator Evaluation Board

1 Introduction

The LM5015 Isolated DC-DC regulator evaluation board provides a low cost and fully functional DC-DC regulator without employing any discrete power MOSFET. The evaluation board can be configured as either an Isolated Two-Switch Forward DC-DC Regulator, or an Isolated Two-Switch Flyback DC-DC Regulator. The factory default configuration of the evaluation board is forward topology. The forward converter configuration will produce about 2% higher efficiency and lower output ripple voltage than the flyback. Whereas, the Flyback configuration costs slightly less. Suggestion to reconfigure the evaluation board as an Isolated Two-Switch Flyback DC-DC Regulator is provided at the end of this document.

For detailed features and technical information of the LM5015 device, see the *LM5015 High Voltage Monolithic Two-Switch Forward DC-DC Regulator Data Sheet* (SNVS538). For non-isolated applications, see the *AN-1725 LM5015 Non-Isolated Two-Switch DCDC Regulator Evaluation Board User's Guide* (SNVA292).

The evaluation board features:

- Input Voltage: 36V to 72V
- Isolated Output Voltage: 5V
- Output Current: 0A minimum, 2.5A nominal, and 3A maximum
- Input UVLO Threshold: 34V nominal
- Measured Efficiency: 86% (V_{IN} = 48V, I_{OUT} = 2.5A)
- Switching Frequency: 300 kHz
- Ability to Synchronize to External Clock
- Ability to Be Remote Controlled (Enable/Disable)
- Two Layer PC Board and Top Side Component Placement
- Configurable as Either a Forward (Factory Default) or a Flyback Regulator
- Board Size (WxLxH): 2.5 in. x 3.5 in. x 0.63 in

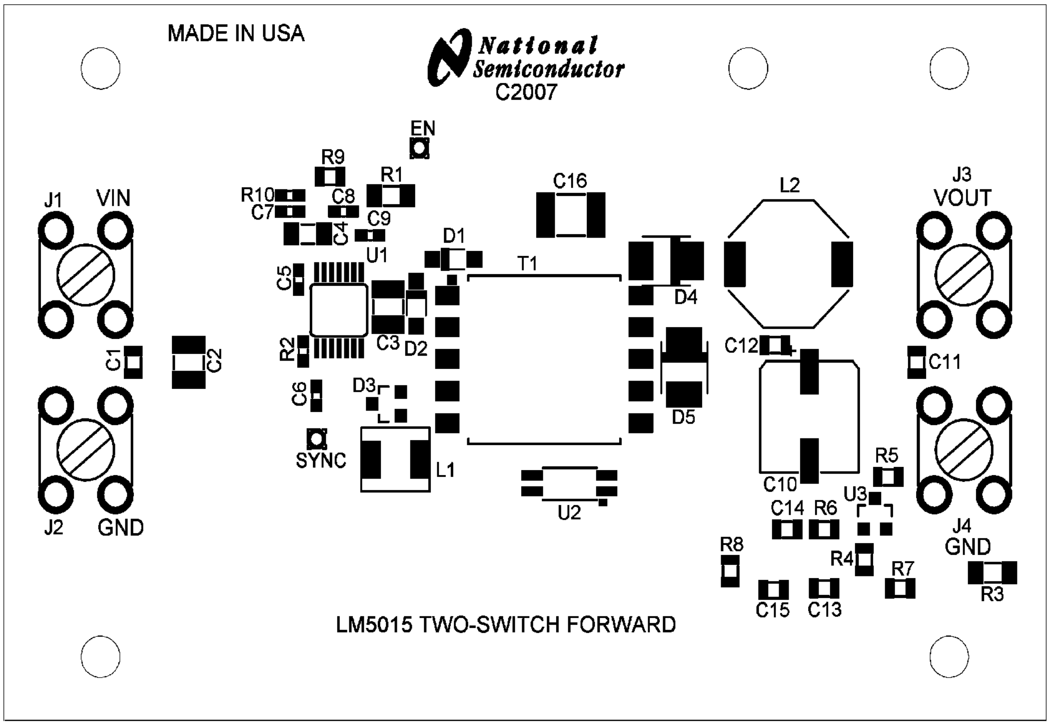


Figure 1. Evaluation Board Layout

2 Board Connections/Start-up

Figure 1 shows the PC board layout. The input connections are made to connectors J1 (high potential) and J2 (input return). The load is connected between connectors J3 (5V) and J4 (5V return). Ensure the wires are adequately sized for the intended load current.

A DC power supply capable of at least 75V and 0.5A is recommended as the input power source for the evaluation board. Use the output over-voltage and over-current limit features of the DC power supply to protect the board against damage by errant connections.

A resistive load is optimal, but an appropriate electronic load is acceptable. The maximum load current is 3A. Exceeding this current will cause the LM5015 to enter cycle-by-cycle peak current limit mode, and the output voltage will fall below the regulated 5V. Current limit mode is triggered whenever the primary switch current exceeds 1.2A (nominal).

During the first power up, the load should be kept reasonably low (<0.1A). Before start-up, a voltmeter should be connected to the input terminals, and to the output terminals. The load current should be monitored with an ammeter or a current probe. It is recommended that the input voltage be increased gradually.

Before the input voltage reach about 34V, which is the evaluation board's Under Voltage Lock-Out (VULO) threshold preset with R9 and R10, there should be no output voltage, and the input current should be lower than 10 mA. Otherwise, remove power immediately and verify if the input polarity is reversed.

When the input voltage is increased to 36V, the output voltage should be established at 5V nominal. If that indicates correctly, increase the input voltage gradually to 72V maximum and the output voltage should be regulated at 5V ±1.5% over the entire input voltage range from 36V to 72V. Otherwise, remove power and check if the connection is correct.

Once the proper setup has been established, full load can be applied. A final check of efficiency is suggested to confirm that the unit is operating properly. Efficiency significantly lower than 80% at full load indicates a problem.

The evaluation board can be synchronized to an external clock of faster than the board's native oscillator frequency, which is twice the switching frequency F_{SW}. Note that the LM5015 oscillator uses a divide-by-2 circuit and the actually switching frequency is half the oscillator frequency set by R2. Since the evaluation board's switching frequency is 300 kHz, the external clock should be faster than 600 kHz. The external clock signal should feed into the plated via hole of the SYNC port, referenced to the AGND node. Refer to the LM5015 datasheet for the requirement of the external clock signal for successful synchronization.

The evaluation board can be remote controlled for enabling and disabling. The control port on the PC board is the plated via hole dedicated to EN node. The remote control signal should be referenced to the AGND node. Refer to the LM5015 datasheet for detailed information of remote control.

3 Isolated Two-Switch Forward DC-DC Regulator

Figure 2 shows the schematic of the evaluation board in a default configuration of a Two-Switch Forward DC-DC regulator. The two MOSFET switches are integrated in the LM5015, and the regulator is implemented without using any discrete power MOSFET. A transformer winding between pins 4 and 5 of T1 is used to produce 10V Vcc for the LM5015, thus blocking the internal LDO regulator during normal operation and improving efficiency. Refer to Figure 6 for the schematic of optional Isolated Two-Switch Flyback DC-DC Regulator.

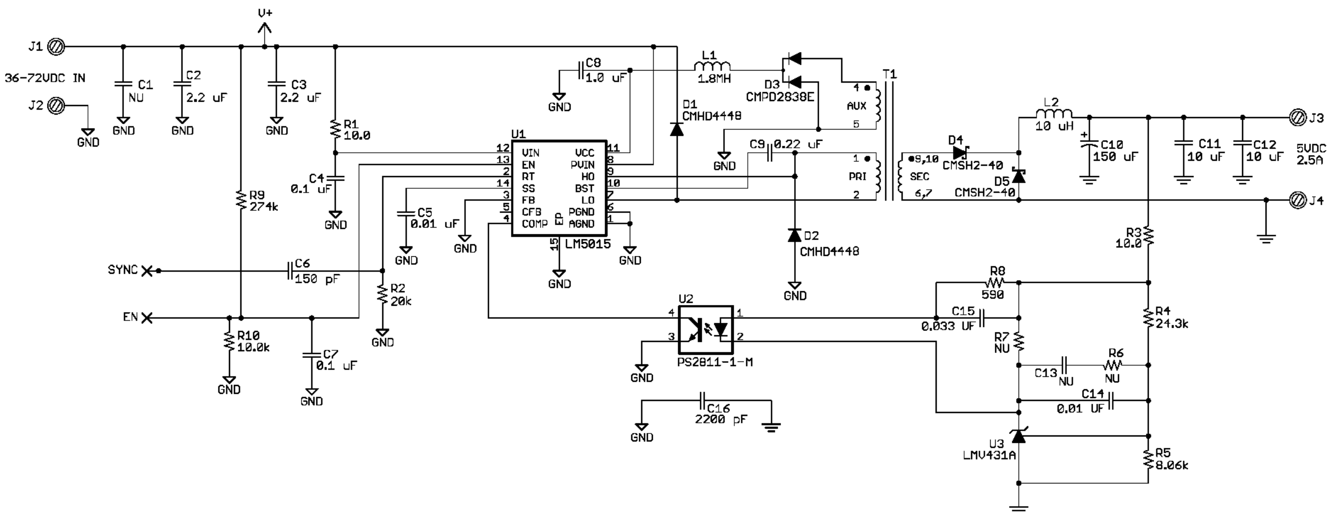


Figure 2. Schematic of Isolated Two Forward DC-DC Regulator (Factory Default)

4 Board Layout and Probing

The following should be kept in mind when the board is powered:

- The LM5015, and the diodes D3 and D4 will be hot to the touch when operating at high input voltage and/or high load current.
- Use CAUTION when probing the circuit at high input voltages. 72 volts is enough to produce shocks and sparks.
- At maximum load current (3A), the wire size and length used to connect the load become important. Ensure there is not a significant voltage drop along the wires.

5 Typical Performance Characteristics

Figure 3 shows the overall efficiency of the evaluation board in the Two-Switch Forward configuration.

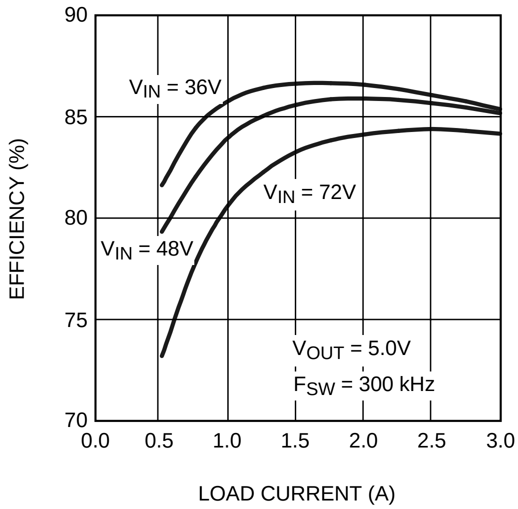
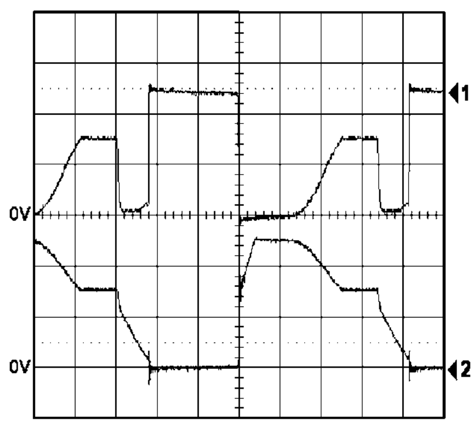


Figure 3. Evaluation Board Efficiency vs Input Voltage vs Load

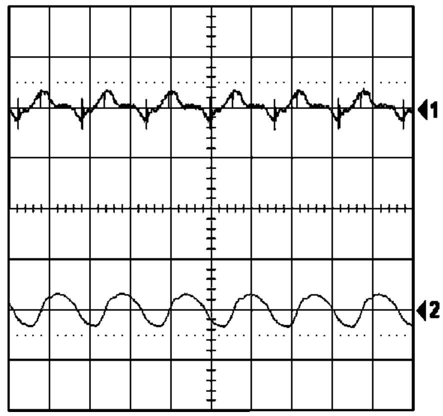
Figure 4 shows key voltage waveforms at switch nodes HO and LO under full load (2.5A) and mid input voltage (48V).



Horizontal Resolution: 0.5 µs/div
Trace 1: The HO pin voltage. 20V/div
Trace 2: The LO pin voltage. 20V/div
Operating condition: Vin = 48V, Vout = 5V, Iout = 2.5A

Figure 4. Key Voltage Waveforms at the HO and LO Pins

Figure 5 shows the input ripple current and output ripple voltage full load (2.5A) and mid input voltage (48V).



Horizontal Resolution: 2 µs/div
Trace 1: The output voltage ripples (ac coupled). 50 mV/div
Trace 2: The input current ripples (ac coupled). 100 mA/div
Operating condition: Vin = 48V, Vout = 5V, Iout = 2.5A

Figure 5. Input Ripple Current and Output Ripple Voltage

6 Schematic of Isolated Two-Switch Flyback DC-DC Regulator

Figure 6 shows the schematic to reconfigure the evaluation board as an Isolated Two-Switch Flyback DC-DC regulator. Refer to the changes in BOM at the end of this article. Note that the use of dual-diode D3 herein is owing to the D3 footprint on the PC board. Only the high side of the dual-diode D3 is used in Flyback configuration, and the low side diode is always reverse biased during normal operation.

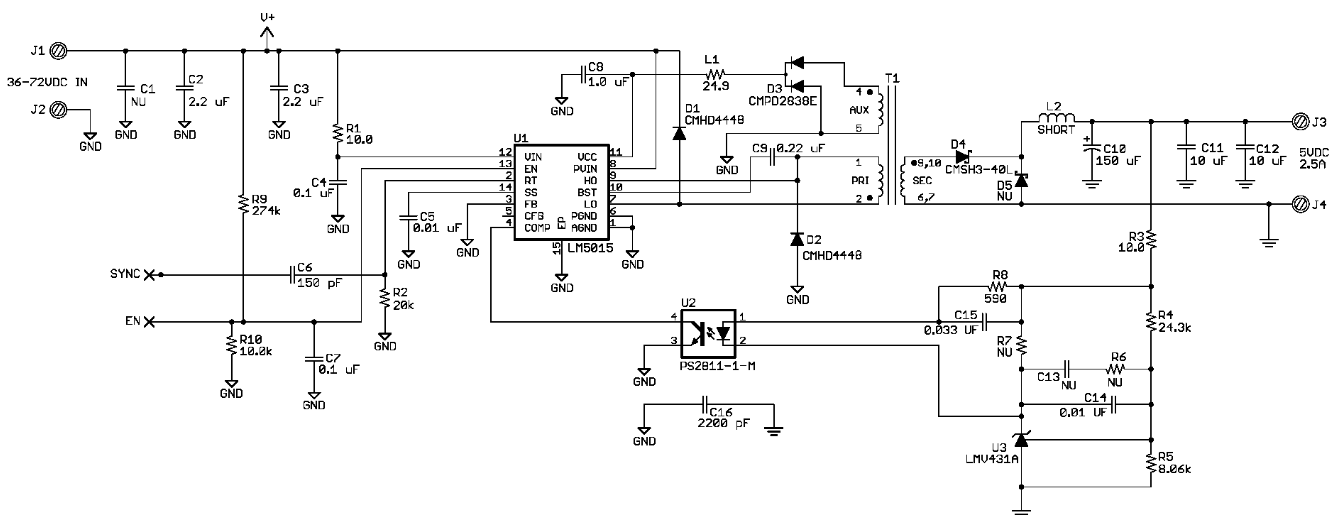
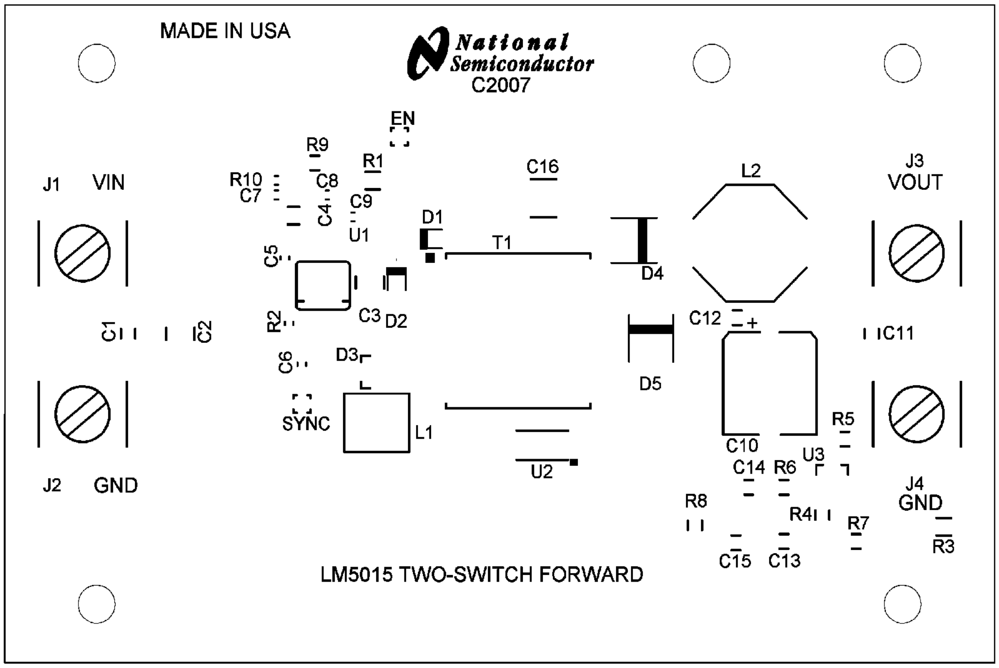


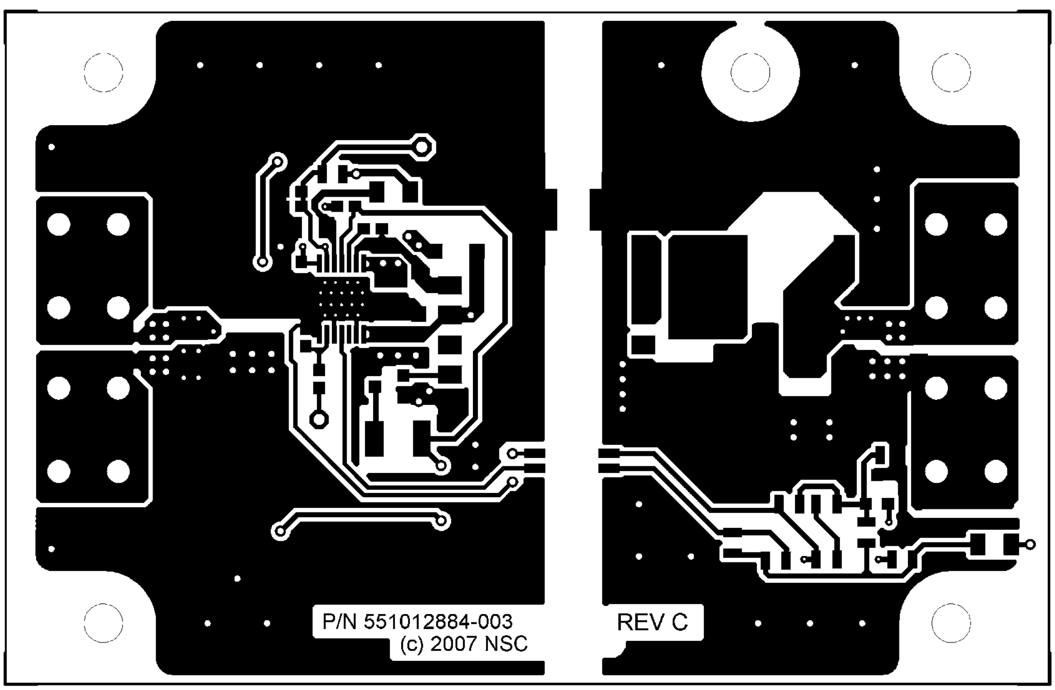
Figure 6. Schematic of Isolated Two-Switch Flyback DC-DC Regulator Configuration

7 Evaluation Board PCB



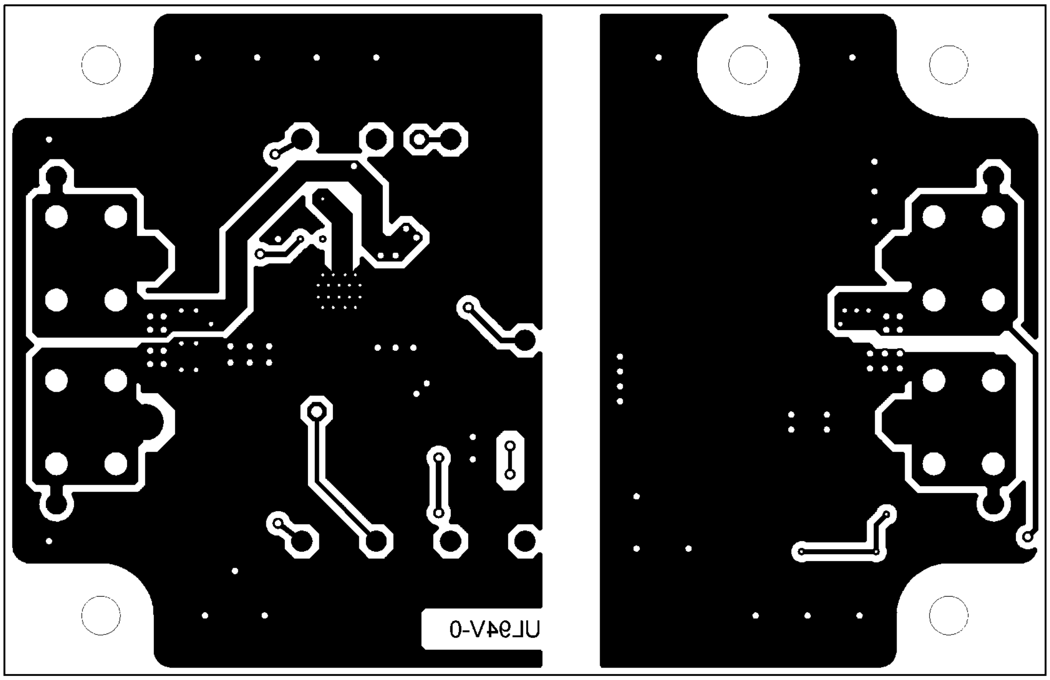
SILKSCREEN (PLACE) LAYER AS VIEWED FROM TOP

Figure 7. Sikscreen



TOP (COMPONENT) LAYER AS VIEWED FROM TOP

Figure 8. Top Layer



BOTTOM (SOLDER) LAYER AS VIEWED FROM TOP

Figure 9. Bottom Layer

8 Bill of Materials (BOM)

Table 1. Isolated Two-Switch Forward DC-DC Regulator (Factory Default)

Item	Part Number	Description	Value
PCB	551012884-003 REV C	LM5015 Two-Switch Forward ISOLATED	
C1	NU	DO NOT INSTALL	
C2	HMK325BJ225KN-T	CAPACITOR, CER, CC1210, TAIYO YUDEN	2.2 µF, 100V
C3	HMK325BJ225KN-T	CAPACITOR, CER, CC1210, TAIYO YUDEN	2.2 µF, 100V
C4	C3216X7R2A104K	CAPACITOR, CER, CC1206, TDK	0.1 µF, 100V
C5	C1608X7R1H103K	CAPACITOR, CER, CC0603, TDK	0.01 µF, 50V
C6	C0603C151J5GACTU	CAPACITOR, CER, CC0603, KEMET	150 pF, 50V
C7	C0603C104K5RACTU	CAPACITOR, CER, CC0603, KEMET	0.1 µF, 50V
C8	ECJ-1VB1E105K	CAPACITOR, CER, CC0603, PANASONIC-ECG	1µF, 25V
C9	GRM188R71E224KA88D	CAPACITOR, CER, CC0603, MURATA	0.22 µF, 25V
C10	APXA6R3ARA151MH70G	CAPACITOR, AL ELEC, NIPPON CHEMI-CON	150 µF, 6.3V
C11	LMK212BJ106KD-T	CAPACITOR, CER, CC0805, TAIYO YUDEN	10 µF, 10V
C12	LMK212BJ106KD-T	CAPACITOR, CER, CC0805, TAIYO YUDEN	10 µF, 10V
C13	NU	DO NOT INSTALL	
C14	C0805C103K5RAC	CAPACITOR, CER, CC0805, KEMET	0.01 µF, 50V
C15	C0805C333K5RAC	CAPACITOR, CER, CC0805, KEMET	0.033 µF, 50V
C16	C4532X7R3D222K	CAPACITOR, CER, CC1812, TDK	2.2 nF, 2 kV
D1	CMHD4448	DIODE, SOD-123, CENTRAL	75V, 250 mA
D2	CMHD4448	DIODE, SOD-123, CENTRAL	75V, 250 mA
D3	CMPD2838E	DIODE, DUAL, SOT-23, CENTRAL	75V, 200 mA
D4	CMSH2-40	DIODE, SCHOTTKY, SMB, CENTRAL	40V, 2A

Table 1. Isolated Two-Switch Forward DC-DC Regulator (Factory Default) (continued)

Item	Part Number	Description	Value
D5	CMSH2-40	DIODE, SCHOTTKY, SMB, CENTRAL	40V, 2A
L1	LPS4012-185MLB	INDUCTOR, COILCRAFT	1.8 µH,
L2	SRU1048-100Y	INDUCTOR, BOURNS	10 µH, 3.7A
R1	CRCW120610R0J	RESISTOR, 1206	10 Ω
R2	CRCW06032002F	RESISTOR, 0603	20k
R3	CRCW120610R0J	RESISTOR, 1206	10 Ω
R4	CRCW08052432F	RESISTOR, 0805	24.3k
R5	CRCW08058061F	RESISTOR, 0805	8.06K
R6	NU	DO NOT INSTALL	
R7	NU	DO NOT INSTALL	
R8	CRCW08055900F	RESISTOR, 0805	590 Ω
R9	CRCW08052743F	RESISTOR, 0805	274k
R10	CRCW06031002F	RESISTOR, 0603	10k
T1-A	CA2983-CL	FORWARD TRANSFORMER, COILCRAFT	OPTION 1
T1-B	PA2194NL	FORWARD TRANSFORMER, PULSE	OPTION 2
U1	LM5015	2-SW FWD REG, TSSOP-14EP, Texas Instruments	
U2	PS2811-1-M	OPTO-COUPLER, NEC	
U3	LMV431	REFERENCE, SOT23-3, Texas Instruments	

Table 2. Bill of Materials (BOM) Changes to Configure the Evaluation Board as an Isolated Two-Switch Flyback DC-DC Regulator With 5V 2.5A Output

Item	Part Number	Description	Value
D4	CMDH3-40L	DIODE, SCHOTTKY, SMC, CENTRAL	40V, 3A
D5	NU	DO NOT INSTALL	
L1	CRCW120624R9J	RESISTOR, 1206	24.9 Ω
L2	SHORT	AWG 24 BUS WIRE	0 Ω
T1-A	GA3372-AL	FLBACK TRANSFORMER, COILCRAFT	OPTION 1
T1-B	PA2367NL	FLYBACK TRANSFORMER, PULSE	OPTION 2

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