

LM5176 Wide-VIN Buck-Boost Controller EVM

The LM5176EVM-HP demonstrates a flexible high power buck-boost design using the LM5176 wide-vin Buck-Boost Controller. The evaluation module is configured to operate from input voltage range of 6 V-36 V and provide a regulated 12-V output with up to 12 A of load current.

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1 Features

Table 1. Board Specifications

PARAMETER	VALUE
Input Voltage	6 V to 36 V
Output Voltage	12 V
Maximum Output Current	12 A
Default Switching Frequency	250 kHz
Board Size (6 layers)	3.6 in x 3.6 in

- Smooth Buck-Boost operation
- Ultra high (>98%) peak power conversion efficiency
- Adjustable output voltage using feedback resistor divider selection
- Resistor programmable switching frequency with optional synchronization (SYNC)
- Cycle-by-cycle overcurrent protection via shunt resistor current sensing
- Optional hiccup mode overload protection
- Programmable VIN UVLO threshold and hysteresis
- Constant Output Voltage and Constant Output Current Options
- Optional frequency dithering for reduced EMI
- Power good indicator
- Optional parallel FET footprints provide flexibility to further extend output power capability

2 Connector, Test Point and Selection Switch Descriptions

2.1 Connector and Test Point Descriptions

This EVM includes I/O connectors and test points as shown in [Table 2](#). The power supply must be connected to input connectors, J1 and J2. The load must be connected to output connectors, J3 and J4.

Table 2. Connectors and Test Points

REFERENCE DESIGNATOR	DESCRIPTION
J1	Input voltage positive connection
J2	Input voltage return connection
J3	Output voltage connection
J4	Output voltage return connection
TP1 (VIN)	Input voltage positive test point
TP2 (GND)	Input voltage return test point
TP3 (VOUT)	Output voltage positive test point
TP4 (GND)	Output voltage return test point
TP5 (PGOOD)	Power Good output
TP6 (BIAS)	BIAS voltage test point
TP7(SYNC)	SYNC input

2.2 Selection Switch Descriptions

2.2.1 S1 Mode

This switch provides selection of different operation modes detailed as following:

- Switch in position 2 (Mode pin tied to 93.1kΩ resistor), Hiccup mode enabled and CCM.
- Switch in position 3 (Mode pin tied to VCC), Hiccup disabled and CCM.

Note 1:For more information on MODE pin function please refer to the part datasheet.

2.2.2 S2 ENABLE

This switch enables/disables LM5176 on the EVM, or it can be used to set adjustable VIN UVLO.

- Switch in position 1 (EN pin tied GND), LM5176 disabled.
- Switch in position 2 (EN pin tied to resistor divider network consist of R13 and R18), EN pin along the resistor divider network to set LM5176 UVLO threshold.
- Switch in position 3 (EN pin tied VCC), LM5176 enabled.

2.2.3 S3 DITHER

This switch enables/disables frequency dithering feature on the EVM.

- Switch in position 1 (EN pin tied GND), frequency dithering feature disabled.
- Switch in position 2 (EN pin tied to C27), frequency dithering feature enabled.
- No connection in position 3, do not apply switch to this position.

3 Test Setup and Procedure

3.1 Test Setup

Figure 1 shows a typical test setup to evaluate the LM5176EVM-HP

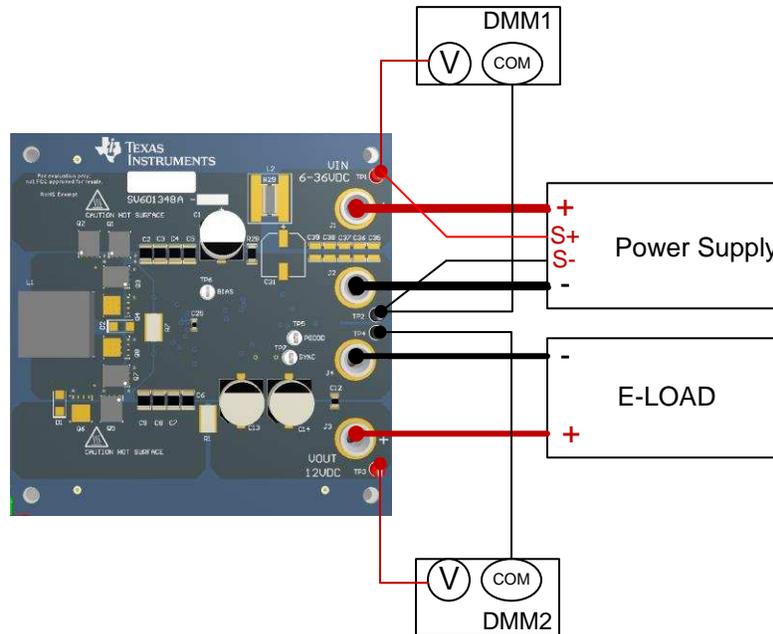


Figure 1. Typical EVM Connection Diagram

3.2 Test Procedure

Step 1: Set the power supply current limit to 1 A. Turn off the power supply. Connect the positive output of the power supply to J1 and the negative output to J2.

Step 2: Connect the load to J3 for the positive connection and J4 for the negative connection.

Step 3: Set the power supply voltage to 9V and the load to 0.1 A. The electronic load voltage must be in regulation with a nominal 12 V output.

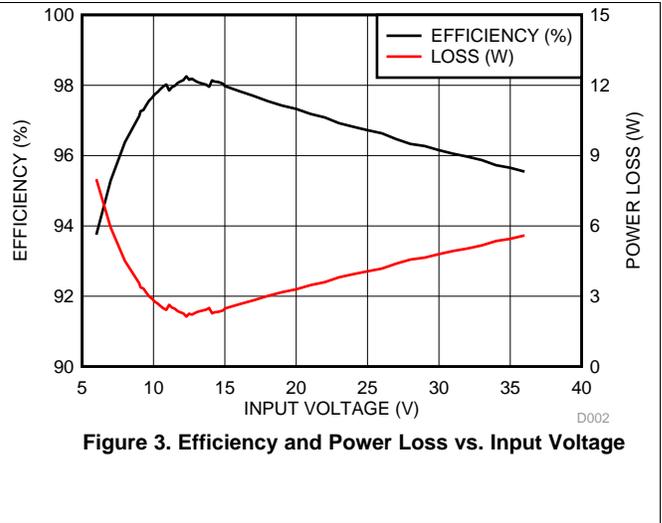
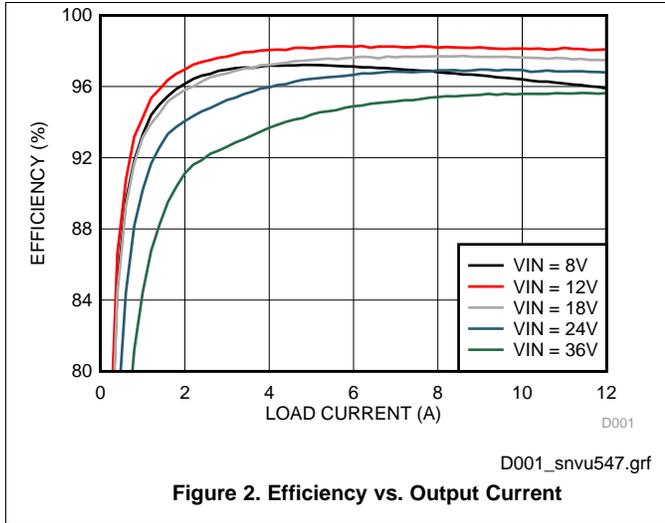
Step 4: Slowly increase the load while monitoring the output voltage between TP3 and TP4. It must remain in regulation with a nominal 12 V output as the load is increased up to 10 A.

Step 5: Slowly sweep the input voltage from 6 V to 36 V. The output voltage must remain in regulation with a nominal 12 V output.

Step 6: Turn off the load, and decrease the input voltage down to 0 V to shut down the buck-boost converter, and then turn on the load to discharge the output capacitors.

4 Test Data and Performance Curve

4.1 Efficiency



4.2 Steady State Waveforms

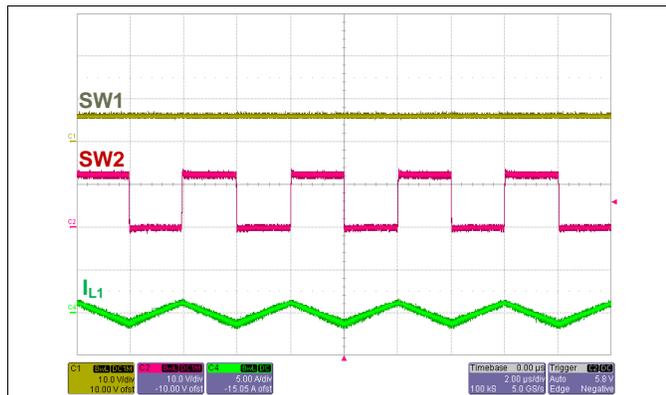


Figure 4. SW1, SW2, I_L Wave ($V_{IN}=6\text{ V}$, $I_{OUT}=0\text{ A}$)

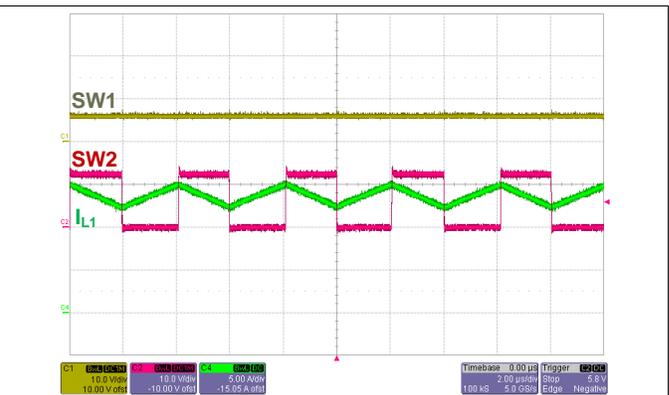


Figure 5. SW1, SW2, I_L Wave ($V_{IN}=6\text{ V}$, $I_{OUT}=7\text{ A}$)

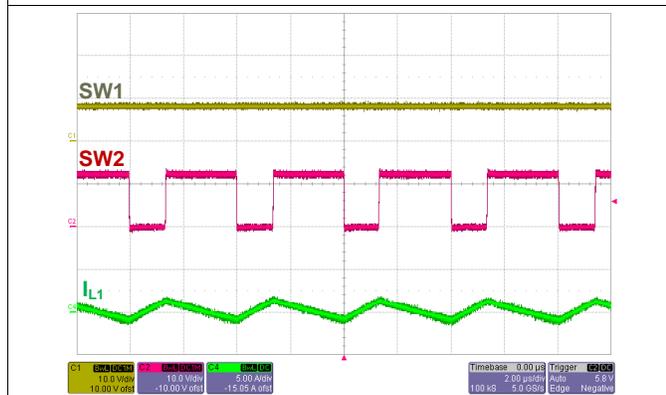


Figure 6. SW1, SW2, I_L Wave ($V_{IN}=8\text{ V}$, $I_{OUT}=0\text{ A}$)

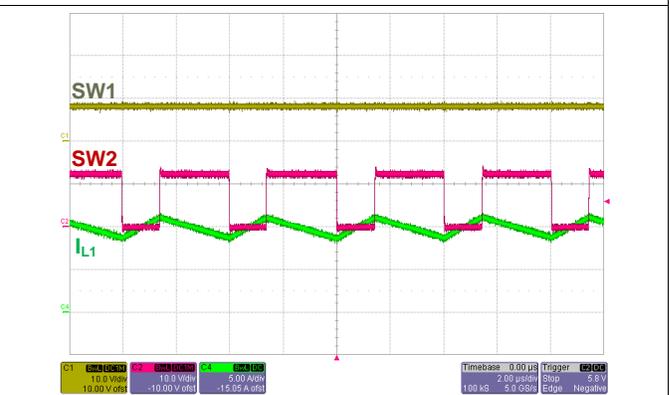


Figure 7. SW1, SW2, I_L Wave ($V_{IN}=8\text{ V}$, $I_{OUT}=7\text{ A}$)

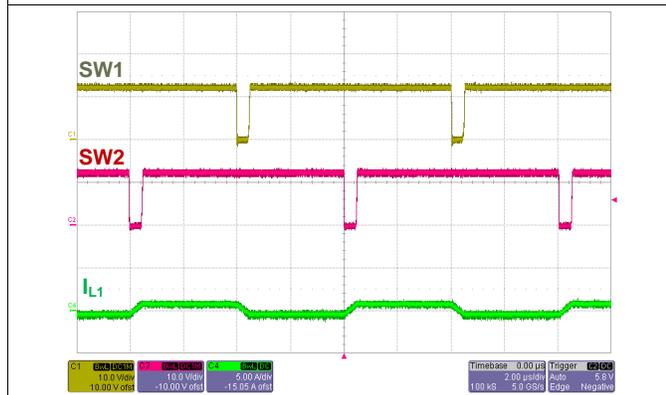


Figure 8. SW1, SW2, I_L Wave ($V_{IN}=12\text{ V}$, $I_{OUT}=0\text{ A}$)

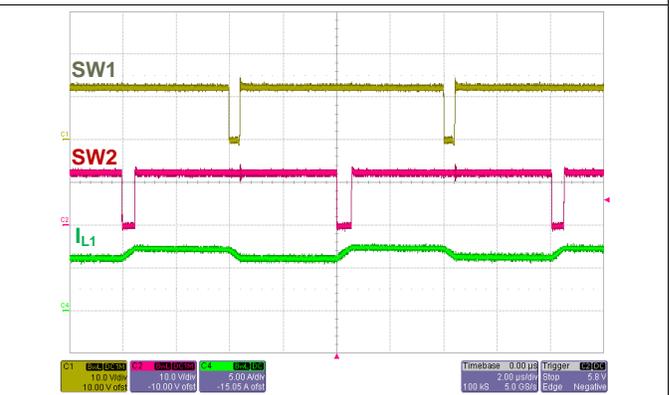


Figure 9. SW1, SW2, I_L Wave ($V_{IN}=12\text{ V}$, $I_{OUT}=7\text{ A}$)

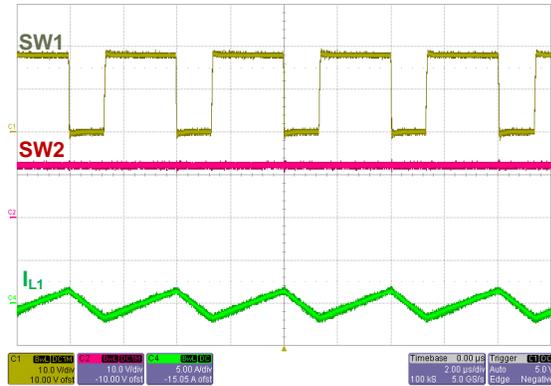


Figure 10. SW1, SW2, I_L Wave ($V_{IN} = 18\text{ V}$, $I_{OUT} = 0\text{ A}$)

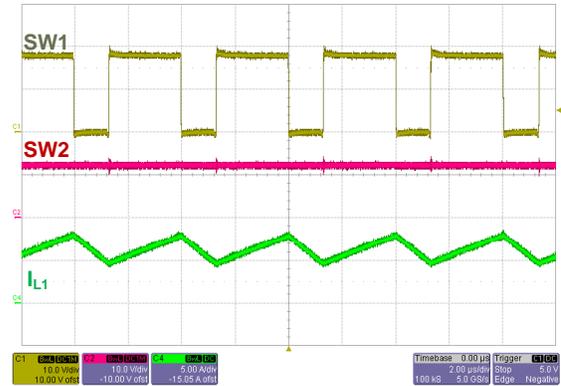


Figure 11. SW1, SW2, I_L Wave ($V_{IN} = 18\text{ V}$, $I_{OUT} = 7\text{ A}$)

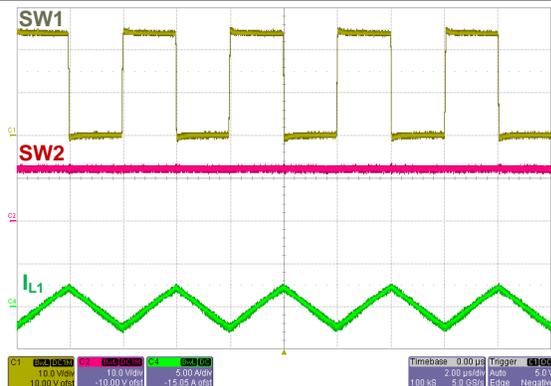


Figure 12. SW1, SW2, I_L Wave ($V_{IN} = 24\text{ V}$, $I_{OUT} = 0\text{ A}$)

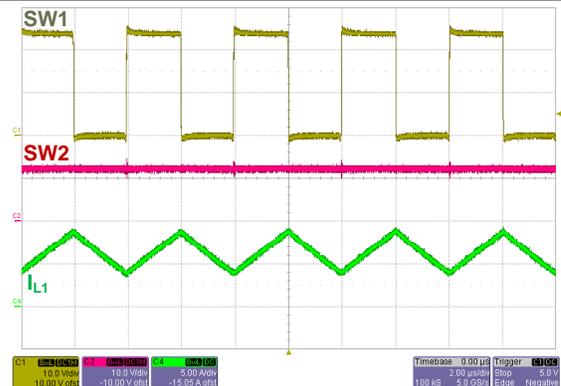


Figure 13. SW1, SW2, I_L Wave ($V_{IN} = 24\text{ V}$, $I_{OUT} = 7\text{ A}$)

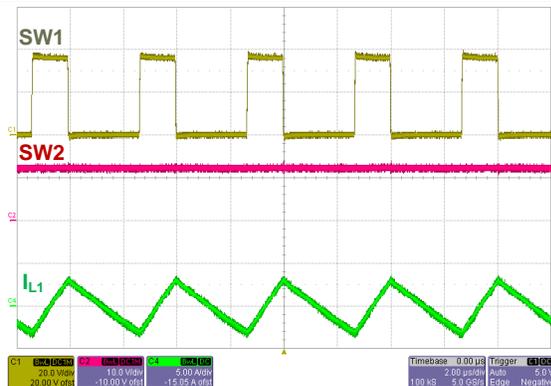


Figure 14. SW1, SW2, I_L Wave ($V_{IN} = 36\text{ V}$, $I_{OUT} = 0\text{ A}$)

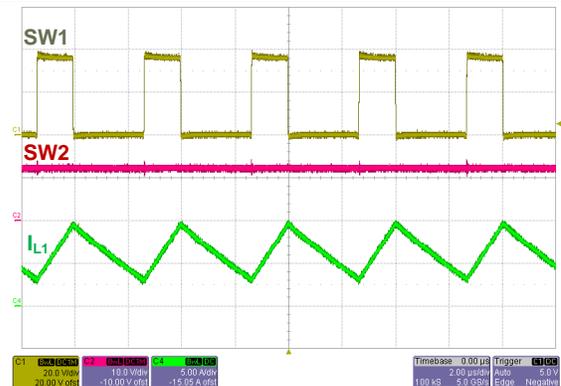


Figure 15. SW1, SW2, I_L Wave ($V_{IN} = 36\text{ V}$, $I_{OUT} = 7\text{ A}$)

4.3 Step Load Response

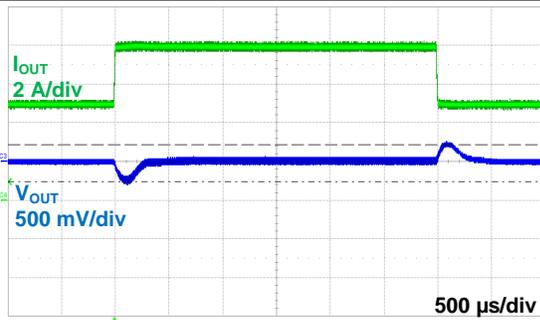


Figure 16. Load Step ($V_{IN} = 7\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

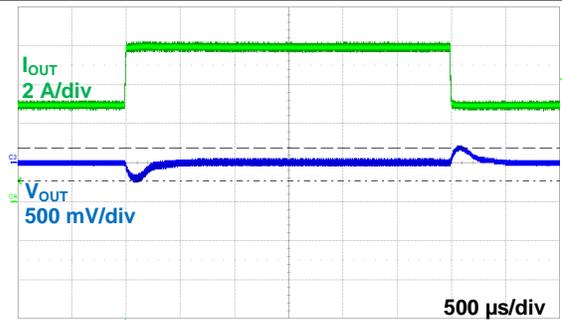


Figure 17. Load Step ($V_{IN} = 8\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

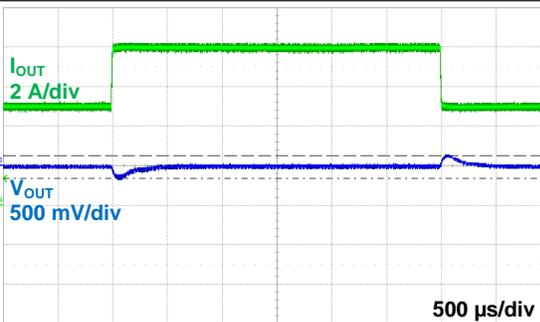


Figure 18. Load Step ($V_{IN} = 12\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

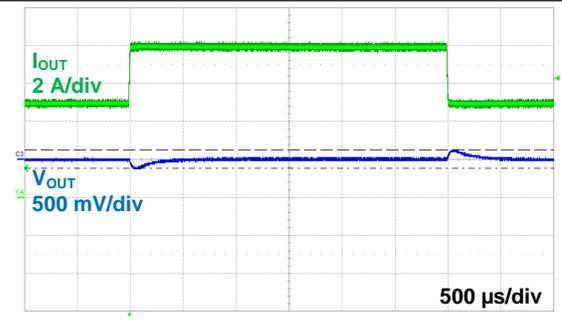


Figure 19. Load Step ($V_{IN} = 18\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

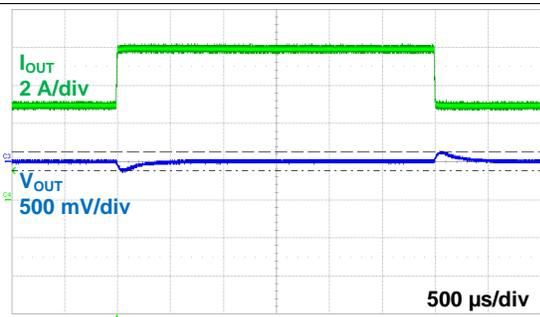


Figure 20. Load Step ($V_{IN} = 24\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

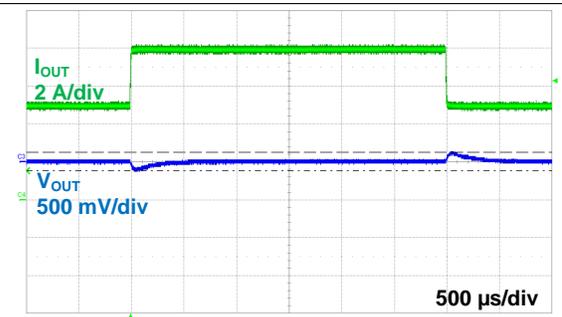
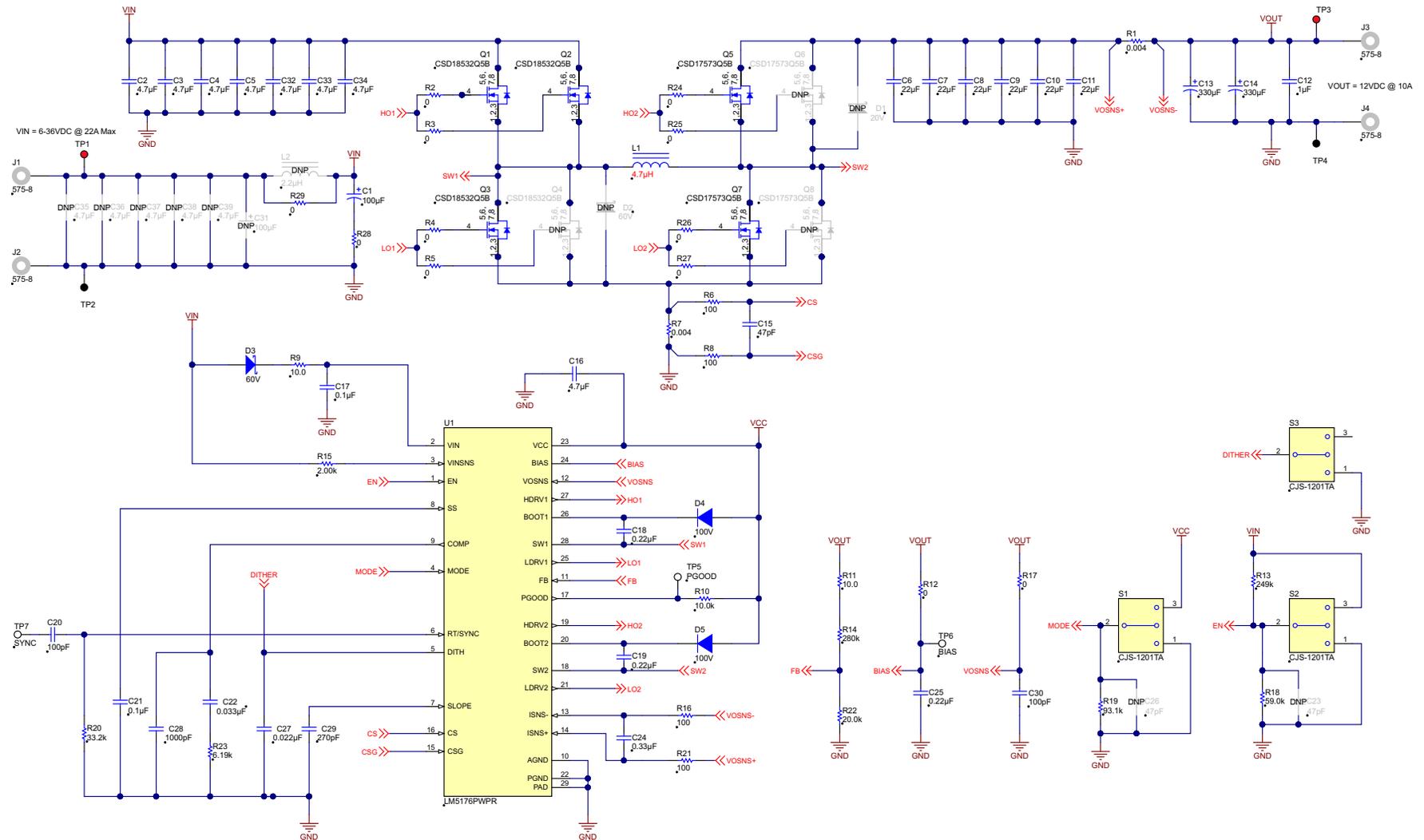


Figure 21. Load Step ($V_{IN} = 36\text{ V}$, $I_{OUT} = 5\text{ A} - 8\text{ A}$)

5 LM5176EVM-HP Schematic



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Figure 22. 4-Switch Buck-Boost Converter Schematic

6 Board Layout

Figure 23 through Figure 30 show the design of the LM5176EVM-HP PCB.

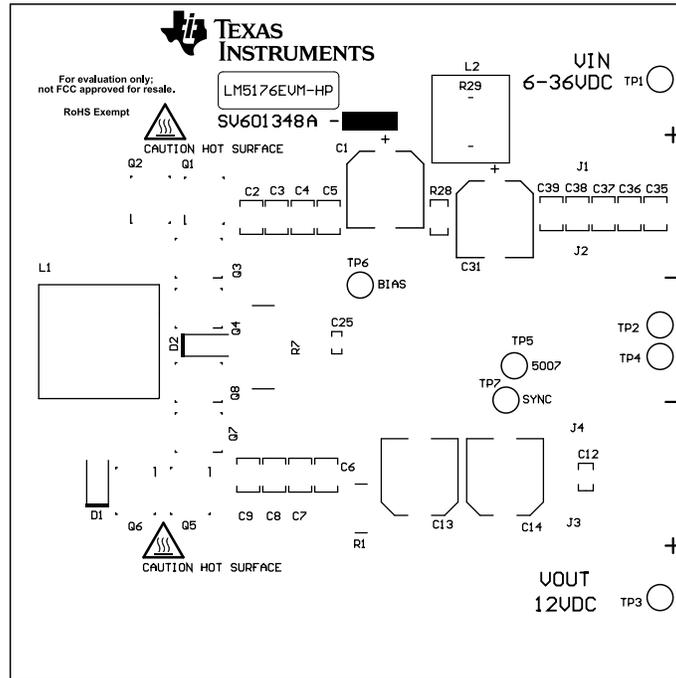


Figure 23. Top Silkscreen

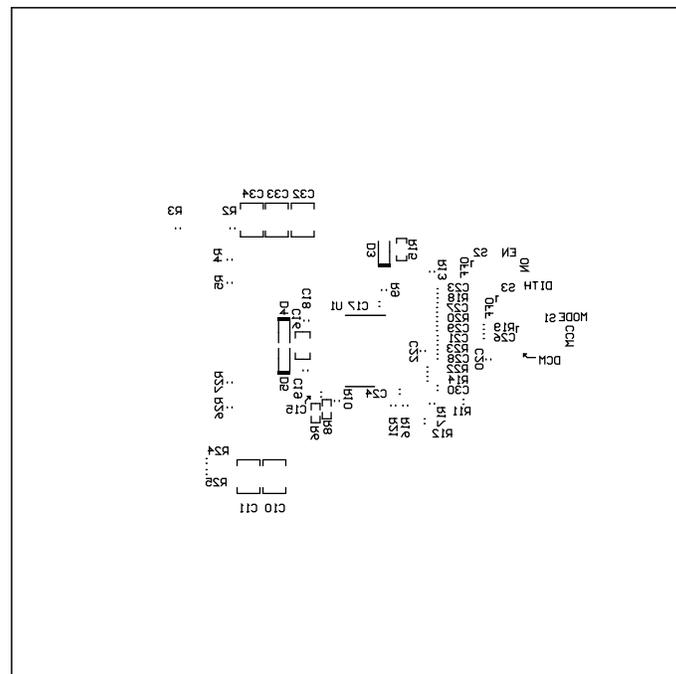


Figure 24. Bottom Silkscreen

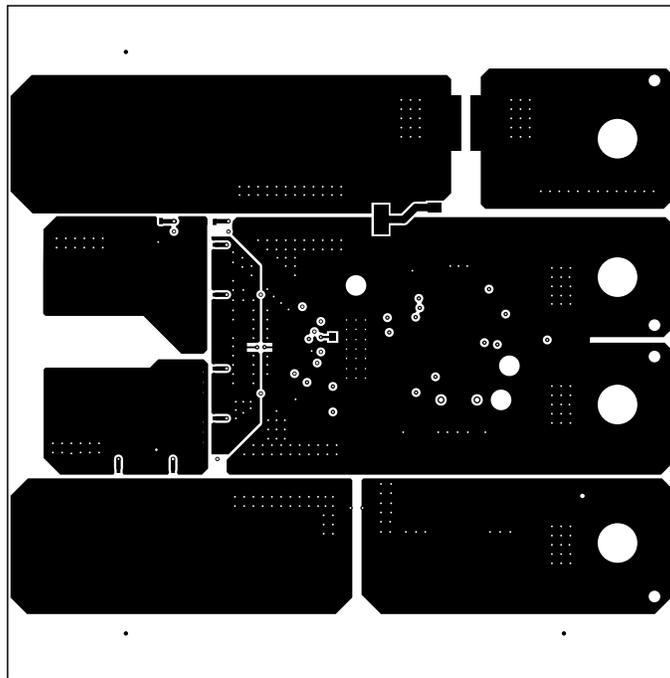


Figure 25. Top Layer

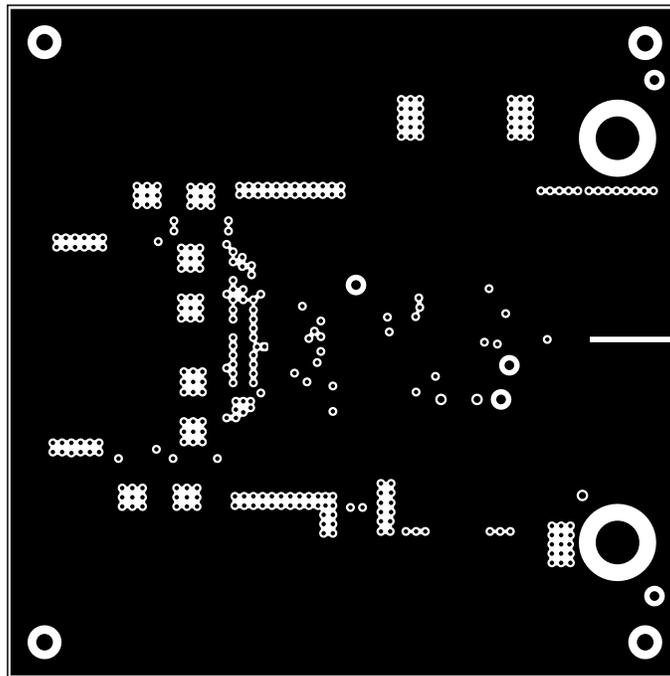


Figure 26. Mid-Layer 1

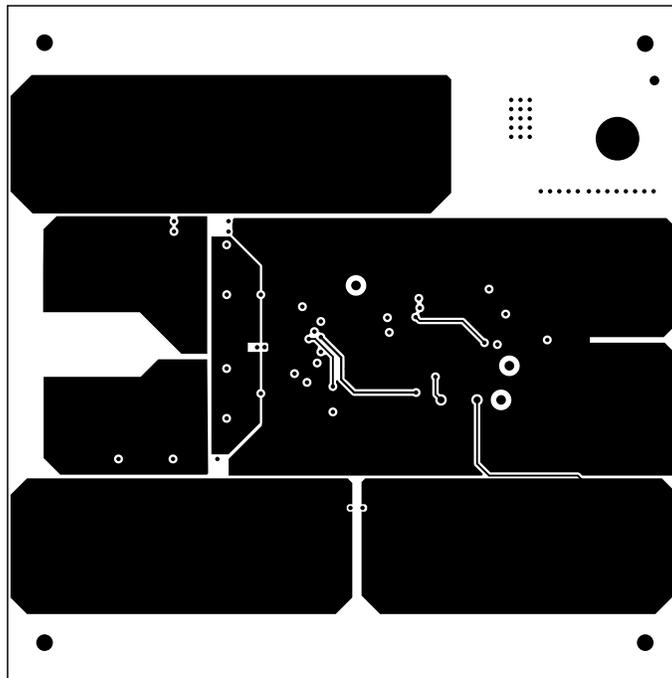


Figure 27. Mid-Layer 2

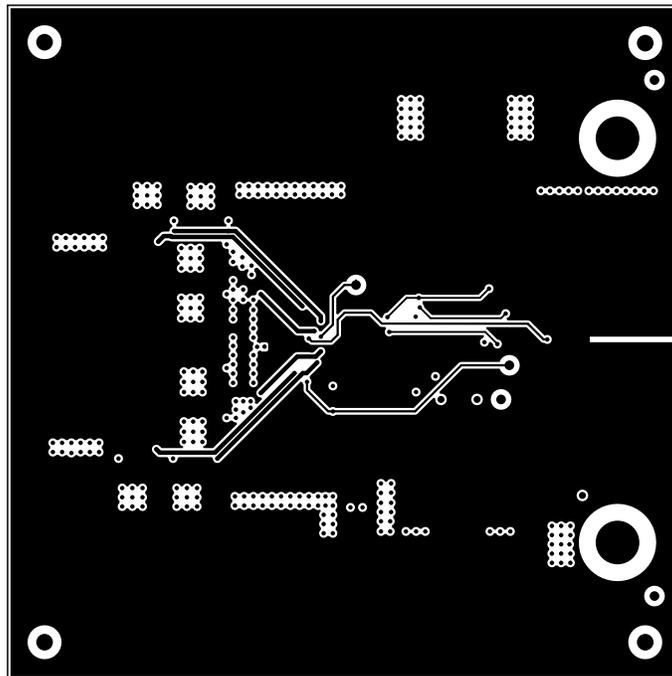


Figure 28. Mid-Layer 3

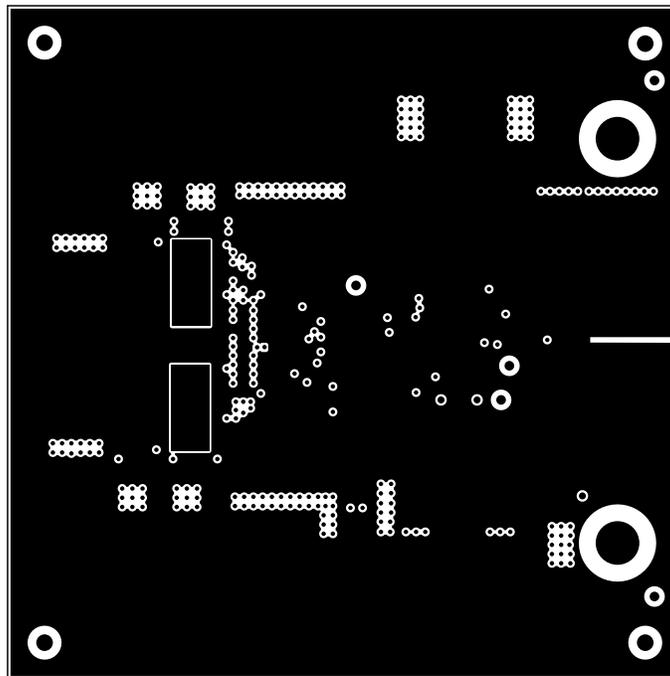


Figure 29. Mid-Layer 4

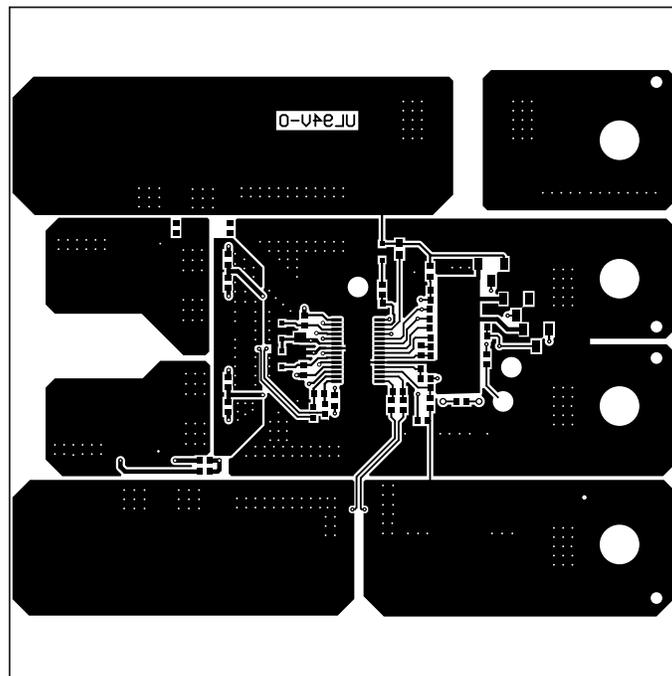


Figure 30. Bottom Layer

7 LM5176EVM-HP Bill of Materials

Table 3. Bill of Materials

REF DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
PCB	1	Printed Circuit Board	SV601348	Any
C1	1	CAP ALUM POLY 100UF 20% 63V SMD	PCR1J101MCL1GS	Nichicon
C2, C3, C4, C5, C32, C33, C34	7	CAP CER 4.7UF 80V X7R 1210	GRM32ER71K475KE14L	MuRata
C6, C7, C8, C9, C10, C11	6	CAP CER 22UF 25V X7R 1210	GRM32ER71E226KE15L	MuRata
		Alternate part: CAP CER 22UF 25V X5R 1210	885012109014	Würth Elektronik
C12	1	CAP, CERM, 1 μ F, 25 V, +/- 10%, X7R, 0805	GRM219R71E105KA88D	MuRata
		Alternate part: CAP CER 22UF 25V X5R 1210	885012109014	Würth Elektronik
C13, C14	2	CAP, OS-CON, 330 μ F, 16 V, +/- 20%, 0.016 ohm, 10x10.3 SMD	16SVP330M	Sanyo
		Alternate part: CAP ALUM POLY 330UF 20% 16V SMD	875115360004	Würth Elektronik
C15	1	CAP, CERM, 47pF, 50V, +/-5%, COG/NP0, 0603	Std	Std
C16	1	CAP, CERM, 4.7 μ F, 16 V, +/- 10%, X7R, 0805	Std	Std
C17	1	CAP, CERM, 0.1 μ F, 100V, +/-10%, X7R, 0603	Std	Std
C21	1	CAP, CERM, 0.1 μ F, 100V, +/-10%, X7R, 0603	Std	Std
C18, C19	2	CAP, CERM, 0.22 μ F, 25 V, +/- 10%, X7R, 0603	Std	Std
C25	1	CAP, CERM, 0.22 μ F, 25 V, +/- 10%, X7R, 0603	Std	Std
C20	1	CAP, CERM, 100pF, 100V, +/-5%, COG/NP0, 0603	Std	Std
C30	1	CAP, CERM, 100pF, 100V, +/-5%, COG/NP0, 0603	Std	Std
C22	1	CAP, CERM, 0.033 μ F, 50 V, +/- 10%, X7R, 0603	Std	Std
C28	1	CAP, CERM, 1000 pF, 100 V, +/- 5%, COG/NP0, 0603	Std	Std
C29	1	CAP, CERM, 270 pF, 50 V, +/- 5%, COG/NP0, 0603	Std	Std
C27	1	CAP, CERM, 0.022 μ F, 50V, +/-10%, X7R, 0603	Std	Std
C24	1	CAP, CERM, 0.33 μ F, 16 V, +/- 10%, X7R, 0603	Std	Std
D3	1	DIODE SCHOTTKY 60V 1A SOD323F	PMEG6010CEJ,115	NXP Semiconductors
D4, D5	2	Diode, Ultrafast, 100V, 0.25A, SOD-323	BAS316,115	NXP Semiconductors
H1, H2, H3, H4	4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastner Supply
H5, H6, H7, H8	4	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
J1, J2, J3, J4	4	Standard Banana Jack, Uninsulated, 15A	108-0740-001	Emerson Network Power
L1	1	Inductor, Shielded, Composite, 4.7 μ H, 29 A, 0.00335 ohm	XAL1510-472MEB	Coilcraft
		Alternate part: 4.7 μ H Shielded Wirewound, 17A, 3.5 mOhm	74439370047	Würth Elektronik
Q1, Q2, Q3	3	MOSFET N-CH, 60V, 23A, 8VSON	CSD18532Q5B	Texas Instruments
Q5, Q7	2	MOSFET N-CH, 30V, 100A, 8VSON	CSD17573Q5B	Texas Instruments
R1	1	RES 0.004 OHM 3W 1% 2512 WIDE	KRL6432E-M-R004-F-T1	Susumu
R2, R3, R4, R5, R24, R25, R26, R27	8	RES, 0 ohm, 5%, 0.1W, 0603	Std	Std
R12, R17	2	RES, 0 ohm, 5%, 0.1W, 0603	Std	Std
R6, R8, R16, R21	4	RES, 100 ohm, 1%, 0.1W, 0603	Std	Std
R7	1	RES, 0.004, 1%, 6 W, 4320_WIDE	KRL11050-C-R004-F-T1	Susumu Co Ltd
R9, R11	2	RES, 10.0 ohm, 1%, 0.1W, 0603	Std	Std

Table 3. Bill of Materials (continued)

REF DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
R10	1	RES, 10.0k ohm, 1%, 0.1W, 0603	Std	Std
R13	1	RES, 249k ohm, 1%, 0.1W, 0603	Std	Std
R14	1	RES, 280k ohm, 1%, 0.1W, 0603	Std	Std
R15	1	RES, 2.00 k, 1%, 0.1 W, 0603	Std	Std
R18	1	RES, 59.0k ohm, 1%, 0.1W, 0603	Std	Std
R19	1	RES, 93.1 k, 1%, 0.1 W, 0603	Std	Std
R20	1	RES, 33.2 k, 1%, 0.1 W, 0603	Std	Std
R22	1	RES, 20.0k ohm, 1%, 0.1W, 0603	Std	Std
R23	1	RES, 6.19 k, 1%, 0.1 W, 0603	Std	Std
R28	1	RES, 0, 5%, 0.25 W, 1206	Std	Std
R29	1	RES, 0, 5%, 2 W, 2512 WIDE	Std	Std
S1, S2, S3	3	Slide SW, SPDT 0.1A 50VDC	CJS-1201TA	Copal Electronics
TP1, TP3	2	Test Point, Compact, Red, TH	5005	Keystone
TP2, TP4	2	Test Point, Compact, Black, TH	5006	Keystone
TP5	1	Test Point, Compact, White, TH	5007	Keystone
TP6, TP7	2	Test Point, Compact, White, TH	5007	Keystone
U1	1	55V Wide VIN 4-Switch Synchronous Buck-Boost Controller, HTSSOP-28	LM5176PWP	Texas Instruments
C23, C26	0	CAP, CERM, 47pF, 50V, +/-5%, C0G/NP0, 0603	Std	Std
C35, C36, C37, C38, C39	0	CAP CER 4.7UF 80V X7R 1210	Std	Std
C31	0	CAP ALUM POLY 100UF 20% 63V SMD	PCR1J101MCL1GS	Nichicon
D1	0	DIODE SCHOTTKY 20V 5A PMDS	RSX501L-20TE25	Rohm Semiconductor
D2	0	DIODE SCHOTTKY 60V 3A PMDS	RB050L-60TE25	Rohm Semiconductor
Q4	0	MOSFET, N-CH, 60 V, 100 A, TDSO-8	BSC028N06NS	Infineon Technologies
Q6, Q8	0	MOSFET, N-CH, 25 V, 100 A, TDSO-8	BSC014NELSI	Infineon Technologies

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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.
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 - 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/lstds/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/lstds/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.

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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。

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東京都新宿区西新宿 6 丁目 2 4 番 1 号
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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, INDEMNITY 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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