TPS2H000-Q1 Evaluation Module (EVM)

The TPS2H000-Q1 evaluation module is designed to evaluate the TPS2H000-Q1 integrated circuit. This user's guide provides the connectors and test point descriptions, the schematic, bill of materials, and board layout of the EVM.

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1 Introduction

Texas Instruments' TPS2H000-Q1 evaluation module contains a TPS2H000-Q1 integrated circuit (IC), supporting dual-channel high-side switch application. The purpose of this EVM is to facilitate evaluation of the TPS2H000-Q1 for resistive, capacitive, and inductive load.

1.1 Descriptions

The TPS2H000-Q1 family is a fully protected dual-channel high-side power switch, with integrated NMOS power FET and charge pump.

Full diagnostics and highly accurate current sense features enable intelligent control of the load. The device diagnostic reporting has two versions to support both digital status output and analog current sense. The diagnostics can be disabled for multiplexing the sense pin between different devices. Thermal shutdown behaviors such as latch off or auto-retry are internally fixed in the part.

The externally-adjustable current limit improves the reliability of the whole system by limiting the inrush or overload current.

1.2 Applications

The EVM is used in the following applications:

1. Multi-channel LED drivers
2. Multi-channel high-side power switches
3. Multi-channel high-side relay drivers

1.3 Features

The EVM has the following features:

1. Operating voltage: 3.4–40 V
2. Operating junction temperature: –40 to 150°C
3. Highly accurate current sense
4. Adjustable current limit with external resistor
5. Multiplex high accuracy current sense or ST report
6. Tested according to AECQ100-12

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2 TPS2H000-Q1 Schematic

Figure 1 and Figure 2 illustrate the EVM schematic.

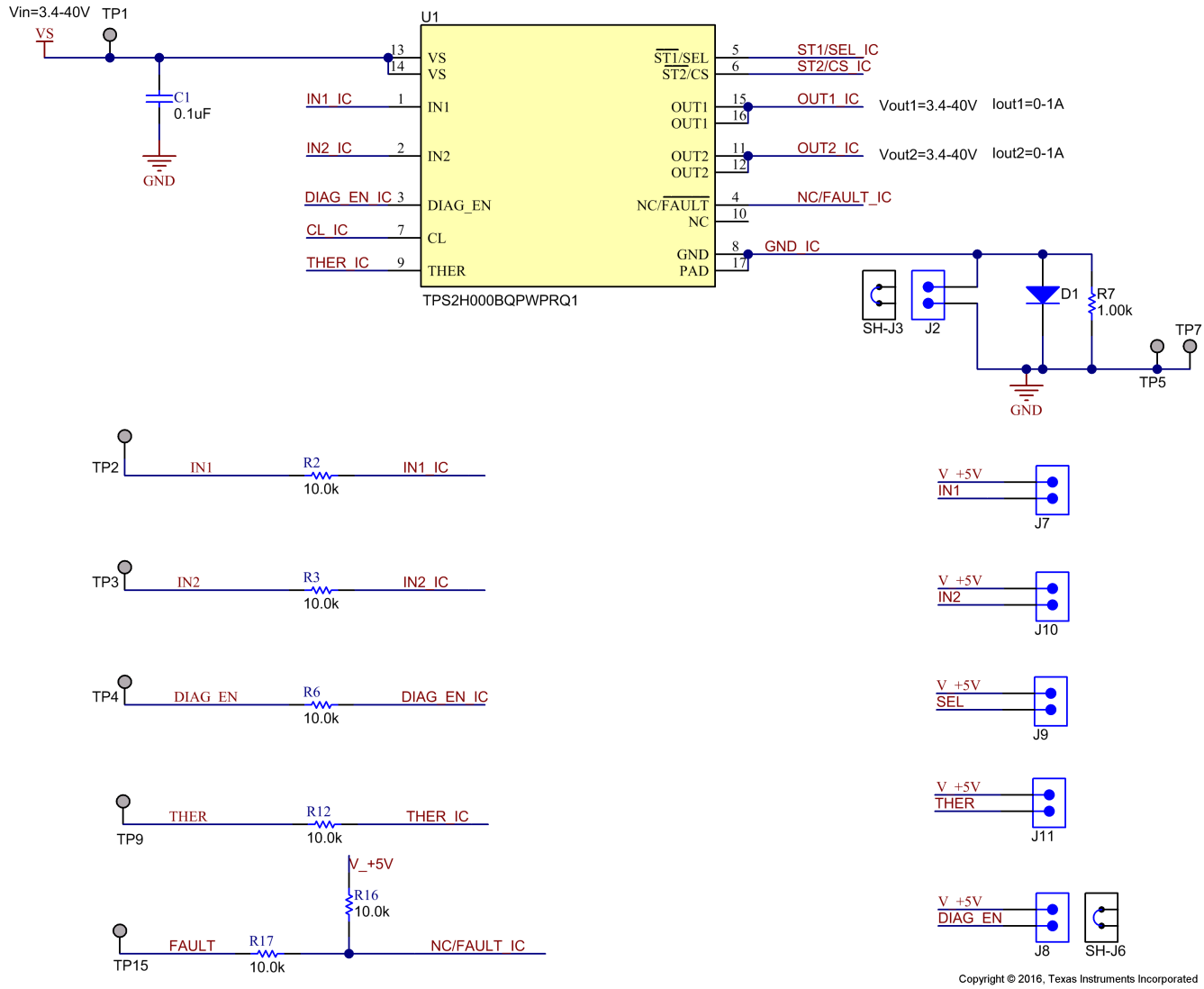


Figure 1. TPS2H000-Q1EVM Schematic 1

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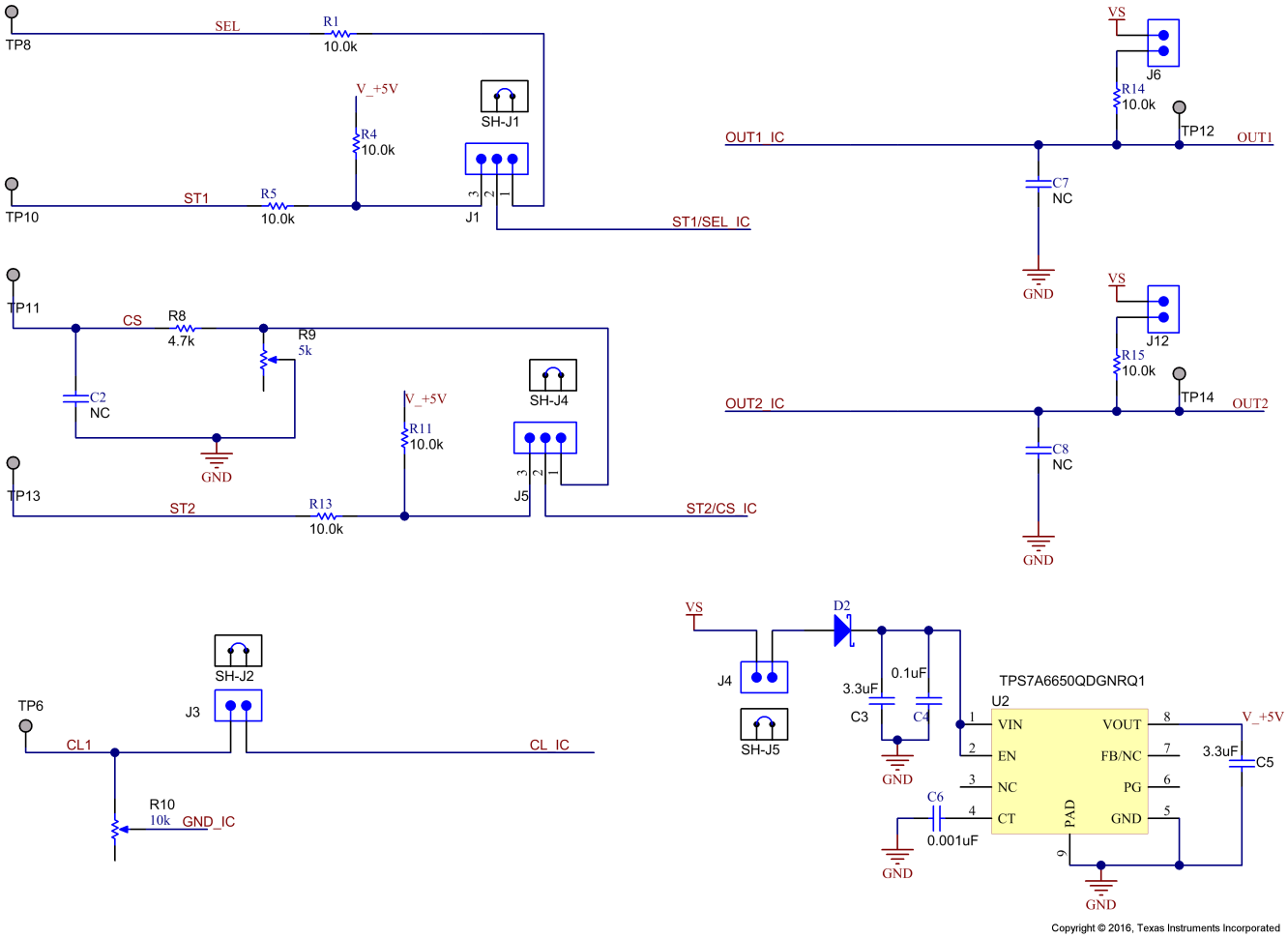


Figure 2. TPS2H000-Q1EVM Schematic 2

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3 Connections Descriptions

Table 1 lists and describes the connectors.

Table 1. Connectors

Connector	Description
VS	The board positive input supply voltage connector, the drain terminal of DMOS.
GND	The board GND connector, the return connection to the input power supply.
IN1	The board input connector, controls CH1 output. 3.3-V or 5-V control signal connection pin.
IN2	The board input connector, controls CH2 output. 3.3-V or 5-V control signal connection pin.
OUT1	CH1 output pin connector, the source terminal of DMOS.
OUT2	CH2 output pin connector, the source terminal of DMOS.
ST1	CH1 status output connector, only works with version A.
ST2	CH2 status output connector, only works with version A.
SEL	The channel selection connector, used to select which channel the CS pin sense is for, only effective for version B.
FAULT	The board state report connector, only works with version B, can get the OR value for the fault of 2CH.
CS	The board current sense output connector, only works with version B.
CL	The board current limit output connector.
DIAG_EN	The board DIAG_EN input connector, 3.3-V or 5-V control signal connection pin.
THER	The thermal shutdown behavior control connector.

Table 2 lists and describes the jumpers.

Table 2. Jumpers

Jumper	Description
J1	This jumper is used to select the SEL/ST1 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.
J2	This jumper is used to short IC GND and board GND. When floating, there will be a diode in parallel with a resistor between IC GND and board GND, which is designed for the reverse polarity protection.
J3	This jumper is used to isolate CL_IC from CL.
J4	This jumper is used to set a power supply for LDO when connected, for easy test use.
J5	This jumper is used to select the CS/ST2 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.
J6	This jumper is used to set a pullup for OUT1, if off-state open load/ short to battery are required.
J7	When floating, IN1 is controlled by outsource. When connected, IN1 is pulled up to version, for easy test use.
J8	When floating, DIAG_EN is controlled by outsource. When connected, DIAG_EN is pulled up to version, for easy test use.
J9	When floating, SEL is controlled by outsource. When connected, SEL is pulled up to version, for easy test use.
J10	When floating, IN2 is controlled by outsource. When connected, IN2 is pulled up to version, for easy test use.
J11	When floating, THER is controlled by outsource. When connected, THER is pulled up to version, for easy test use.
J12	This jumper is used to set a pullup for OUT2, if off-state open load/ short to battery are required.

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4 TPS2H000-Q1 EVM Assembly Drawings and Layout

Figure 3 through Figure 6 show the design of the TPS2H000-Q1 printed-circuit board (PCB). The EVM has been designed using FR4 material, four-layer (2s2p), 2-µm × 70-µm Cu in the top and bottom layers, and 2-µm × 35-µm Cu in internal plane layers. All components are in an active area on the top side and all active traces connect to the top and bottom layers allowing easy viewing, probing, and evaluation. Moving components to both sides of the PCB can offer additional size reduction for space-constrained systems.

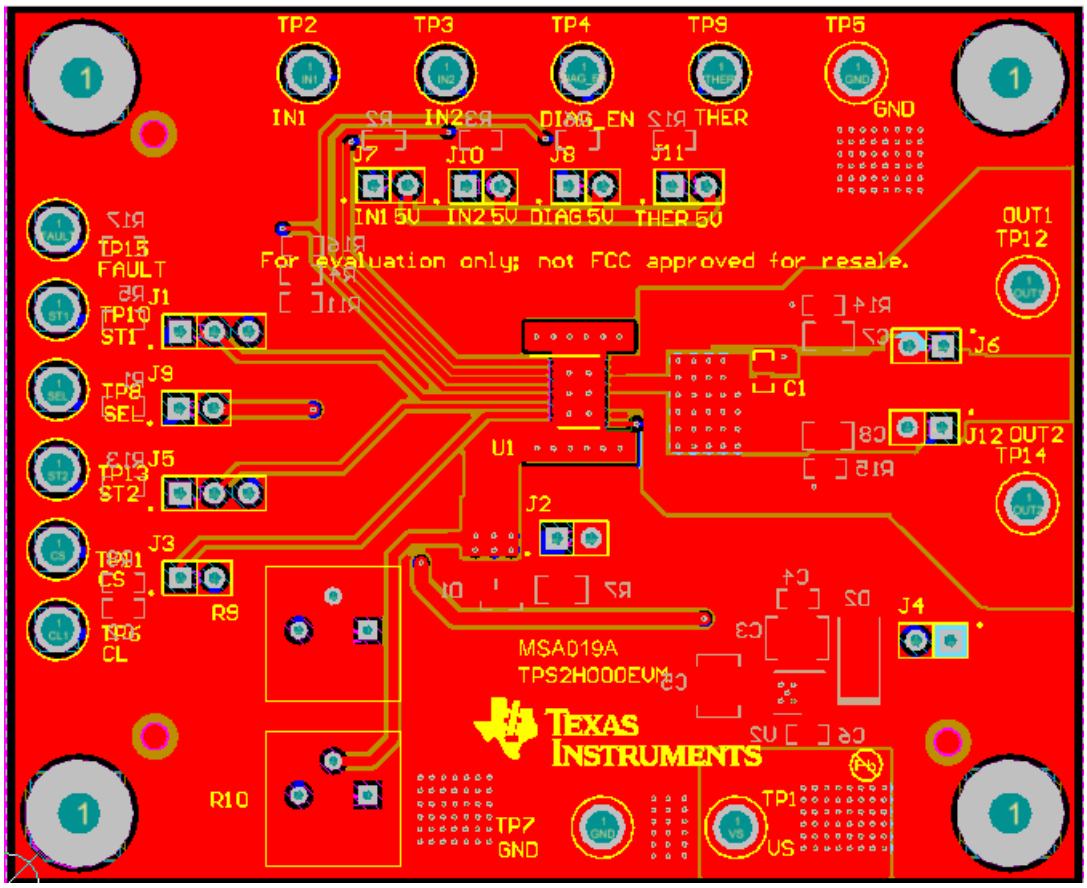


Figure 3. TPS2H000-Q1EVM First Layer (Top View)

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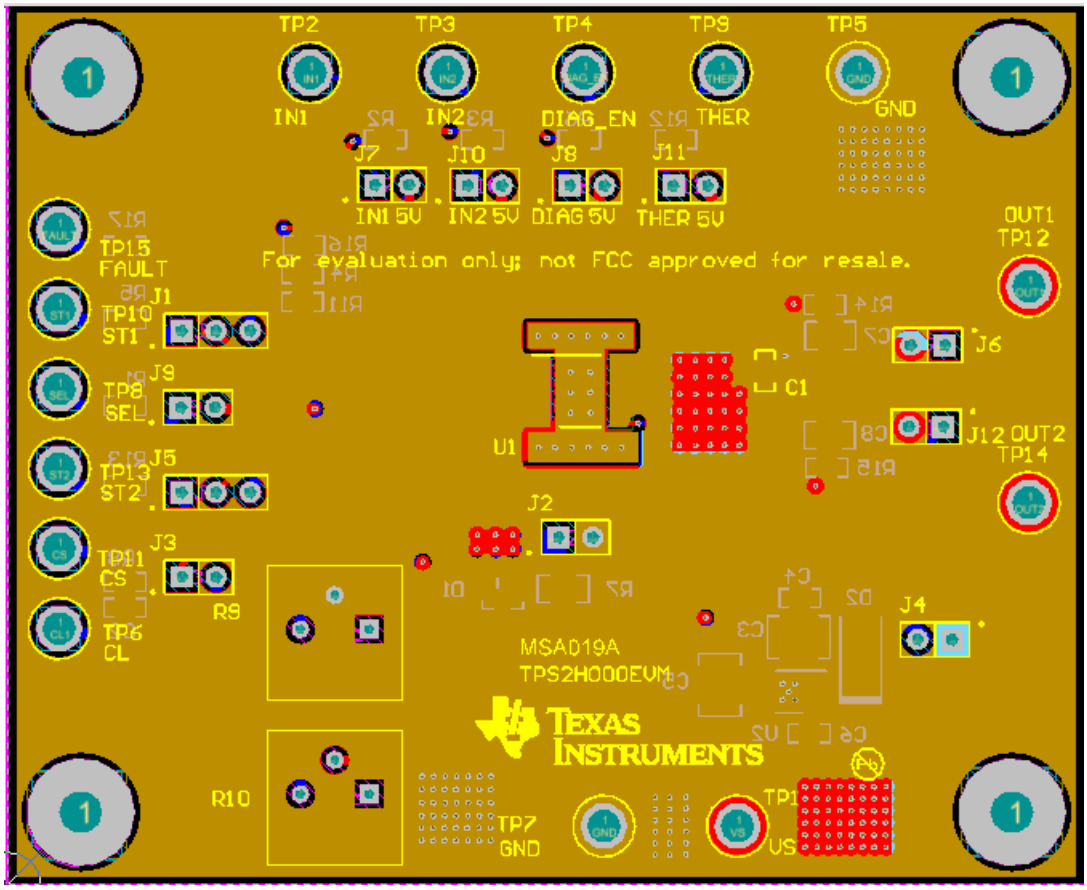


Figure 4. TPS2H000-Q1EVM Second Layer GND (Top View)

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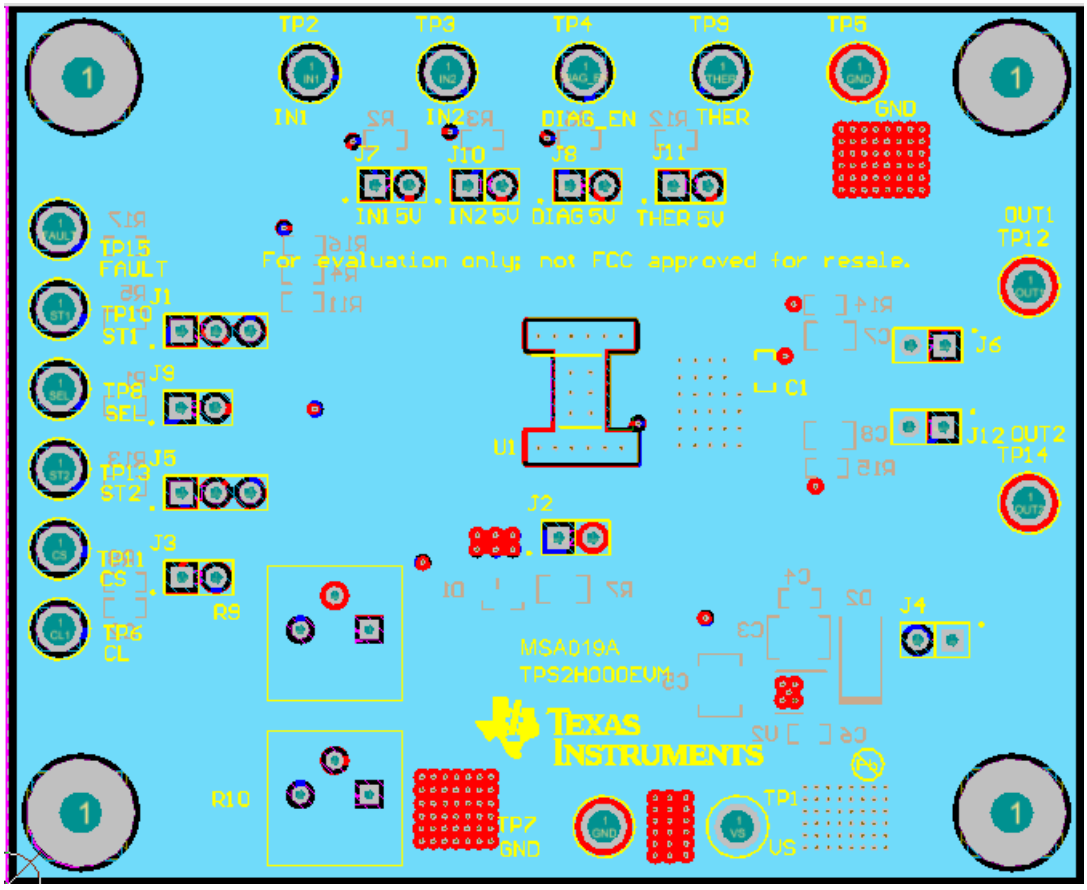


Figure 5. TPS2H000-Q1EVM Third Layer VCC (Top View)

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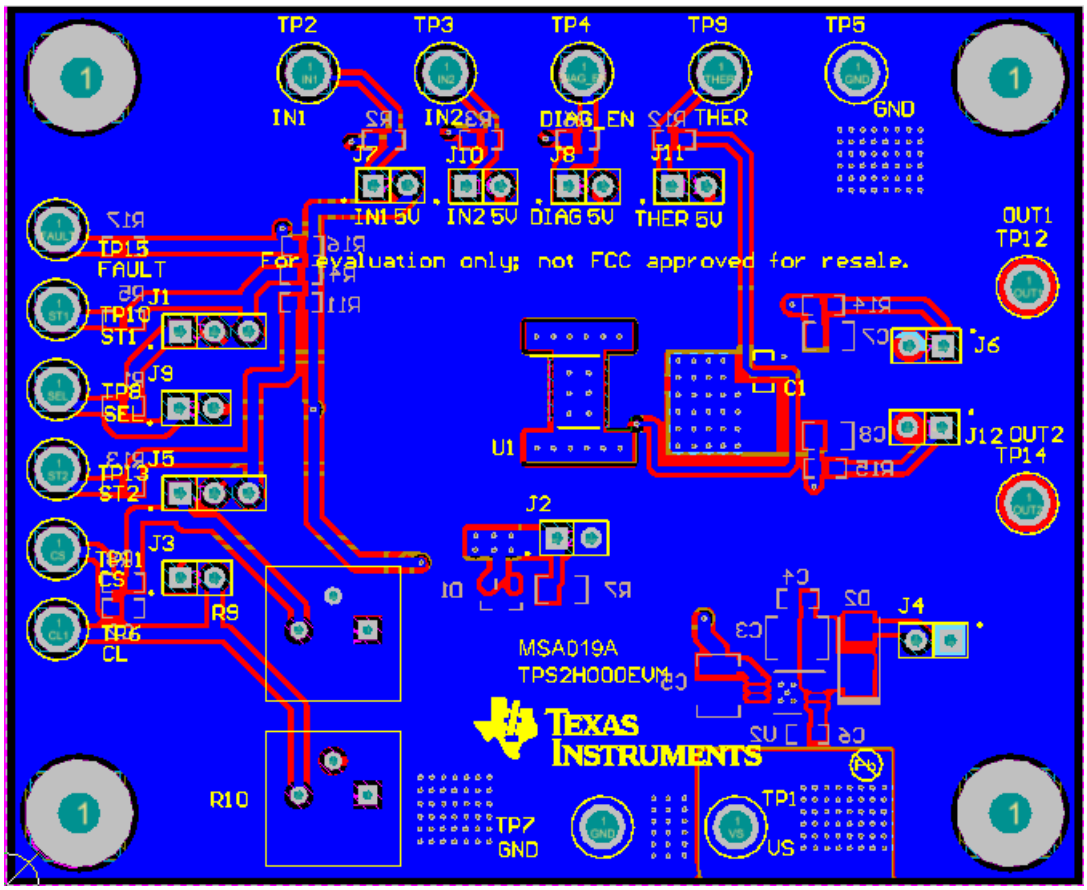


Figure 6. TPS2H000-Q1EVM Fourth Layer (Top View)

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5 Variable Resistor for CS and CL

5.1 Current Sense Resistor

For version B, highly accurate current sensing allows for better real-time monitoring and more accurate diagnostics, without further calibration. It provides realtime output current monitoring. A current mirror is used to source 1/K of the load current, and is reflected as $V_{CS} = I_{CS} \times R_{CS}$. Please ensure the CS voltage is in the linear region (0 V–4 V) when in normal operation.

Also, when a fault condition occurs, current sensing works as a diagnostic report pin. When an open load or short to the battery happens in on-state, V_{CS} almost equals to zero. When a current limit, thermal shutdown/swing, open load or short to battery occurs in off-state, the voltage is clamped at $V_{CS,H}$.

$$R_{CS} = \frac{V_{CS}}{I_{CS}} = \frac{V_{CS} \times K_{CS}}{I_{out}} \quad (1)$$

R9 is a variable resistor, from 0 Ω to 5 kΩ (clockwise direction to minimum, counter-clockwise direction to the maximum). The CS resistor can be changed through R9.

5.2 Current Limit Resistor

An external resistor is used to convert a proportional load current into a voltage, which is compared with an internal reference voltage. When the voltage on the CL pin exceeds the reference voltage, the current is clamped.

The inherent current limit is still present when using an external current limit. The smaller one of the internal or external set values will decide the actual nominal current limit. When not using an externally adjustable current, tie the CL pin to ground.

Equation 2 is an example of setting the current limit at 0.5 A.

$$I_{CL} = \frac{V_{CL,th}}{R_{CL}} = \frac{I_{out}}{K_{CL}}$$

$$R_{CL} = \frac{V_{CL,th} \times K_{CL}}{I_{out}} \quad (2)$$

R10 is a variable resistor, from 0 Ω to 10 kΩ (clockwise direction to minimum, counter-clockwise direction to the maximum). The CL resistor can be changed through R10. When 0 Ω, there is no external current limit function, internal current limit will be active.

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6 Bill of Materials

Table 3 lists the TPS2H000-Q1 BOM.

Table 3. TPS2H000-Q1 Bill of Materials

Designator	Comment	Description	Footprint	Qty
C1, C2, C4	GRM188R71H104KA93D	CAP, CERM, 0.1uF, 50V, +/-10%, X7R, 0603	0603	3
C7, C8	08051C103JAT2A	NC	0805_HV	2
C3, C5	C3225X7R1H335M	CAP, CERM, 3.3uF, 50V, +/-20%, X7R, 1210	1210	2
C6	06035A102KAT2A	CAP, CERM, 1000pF, 50V, +/-10%, C0G/NP0, 0603	0603	1
'TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15	Suggest using a net name here	Terminal, Turret, TH, Double	Keystone1502-2	15
D1	BAS21-7-F	Diode, Switching, 200V, 0.2A, SOT-23	SOT-23	1
D2	B150-13-F	Diode, Schottky, 50V, 1A, SMA	SMA	1
FID1, FID2, FID3	Fiducial	Fiducial mark. There is nothing to buy or mount.	Fiducial10-20	0
H1, H2, H3, H4	NY PMS 440 0025 PH	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	4
H5, H6, H7, H8	1902C	Standoff, Hex, 0.5"L #4-40 Nylon	Keystone_1902C	4
J2, J3, J4, J6, J7, J8, J9, J10, J11, J12	TSW-102-07-G-S	Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	TSW-102-07-G-S	10
J1, J5	TSW-103-07-G-S	Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	TSW-103-07-G-S	2
R1, R2, R3, R4, R5, R6, R11, R12, R13, R14, R15, R16, R17	CRCW060310K0FKEA	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	13
R10	3386P-1-103LF	TRIMMER, 10k ohm, 0.5W, TH	BOURNS_3386P	1
R7	CRCW08051K00FKEA	RES, 1.00k ohm, 1%, 0.125W, 0805	0805_HV	1
R8	CRCW06034K70JNEA	RES, 4.7k ohm, 5%, 0.1W, 0603	0603	1
R9	3386P-1-502LF	TRIMMER, 5k ohm, 0.5W, TH	BOURNS_3386P	1
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	969102-0000-DA	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	6
U1	TPS4H000AQPWPRQ1	40 V/1000 mohm Quad Channels Smart High Side Power Switch, PWP0020N	PWP0020N	1
U2	TPS7A6650QDGNRQ1	High-Voltage Ultralow-Iq Low-Dropout Regulator, DGN0008D	DGN0008D	1

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3 *Regulatory Notices:*

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      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      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

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- *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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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.

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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

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If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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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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.

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