TPS92638EVM User's Guide

1 Introduction

The TPS92638-Q1 evaluation module is designed to evaluate the TPS92638-Q1 integrated circuit (IC) in a typical LED application. This user's guide provides descriptions for the connectors and test points as well as the schematic, bill of materials, and PCB layout of the evaluation module (EVM).

For features and a description of the TPS92638-Q1 device, see the device data sheet, SLVSCK5.

2 Connector and Test Point Descriptions

Table 1. Connectors

CONNECTOR	NAME	DESCRIPTION
CN1	VBAT	This connector is the positive input supply voltage.
CN2	STOP	This connector is the positive STOP input power supply. When a high level is on the connector, the current on the load is determined by 200 × V_{REF} / (R12 // R13). When the level on the CN2 connector is low, the current on the load is determined by 200 × V_{REF} / R13.
CN3	GND	The CN3 connector is TPS92638-Q1 EVM ground. This connector is the return connection to the input power supply.
CN4	EN	This connector is the enable pin input for device enable and shutdown.
CN5	PWM1	This connector is the PWM1 input for channel 1 and channel 2.
CN6	PWM2	This connector is the PWM2 input for channel 3 and channel 4.
CN7	PWM3	This connector is the PWM3 input for channel 5 and channel 6.
CN8	PWM4	This connector is the PWM4 input for channel 7 and channel 8.
CN9	FAULT	This connector is the I/O pin. The $\overline{\text{FAULT}}$ status output of the LED driver when an open-load condition, LED short GND, LED short battery, thermal shutdown, reference resistor short is detected. This pin can also be pulled high depend on the behavior required by the application. For additional detail, see the fault table in the TPS92638-Q1 data sheet.
CN10	TEMP_IN	This connector is the input that supplies the voltage source to potentiometer R9. The voltage is divided by the potentiometer R9 which is then sent to the TEMP pin which is used to set the thermal foldback threshold. See Section 3.4 for additional information.

Table 2. Jumpers

JUMPER	DESCRIPTION
J1	This jumper connects the SUPPLY pin and the FAULT pullup circuit. This jumper is open by default. When this jumper is shorted, the FAULT pullup circuit is enabled.
J2	This jumper is used to connect the SUPPLY and EN pins together.
J3	This jumper is used to short PWM1 to the VIN pin when there is no external signal to control PWM1.
J4	This jumper is used to short PWM2 to the VIN pin when there is no external signal to control PWM2.
J5	This jumper is used to short PWM3 to the VIN pin when there is no external signal to control PWM3.
J6	This jumper is used to short PWM4 to the VIN pin when there is no external signal to control PWM4.
J7	This jumper is used to connect the FAULT pullup circuit and the $\overline{\text{FAULT}}$ pin together. This jumper is open by default.
J8	This jumper is used for connect the divided voltage to the TEMP pin.
J9	This jumper is used to connect REFH pin to ground. This jumper is usually used to test the REFH short to ground.
J10	This jumper is used to connect R12 to the REFH pin.
J11	This jumper is used to connect the input ground of the IC to ground of the board.
J12	This jumper is used to connect R13 to the REF pin.
J13	This jumper is used to connect the REF pin to ground. This jumper is usually used to test the REF short to ground.
J14	This jumper is used to connect the LED strings to the IOUT8 pin.
J15	This jumper is used to connect the LED strings to the IOUT7 pin.
J16	This jumper is used to connect the LED strings to the IOUT6 pin.
J17	This jumper is used to connect the LED strings to the IOUT5 pin.
J18	This jumper is used to connect the LED strings to the IOUT4 pin.
J19	This jumper is used to connect the LED strings to the IOUT3 pin.
J20	This jumper is used to connect the LED strings to the IOUT2 pin.
J21	This jumper is used to connect the LED strings to the IOUT1 pin.
J22	This jumper is used to connect the IOUT1 pin to the board gound. This jumper is usually used to test the IOUT1 short to ground protection.

3 TPS92638EVM Assembly Drawings and Layout

3.1 Board Design and Layout

Figure 1, Figure 2, and Figure 2 show the design of the TPS92638-Q1 printed-circuit board (PCB). The EVM has been designed using a two-layer, 2-oz, copper-clad circuit board that is 91 mm × 101 mm. All components 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 the TPS92638-Q1 control IC in a practical double-sided application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space constrained systems.

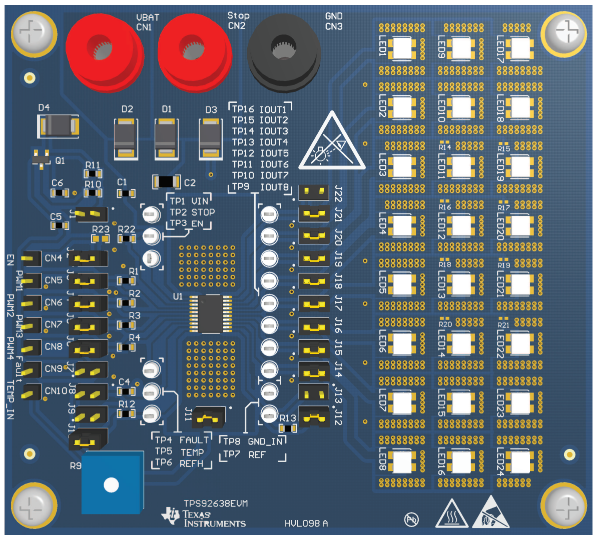


Figure 1. TPS92638EVM Component Placement (Top view)

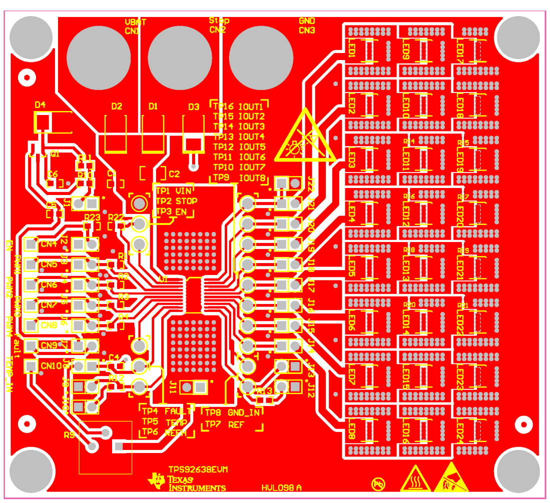


Figure 2. TPS92638EVM Top Copper (Top View)

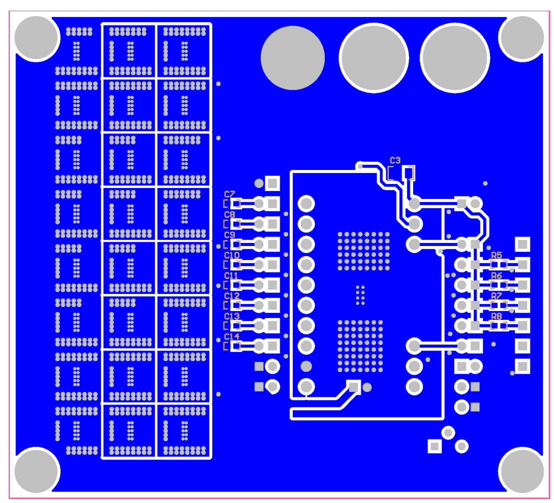


Figure 3. TPS92638EVM Bottom Copper (Bottom View)

3.2 LED Current Setting

Eight LED output channels are controlled through separate linear current regulators. The current in each channel is set by a common external resistor. The device also features two current levels, intended for stoplight and taillight applications. The internal current reference, I_{REF}, has two possible values depending on the state of the STOP input which are defined as follows:

- When the STOP pin is low, the output current is defined by R_{REF}, the current drawn from the REF pin.
- When the STOP pin is high, the output current is defined by the R_{REFH} // R_{REF}, the current drawn from the REFH and REF pins.

Use Equation 1 and Equation 2 to calculate the current setting.

$$I_{OUT} = \frac{V_{REF} \times Gi}{R_{REF}}$$

where

- V_{REF} equals to 1.222 V
- Gi is 200
- R_{REF} is the resistor connected to REF pin, which is R13 (1)

$$I_{OUTH} = \frac{V_{REF} \times Gi}{R_{REF} / / R_{REFH}}$$

where

- V_{REF} equals to 1.222 V
- Gi is 200
- R_{REFH} is the resistor connected to REFH pin, which is R12 (2)

3.3 Power Dissipation and Thermal Considerations

Use Equation 3 to calculate the power dissipation (P_D) of the IC.

$$P_D = V_{VIN} \times I_{VIN} - \Sigma_{x=1}^{8} n_x \times V_{(LEDx)} \times I_{(LEDx)} - \frac{V_{REF}^{2}}{R_{(SET)}}$$

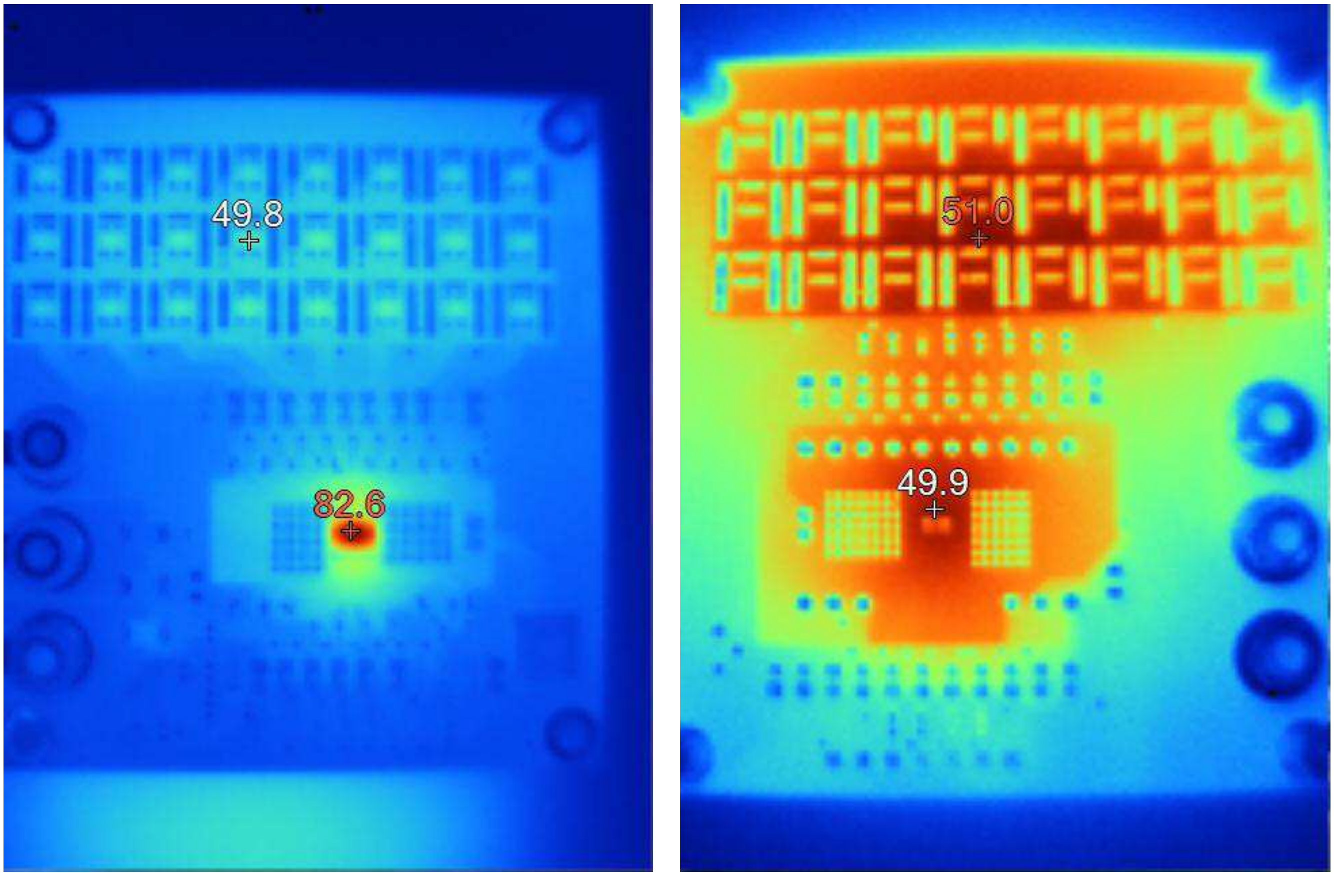
where

- n_X = Number of LEDs for X channel
- $V_{(LEDx)}$ = Voltage drop across one LED for X channel
- V_{REF} = Reference voltage, typically 1.222 V
- $R_{(SET)}$ = Current set resistor
- $I_{(LEDx)}$ = Average LED current for channel X (3)

To manage the power dissipation, the voltage drop (VIN – n_X × $V_{(LEDx)}$) of the IC must be controlled, especially under a high current.

Figure 4 shows the low-current thermal performance for the EVM when V_{VBAT} is 12 V and the STOP pin is open.

Top of PCB **Bottom of PCB**

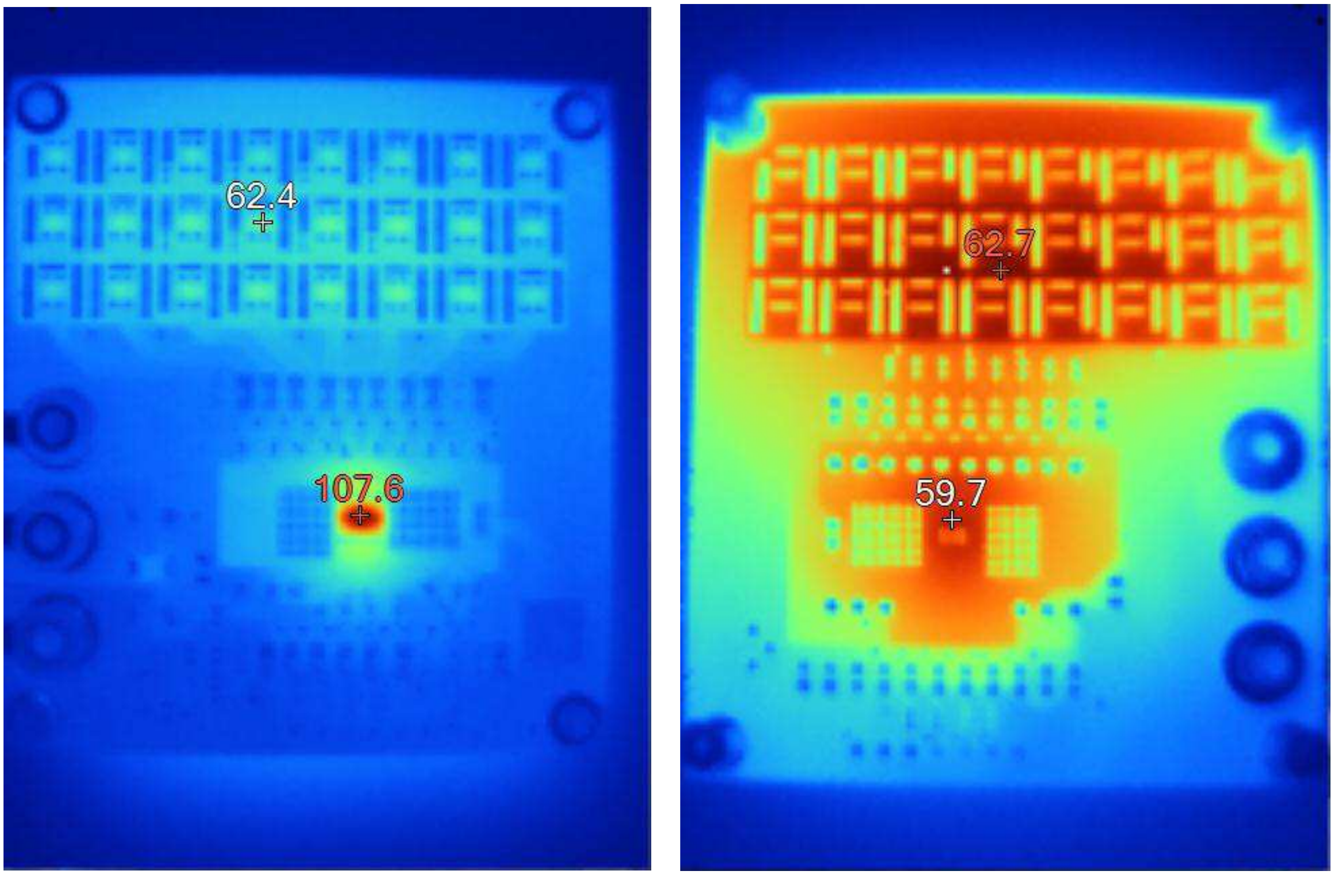


Temperature listed is in Celsius (°C).

Figure 4. Thermal Performance of Low Current

Figure 5 shows the high-current thermal performance for the EVM when VBAT is open and V_{STOP} is 12 V.

Top of PCB **Bottom of PCB**



Temperature listed is in Celsius (°C).

Figure 5. Thermal Performance of High Current

3.4 Thermal Foldback Function

The TPS92638-Q1 device integrates thermal shutdown protection to prevent the IC from overheating. In addition, to prevent LEDs from flickering because of rapid thermal changes, the device includes a programmable thermal-current foldback feature to reduce power dissipation at high junction temperatures.

The TPS92638-Q1 device reduces the LED current as the silicon junction temperature of the TPS92638-Q1 device increases (see Figure 6). By mounting the TPS92638-Q1 device on the same thermal substrate as the LEDs, this feature can also limit the dissipation of the LEDs. As the junction temperature of the TPS92638-Q1 device increases, the device reduces the regulated current, as well reducing the dissipated power in the TPS92638-Q1 device and in the LEDs. The current reduction is from the 100% level at typically 2% of $I_{setting}$ per ºC until the point at which the current drops to 50% of the full value. Above the T_{th} + 20 ºC temperature, the current remains at approximately 50% of the full value until the temperature reaches the over-temperature shutdown threshold, $T_{(shutdown)}$.

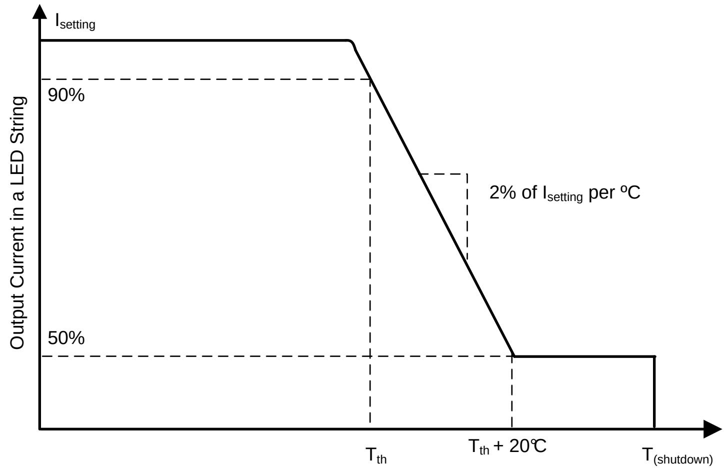


Figure 6.

Changing the voltage on the TEMP pin adjusts the temperature at which the current reduction begins. With TEMP floating, T_{th} is approximately 110 ºC. T_{th} increases as the voltage at TEMP pin (V_{TEMP}) declines (see Figure 7) and is calculated using Equation 4.

$$T_{th} = -121.7 \times V_{TEMP} + 228.32 \quad (4)$$

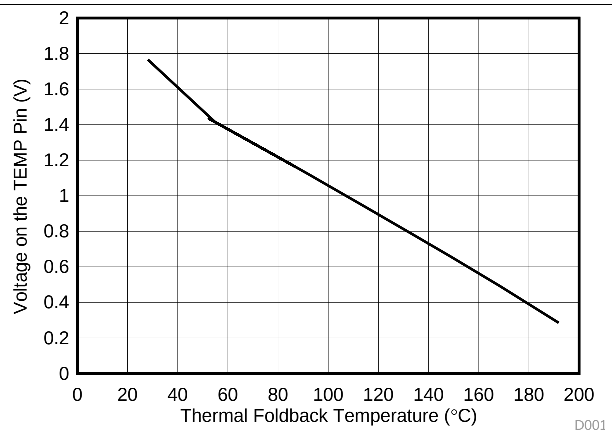


Figure 7. V_{TEMP} vs T_{th}

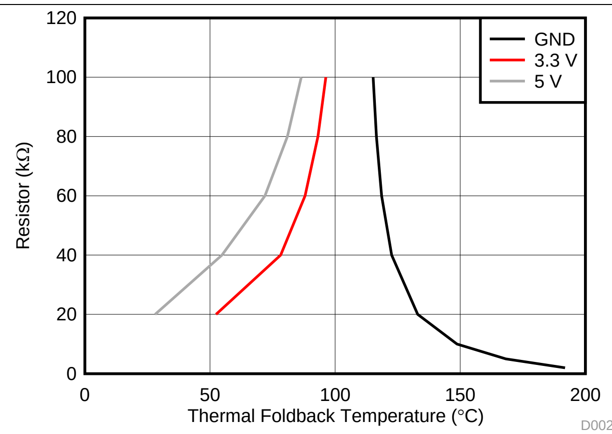


Figure 8. Pullup and Pulldown Resistors vs T_{th}

Figure 8 shows how T_{th} varies with a pulldown resistor to GND or with a pullup resistor to 3 V and 5 V. The gray and red lines indicate the relationship between the pullup resistor and T_{th}. The black (GND) line indicates the relationship between the pulldown resistor and T_{th}.

3.5 Fault Function

The device fault pins can be connected to the microcontroller (MCU) for fault reporting. Both fault pins are open-drain transistors with internal weak pullup. In case of no MCU, up to 30 TPS92638-Q1 $\overline{\text{FAULT}}$ pins can be connected together. When a single device or more devices have errors, causing one or more $\overline{\text{FAULT}}$ pins to go low, the connected FAULT bus is pulled down. When the $\overline{\text{FAULT}}$ pin goes low all device outputs shut down. Figure 9 shows the fault-line bus connection.

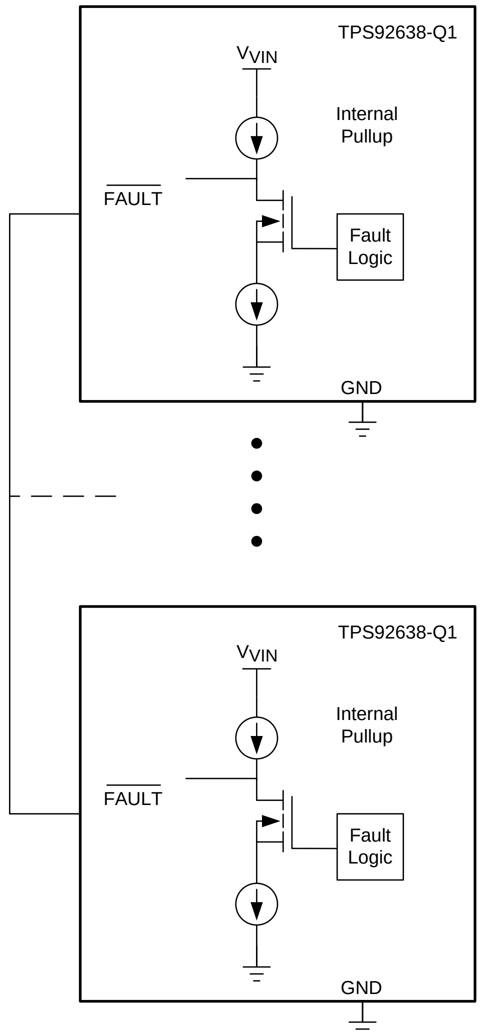


Figure 9. TPS92638-Q1 Fault Bus

4 Schematic and Bill of Materials

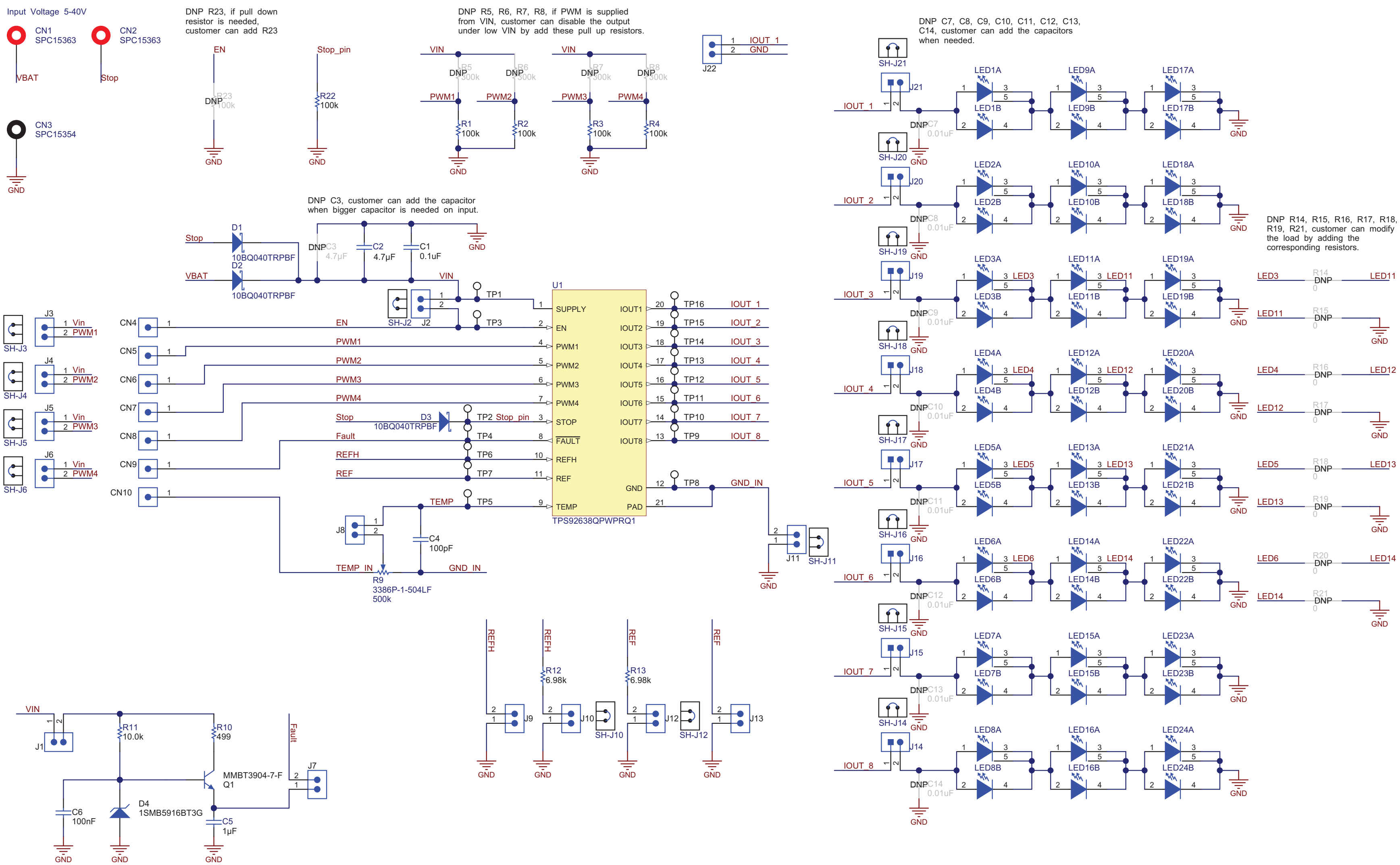


Figure 10. TPS92638EVM Schematic

Table 3. TPS92638EVM Bill of Materials

DESIGNATOR	QUANTITY	DESCRIPTION	MANUFACTURER	PART NUMBER
!PCB	1	Printed Circuit Board	Any	HVL098
C1	1	Capacitor, Ceramic, 0.01 µF, 100 V, ±5%, X7R, 0603	AVX	06031C103JAT2A
C2	1	Capacitor, Ceramic, 4.7 µF, 50 V, ± 10%, X5R, 1206	MuRata	GRM319R61H475KA12
C4, C6	2	Capacitor, Ceramic, 0.1 µF, 25 V, ±10%, X7R, 0603	Kemet	C0603X104K3RACTU
C5	1	Capacitor, Ceramic, 1 µF, 6.3 V, +80/–20%, Y5V, 0603	Kemet	C0603C105Z9VACTU
CN1, CN2	2	Banana jack, solder lug, red, TH	Tenma	SPC15363
CN3	1	Banana jack, solder lug, black, TH	Tenma	SPC15354
CN4, CN5, CN6, CN7, CN8, CN9, CN10	7	Header, TH, 100 mil, 1 pos, Gold plated, 230 mil above insulator	Samtec, Inc.	TSW-101-07-G-S
D1, D2, D3	3	Diode, Schottky, 40V , 1 A, SMB	International Rectifier	10BQ040TRPBF
D4	1	Diode, Zener, 4.3 V, 550 mW, SMB	ON Semiconductor	1SMB5916BT3G
H1, H2, H3, H4	4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	BXYZF Fastener Supply	NY PMS 440 0025 PH
H5, H6, H7, H8	4	Standoff, Hex, 0.5"L #4-40 Nylon	Keystone	1902C
J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12, J13, J14, J15, J16, J17, J18, J19, J20, J21, J22	22	Header, TH, 100 mil, 2 × 1, Gold plated, 230 mil above insulator,	Samtec, Inc.,	TSW-102-07-G-S
LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9, LED10, LED11, LED12, LED13, LED14, LED15, LED16, LED17, LED18, LED19, LED20, LED21, LED22, LED23, LED24	24	LED, Warm White, SMD	Cree	MLCAWT-A1-0000-000WE7
Q1	1	Transistor, NPN, 40 V, 0.2 A, SOT-23	Diodes Inc.	MMBT3904-7-F
R1, R2, R3, R4	4	RES, 100 kΩ, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603100KFKEA
R9	1	Trimmer, 500 kΩ, 0.5 W, TH	Bourns	3386P-1-504LF
R10	1	RES, 499 Ω, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603499RFKEA
R11	1	RES, 10.0 kΩ, 1%, 0.1 W, 0603	Vishay-Dale	CRCW060310K0FKEA
R12, R13	2	RES, 6.98 kΩ, 1%, 0.1W, 0603	Vishay-Dale	CRCW06036K98FKEA
R22	1	RES, 100 kΩ, 1%, 0.1 W, 0603	Yageo America	RC0603FR-07100KL
SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J10, SH-J11, SH-J12, SH-J14, SH-J15, SH-J16, SH-J17, SH-J18, SH-J19, SH-J20, SH-J21	16	Shunt, 100 mil, Gold plated, Black	3M	969102-0000-DA
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16	16	Test Point, TH, Miniature, White	Keystone	5002
U1	1	Eight-Channel Linear LED Driver with PWM Dimming, PWP0020B	Texas Instruments	TPS92638QPWPRQ1

Revision History

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*:

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   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

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If User uses EVMs in 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 *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.

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