TPS4H160-Q1 Evaluation Module

The TPS4H160-Q1 evaluation module is designed to evaluate the TPS4H160-Q1 integrated circuit. This user's guide provides the connectors and test point description, the schematic, bill of materials, and board layout of the EVM.

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1 Introduction

TI's TPS4H160-Q1 evaluation module (EVM) contains a TPS4H160-Q1 integrated circuit (IC), supporting quad-channel high-side switch applications. The purpose of this EVM is to facilitate evaluation of the TPS4H160-Q1 for resistive, capacitive, and inductive load.

1.1 Descriptions

The TPS4H160-Q1 family is a fully-protected quad-channel, high-side power switch, with integrated NMOS power FET and charge pump.

Full diagnostics and high accuracy 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 report. The diagnostics can be disabled for multiplexing the sense pin between different devices. Thermal shutdown behaviors as latch off or auto-retry are internally fixed in the part.

External programmable current limit improves the whole system’s reliability by limiting the inrush or overload current.

1.2 Applications

This EVM is used in the following applications:

1. Multi-channel LED drivers, bulb drivers
2. Multi-channel high-side power switches
3. Multi-channel high-side relay drivers
4. PLC digital output drivers

1.3 Features

This 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. Programmable current limit with external resistor
5. Multiplex high accuracy current sense or ST report
6. Tested according to AECQ100-12
7. Certification of ISO7637-2 and ISO16750-2

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2 TPS4H160-Q1 Schematic

Figure 1 illustrates the EVM schematic.

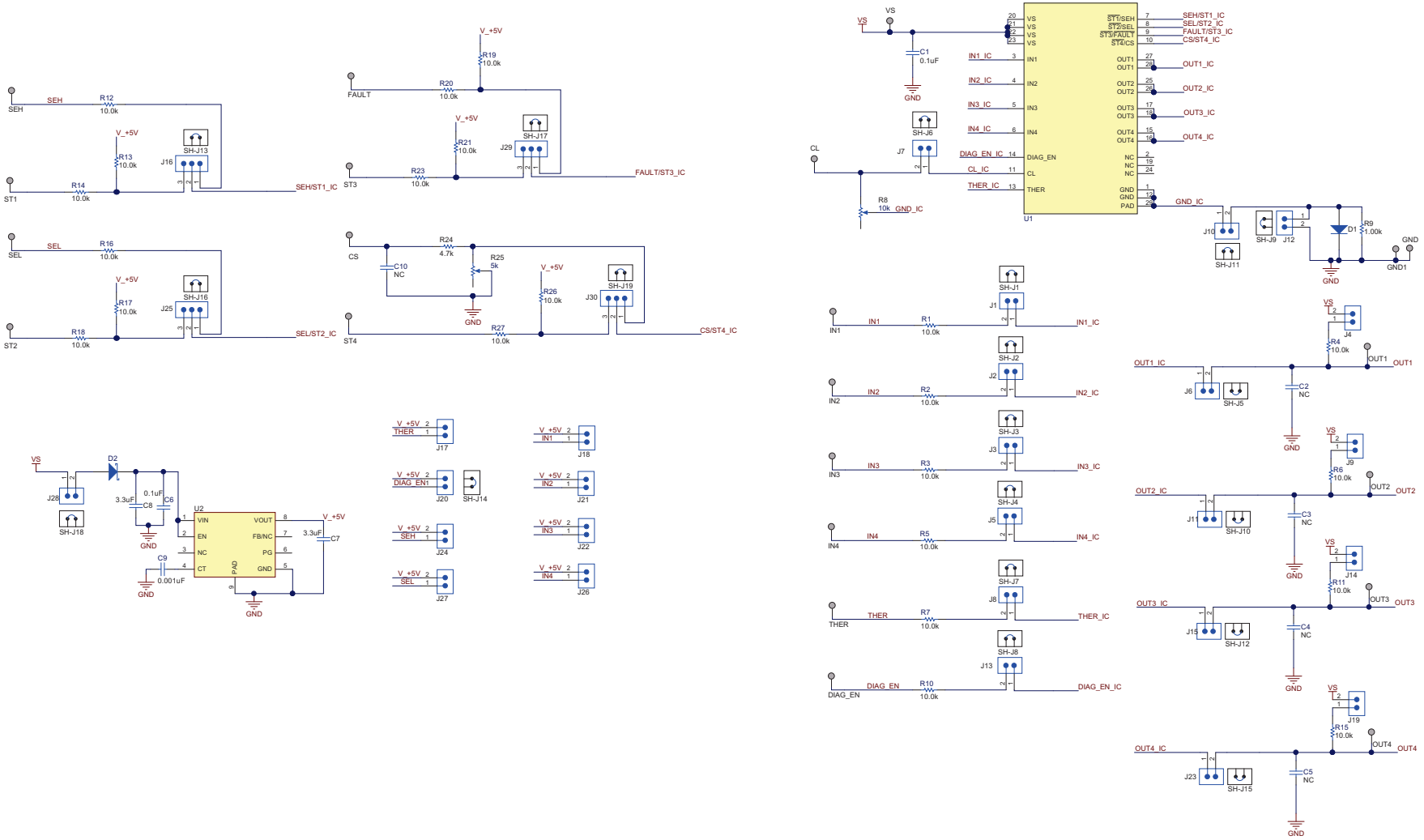


Figure 1. TPS4H160-Q1EVM Schematic

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3 Connection Descriptions

This section describes the connectors on the EVM as well and how to properly connect, set up, and use the TPS4H160-Q1 EVM.

3.1 Connectors

VS – The board's positive input supply voltage connector, the drain terminal of DMOS.

GND – The board's GND connector, the return connection to the input power supply.

IN1 – The board's input connector; controls CH1 output. 3.3-V or 5-V control signal connection pin.

IN2 – The board's input connector; controls CH2 output. 3.3-V or 5-V control signal connection pin.

IN3 – The board's input connector; controls CH3 output. 3.3-V or 5-V control signal connection pin.

IN4 – The board's input connector; controls CH4 output. 3.3-V or 5-V control signal connection pin.

OUT1 – The board's CH1 output pin connector, the source terminal of DMOS.

OUT2 – The board's CH2 output pin connector, the source terminal of DMOS.

OUT3 – The board's CH3 output pin connector, the source terminal of DMOS.

OUT4 – The board's CH4 output pin connector, the source terminal of DMOS.

ST1 – The board's CH1 status output connector, only effective for version A.

ST2 – The board's CH2 status output connector, only effective for version A.

ST3 – The board's CH3 status output connector, only effective for version A.

ST4 – The board's CH4 status output connector, only effective for version A.

SEH – The high-bit channel selection connector, combining with SEL to select which channel CS pin sense for, only effective for version B.

SEL – This is the low-bit channel selection connector, combining with SEH to select which channel CS pin sense for, only effective for version B.

FAULT – The board's states report connector, only effective for version B, can get the OR value for 4-CHs fault.

CS – The board's current sense output connector, only effective for version B.

CL – The board's current limit output connector.

DIAG_EN – The board's DIAG_EN input connector, 3.3-V or 5-V control signal connection pin.

THER – This is the thermal shutdown behavior control connector.

3.2 Jumpers

J1 – This jumper isolates IN1_IC from IN1.

J2 – This jumper isolates IN2_IC from IN2.

J3 – This jumper isolates IN3_IC from IN3.

J4 – This jumper sets a pullup for OUT1, if off-state open load or short to battery are required.

J5 – This jumper isolates IN4_IC from IN4.

J6 – This jumper isolates OUT1_IC from OUT1.

J7 – This jumper isolates CL_IC from CL.

J8 – This jumper isolates THER_IC from THER.

J9 – This jumper sets a pullup for OUT2, if off-state open load or short to battery are required.

J10 – This jumper isolates GND_IC from board GND.

J11 – This jumper isolates OUT2_IC from OUT2.

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J12 – This jumper shorts IC GND and board GND. When floating, there is a diode in parallel with a resistor between IC GND and board GND, is designed for the reverse polarity protection.

J13 – This jumper isolates DIAG_EN_IC from DIAG_EN.

J14 – This jumper sets a pullup for OUT3, if off-state open load or short to battery are required.

J15 – This jumper isolates OUT3_IC from OUT3.

J16 – This jumper selects SEH/ST1 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.

J17 – When floating, THER is controlled by outsource. When connected, THER is pulled up to 5 V for easy- test usage.

J18 – When floating, IN1 is controlled by outsource. When connected, IN1 is pulled up to 5 V for easy-test usage.

J19 – This jumper sets a pullup for OUT4, if off-state open load or short to battery are required.

J20 – When floating, DIAG_EN is controlled by outsource. When connected, DIAG_EN is pulled up to 5 V for easy- test usage.

J21 – When floating, IN2 is controlled by outsource. When connected, IN2 is pulled up to 5 V for easy-test usage.

J22 – When floating, IN3 is controlled by outsource. When connected, IN3 is pulled up to 5 V for easy-test usage.

J23 – This jumper isolates OUT4_IC from OUT4.

J24 – When floating, SEH is controlled by outsource. When connected, SEH is pulled up to 5 V for easy-test usage.

J25 – This jumper selects SEL/ST2 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.

J26 – When floating, IN4 is controlled by outsource. When connected, IN4 is pulled up to 5 V for easy-test usage.

J27 – When floating, SEL is controlled by outsource. When connected, SEL is pulled up to 5 V for easy-test usage.

J28 – This jumper sets a power supply for LDO when connected, for easy test usage.

J29 – This jumper selects FAULT/ST3 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.

J30 – This jumper selects CS/ST4 functions, version A short pin 2 and pin 3, version B short pin 2 and pin 1.

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4 TPS4H160-Q1 EVM Assembly Drawings and Layout

Figure 2 to Figure 5 show the design of the TPS4H160-Q1 printed-circuit board (PCB). The EVM is designed using FR4 material, four-layer (2s2p), 2 × 70-µm Cu in top and bottom layers, and 2 × 35-µm Cu in internal plane layers. All components are in an active area on the top side and all active traces to the top and bottom layers to allow the user to easily view, probe, and evaluate. Moving components to both sides of the PCB offers additional size reduction for space-constrained systems.

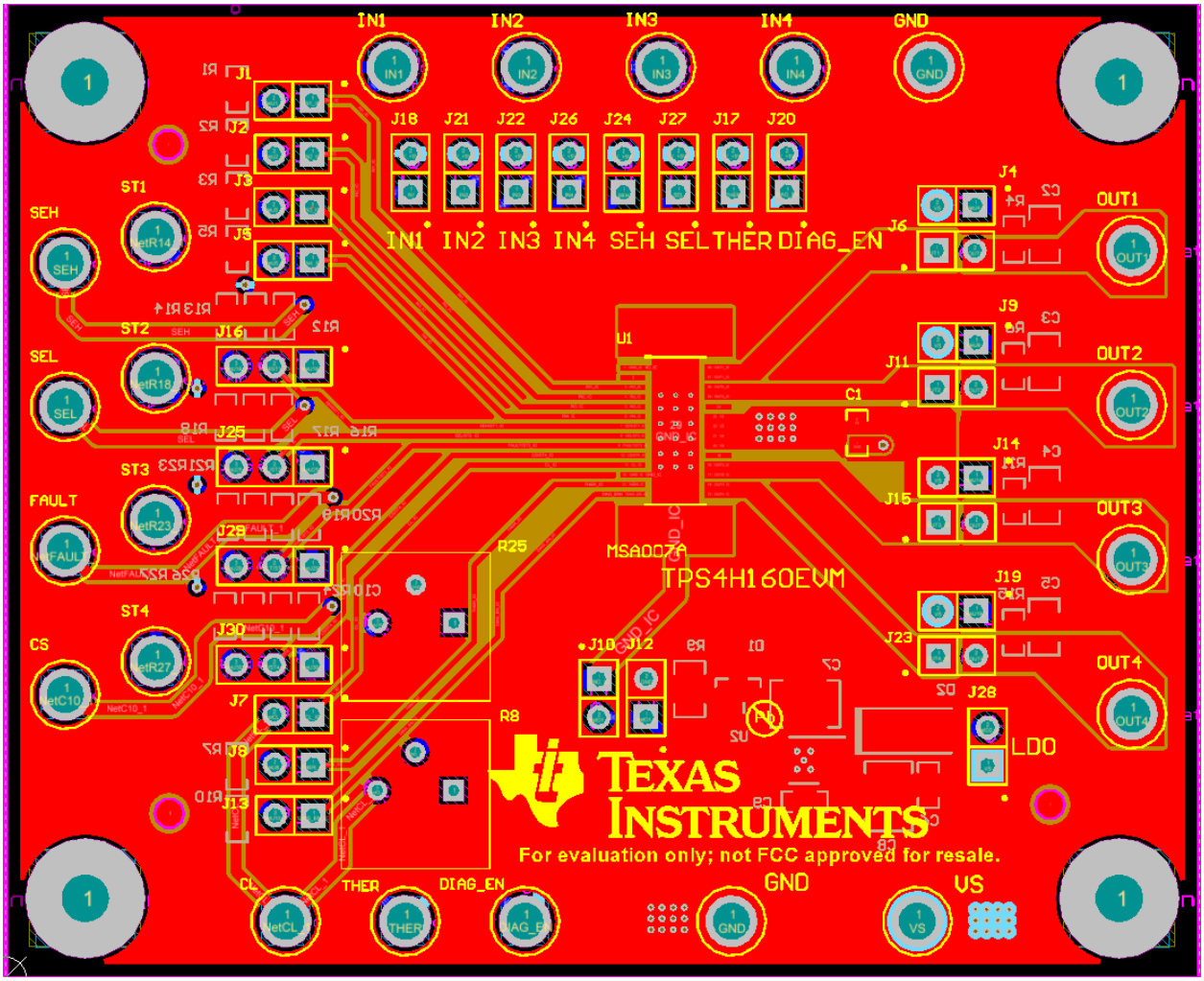


Figure 2. TPS4H160-Q1EVM First Layer (Top View)

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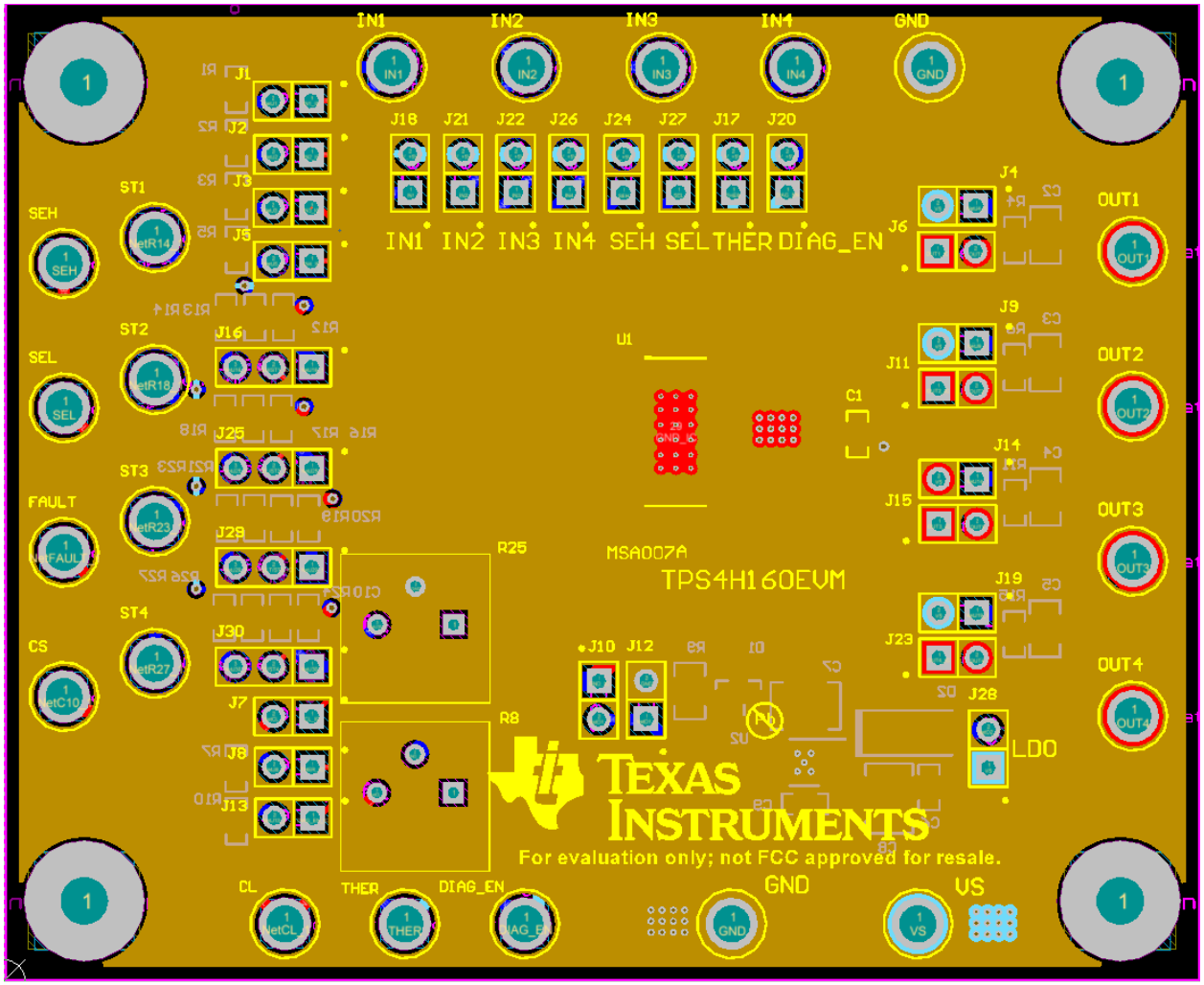


Figure 3. TPS4H160-Q1EVM Second Layer GND (Top View)

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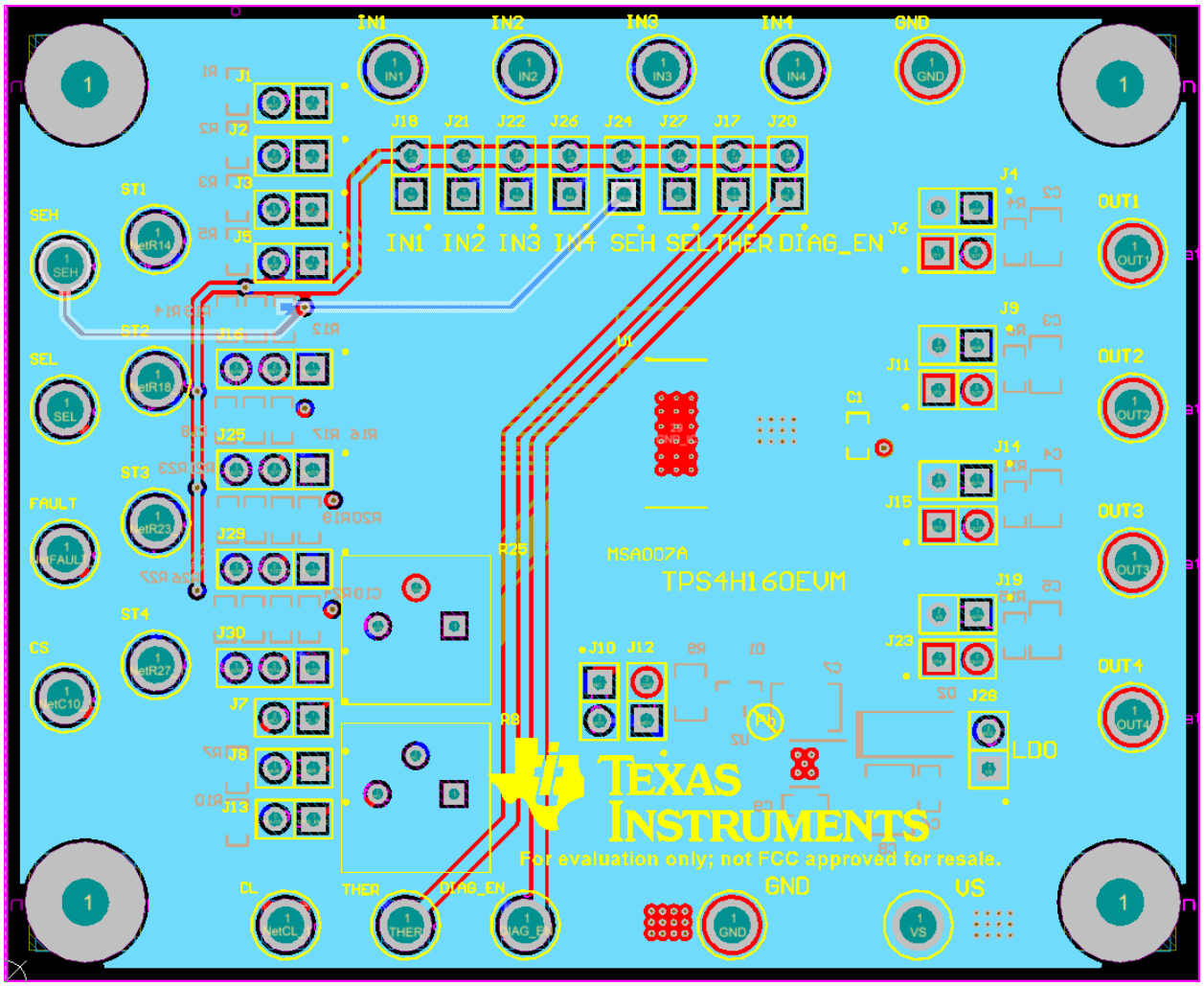


Figure 4. TPS4H160-Q1EVM Third Layer VCC (Top View)

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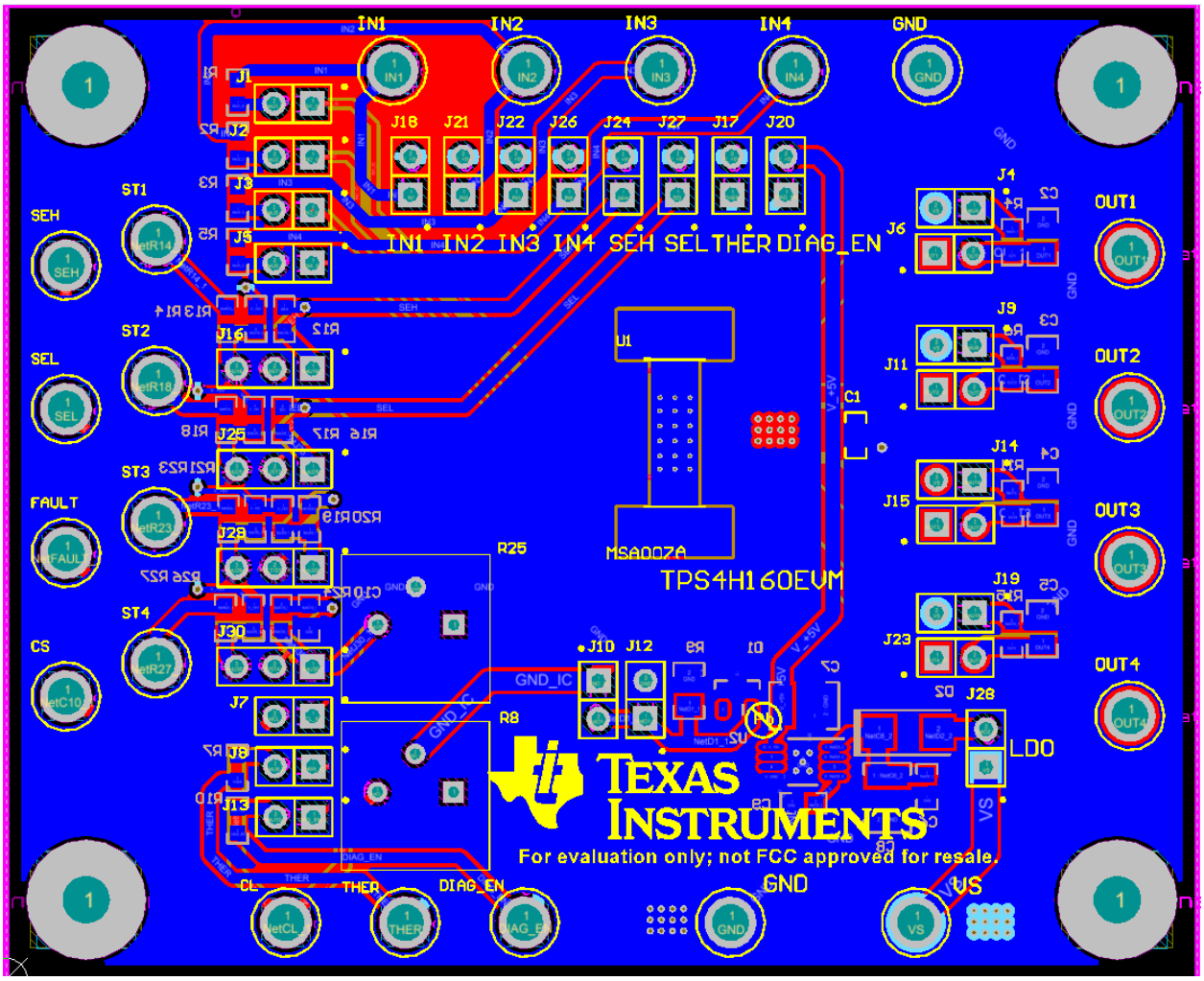


Figure 5. TPS4H160-Q1EVM Fourth Layer (Top View)

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5 Variable Resistor for CS and CL

5.1 Current Sense Resistor

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

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

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

R25 is a variable resistor, from 0-Ω to 5-kΩ (clockwise direction to minimum, counterclockwise direction to the maximum). Change the CS resistor through R25.

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 (Ilim,nom) is still present when using an external current limit. The smaller one of the internal or external set value decides the actual nominal current limit. If it is decided to not use an external programmable current, tie the CL pin to ground.

Equation 2 is the equation of the current limit resistor.

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

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

R8 is a variable resistor, from 0-Ω to 5-kΩ (clockwise direction to minimum, counterclockwise direction to the maximum). Change the CL resistor through R8. When 0-Ω, there is no external current limit function, the internal current limit is active.

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6 Bill of Materials

Table 1 lists the EVM BOM.

Table 1. Bill of Materials

Designator	Comment	Description	Footprint	Qty
C1, C6, C10	GRM188R71H104KA93D	CAP, CERM, 0.1uF, 50V, +/-10%, X7R, 0603	0603	3
C2, C3, C4, C5	08051C103JAT2A	NC	0805_HV	4
C7, C8	C3225X7R1H335M	CAP, CERM, 3.3uF, 50V, +/-20%, X7R, 1210	1210	2
C9	06035A102KAT2A	CAP, CERM, 1000pF, 50V, +/-10%, C0G/NP0, 0603	0603	1
CL, CS, DIAG_EN, FAULT, GND, IN1, IN2, IN3, IN4, OUT1, OUT2, OUT3, OUT4, SEH, SEL, ST1, ST2, ST3, ST4, THER, VS	Suggest using a net name here	Terminal, Turret, TH, Double	Keystone1502-2	21
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	3
GND1	GND	Terminal, Turret, TH, Double	Keystone1502-2	1
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
J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12, J13, J14, J15, J17, J18, J19, J20, J21, J22, J23, J24, J26, J27, J28	TSW-102-07-G-S	Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	TSW-102-07-G-S	26
J16, J25, J29, J30	TSW-103-07-G-S	Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	TSW-103-07-G-S	4
R1, R2, R3, R4, R5, R6, R7, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R23, R26, R27	CRCW060310K0FKEA	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	22
R8	3386P-1-103LF	TRIMMER, 10k ohm, 0.5W, TH	BOURNS_3386P	1
R9	CRCW08051K00FKEA	RES, 1.00k ohm, 1%, 0.125W, 0805	0805_HV	1
R24	CRCW06034K70JNEA	RES, 4.7k ohm, 5%, 0.1W, 0603	0603	1
R25	3386P-1-502LF	TRIMMER, 5k ohm, 0.5W, TH	BOURNS_3386P	1
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12, SH-J13, SH-J14, SH-J15, SH-J16, SH-J17, SH-J18, SH-J19	969102-0000-DA	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	19
U1	TPS4H160BQPWPRQ1	40V/140mohm Quad Channels Smart High Side Power Switch, PWP0028C	PWP0028C_N	1
U2	TPS7A6650QDGNRQ1	High-Voltage Ultralow-Iq Low-Dropout Regulator, DGN0008D	DGN0008D_N	1

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STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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:*

      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*

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.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required 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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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

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4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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