User's Guide
SNVU584–February 2018

LM5036EVM-294 Evaluation Module

This user's guide describes the characteristics, operation, and use of the LM5036EVM-294 Evaluation Module (EVM). A complete schematic diagram, printed-circuit board layouts, and bill of materials (BOM) are included in this document. The power supply accepts a DC input voltage (36 VDC to 75 VDC), and produces an output voltage of 12 VDC for loads up to 8 A and a current limit of 10 A.

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Trademarks

1 General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

Always follow TI's setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center for further information.

Save all warnings and instructions for future reference.

WARNING

Failure to follow warnings and instructions may result in personal injury, property damage or death due to electrical shock and burn hazards.

The term *TI HV EVM* refers to an electronic device typically provided as an open framed, unenclosed printed-circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use or application are strictly prohibited by Texas Instruments. If you are not suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety:
   a. Keep work area clean and orderly.
   b. Qualified observers must be present any time circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50 Vrms and 75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
   e. Use stable and non-conductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety:
   a. As a precautionary measure, it is always good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   b. DE-energize the TI HV EVM and all its inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Re-validate that the TI HV EVM power has been safely DE-energized.
   c. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   d. Once EVM readiness is complete, energize the EVM as intended.

WARNING

High voltages of DC are present on this evaluation board during operation and even for a while after powering off. To evaluate this module, the individuals involved must be qualified with adequate knowledge and skills of high voltage from electrical engineering practice. Severe injury, including death, can occur from insufficient personal capability.

The DC voltage source with isolation should meet the IEC60950 reinforced insulation standards are suggested to be necessary for performing evaluation on this EVM.

Extreme caution should be taken to eliminate the possibility of an electric shock and heat burn. Please see *General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines* for safety concerns and precautions.

Read and understand this user's guide thoroughly before starting any physical evaluation.

1. Personal Safety:
   a. Wear personal protective equipment, for example, latex gloves or safety glasses with side shields or protect the EVM in an adequate lucent plastic box with interlocks from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

2 Introduction

The LM5036EVM-294 is used to help evaluate the LM5036 half-bridge PWM controller with integrated auxiliary bias supply in high-density power solutions for telecom and industrial power converters. This EVM is a standalone isolated half-bridge DC-DC power converter controlled by the LM5036 device.

In the package delivered, one EVM is included (LM5036). In the same package, a hard copy of *General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines* is also included.

This user's guide provides basic evaluation instructions from a viewpoint of system operation in a standalone half-bridge DC-DC power converter.

CAUTION

Do not leave the EVM powered **ON** when unattended.

2.1 Features

This EVM supports the following features:

- Highest integration controller for small form factor, high-density power converters
- Fully regulated pre-biased start-up
- Enhanced cycle-by-cycle current limiting with pulse matching
- Configurable latch operation
- Optimized maximum duty cycle for primary side FET's
- Integrated 100-V, 100-mA auxiliary supply
- A 100-V high-voltage start-up regulator
- Integrated 100 V/2 A MOSFET drivers for primary-side FETs
- A 5-V SR-PWM output with intelligent soft-start, allowing linear turn-ON into pre-biased load

- Reverse current protection
- Programmable hiccup mode OCP
- Input voltage feed-forward
- Programmable SR dead time adjustments
- Programmable line UVLO and OVP
- Resistor-programmable 2-MHz oscillator
- Two-level thermal protection

2.2 Applications

This EVM is used in the following applications:

- Isolated DC-DC power modules
- Isolated RF power amplifier power supplies
- Telecom, data communication power supplies
- Industrial and automotive power supplies

2.3 Description

The LM5036EVM-294 is an EVM for a half-bridge PWM controller with an integrated auxiliary bias supply. This EVM accepts a DC input up to 75 V, delivers a nominal output voltage of 12 VDC, an output current of 8 A, and a current limit of 10 A.

This highly-integrated controller employs a soft-start scheme which allows fully regulated and monotonic start-up of the power converter into pre-biased load conditions. The LM5036 device also features an enhanced cycle-by-cycle (CBC) current limiting with pulse matching which maintains the voltage balance of the half-bridge capacitor divider and therefore ensures flux balance of the transformer during CBC operation. An input-voltage compensation function is also implemented in the LM5036 to minimize the variation of the current-limit level over the entire input range.

Additional features of the LM5036 include configurable latch operation, optimized maximum duty cycle for the primary FETs, reverse current protection, auxiliary supply synchronous and asynchronous mod operation, input-voltage feed forward (IVFF), integrated gate drivers for the half-bridge converter, programmable dead-time between the primary FETs and synchronous rectifiers (SRs), and a 2-MHz capable oscillator with synchronization capability and two-level thermal shutdown protection, and so forth.

NOTE: This EVM does not have an input fuse, and relies on the input-current limit from its DC Voltage source.

3 Test Setup and Procedure

3.1 Test Equipment

3.1.1 DC Source

The input source shall be a variable DC source capable of supplying up to 100 VDC with a current rating of 5 A and a power rating of 200 W. The DC voltage source used must meet IEC60950 reinforced insulation requirement. Next, connect the DC source to J1 (+) and J2 (–) as Figure 1 shows.

3.1.2 Multimeters

Multimeters are used to measure the output voltage, a DC voltage meter capable of 0-V to 20-V input range, and a display capable of displaying at least 4 digits. Connect the voltage meter to TP5 and TP6 as Figure 1 shows.

3.1.3 Output Load

Use a DC load capable of receiving 0 VDC to 20 VDC, 0 A to 15 A and 0 W to 200 W or greater ratings. It should also be capable of displaying values such as load current and load power. Connect the load to J3 as Figure 1 shows.

3.1.4 Wire Gauge

The wire gauge must be rated for at least 15 A, or no thinner than #14 AWG, with the total length of wire less than 8 feet (4 feet input, 4 feet return).

3.1.5 Oscilloscope

Set the oscilloscope channel with 20-MHz bandwidth.

3.2 Recommended Test Setup

Figure 1. Test Setup With Load

3.3 Test Procedure

Use the following procedures for testing:

1. When working at the ESD workstation, TI recommends turning ON the ionizer before the EVM is removed from the ESD protective packaging and before power is applied to the EVM. Wear safety glasses at all times. The voltage on the EVM can get up to 100 VDC.
2. Set the current limit of the DC input source to 5 A.
3. Set the input DC source voltage to 0 VDC.
4. Set the load current to 0 A and keep the load OFF.
5. Hook up the input and output terminals of the EVM to the DC input source and load respectively.
6. Set the DC input source voltage to 36 VDC and turn ON the DC source.
7. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
8. Increase the load current to 8 A.
9. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
10. Increase the DC source voltage to 48 VDC.

11. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
12. Reduce the load current to 0 A.
13. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
14. Increase the DC source voltage to 75 VDC.
15. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
16. Increase the load current to 8 A.
17. Read the voltage meter display; verify that the measured value falls within the limits (11.9 V to 12.2 V).
18. Decrease the DC source voltage to 48 VDC.
19. **Gradually** increase the load current while monitoring the output voltage.
20. Stop increasing the load current when the current limit operation is activated. This will be indicated by the controller entering hiccup mode (Figure 16 and Figure 17).
21. Read the load current value which is the current-limit level. Verify that the value falls within the current limit value (from 9.5 A to 10.5 A).

3.4 List of Terminals

Table 1 lists the terminals on the LM5036EVM-294.

Table 1. List of Terminals

Terminal Points	Name	Description
J1	Vin+	Positive input terminal
J2	PGND	Primary-side ground
J3	Vout	Positive output terminal
J4	OVP/Latch configuration	Connect jumper J4 for OVP mode. Remove jumper for latch mode
J5	Bode plot measurement	Connect jumper for normal operation. Remove jumper for bode plot measurement using frequency analyzer
J6	OVP/Latch configuration	Connect jumper J6 for OVP mode. Remove jumper for latch mode
J7	Vout	Accurate output voltage measurement

3.5 Test Points

Table 2 describes the test points on the LM5036EVM-294.

Table 2. List of Test Points

Test Points	Name	Description
TP1	VIN	Input voltage terminal
TP2	PGND	Primary-side ground
TP3	RC	Remote control. Pulldown to GND will disable the half-bridge converter and reset the latch.
TP4	VBias	Pre-bias source terminal
TP5	Vout	Output voltage terminal
TP6	SGND	Secondary-side ground
TP7	Small signal output	Small signal output for bode plot measurement using frequency analyzer
TP8	Small signal input	Small signal input for bode plot measurement using frequency analyzer
TP9	SW	Primary-side switch node

4 Performance Specifications

Table 3 list the LM5036EVM-294 design requirements.

Table 3. Design Requirements

Parameters	Test Conditions	MIN	TYP	MAX	Units
Input Characteristics					
DC voltage range		36	48	75	VDC
Load regulation			0.2%		
Line regulation			0.1%		
UVLO line voltage ON			34		VDC
UVLO line voltage OFF			32		VDC
OVP line voltage ON			80		V
OVP line voltage OFF			78		V
Latch threshold			80		V
V_{AUX1}	Off-state auxiliary output voltage		12.6		V
	On-state auxiliary output voltage		9		V
Max. load current for auxiliary supply			100		mA
Input DC current	Input = 36 VDC, full load = 8 A		2.858		A
	Input = 48 VDC, full load = 8 A		2.161		A
	Input = 75 VDC, full load = 8 A		1.416		A
Output Characteristics					
Vout output voltage	No load to full load = 8 A		12		VDC
Iout output current	35 to 75 VDC			8	A
Output current limit	35 to 75 VDC		10		A
Output voltage ripple	75 VDC and full load = 8 A		120		mVpp
System Characteristics					
Switching frequency			200		kHz
Peak efficiency	36 VDC, Load = 5.5 A		94.41%		
Maximum load efficiency	48 VDC, Load = 8 A		93.46%		
Operating temperature	Natural convection	–40		85	°C

NOTE: The LM5036EVM-294 is rated to operate from –40°C to 85°C, a fan is recommended but not required for operating at room temperature. A fan with a minimum 200 LFM of air flow is required when ambient temperature is above the room temperature.

5 Configuring ON_OFF Pin

Table 4 shows the configuration of the ON_OFF pin to use them as either overvoltage protection or a latch function pin.

Table 4. Configuration of ON_OFF Pin

ON_OFF Function	Switches	
	S1	S2
OVP	ON	ON
Latch	OFF	OFF

6 Typical Characteristic Curve

Figure 2 through Figure 4 present the typical analysis curves for the LM5036EVM-294.

6.1 Efficiency Plot

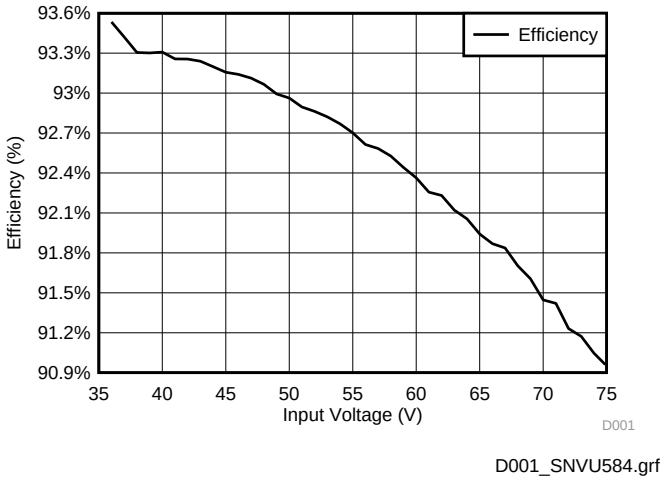

Figure 2. Efficiency vs Input Voltage at Full Load

6.2 Efficiency vs Load Current

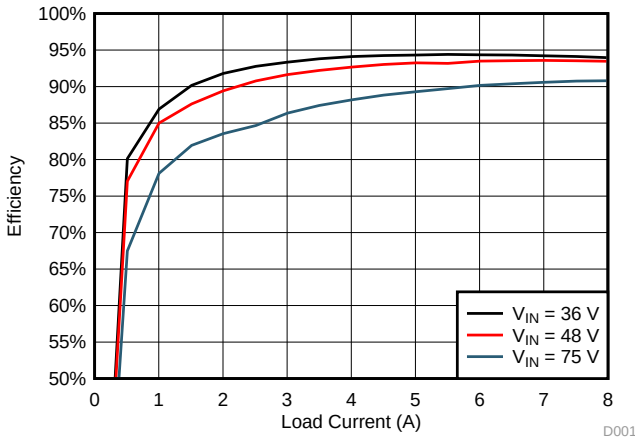

Figure 3. Efficiency vs Load Current (A) at Vin = 36 VDC, 48 VDC, and 75 VDC

6.3 Load Regulation

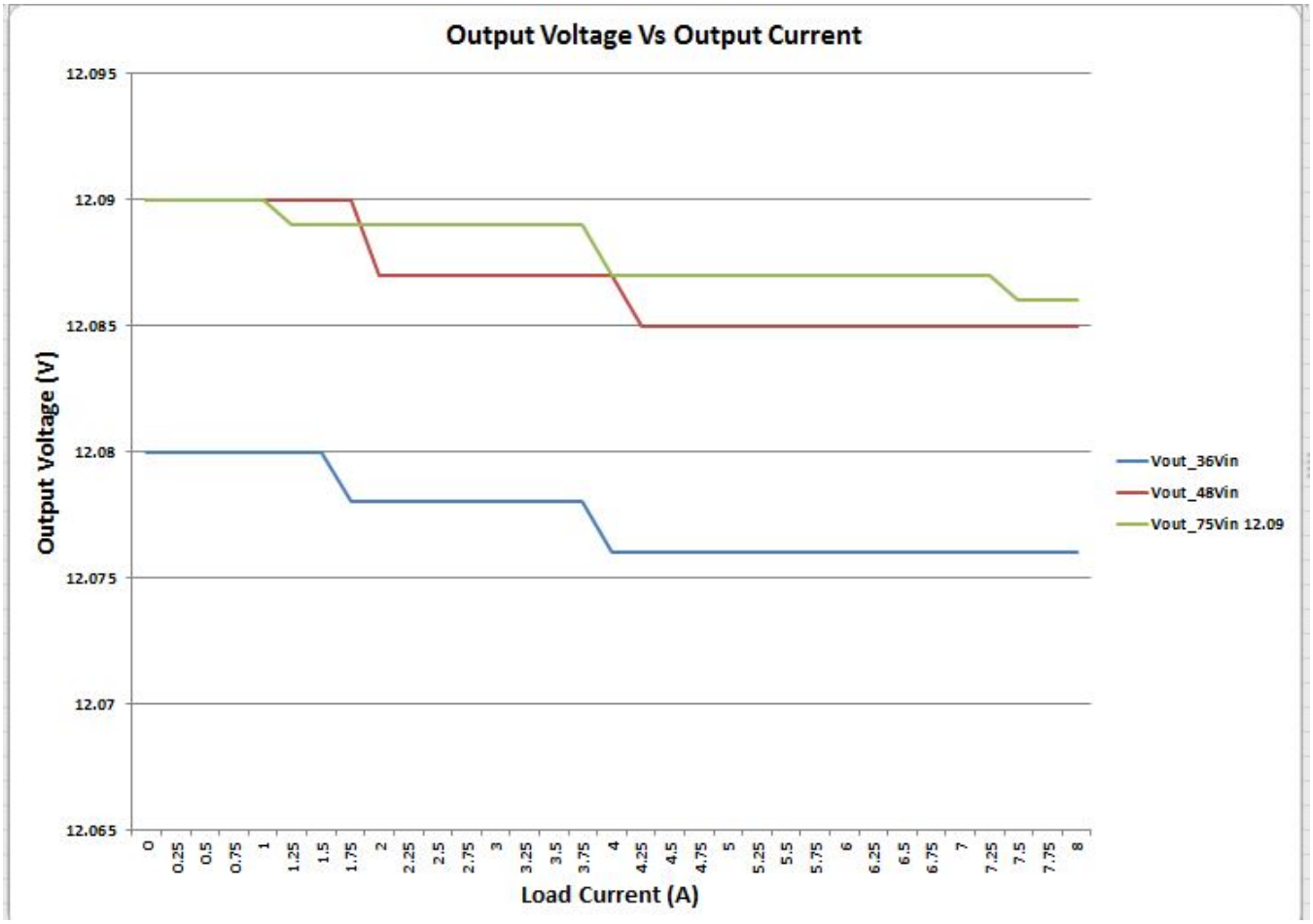

Figure 4. Output Voltage vs Output Current

6.4 Startup Waveform

Figure 5 and Figure 6 show the normal startup waveforms with zero bias voltage, where Output Inductor Current : (CH1), Switching node : (CH2) and Vout: (CH4)

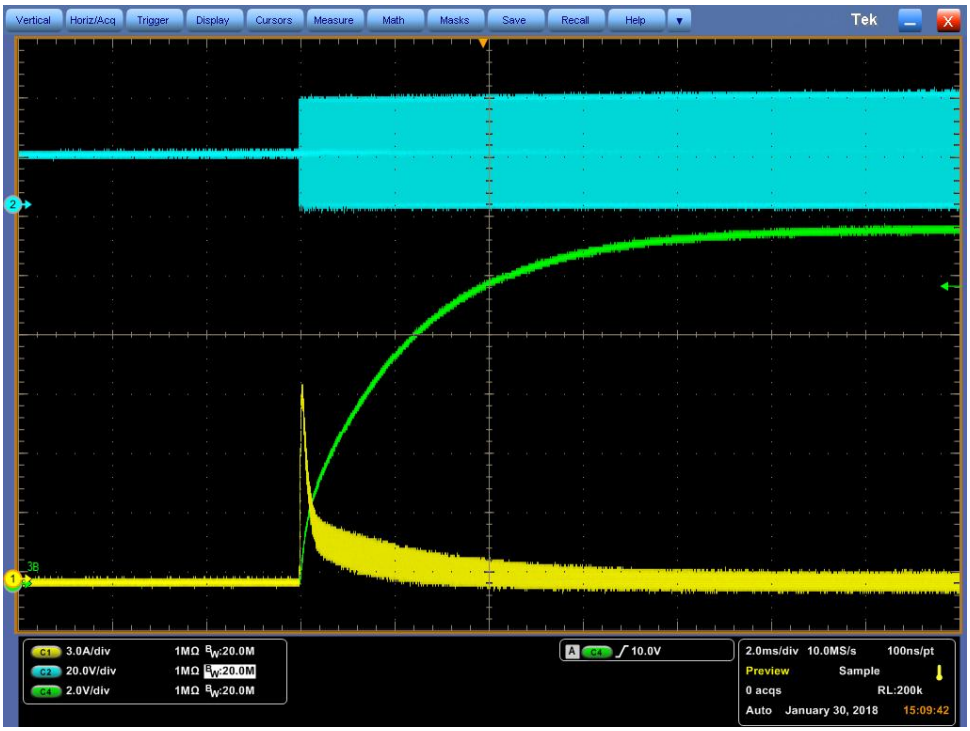

Figure 5. Vin = 48 V, Iout = 0 A

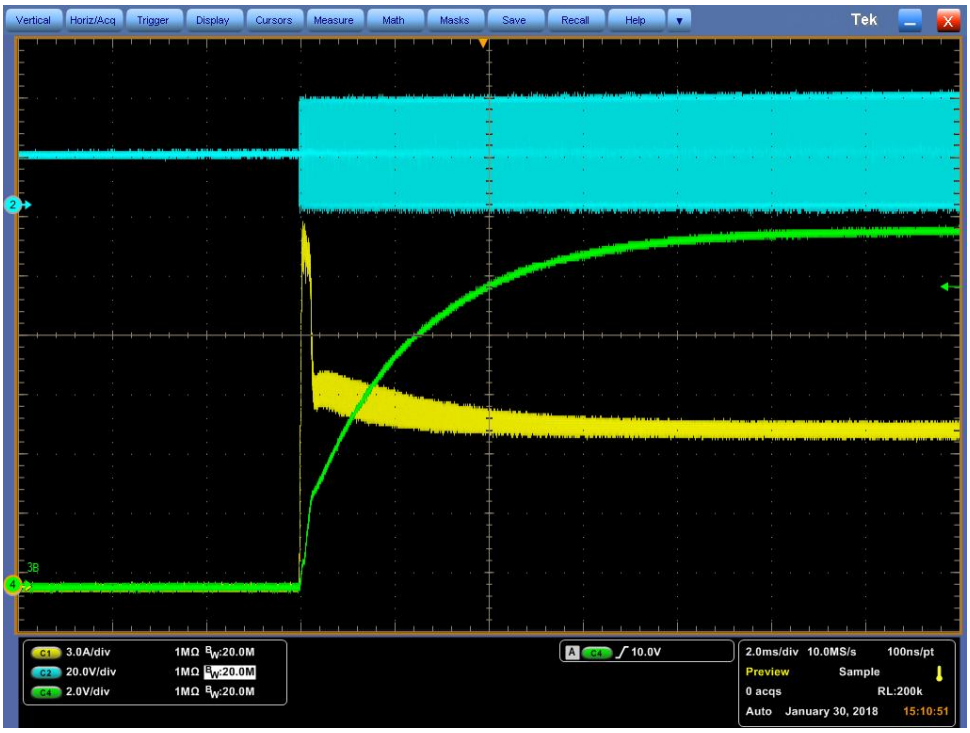

Figure 6. Vin = 48 V, Iout = 8 A

6.5 Pre-Biased Startup Waveform

Figure 7 and Figure 8 show the Pre-biased startup waveforms, where Output Inductor Current : (CH1), Switching node : (CH2) and Vout:(CH4).

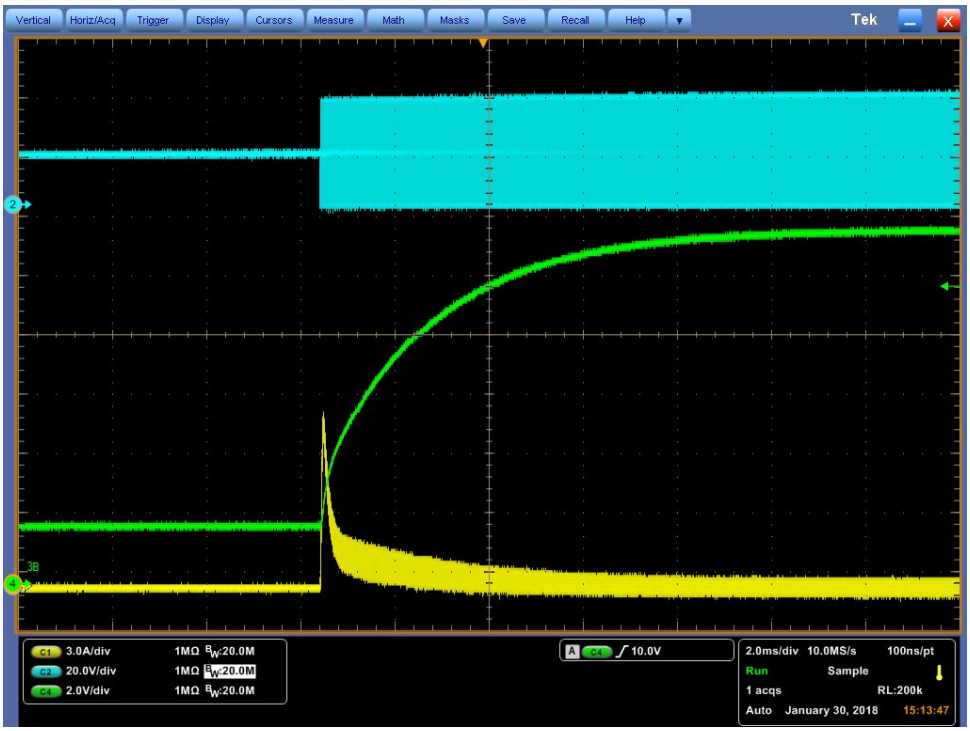

Figure 7. Vin = 48 V, VBias = 2 V

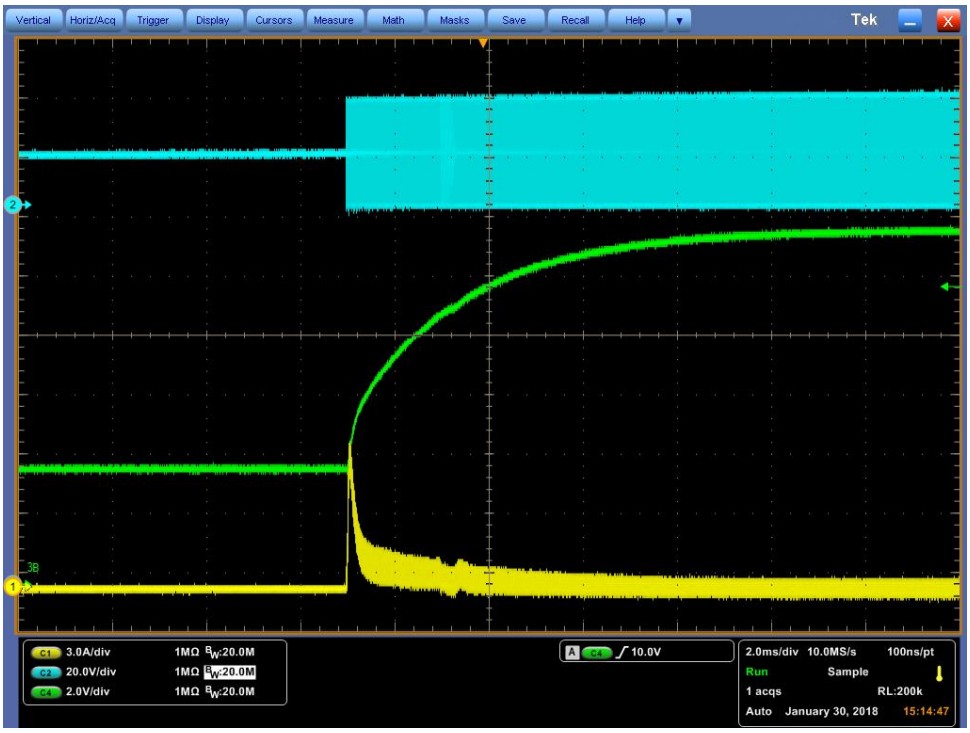

Figure 8. Vin = 48 V, VBias = 4 V

6.6 Load Transient Waveform

Figure 9are the Load transient waveform, where Output Inductor Current: (CH2) and AC coupled output voltage: (CH4) captured at the fastest slew rate.

Figure 9. Vin = 48 V, Iout = 0A-8A-0A

6.7 Output Voltage Ripple

Figure 10 and Figure 11 are the Output voltage ripple waveform, where Output inductor current : (CH1) and AC coupled output voltage Vout: (CH4).

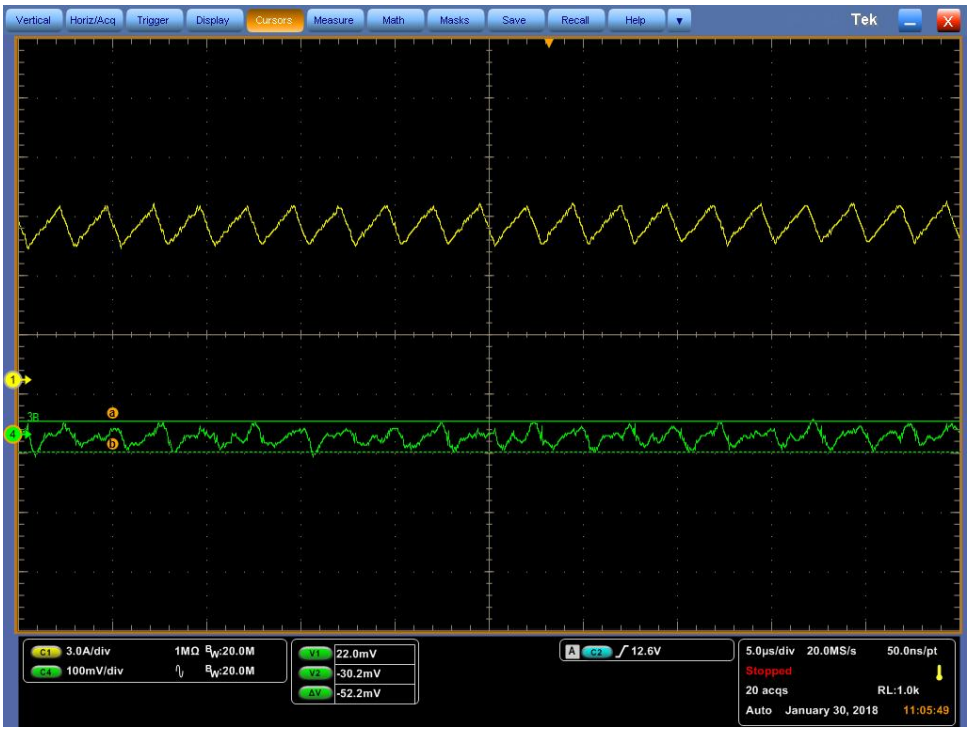

Figure 10. Vin = 48 V, Iout = 8 A

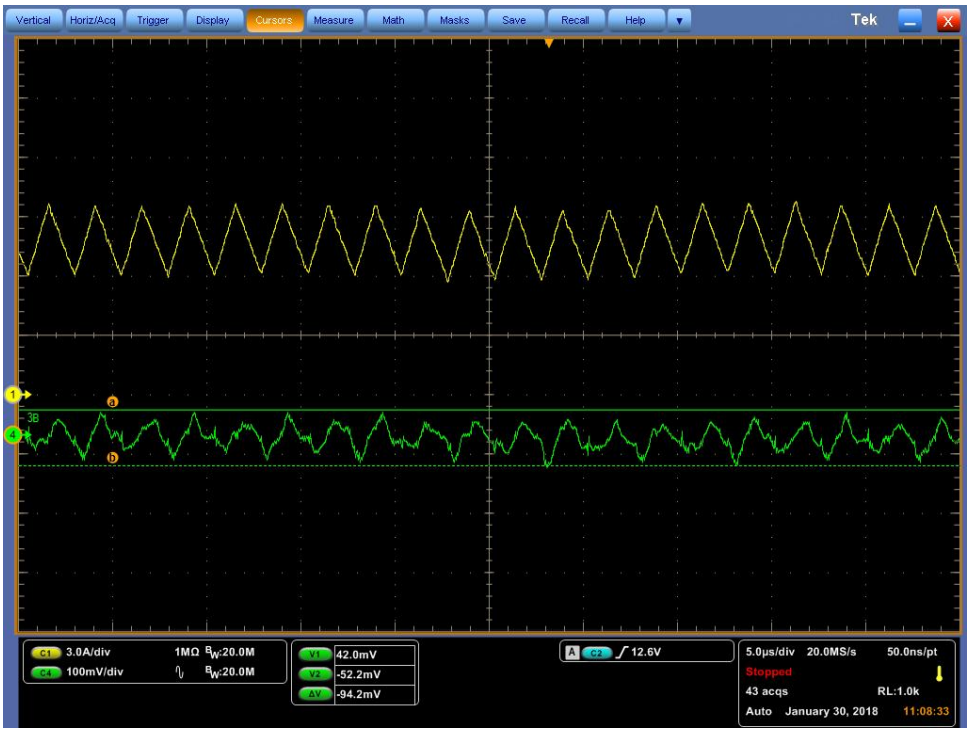

Figure 11. Vin = 75 V, Iout = 8 A

6.8 Steady State Waveform

Figure 12 through Figure 15 are the Steady-State waveform, where Inductor current: (CH1), Switching node SW: (CH2), AUX Switching node : (CH3) and Vout: (CH4).

Figure 12. Vin = 48 V, Iout = 0 A

Figure 13. Vin = 48 V, Iout = 8 A

Figure 14. Vin = 75 V, Iout = 0 A

Figure 15. Vin = 75 V, Iout = 8 A

6.9 Hiccup Mode (OCP)

Figure 16and Figure 17show the timing diagram of the hiccup mode activated by continuous CBC operation, where Output current limit: (CH1), Hiccup Capacitor voltage : (CH2) and Output voltage: (CH4).

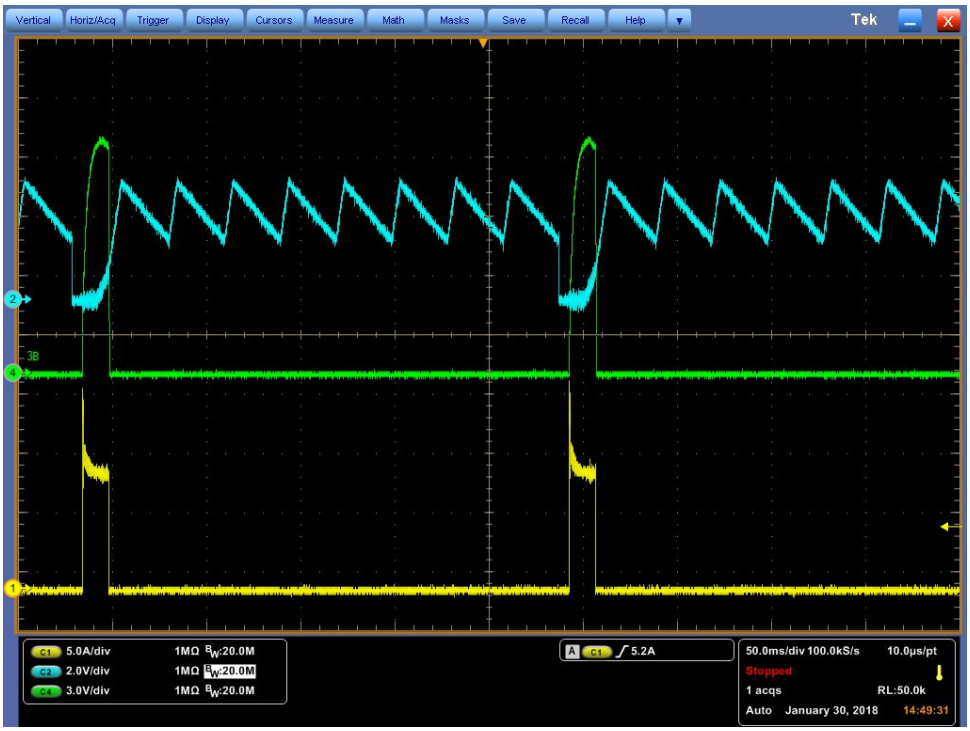

Figure 16. Vin = 36 V, Iout = 10 A

Figure 17. Vin = 48 V, Iout = 10 A

6.10 Latch Operation

Figure 18 shows the Latch operation, capturing Output voltage and Switching node when Input voltage exceeds the latch threshold of 80 V. (CH3): SW Node, (CH4): Vout

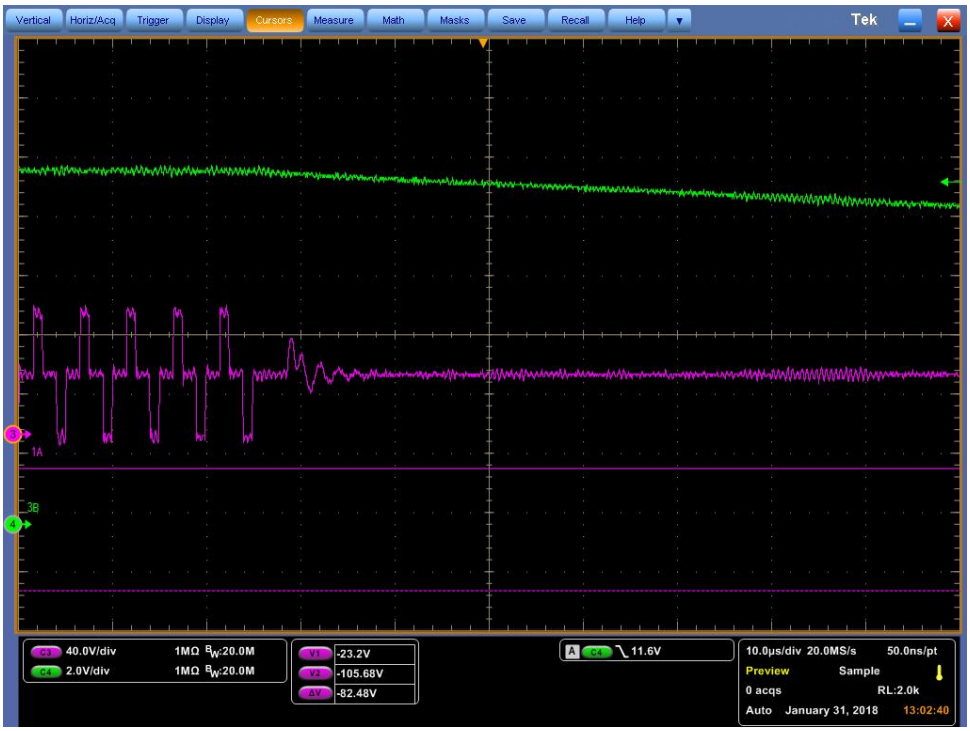

Figure 18. Latch Operation

6.11 Thermal Characteristics

Figure 19 through Figure 21 show the board temperature at full load (8 A) at ambient temperature.

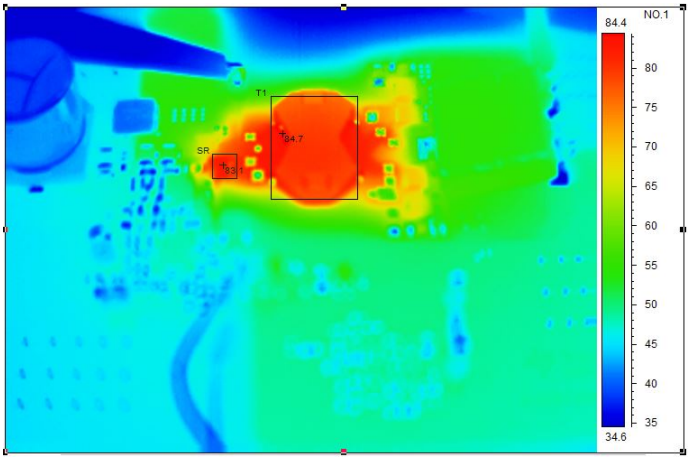

Figure 19. Thermal Scan Vin = 36 V, Iout = 8 A

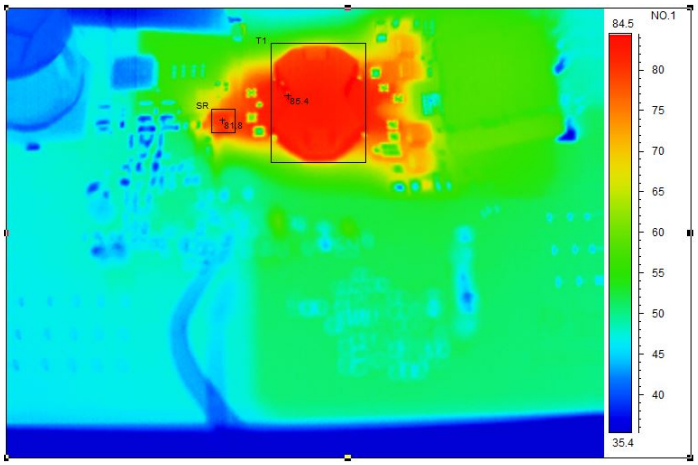

Figure 20. Thermal Scan Vin = 48 V, Iout = 8 A

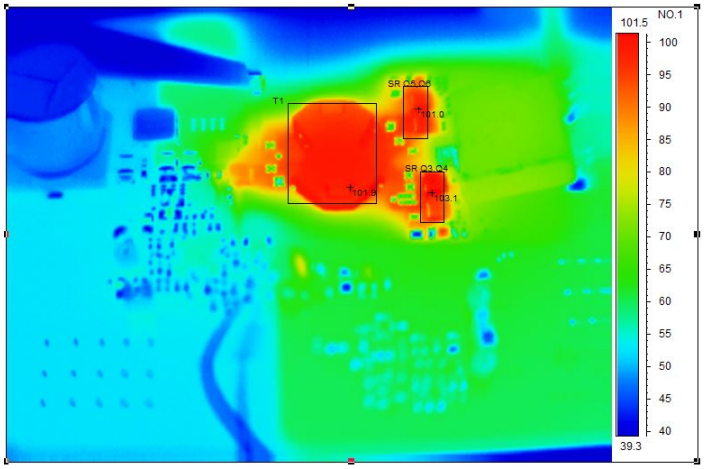

Figure 21. Thermal Scan Vin = 75 V, Iout = 8 A

7 EVM PCB Layout

Figure 22 and Figure 23 show the design of the PCB assembly. Figure 33 through Figure 33 show the 10 layers of layout files of LM5036 printed circuit board. has 10 PCB layers. The PCB dimensions of the LM5036EVM-294 follow: L × W = 195 x 125 inches (actual dimensions are not reflected in this user's guide).

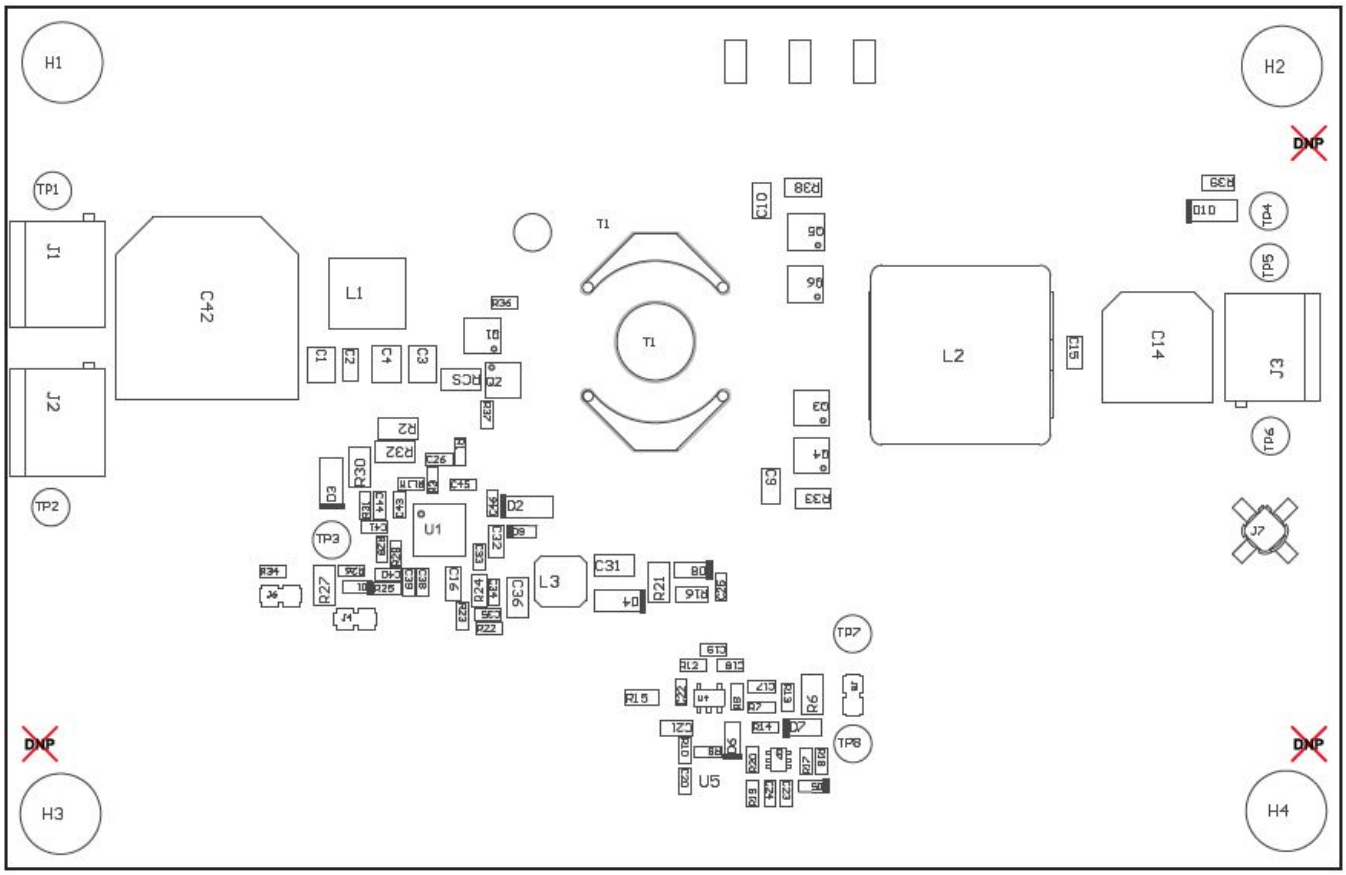

Figure 22. LM5036 EVM: Top Layer PCB Assembly File

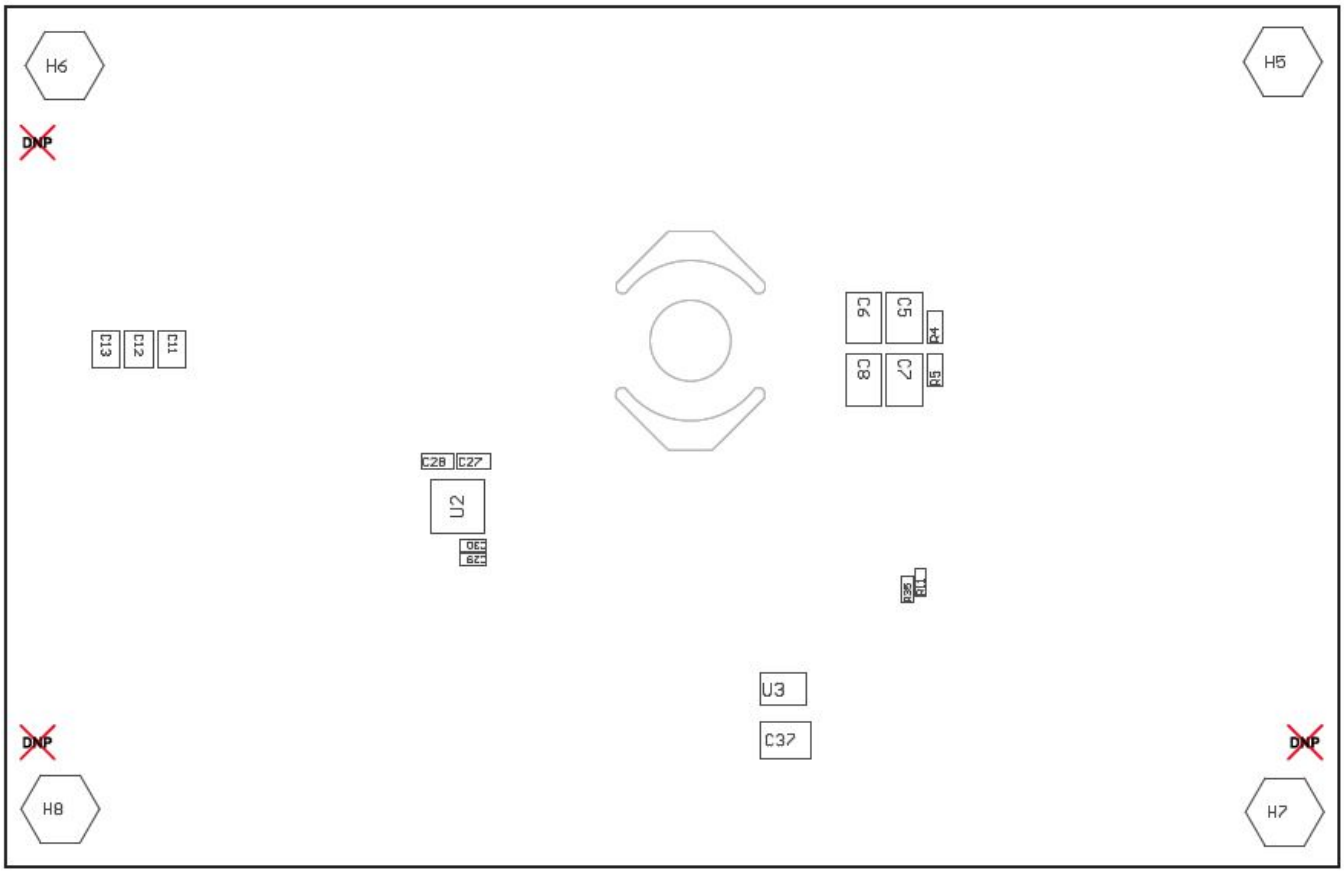

Figure 23. LM5036 EVM: Bottom Layer PCB Assembly File

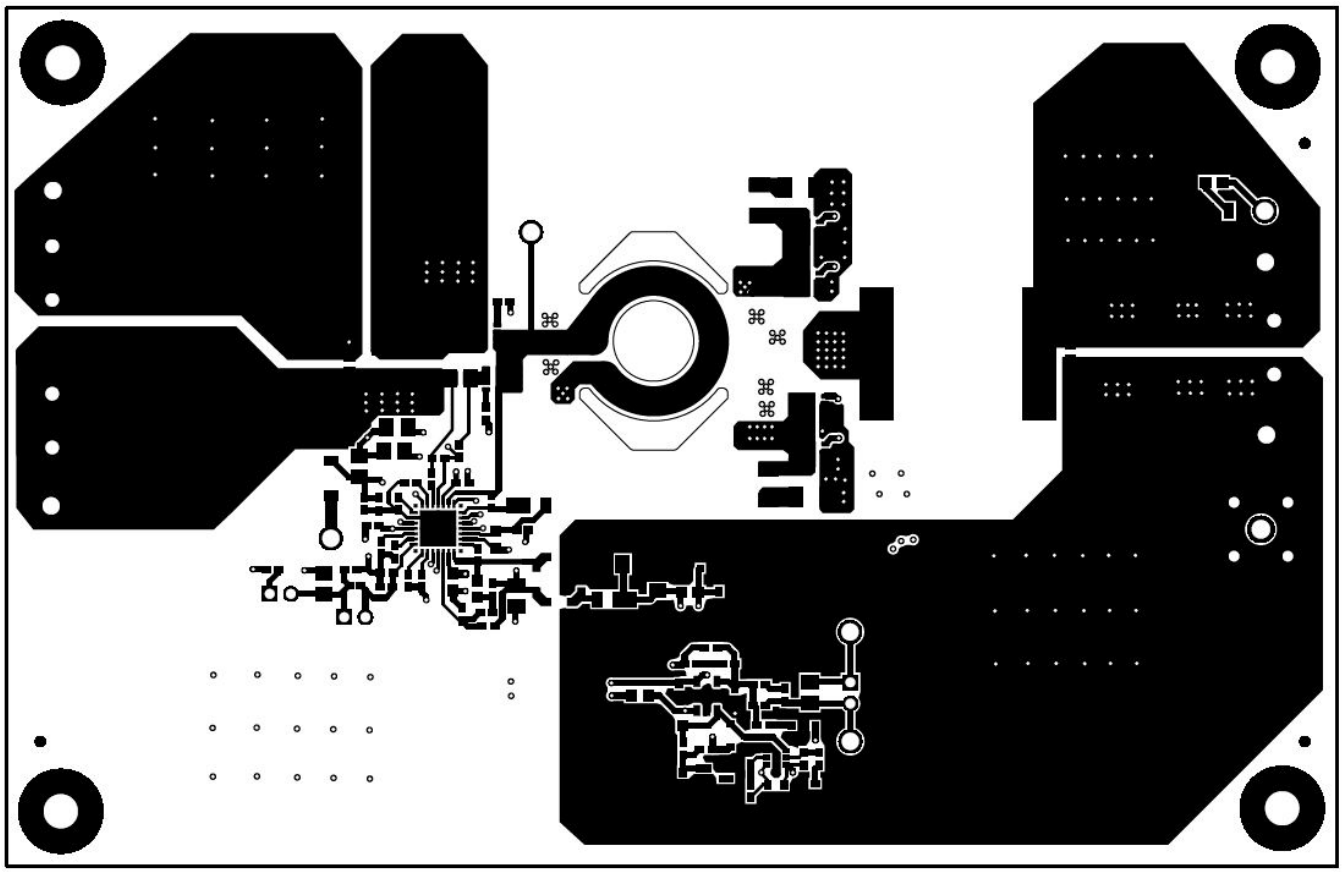

Figure 24. LM5036 EVM: Layer 1 PCB Assembly layout

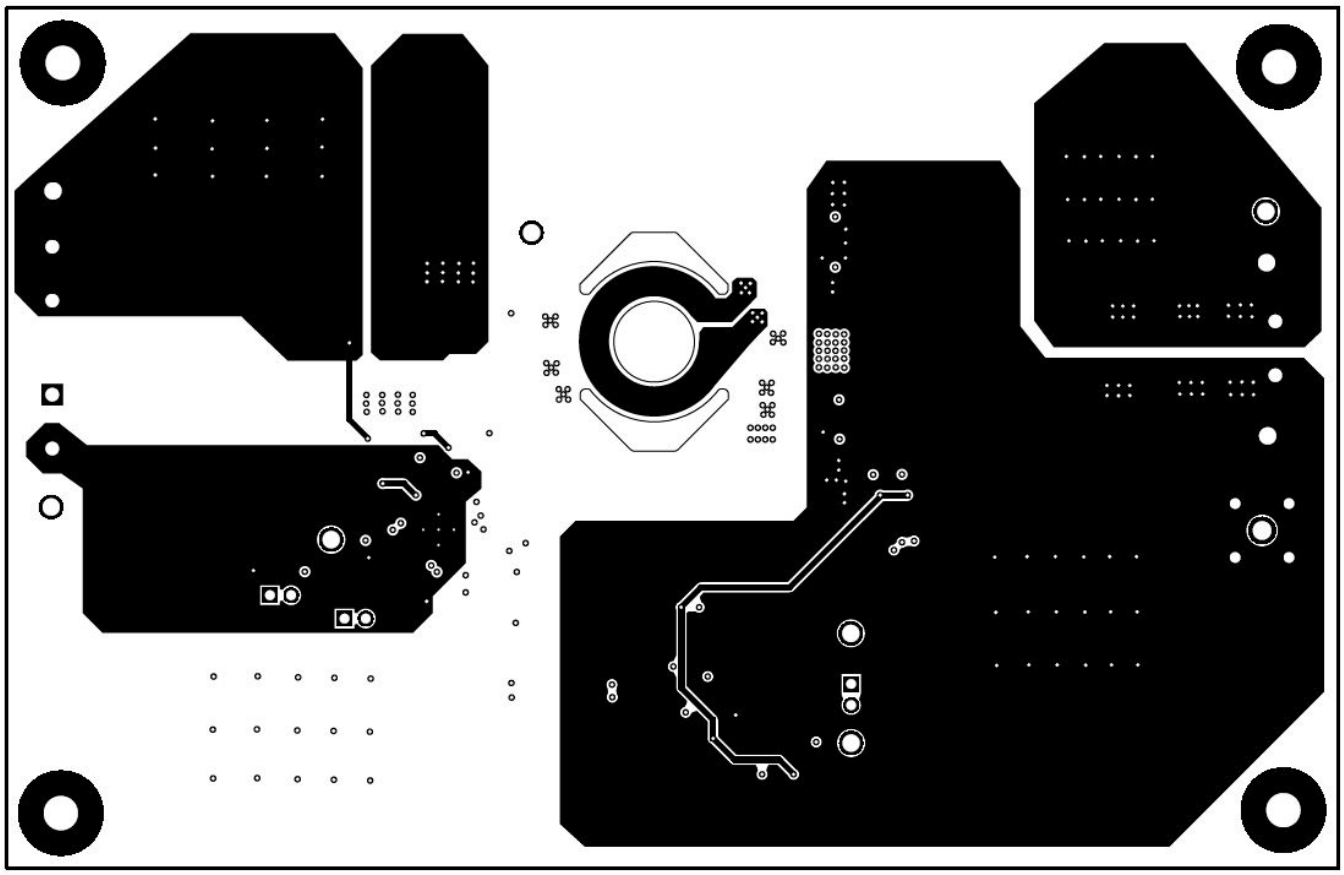

Figure 25. LM5036 EVM: Layer 2 PCB Assembly layout

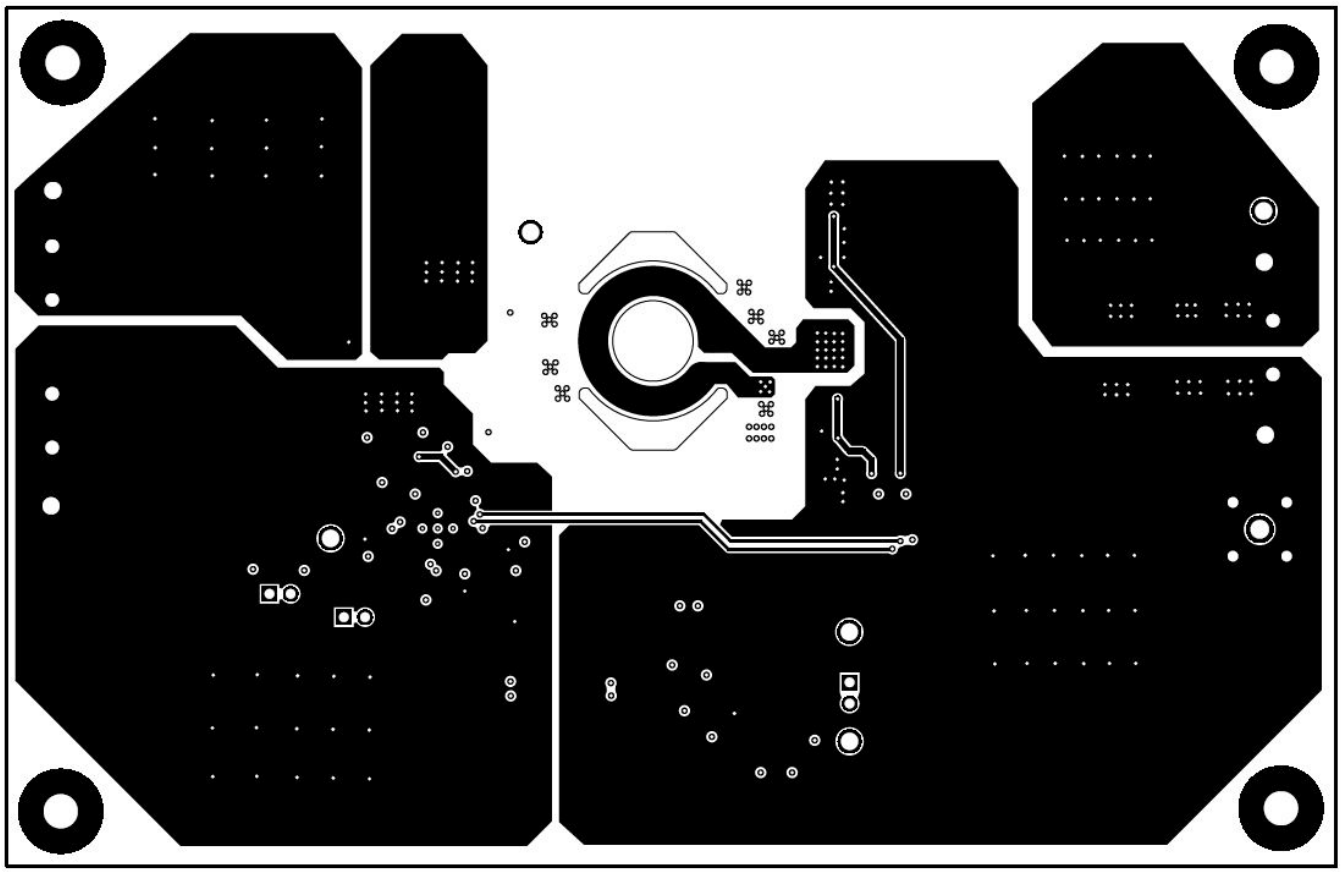

Figure 26. LM5036 EVM: Layer 3 PCB Assembly layout

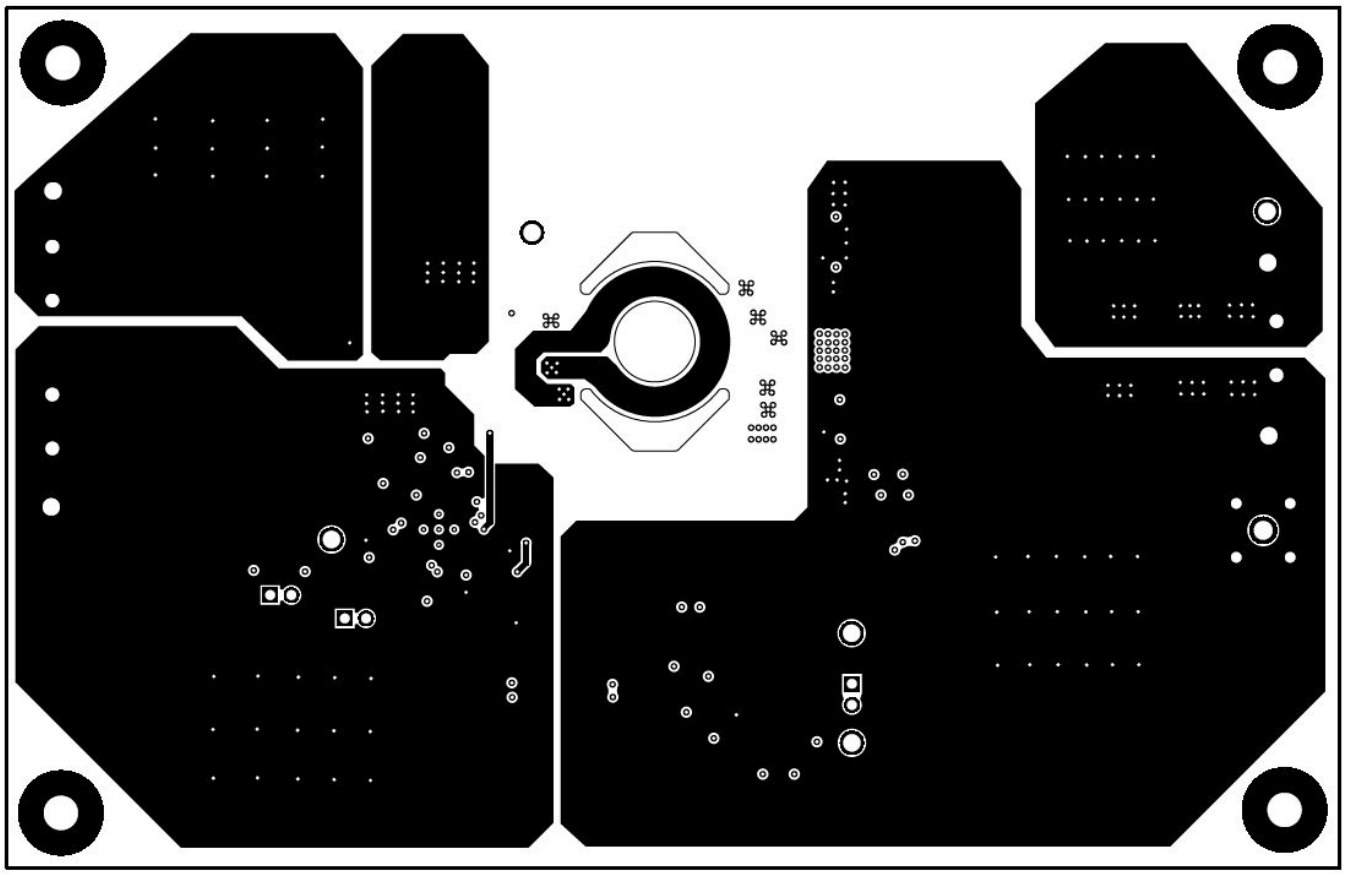

Figure 27. LM5036 EVM: Layer 4 PCB Assembly layout

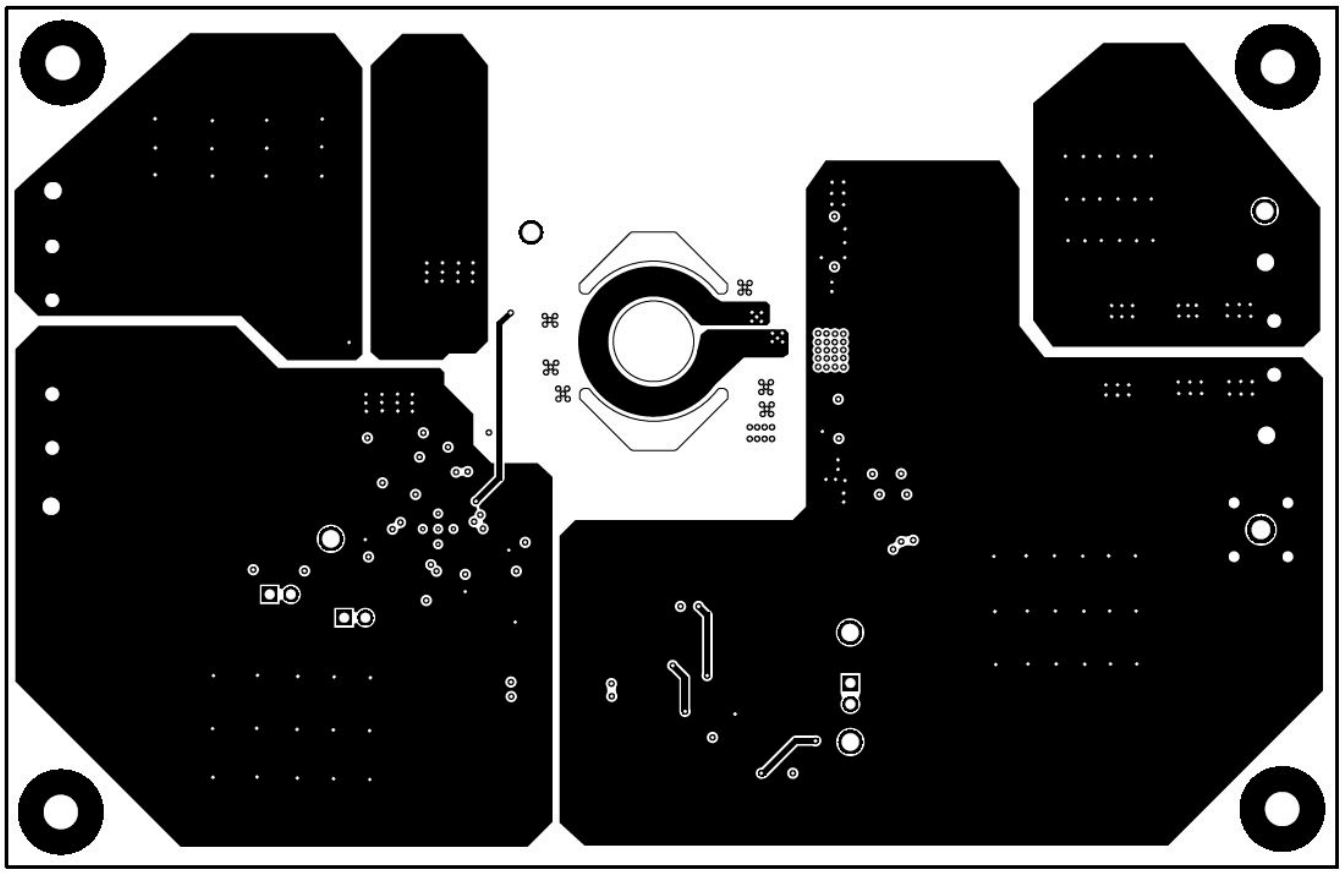

Figure 28. LM5036 EVM: Layer 5 PCB Assembly layout

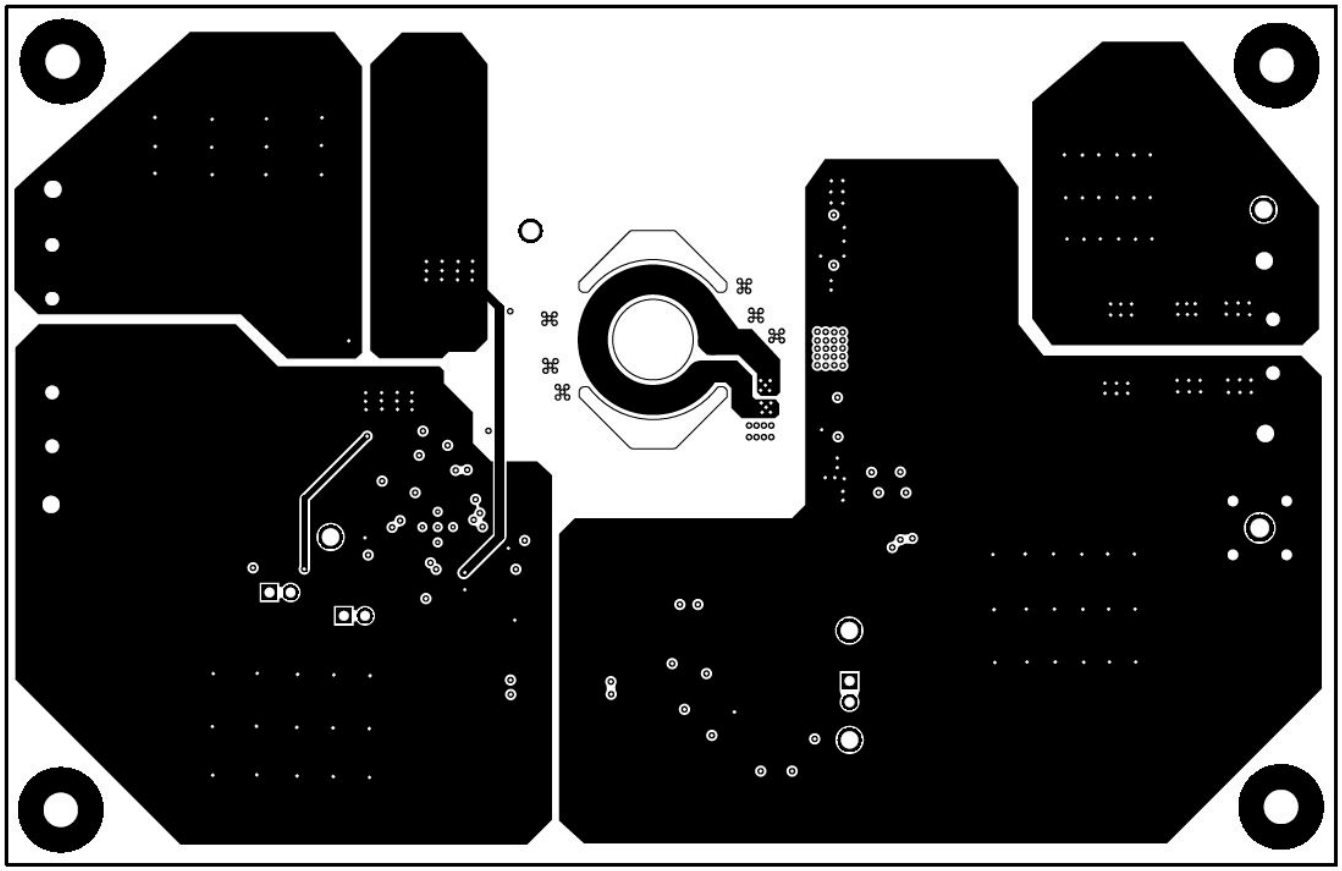

Figure 29. LM5036 EVM: Layer 6 PCB Assembly layout

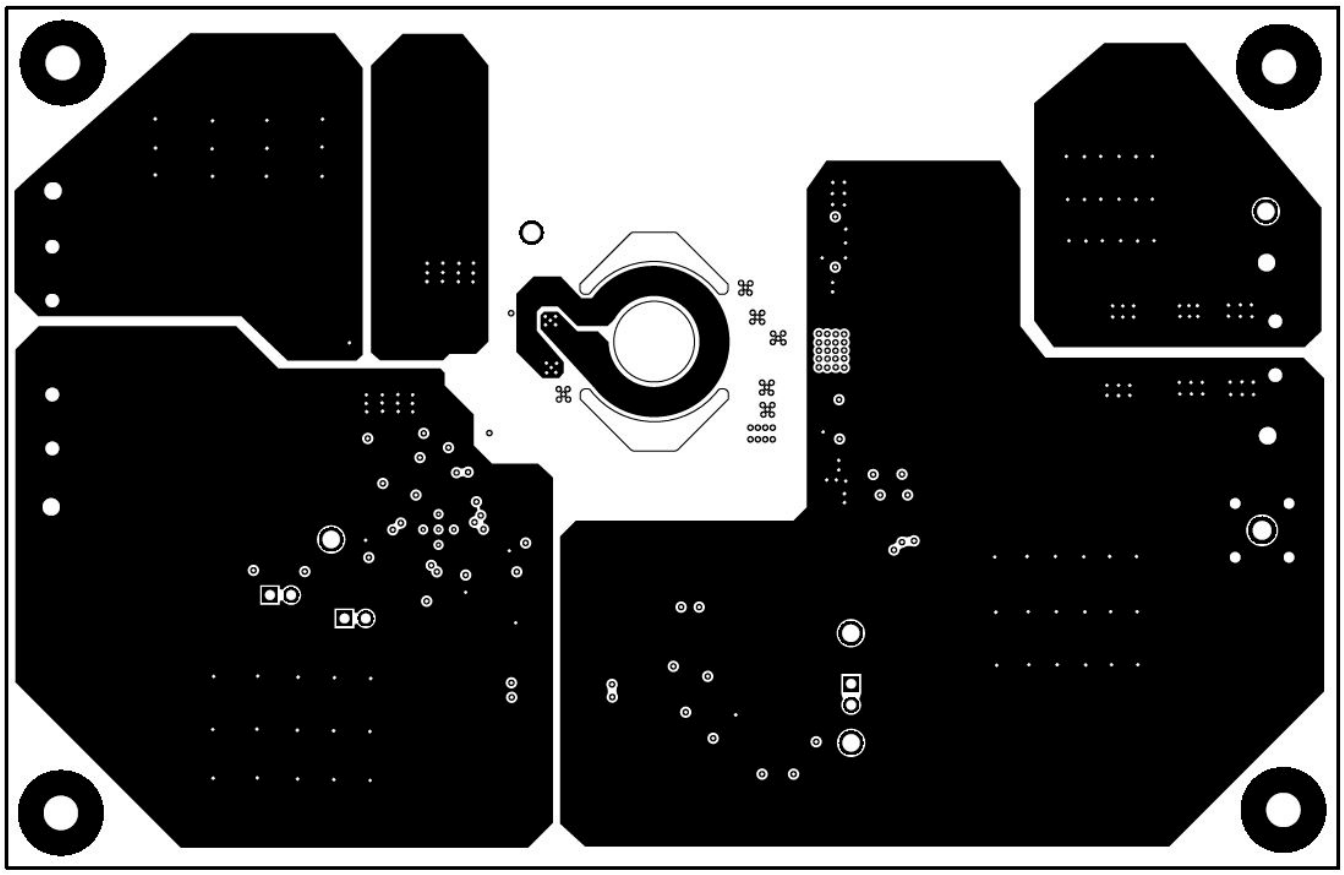

Figure 30. LM5036 EVM: Layer 7 PCB Assembly layout

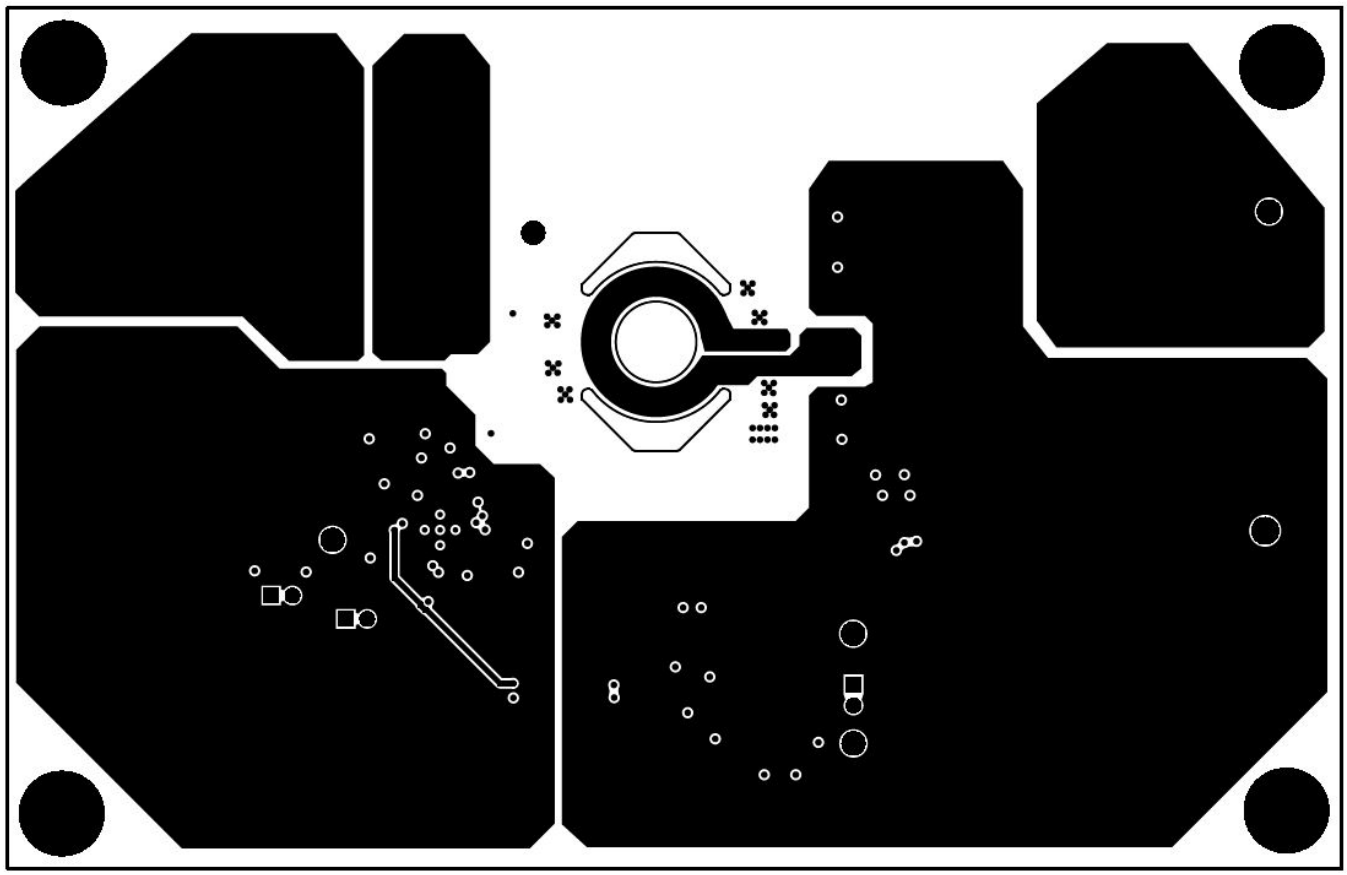

Figure 31. LM5036 EVM: Layer 8 PCB Assembly layout

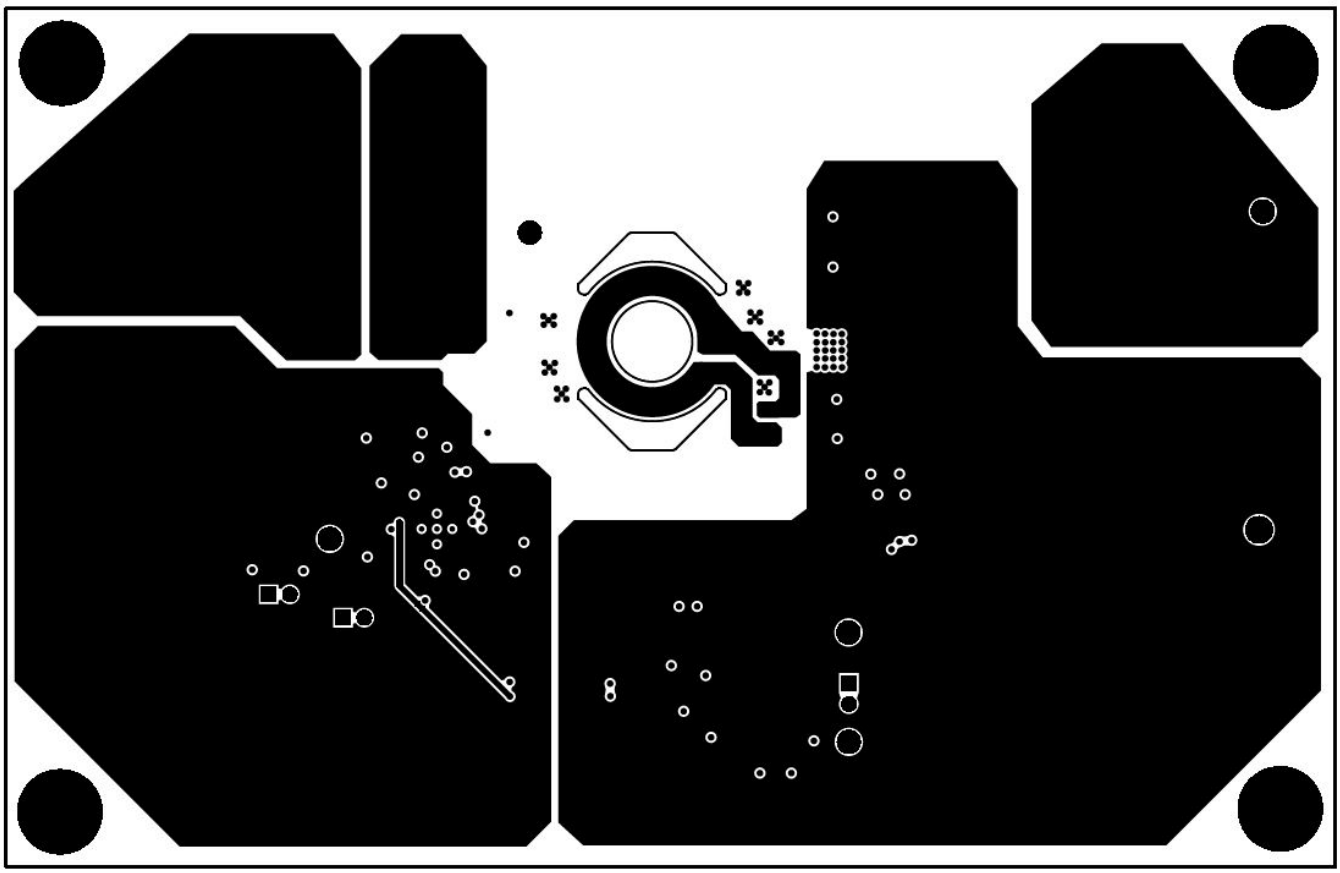

Figure 32. LM5036 EVM: Layer 9 PCB Assembly layout

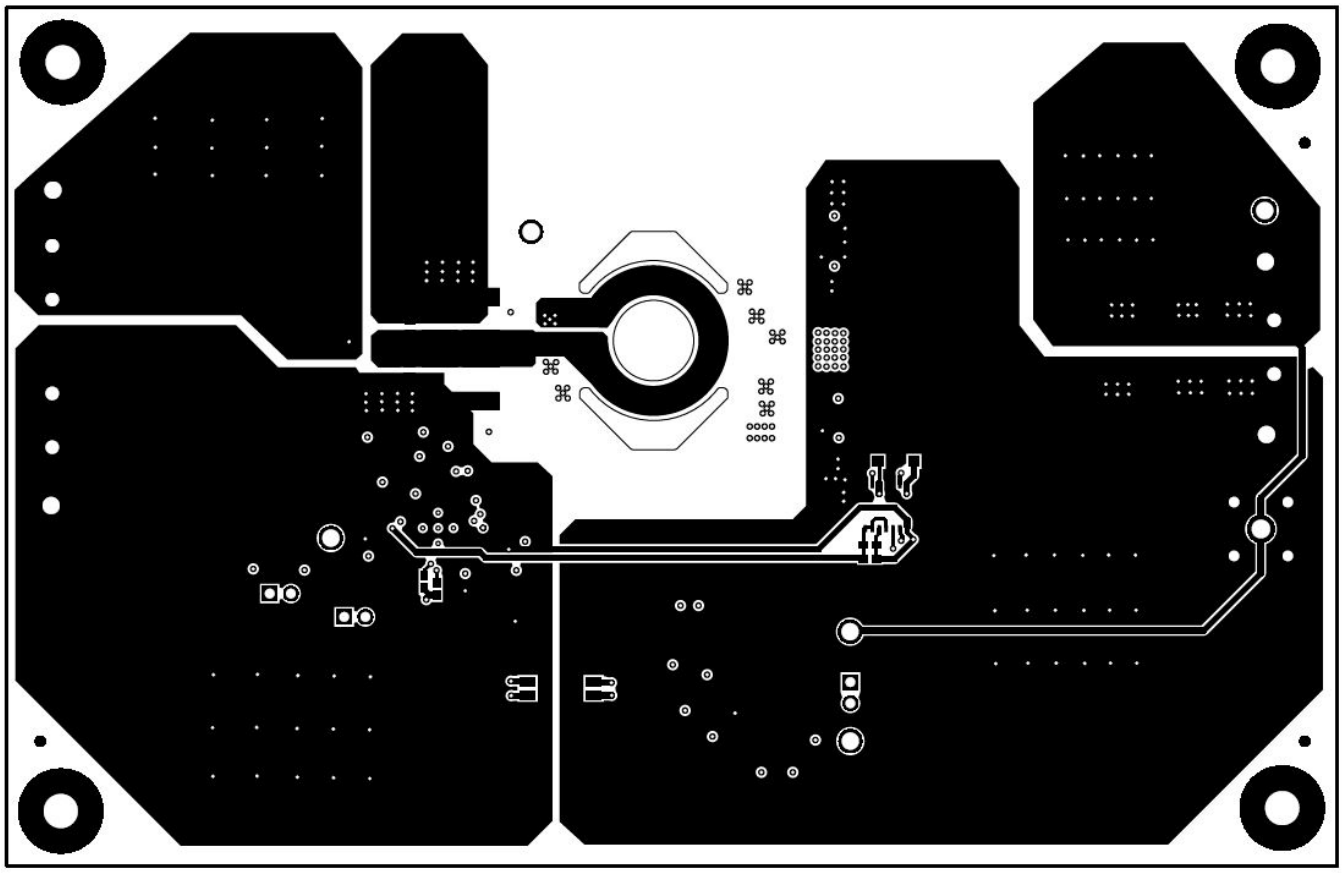

Figure 33. LM5036 EVM: Layer 10 PCB Assembly Layout

8 Schematic and Bill of Materials

This section contains the EVM schematic and the bill of materials required to execute this EVM schematic.

8.1 Schematic

Figure 34 illustrates the EVM schematic.

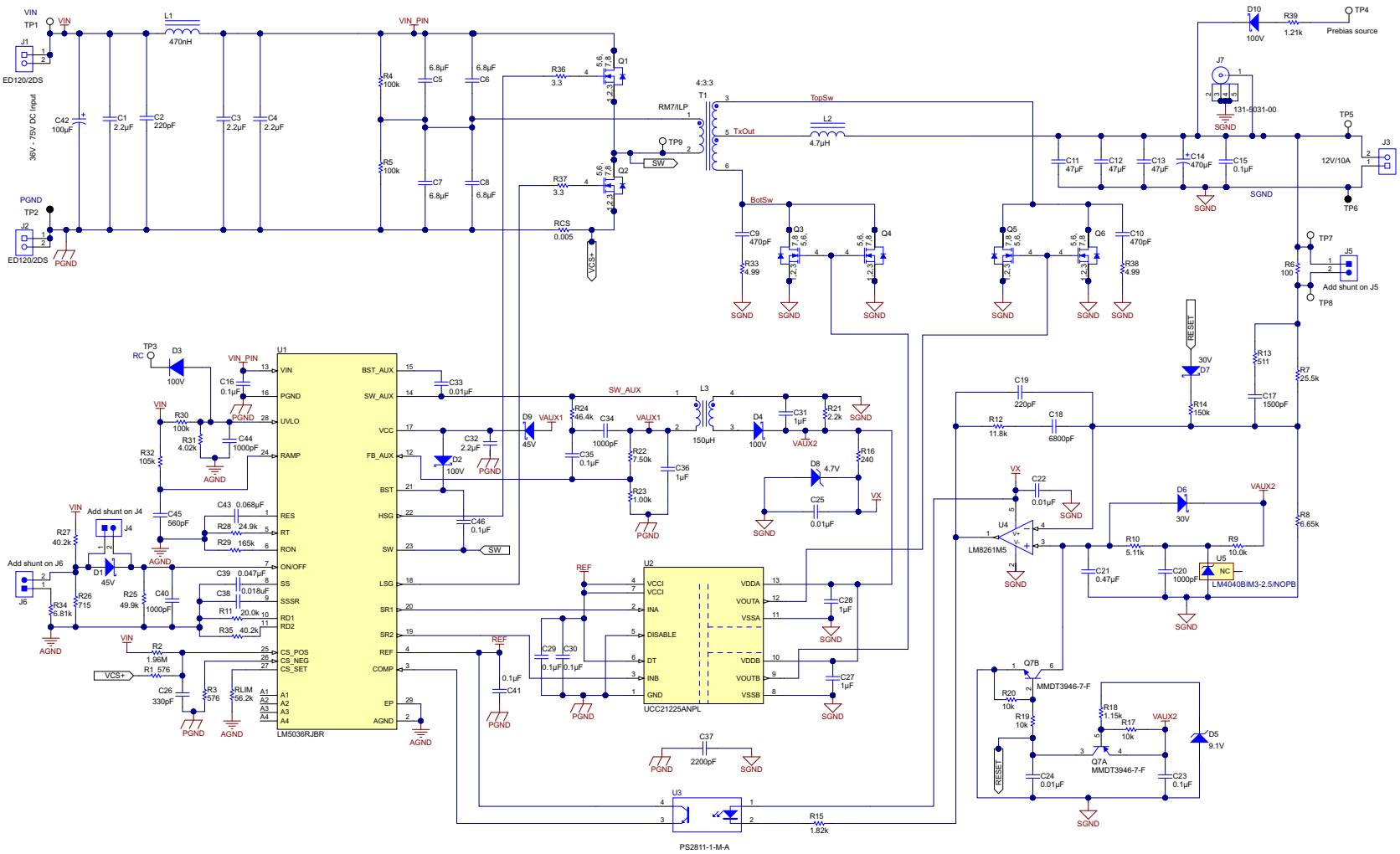

Figure 34. LM5036 Schematic Diagram

8.2 Bill of Materials

Table 5 lists the EVM BOM.

Table 5. LM5036 Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C1, C3, C4	3	2.2uF	CAP, CERM, 2.2 µF, 100 V,±10%, X7R, 1210	1210	GRM32ER72A225KA35L	Murata
C2	1	220pF	CAP, CERM, 220 pF, 100 V,±10%, X7R, 0603	0603	GRM188R72A221KA01D	Murata
C5, C6, C7, C8	4	6.8uF	CAP, CERM, 6.8 µF, 50 V,±10%, X7R, 1812	1812	C4532X7R1H685K250KB	TDK
C9, C10	2	470pF	CAP, CERM, 470 pF, 100 V,±10%, C0G/NP0, 1206	1206	12061A471KAT2A	AVX
C11, C12, C13	3	47uF	CAP, CERM, 47 µF, 16 V,±10%, X5R, 1210	1210	GRM32ER61C476KE15L	Murata
C14	1	470uF	CAP, Aluminum Polymer, 470 µF, 16 V,±20%, 0.01 ohm, JC0 SMD	JC0	16SVPE470M	Panasonic
C15	1	0.1uF	CAP, CERM, 0.1 µF, 25 V,±10%, X7R, 0603	0603	06033C104KAT2A	AVX
C16	1	0.1uF	CAP, CERM, 0.1 µF, 100 V,±10%, X7R, 0603	0603	GRM188R72A104KA35D	Murata
C17	1	1500pF	CAP, CERM, 1500 pF, 50 V,±5%, X7R, 0402	0402	GRM155R71H152JA01D	Murata
C18	1	6800pF	CAP, CERM, 6800 pF, 25 V,±10%, X7R, 0402	0402	GRM155R71E682KA01D	Murata
C19	1	220pF	CAP, CERM, 220 pF, 50 V,±10%, X7R, 0402	0402	GRM155R71H221KA01D	Murata
C20	1	1000pF	CAP, CERM, 1000 pF, 25 V,±10%, X7R, 0402	0402	885012205044	Wurth Elektronik
C21	1	0.47uF	CAP, CERM, 0.47 µF, 6.3 V,±10%, X7R, 0603	0603	GRM188R70J474KA01D	Murata
C22, C25	2	0.01uF	CAP, CERM, 0.01 µF, 16 V,±10%, X7R, 0402	0402	C1005X7R1C103K050BA	TDK
C23, C29, C30, C35, C41, C46	6	0.1uF	CAP, CERM, 0.1 µF, 25 V,±10%, X7R, 0402	0402	GRM155R71E104KE14D	Murata
C24, C33	2	0.01uF	CAP, CERM, 0.01 µF, 25 V,±10%, X7R, 0402	0402	GCM155R71E103KA37D	Murata
C26	1	330pF	CAP, CERM, 330 pF, 25 V,±5%, C0G/NP0, 0402	0402	GRM1555C1E331JA01D	Murata
C27, C28	2	1uF	CAP, CERM, 1 µF, 25 V,±10%, X7R, 0603	0603	C1608X7R1E105K080AB	TDK
C31, C36	2	1uF	CAP, CERM, 1 µF, 25 V,±10%, X7R, 0805	0805	C0805C105K3RACTU	Kemet
C32	1	2.2uF	CAP, CERM, 2.2 µF, 16 V,±10%, X7R, 0603	0603	CC0603KRX7R7BB225	Yageo America
C34	1	1000pF	CAP, CERM, 1000 pF, 25 V,±5%, X7R, 0402	0402	C0402C102J3RACTU	Kemet
C37	1	2200pF	CAP, CERM, 2200 pF, 2000 V,±10%, X7R, 1812	1812	C4532X7R3D222K130KA	TDK
C38	1	0.018uF	CAP, CERM, 0.018 uF, 25 V, ±10%, X7R, 0402	0402	GRM155R71E183KA61D	Murata
C39	1	0.047uF	CAP, CERM, 0.047 µF, 16 V,±10%, X7R, 0402	0402	GRM155R71C473KA01D	Murata
C40, C44	2	1000pF	CAP, CERM, 1000 pF, 16 V,±10%, X7R, 0402	0402	GRM155R71C102KA01D	Murata
C42	1	100uF	CAP, AL, 100 µF, 100 V, ±20%, 0.17 ohm, AEC-Q200 Grade 2, SMD	SMT Radial J16	EEV-FK2A101M	Panasonic
C43	1	0.068uF	CAP, CERM, 0.068 µF, 16 V,±10%, X7R, 0402	0402	GRM155R71C683KA88D	Murata
C45	1	560pF	CAP, CERM, 560 pF, 50 V,±5%, C0G/NP0, 0402	0402	GRM1555C1H561JA01D	Murata
D1, D9	2	45V	Diode, Schottky, 45 V, 0.1 A, SOD-523	SOD-523	SDM10U45-7-F	Diodes Inc.
D2, D4, D10	3	100V	Diode, Schottky, 100 V, 2 A, PowerDI123	PowerDI123	DFLS2100-7	Diodes Inc.
D3	1	100V	Diode, Ultrafast, 100 V, 0.15 A, SOD-123	SOD-123	1N4148W-7-F	Diodes Inc.
D5	1	9.1V	Diode, Zener, 9.1 V, 300 mW, SOD-523	SOD-523	BZT52C9V1T-7	Diodes Inc.

Table 5. LM5036 Bill of Materials (continued)

D6, D7	2	30V	Diode, Schottky, 30 V, 0.2 A, SOD-323	SOD-323	BAT54WS-7-F	Diodes Inc.
D8	1	4.7V	Diode, Zener, 4.7 V, 250 mW, SOD-323	SOD-323	CMDZ4L7 TR	Central Semiconductor
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	3		Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block	ED120/2DS	On-Shore Technology
J4, J5, J6	3		Header, 2mm, 2x1, Gold, TH	Header, 2mm, 2x1, TH	TMM-102-01-F-S	Samtec
J7	1		Compact Probe Tip Circuit Board Test Points, TH, 25 per	TH Scope Probe	131-5031-00	Tektronix
L1	1	470nH	Inductor, Shielded Drum Core, Powdered Iron, 470 nH, 17.5 A, 0.004 ohm, SMD	IHLP-2525CZ	IHLP2525CZERR47M01	Vishay-Dale
L2	1	4.7uH	Inductor, Shielded, Powdered Iron, 4.7 µH, 25 A, 0.0055 ohm, AEC-Q200 Grade 0, SMD	16.9x16.9 mm	SRP1770TA-4R7M	Bourns
L3	1	150uH	Coupled inductor, 150 µH, 0.29 A, 3.82 ohm, SMD	Coupled Inductor, 4.8x4.8mm, SMT	LPD5030V-154ME	Coilcraft
Q1, Q2, Q3, Q4, Q5, Q6	6	100V	MOSFET, N-CH, 100 V, 50 A, DQG0008A (VSON-CLIP-8)	DQG0008A	CSD19537Q3	Texas Instruments
Q7	1	40 V	Transistor, NPN/PNP Pair, 40 V, 0.2 A, SOT-363	SOT-363	MMDT3946-7-F	Diodes Inc.
R1, R3	2	576	RES, 576, 0.1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	ERA2AEB5760X	Panasonic
R2	1	1.96Meg	RES, 1.96 M, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ6ENF1964V	Panasonic
R4, R5	2	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R6	1	100	RES, 100, 1%, 0.125 W, 0805	0805	CRCW0805100RFKEA	Vishay-Dale
R7	1	25.5k	RES, 25.5 k, 1%, 0.063 W, 0402	0402	CRCW040225K5FKED	Vishay-Dale
R8	1	6.65k	RES, 6.65 k, 1%, 0.063 W, 0402	0402	CRCW04026K65FKED	Vishay-Dale
R9	1	10.0k	RES, 10.0 k, 1%, 0.063 W, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R10	1	5.11k	RES, 5.11 k, 1%, 0.063 W, 0402	0402	CRCW04025K11FKED	Vishay-Dale
R11	1	20.0k	RES, 20.0 k, 1%, 0.063 W, 0402	0402	CRCW040220K0FKED	Vishay-Dale
R12	1	11.8k	RES, 11.8 k, 1%, 0.063 W, 0402	0402	CRCW040211K8FKED	Vishay-Dale
R13	1	511	RES, 511, 1%, 0.063 W, 0402	0402	CRCW0402511RFKED	Vishay-Dale
R14	1	150k	RES, 150 k, 5%, 0.063 W, 0402	0402	CRCW0402150KJNED	Vishay-Dale
R15	1	1.82k	RES, 1.82 k, 1%, 0.1 W, 0603	0603	CRCW06031K82FKEA	Vishay-Dale
R16	1	240	RES, 240, 5%, 0.25 W, 0603	0603	CRCW0603240RJNEAHP	Vishay-Dale
R17, R19, R20	3	10k	RES, 10 k, 5%, 0.063 W, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R18	1	1.15k	RES, 1.15 k, 1%, 0.063 W, 0402	0402	CRCW04021K15FKED	Vishay-Dale
R21	1	2.2k	RES, 2.2 k, 5%, 0.125 W, 0805	0805	ERJ-6GEYJ222V	Panasonic
R22	1	7.50k	RES, 7.50 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04027K50FKED	Vishay-Dale
R23	1	1.00k	RES, 1.00 k, 1%, 0.063 W, 0402	0402	CRCW04021K00FKED	Vishay-Dale
R24	1	46.4k	RES, 46.4k ohm, 1%, 0.1W, 0603	0603	ERJ-3EKF4642V	Panasonic
R25	1	49.9k	RES, 49.9 k, 1%, 0.063 W, 0402	0402	CRCW040249K9FKED	Vishay-Dale
R26	1	715	RES, 715, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402715RFKED	Vishay-Dale

Table 5. LM5036 Bill of Materials (continued)

R27	1	40.2k	RES, 40.2 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW080540K2FKEA	Vishay-Dale
R28	1	24.9k	RES, 24.9 k, 1%, 0.063 W, 0402	0402	CRCW040224K9FKED	Vishay-Dale
R29	1	165k	RES, 165 k, 1%, 0.063 W, 0402	0402	CRCW0402165KFKED	Vishay-Dale
R30	1	100k	RES, 100 k, 1%, 0.125 W, 0805	0805	CRCW0805100KFKEA	Vishay-Dale
R31	1	4.02k	RES, 4.02 k, 1%, 0.063 W, 0402	0402	CRCW04024K02FKED	Vishay-Dale
R32	1	105k	RES, 105 k, 1%, 0.125 W, 0805	0805	CRCW0805105KFKEA	Vishay-Dale
R33, R38	2	4.99	RES, 4.99, 1%, 0.25 W, 1206	1206	CRCW12064R99FKEA	Vishay-Dale
R34	1	6.81k	RES, 6.81 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04026K81FKED	Vishay-Dale
R35	1	40.2k	RES, 40.2 k, 1%, 0.063 W, 0402	0402	CRCW040240K2FKED	Vishay-Dale
R36, R37	2	3.3	RES, 3.3, 5%, 0.063 W, 0402	0402	CRCW04023R30JNED	Vishay-Dale
R39	1	1.21k	RES, 1.21 k, 1%, 0.1 W, 0603	0603	CRCW06031K21FKEA	Vishay-Dale
RCS	1	0.005	RES, 0.005, 1%, 0.5 W, AEC-Q200 Grade 1, 0805	0805	ERJ6LWFR005V	Panasonic
RLIM	1	56.2k	RES, 56.2 k, 1%, 0.063 W, 0402	0402	CRCW040256K2FKED	Vishay-Dale
SH-J1, SH-J2, SH-J3	3	1x2	Shunt, 2mm, Gold plated, Black	2mm Shunt, Closed Top	2SN-BK-G	Samtec
T1	1		Transformer, SMD	EMBEDDED/PLANAR TRANSFORMER	RM7/ILP	FerroxCube
TP1, TP3, TP4, TP5, TP7, TP8, TP9	7		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
TP2, TP6	2		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
U1	1		Half-Bridge PWM Controller with Integrated Auxiliary Supply, RJB0028A (WQFN-28)	RJB0028A	LM5036RJBR	Texas Instruments
U2	1		4A/6A Isolated Dual-Channel Gate Driver, NPL0013A (VLGA-13)	NPL0013A	UCC21225ANPL	Texas Instruments
U3	1		Optocoupler, 2.5 kV, 100-200% CTR, SMT	PS2811-1	PS2811-1-M-A	California Eastern Laboratories
U4	1		Single RRIO, High output Current and High Capacitive Load Op Amp, DBV0005A	DBV0005A	LM8261M5	Texas Instruments
U5	1		Precision Micropower Shunt Voltage Reference, 3-pin SOT-23, Pb-Free	MF03A	LM4040BIM3-2.5/NOPB	Texas Instruments
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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.

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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.

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