AN-2043 LM5035C Evaluation Board

1 Introduction

The LM5035C evaluation board is designed to provide the design engineer with a fully functional power converter based on the half bridge topology to evaluate the LM5035C controller. The LM5035C is a functional variant of the LM5035B half-bridge PWM controller. The amplitude of the SR control signals are 5V instead of the V_{CC} level. The evaluation board is provided in an industry standard quarter-brick footprint.

The performance of the evaluation board is as follows:

- Input operating range: 36V to 75V
- Output voltage: 3.3V
- Output current: 0 to 30A
- Measured efficiency: 89% at 30A, 92% at 15A
- Frequency of operation: 400kHz
- Board size: 2.28 x 1.45 x 0.5 inches
- Load Regulation: 0.2%
- Line Regulation: 0.1%
- Line under-voltage lock-out (UVLO) (33.9V/31.9V on/off)
- Line over-voltage protection (OVP) (79.4V/78.3V off/on)
- Hiccup current limit

The printed circuit board consists of 6 layers; 2 ounce copper outer layers and 3 ounce copper inner layers on FR4 material with a total thickness of 0.062 inches. The unit is designed for continuous operation at rated load at <40°C and a minimum airflow of 200 CFM.

2 Theory of Operation

Power converters based on the half bridge topology offer high efficiency and good power handling capability in applications up to 500 Watts. The operation of the transformer causes the flux to swing in both directions, thereby better utilizing the magnetic core.

The half bridge converter is derived from the Buck topology family, employing separate high voltage (HO) and low voltage (LO) modulating power switches with independent pulse width timing. The main difference between the topologies are, the Half Bridge topology employs a transformer to provide input/output ground isolation and a step down or step up function.

Each cycle, the main primary switch turns on and applies one-half the input voltage across the primary winding, which has 8 turns. The transformer secondary has 2 turns, leading to a 4:1 step-down of the input voltage. For an output voltage of 3.3V, the composite duty cycle (D) of the primary switches varies from approximately 75% (low line) to 35% (high line).

The secondary employs synchronous rectification controlled by the LM5035C. During soft-start, the sync FET body diodes act as the secondary rectifiers until the main transformer energizes the gate drivers. The DLY resistor programs the non-overlap timing for the sync FETs to maximize efficiency while eliminating shoot through current. The Sync FET control signals are sent across the isolation boundary using a digital isolator.

Feedback from the output is processed by an amplifier and reference, generating an error voltage, which is coupled back to the primary side control through an optocoupler. The COMP input to the LM5035C greatly increases the achievable loop bandwidth. The capacitance effect (and associated pole) of the optocoupler is reduced by holding the voltage across the optocoupler constant. The LM5035C voltage mode controller pulse width modulates the error signal with a ramp signal derived from the line voltage (feedforwarding) to reduce the response time to input voltage changes. A standard “type III” network is used for the compensator.

The evaluation board can be synchronized to an external clock with a recommended frequency range of 420KHz to 500KHz.

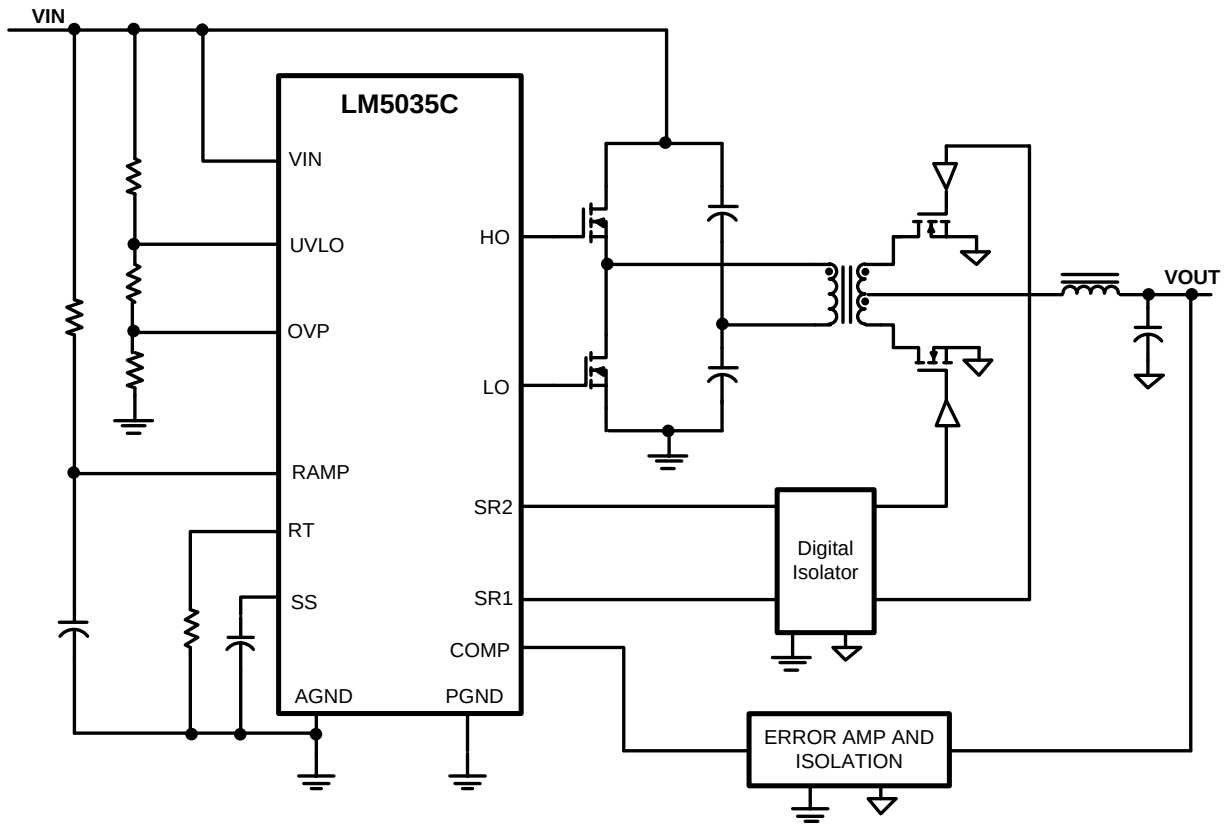


Figure 1. Simplified Half Bridge Converter

3 Powering and Loading Considerations

When applying power to the LM5035C evaluation board, certain precautions need to be followed. A misconnection can damage the assembly.

4 Proper Connections

When operated at low input voltages, the evaluation board can draw up to 3.5A of current at full load. The maximum rated output current is 30A. Be sure to choose the correct connector and wire size when attaching the source supply and the load. Monitor the current into and out of the evaluation board. Monitor the voltage directly at the output terminals of the evaluation board. The voltage drop across the load connecting wires will cause inaccurate measurements. This is especially true for accurate efficiency measurements.

5 Source Power

The evaluation board can be viewed as a constant power load. At low input line voltage (36V) the input current can reach 3.5A, while at high input line voltage (75V) the input current will be approximately 1.5A. Therefore, to fully test the LM5035C evaluation board a DC power supply capable of at least 85V and 5A is required.

The power supply must have adjustments for both voltage and current. The power supply and cabling must present low impedance to the evaluation board. Insufficient cabling or a high impedance power supply will cause voltage droop during turn-on due to the evaluation board inrush current. If large enough, this droop will cause a chattering condition upon power up. This chattering condition is an interaction with the evaluation board undervoltage lockout, the cabling impedance and the inrush current.

6 Loading

An appropriate electronic load, with specified operation down to 1.0V minimum, is desirable. The resistance of a maximum load is 0.11Ω. The high output current requires thick cables! If resistor banks are used there are certain precautions to be taken. The wattage and current ratings must be adequate for a 30A, 100W supply. Monitor both current and voltage at all times. Ensure there is sufficient cooling provided for the load.

7 Air Flow

Full power loading should never be attempted without providing the specified 200 CFM of air flow over the evaluation board. A stand-alone fan should be provided.

8 Powering Up

Using the ON/OFF pin (J2) provided will allow powering up the source supply with the current level set low. It is suggested that the load be kept low during the first power up. Set the current limit of the source supply to provide about 1.5 times the wattage of the load. As you remove the connection from the ON/OFF pin to ground (J1), immediately check for 3.3 volts at the output.

A most common occurrence, that will prove unnerving, is when the current limit set on the source supply is insufficient for the load. The result is similar to having the high source impedance referred to earlier. The interaction of the source supply folding back and the evaluation board going into undervoltage shutdown will start an oscillation, or chatter, that may have undesirable consequences.

A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss you can be reasonably sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

9 Over Current Protection

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 35A) the unit will discharge the softstart capacitor, which disables the power stage. After a delay the softstart is released. The shutdown, delay and slow recharge time of the softstart capacitor protects the unit, especially during short circuit event where the stress is highest.

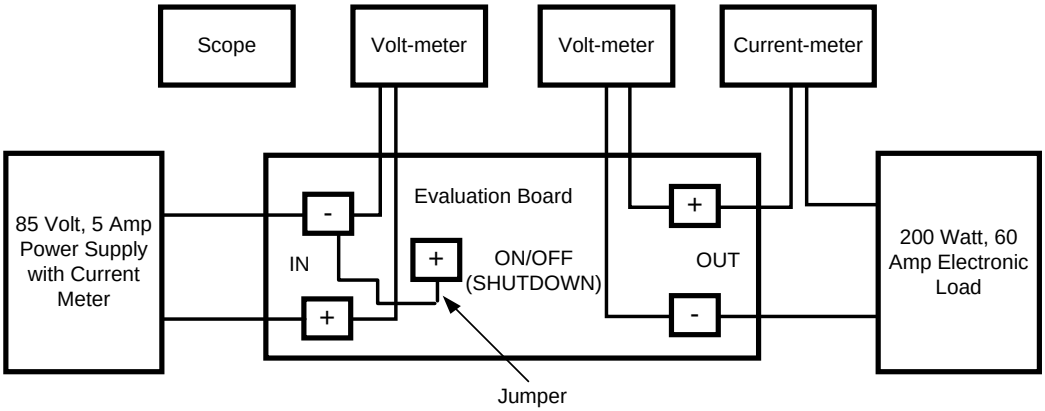


Figure 2. Typical Evaluation Setup

10 Digital Isolator

There is a total of four crossing of the isolation boundary; the power transformer, the feedback and control of the two synchronous MOSFETs. Usually an opto-coupler is used for isolation of the feedback signal since this a relatively slow analog signal. Most opto-couplers are too slow to use for the synchronous MOSFET gate drive. There are fast opto-couplers available but there is a big cost premium. Historically, the most common approach has been to use gate drive transformers to provide isolation for the synchronous gate drive signals. The transformers can be used to directly drive the MOSFET gates or the transformers can be used to just isolate the control signal which is then applied to a gate driver IC on the secondary side. Gate drive transformers have their challenges and limitations. Transformers cannot pass DC. A given size transformer can only pass a finite voltage and time product across the isolation boundary. After each on-time, the transformer needs to be reset, which imposes duty cycle limitations. Further, during a sudden switch-off of the power converter, the DC restorer capacitor on the secondary of the gate drive transformer does not have a quick discharge path. This will keep SR FET's turned on, resulting in a non-monotonic decay of the output voltage.

These limitations can be addressed using a digital isolator. The digital isolators are CMOS devices that use an RF coupler to transmit digital information across the isolation barrier. The isolation capability is up to 2500 VRMS. In simple words, the digital isolators are similar to an opto-coupler. While, the opto-couplers modulate light to transmit electrical signals, the digital isolators modulate an RF signal across a semiconductor barrier. Furthermore, the digital isolators have lower propagation delay than the gate drive transformers and do not suffer volt-second limitations.

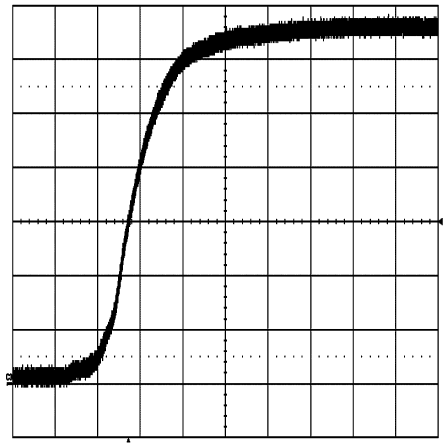
11 Performance Characteristics

11.1 Turn-On Waveforms

A certain sequence of events occurs when applying power to the LM5035C evaluation board. The soft-start capacitor values and other components allow for a minimal output voltage for a short time until the feedback loop can stabilize without overshoot. Figure 1 shows the output voltage during a typical start-up with a 48V input and a load of 5A. There is no overshoot during startup.

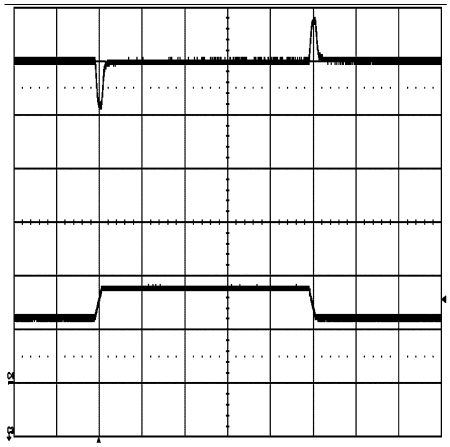
11.2 Output Ripple Waveforms

Figure 3 shows the transient response for a load change from 15A to 22.5A. The upper trace shows minimal output voltage droop and overshoot during the sudden change in output current shown by the lower trace.



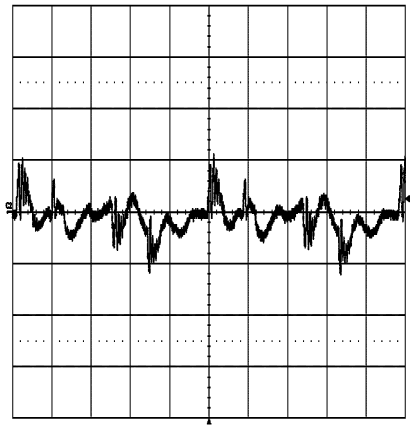
Conditions: Input Voltage = 48VDC Output Current = 5A Trace 1: Output Voltage Volts/div = 500mV Horizontal Resolution = 0.5ms/div

Figure 3. Output Voltage During a Typical Start-Up



Conditions: Input Voltage = 48VDC Output Current = 15A to 22.5A Upper Trace: Output Voltage Volts/div = 50mV Lower Trace: Output Current = 15A to 22.5A to 15A Horizontal Resolution = 0.5ms/div

Figure 4. Transient Response for a Load Change From 15A to 22.5A



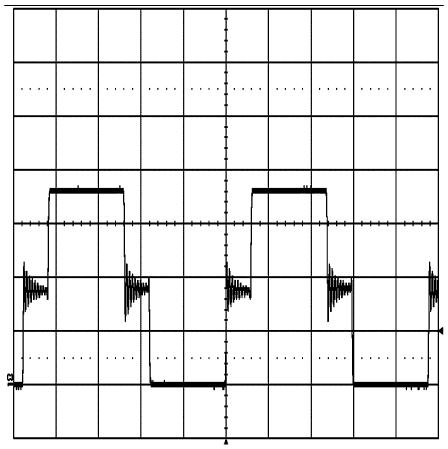
Conditions: Input Voltage = 48VDC Output Current = 30A Bandwidth Limit = 20MHz Trace 1: Output Ripple Voltage Volts/div = 20mV Horizontal Resolution = 1µs/div

Figure 5. Typical Output Ripple Seen Across the Output Terminals

Figure 5 shows typical output ripple seen across the output terminals (with standard 10µF and 1µF ceramic capacitors) for an input voltage of 48V and a load of 30A. This waveform is typical of most loads and input voltages.

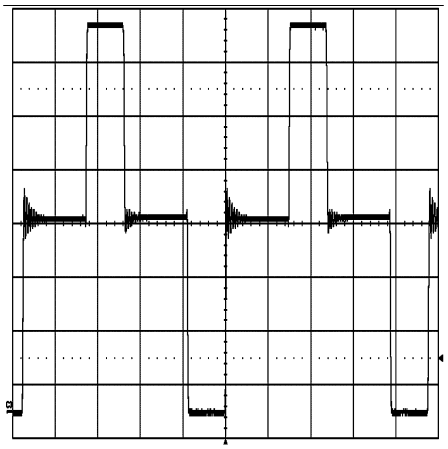
Figure 6 and Figure 7 show the drain voltage of Q1 with a 5A load. Figure 6 represents an input voltage of 36V and Figure 5 represents an input voltage of 72V.

Figure 8 shows the gate voltages of the synchronous rectifiers. The deadtime provided by the 20kΩ DLY resistor is difficult to see at this timescale.



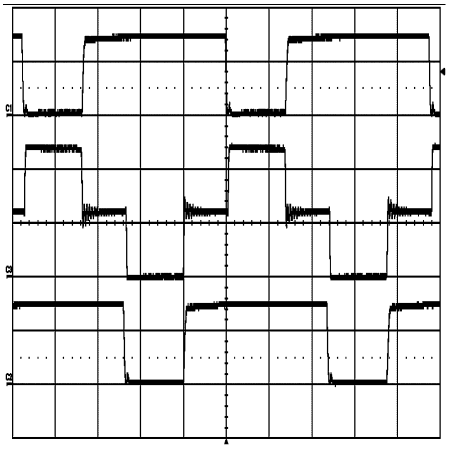
Conditions: Input Voltage = 36VDC Output Current = 5A
Trace 1: Q1 drain voltage Volts/div = 10V Horizontal Resolution = 1µs/div

Figure 6. Drain Voltage of Q1 With a 5A Load (input voltage of 36V)



Conditions: Input Voltage = 72VDC Output Current = 5A
Trace 1: Q2 drain voltage Volts/div = 10V Horizontal Resolution = 1µs/div

Figure 7. Drain Voltage of Q1 With a 5A Load (input voltage of 72V)



Conditions: Input Voltage = 48VDC Output Current = 5A Upper Trace: SR1, Q4 gate Volts/div = 5V Middle Trace: HS, Q2 drain Volts/div = 20V Lower Trace: SR2, Q6 gate Volts/div = 5V Horizontal Resolution = 1µs/div

Figure 8. Gate Voltages of the Synchronous Rectifiers

12 Application Circuit

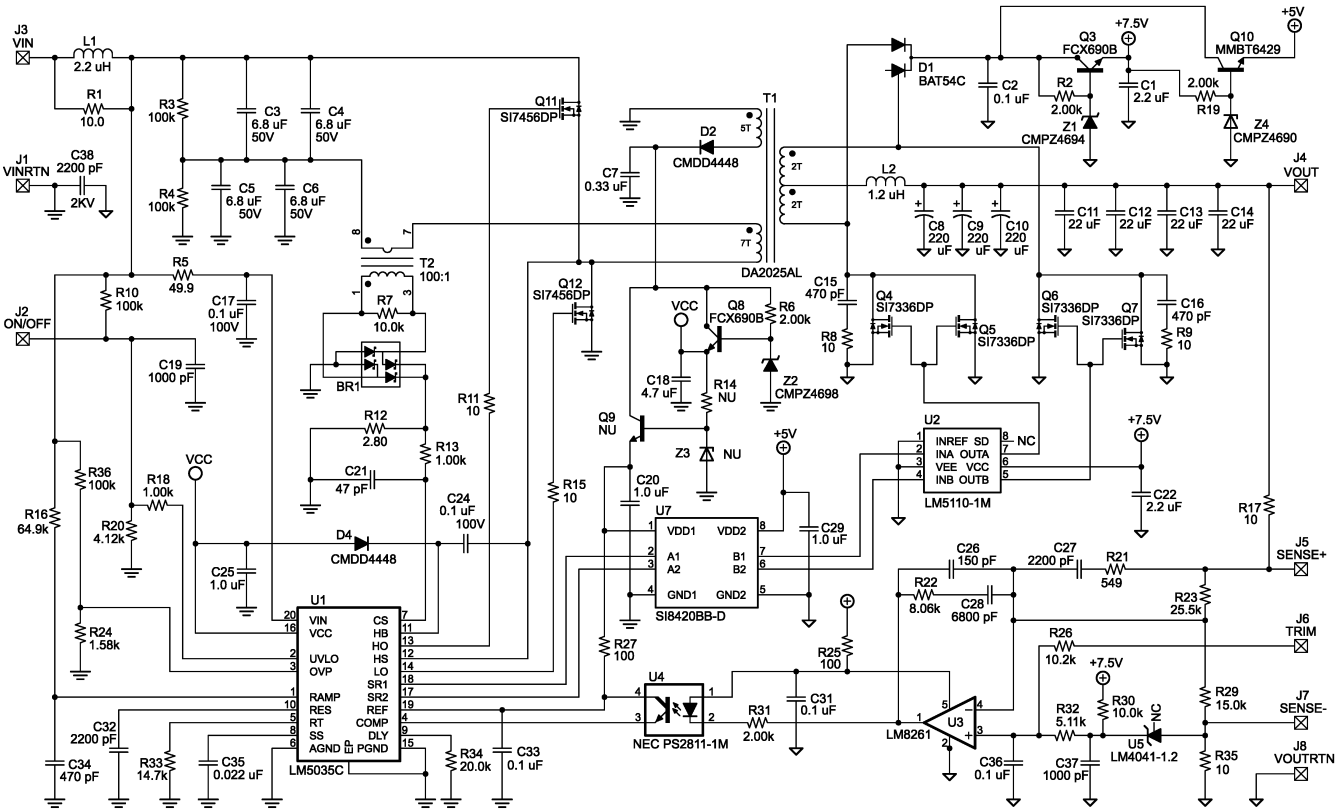


Figure 9. Application Circuit: Input 36 to 75V, Output 3.3V, 30A

Table 1. Bill of Materials (BOM)

Item	Part Description	Qty	Ref Designator	Remark
1	LM5035 Controller MH20	1	U1	TI LM5035
2	LM5110 Dual Driver	1	U2	TI LM5110
3	LM8261 Op Amp SOT23-5	1	U3	TI LM8261
4	LM4041 Ref Amp SOT23	1	U5	TI LM4041
5	Opto-Coupler PS2811-1M	1	U4	NEC PS2811-1M
6	Digital Isolator IC SOIC-8	1	U6	Silicon Labs SI8420BB-D
7	Cer Cap 47pF 50V COG 0603	1	C21	TDK C1608COG1H470J
8	Cer Cap 150pF 50V COG 0603	1	C26	TDK C1608COG1H151J
9	Cer Cap 470pF 50V COG 0603	1	C34	TDK C1608COG1H471J
10	Cer Cap 1000pF 50V X7R 0603	2	C19, C37	TDK C1608X7R1H102K
11	Cer Cap 2000pF 50V COG 0603	2	C27, C32	TDK C1608COG1H222J
12	Cer Cap 6800pF 50V COG 0603	1	C28	TDK C1608COG1H682J
13	Cer Cap 0.022uF 25V COG 0603	1	C35	TDK C1608COG1E223J
14	Cer Cap 0.1uF 50V X7R 0603	3	C2, C33, C36	TDK C1608X7R1H104K
15	Cer Cap 1.0uF 16V X7R 0603	2	C25, C31, C29, C20	TDK C1608X7R1C105K
16	Cer Cap 470pF 50V COG 0805	2	C15, C16	KEMT C0805C471M5RAC
17	Cer Cap 0.1uF 100V X7R 0805	2	C17, C24	TDK C2012X7R2A104K
18	Cer Cap 0.33uF 50V X7R 0805	1	C7	TDK C2012X7R1H334K
19	Cer Cap 2.2uF 16V X7R 0805	2	C1, C22	TDK C2012X7R1C225K

Table 1. Bill of Materials (BOM) (continued)

Item	Part Description	Qty	Ref Designator	Remark
20	Cer Cap 4.7uF 16V X7R 1206	1	C18	TDK C3216X7R1C475K
21	Cer Cap 22uF 6.3V X5R 1206	4	C11–C14	TDK C3216X5R0J226M
22	Cer Cap 2200pF 2000V X7R 1812	1	C38	TDK C4532X7R3D222K
23	Cer Cap 6.8uF 50V X7R 1812	4	C3–C6	TDK C4532X7R1H685M
24	POSCAP 220uF 6.3V	3	C8–C10	Sanyo 6TPE220MI
25	Res 2.8 Ω 0.1W 1% 0603	1	R12	Vishay CRCW06032R80F
26	Res 10 Ω 0.1W 1% 0603	2	R17, R35	Vishay CRCW060310R0F
27	Res 100 Ω 0.1W 1% 0603	3	R25, R27	Vishay CRCW06031000F
28	Res 549 Ω 0.1W 1% 0603	1	R21	Vishay CRCW06035490F
29	Res 1K Ω 0.1W 1% 0603	4	R13, R18	Vishay CRCW06031001F
30	Res 1.58K Ω 0.1W 1% 0603	1	R24	Vishay CRCW06031581F
31	Res 2.0K Ω 0.1W 1% 0603	1	R31	Vishay CRCW06032001F
32	Res 4.12K Ω 0.1W 1% 0603	1	R20	Vishay CRCW06034121F
33	Res 5.11K Ω 0.1W 1% 0603	1	R32	Vishay CRCW06035111F
34	Res 8.06K Ω 0.1W 1% 0603	1	R22	Vishay CRCW06038061F
35	Res 10K Ω 0.1W 1% 0603	2	R7, R30	Vishay CRCW06031002F
36	Res 10.2K Ω 0.1W 1% 0603	1	R26	Vishay CRCW06031022F
37	Res 14.7K Ω 0.1W 1% 0603	1	R33, R46	Vishay CRCW06031472F
38	Res 15K Ω 0.1W 1% 0603	1	R29, R41	Vishay CRCW06031502F
39	Res 20K Ω 0.1W 1% 0603	1	R34	Vishay CRCW06032002F
40	Res 25.5K Ω 0.1W 1% 0603	1	R23	Vishay CRCW06032552F
41	Res 100K Ω 0.1W 1% 0603	2	R3, R4	Vishay CRCW06031003F
42	NU 0805	1	R14	NU
43	Res 10 Ω 1/10W 1% 0805	3	R1, R11, R15	Vishay CRCW080510R0F
44	Res 49.9 Ω 1/10W 1% 0805	1	R5	Vishay CRCW080549R9F
45	Res 2K Ω 1/10W 1% 0805	1	R2, R19	Vishay CRCW08052001F
46	Res 10K Ω 1/10W 1% 0805	1	R6	Vishay CRCW08051002F
47	Res 64.9K Ω 1/10W 1% 0805	1	R16	Vishay CRCW08056492F
48	Res 100K Ω 1/10W 1% 0805	2	R10, R36	Vishay CRCW08051003F
49	Res 10 Ω 1% 2010	2	R8, R9	Vishay CRCW201010R0F
50	Schottky, Diode, 75V 150mA SOT23	1	D1	BAV70-TP
51	Diode, 75V 250mA SOD-323	2	D2, D4	Central CMDD4448
52	Diodes, Rectifier, Bridge, 30V	1	BR1	BAT54BRW
53	Zener 8.2V 5% SOT23	1	Z1	Central CMPZ4694
54	Zener 11V 5% SOT23	1	Z2	Central CMPZ4698
55	Zener 5.6V, 5% SOT23	1	Z4	Central CMPZ4690
	NU SOT23	1	Z3	NU
56	N-FET 100V 25m Ω	2	Q1, Q2	Vishay Si7456DP
57	N-FET 30V 3m Ω	4	Q4–7	Vishay Si7336ADP
58	NPN, ZETEX 45V 2A	2	Q3, Q8	ZETEX FCX690B
59	NPN, ON SEMI 45V, 225mW	1	Q10	MMBT6429LT1G
60	NU	1	Q9	NU
61	Inductor 2.2uH 5.4A	1	L1	TDK RLF7030T-2R2M5R4
62	Inductor 1.2uH 37A	1	L2	Coilcraft SER2010-122MX
63	Transformer 8:5:2:2	1	T1	Coilcraft DA2025-AL
64	Current XFR 100:1, 10A	1	T2	Pulse Engr P8208

Table 1. Bill of Materials (BOM) (continued)

Item	Part Description	Qty	Ref Designator	Remark
65	Test Pin, Brick 0.040X0.5	6	J1–3, J5–7	Mill-Max 3104-2-00-80-00-00-08-0
66	Test Pin, Brick 0.080X0.375	2	J4, J8	Mill-Max 3231-2-00-01-00-00-08-0

13 PCB Layouts

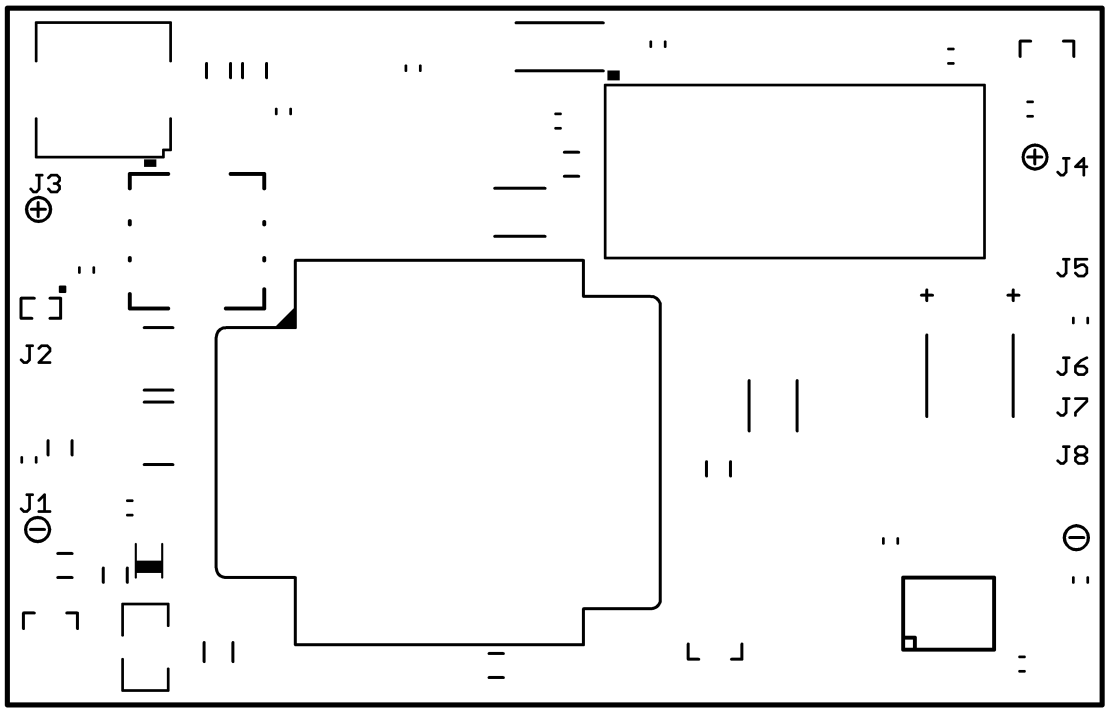


Figure 10. Top Side

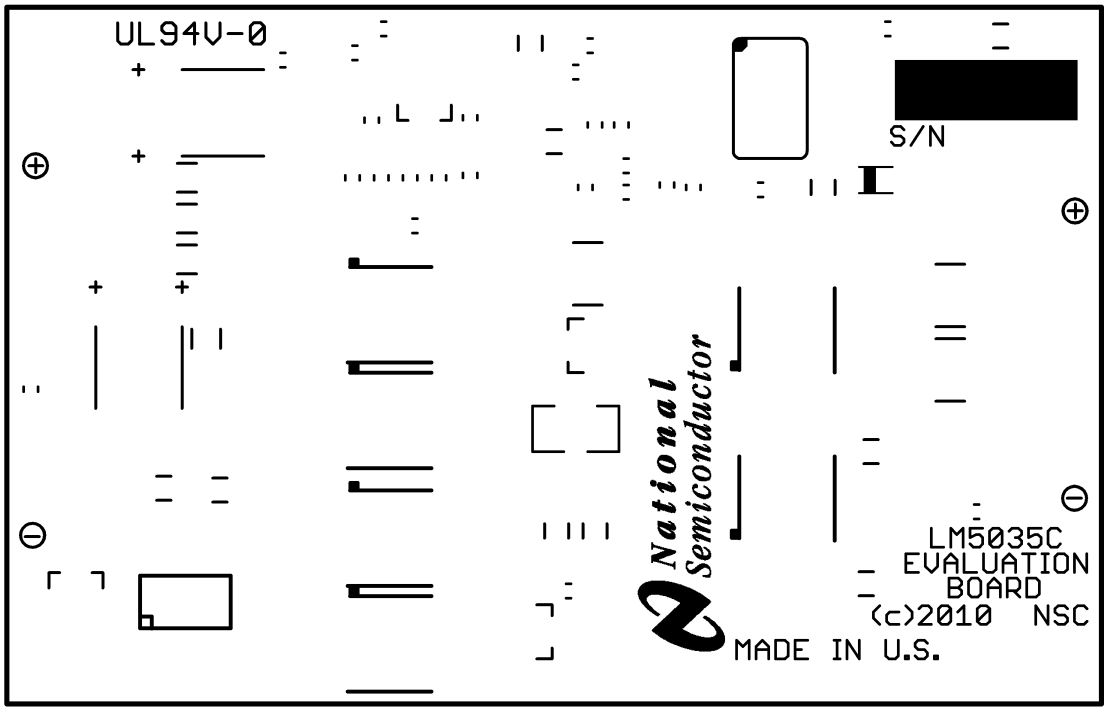


Figure 11. Bottom Side

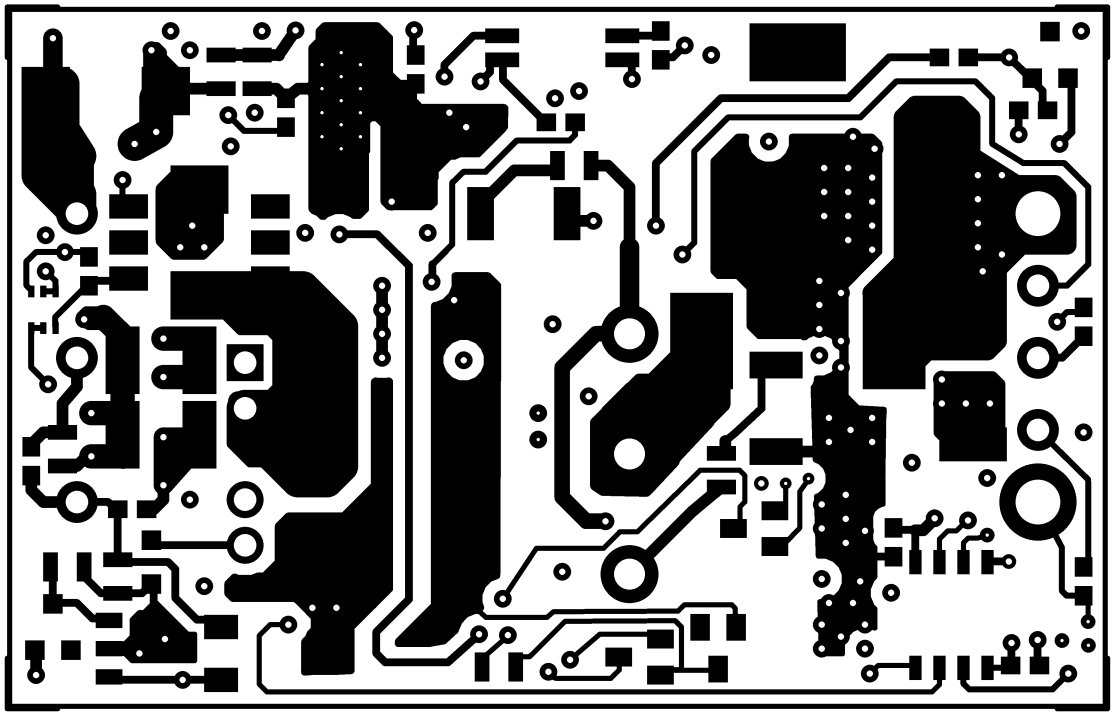


Figure 12. Layer 1

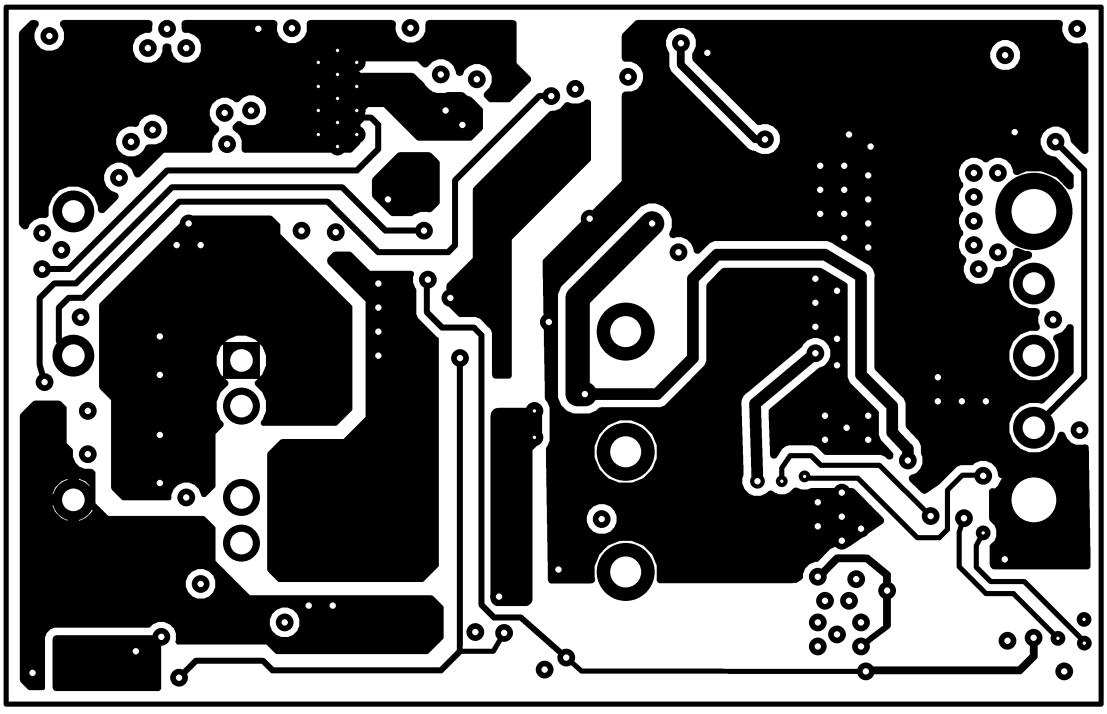


Figure 13. Layer 2

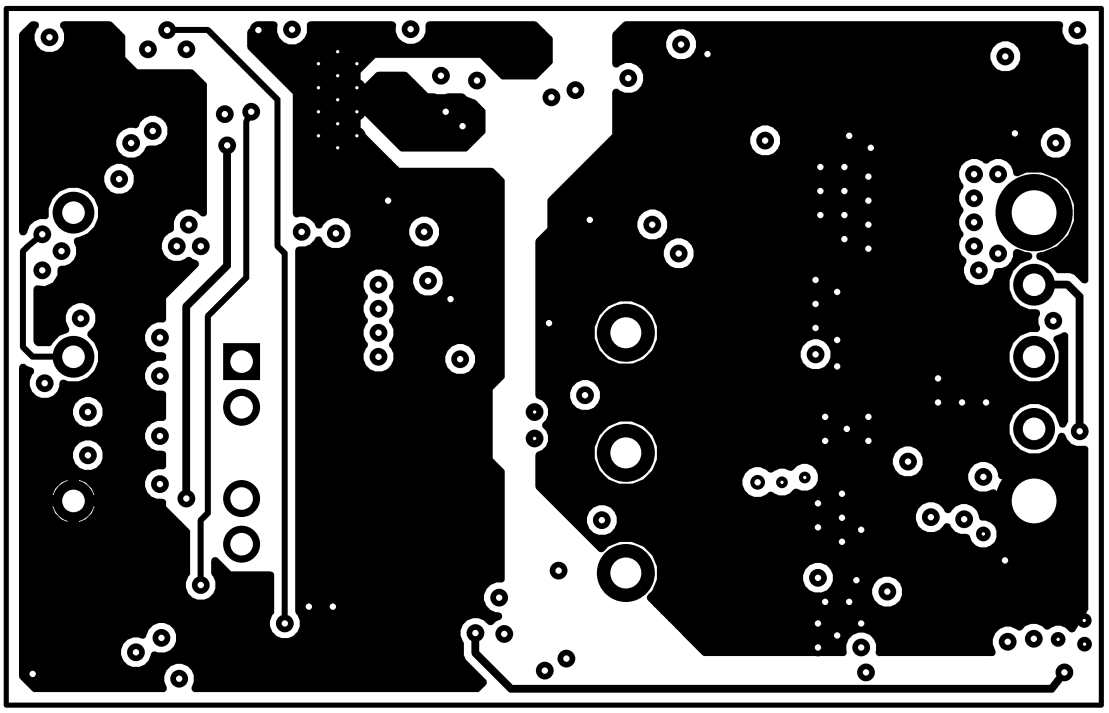


Figure 14. Layer 3

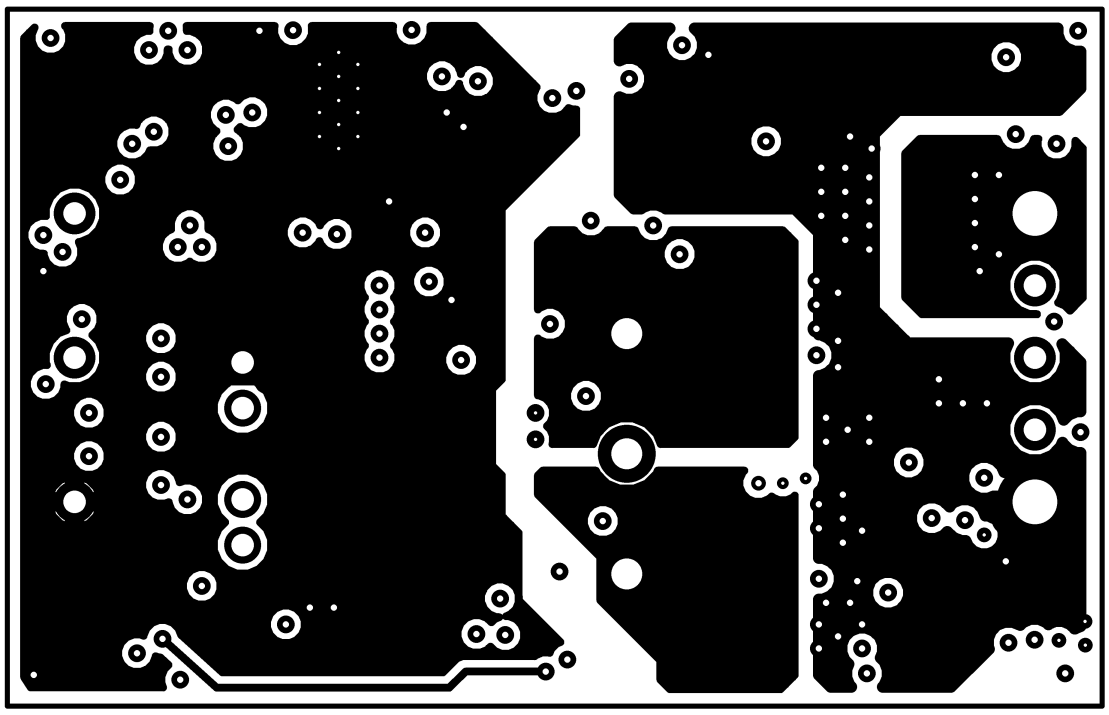


Figure 15. Layer 4

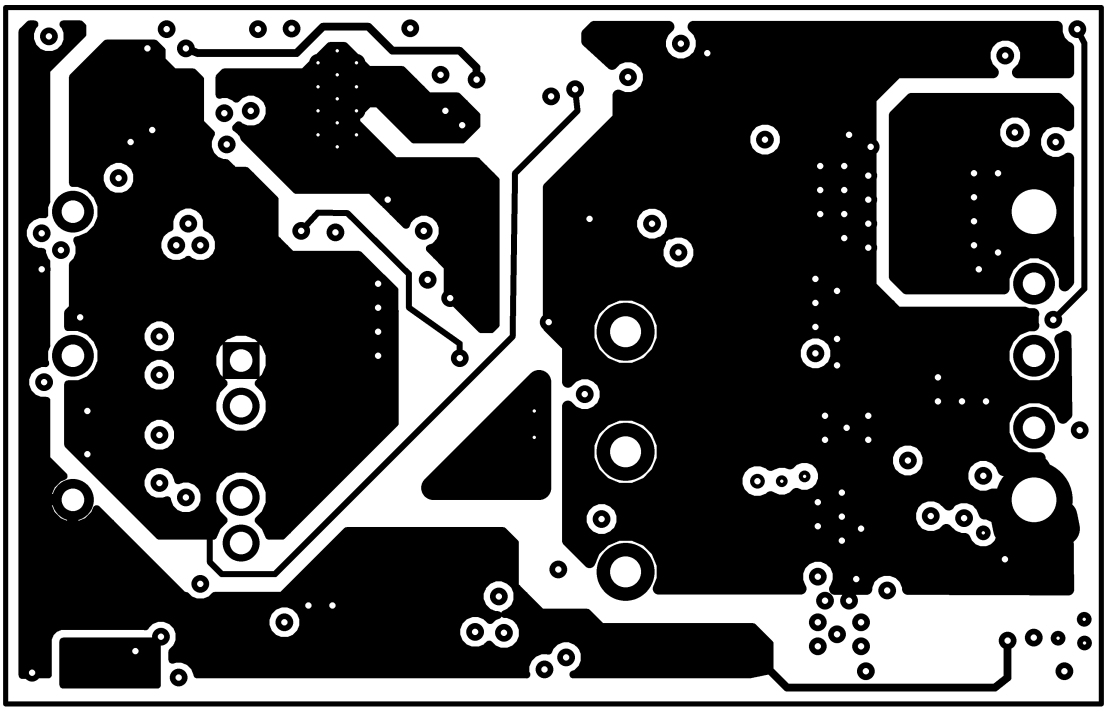


Figure 16. Layer 5

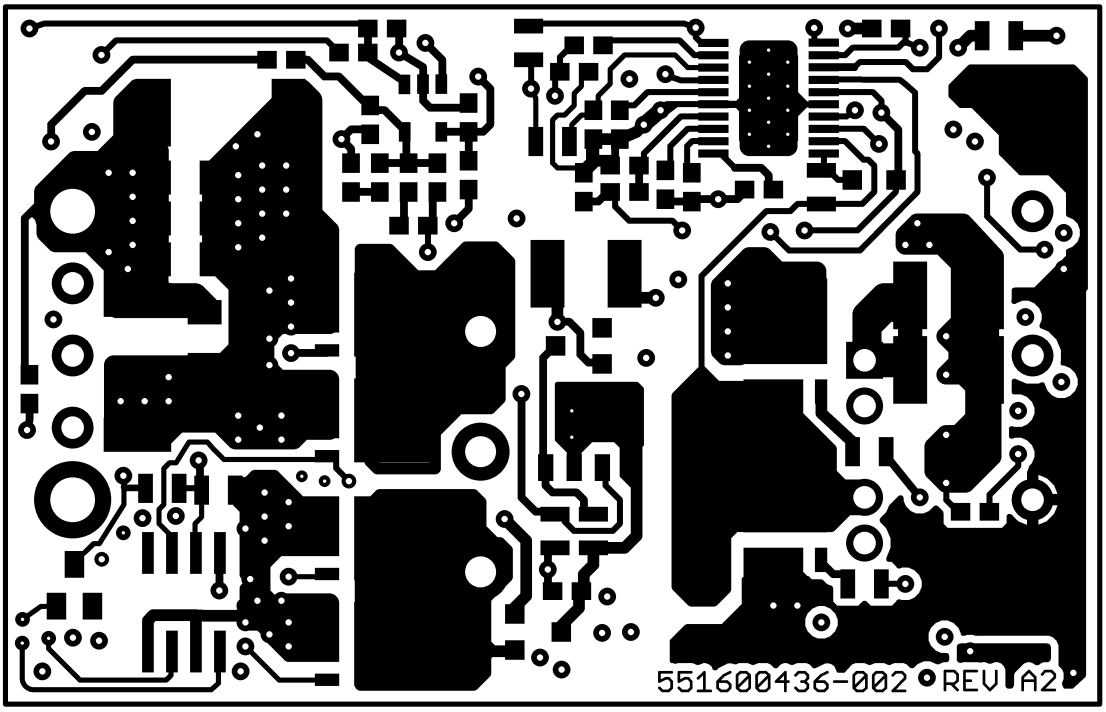


Figure 17. Layer 6

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   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.

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User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

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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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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。
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東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

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。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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