# TPS5420EVM-175 Regulator Evaluation Module

**Contents**



**List of Figures**



**List of Tables**



## 1 Introduction

This user's guide contains background information for the TPS5420 as well as support documentation for the TPS5420EVM-175 evaluation module (HPA175). Also included are the performance specifications, the schematic, and the bill of materials for the TPS5420EVM-175.

PowerPAD is a trademark of Texas Instruments.

## 1.1 Background

The TPS5420 dc/dc converter is designed to provide up to a 2-A continuous, 3-A peak output from an input voltage source of 5.5 V to 36 V. Rated input voltage and output current range for the evaluation module is given in Table 1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS5420 regulator and does not reflect the high input voltages that may be used when designing with this part. The switching frequency is internally set at a nominal 500 kHz. The high-side MOSFET is incorporated inside the TPS5420 package along with the gate drive circuitry. The low drain-to-source on resistance of the MOSFET allows the TPS5420 to achieve high efficiencies and helps to keep the junction temperature low at high output currents. The compensation components are provided internal to the integrated circuit (IC), whereas an external divider allows for an adjustable output voltage. Additionally, the TPS5420 provides an enable input. The absolute maximum input voltage is 36 V.

**Table 1. Input Voltage and Output Current Summary**

| EVM | INPUT VOLTAGE RANGE | OUTPUT CURRENT RANGE |
|---|---|---|
| TPS5420EVM-175 | VIN = 10 V to 36 V | 0 A to 2 A |

## 1.2 Performance Specification Summary

A summary of the TPS5420EVM-175 performance specifications is provided in Table 2. Specifications are given for an input voltage of VIN = 12 V and an output voltage of 5 V, unless otherwise specified. The TPS5420EVM-175 is designed and tested for VIN = 10 V to 36 V. The ambient temperature is 25°C for all measurements, unless otherwise noted. Maximum input voltage for the TPS5420EVM-175 is 36 V.

**Table 2. TPS5420EVM-175 Performance Specification Summary**

| SPECIFICATION | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| VIN voltage range | | | 10 | | 36 | V |
| Output voltage set point | | | | 5.0 | | V |
| Output current range | | $V_{IN}$ = 10 V to 36 V | 0 | | 2.5 | A |
| Line regulation | | $I_O$ = 1 A, VIN = 3 V - 6 V | | ±0.11% | | |
| Load regulation | | VIN = 25 V, $I_O$ = 0 A to 2.5 A | | ±0.1% | | |
| Load transient response | Voltage change | $I_O$ = 0.75 A to 2.25 A | | -40 | | mV |
| | Recovery time | | | 200 | | µs |
| | Voltage change | $I_O$ = 2.25 A to 0.75 A | | +40 | | mV |
| | Recovery time | | | 200 | | µs |
| Loop bandwidth | | VIN = 25 V | | 25.0 | | kHz |
| Phase margin | | VIN = 25 V | | 55 | | ° |
| Input ripple voltage | | $I_O$ = 3 A | | 275 | 300 | mVpp |
| Output ripple voltage | | | | 32 | | mVpp |
| Output rise time | | | | 7 | | ms |
| Operating frequency | | | | 500 | | kHz |
| Maximum efficiency | | VIN = 10 V, $V_O$ = 5 V, $I_O$ = 0.75 A | | 93.2% | | |

## 1.3 Modifications

The TPS5420EVM-175 is designed to demonstrate the small size that can be attained when designing with the TPS5420. A few changes can be made to this module.

### 1.3.1 Output Voltage Set Point

To change the output voltage of the EVM, it is necessary to change the value of resistor R2. Changing the value of R2 can change the output voltage above 1.25 V. The value of R2 for a specific output voltage can be calculated using Equation 1.

$$R2 = 10\ k\Omega \times \frac{1.221\ V}{V_O - 1.221\ V} \quad (1)$$

Table 3 lists the R2 values for some common output voltages. Note that VIN must be in a range so that the minimum on-time is greater than 200 ns, and the maximum duty cycle is less than 87%. The values given in Table 3 are standard values, not the exact value calculated using Equation 1.

**Table 3. Output Voltages Available**

| Output Voltage (V) | R2 Value (kΩ) |
|---|---|
| 1.8 | 21.5 |
| 2.5 | 9.53 |
| 3.3 | 5.90 |
| 5 | 3.24 |

### 1.3.2 Input Voltage Range

The EVM is designed to operate from a 10-V to 36-V input voltage range. The TPS5420 is specified to operate over an input voltage range of 5.5 V to 36 V.

# 2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS5420EVM-175 evaluation module. The section also includes test results typical for the TPS5420EVM-175 and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

## 2.1 Input / Output Connections

The TPS5420EVM-175 is provided with input/output connectors and test points as shown in Table 4. A power supply capable of supplying 2 A should be connected to J1 through a pair of 20 AWG wires. The load should be connected to J3 through a pair of 20 AWG wires. The maximum load current capability should be 2 A. Wire lengths should be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the VIN input voltages with TP2 providing a convenient ground reference. TP3 is used to monitor the output voltage with TP4 as the ground reference.

**Table 4. EVM Connectors and Test Points**

| Reference Designator | Function |
|---|---|
| J1 | VIN, 10 V to 36 V |
| J2 | OUT, 5 V at 2 A maximum |
| JP1 | 2-pin header for enable. Connect EN to ground to disable, open to enable. |
| TP1 | VIN test point at VIN connector |
| TP2 | GND test point at VIN |
| TP3 | Output voltage test point at OUT connector |
| TP4 | GND test point at OUT connector |
| TP5 | Test point between voltage divider network and R3. Used for loop response measurements. |
| TP6 | PH test point |

## 2.2 Efficiency

The TPS5420EVM-175 efficiency peaks at load current of about 0.75 A, and then decreases as the load current increases towards full load. Figure 1 shows the efficiency for theTPS5420EVM-175 at an ambient temperature of 25°C. The efficiency is lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the MOSFETs.

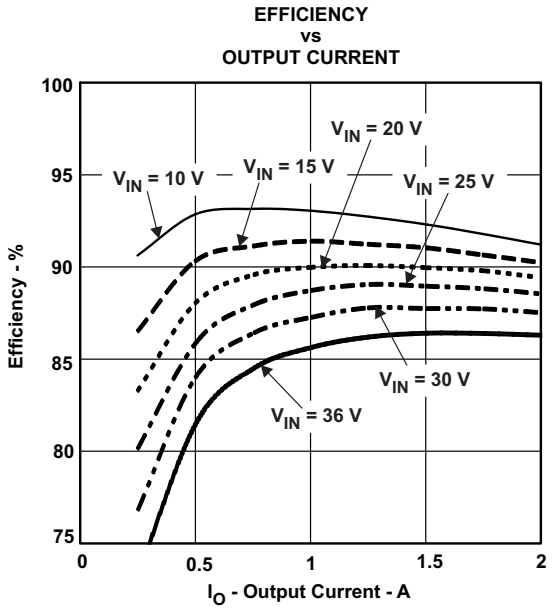


**Figure 1. Measured Efficiency, TPS5420**

## 2.3 Output Voltage Regulation

The output voltage load regulation of the TPS5420EVM-175 is shown in Figure 2; the output voltage line regulation is shown in Figure 3. Measurements are given for an ambient temperature of 25°C.

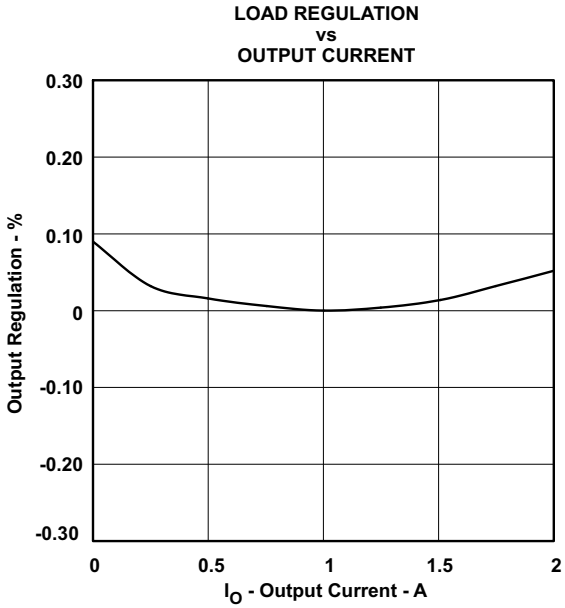


**Figure 2. Load Regulation**

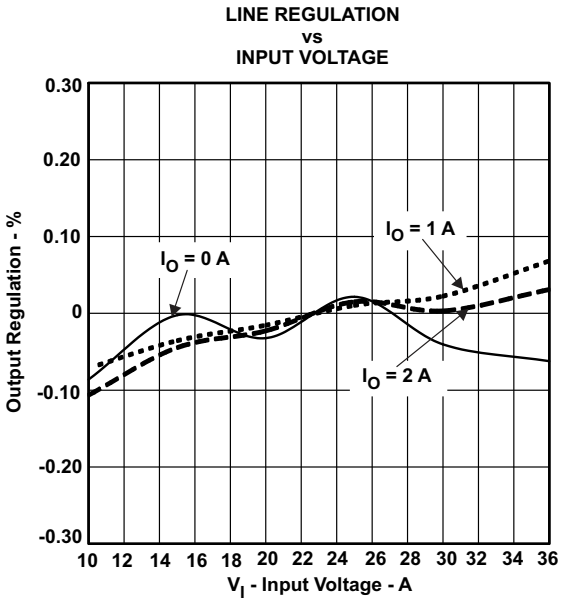


**Figure 3. Line Regulation**

## 2.4 Load Transients

The TPS5420EVM-175 response to load transients is shown in Figure 4. The current step is from 25% to 75% of maximum rated load. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

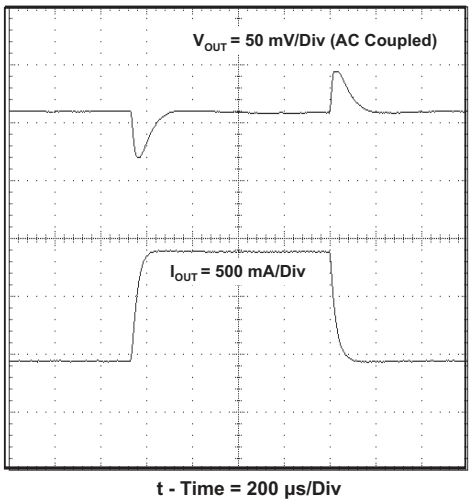


**Figure 4. Load Transient Response, TPS5420**

## 2.5 Loop Characteristics

The TPS5420EVM-175 loop-response characteristics are shown in Figure 5 . Gain and phase plots are shown for VIN voltage of 25 V and a 1-A load current.

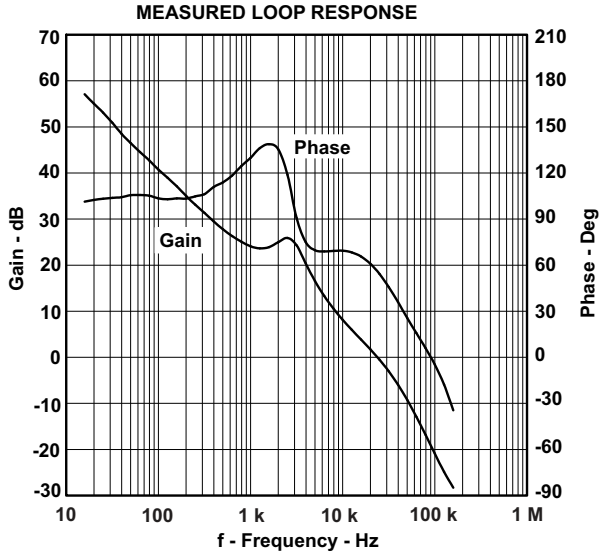


**Figure 5. Measured Loop Response, TPS5420, VIN = 25 V**

## 2.6 Output Voltage Ripple

The TPS5420EVM-175 output voltage ripple is shown in Figure 6. The input voltage is VIN = 25 V for the TPS5420. Output current is the rated full load of 2 A. Voltage is measured directly across output capacitors.

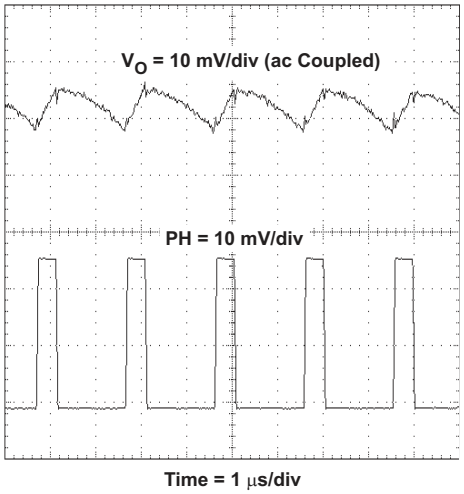


**Figure 6. Measured Output Voltage Ripple, TPS5420**

## 2.7 Input Voltage Ripple

The TPS5420EVM-175 input voltage ripple is shown in Figure 7. The input voltage is VIN = 10 V for the TPS5420. Output current for each device is at full rated load of 2 A.

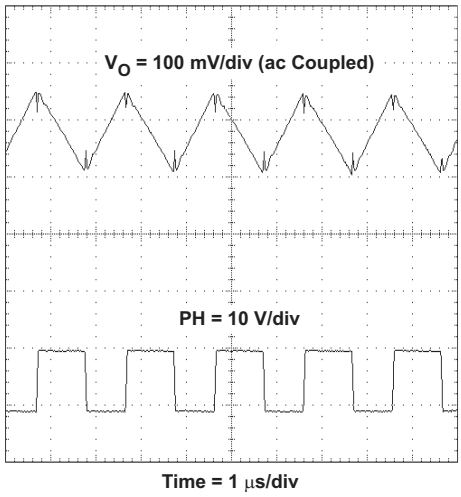


**Figure 7. Input Voltage Ripple, TPS5420**

## 2.8 Powering Up

The TPS5420EVM-175 start-up waveforms are shown in Figure 8 and Figure 9. In Figure 8 the top trace shows VIN whereas the bottom trace shows VOUT. VIN increases from 0 V toward 25 V. When the input voltage reaches the internally set UVLO threshold voltage of 5.3 V, the slow-start sequence begins. The internal reference begins to ramp up linearly at the internally set slow-start rate towards 1.221 V, and the output ramps up toward the set voltage of 5 V. The output may be inhibited by using a jumper at JP1 to tie ENA to GND. When the jumper is removed, ENA is released and the slow-start sequence begins as shown in Figure 9. The top trace shows the ENA signal and the bottom trace shows VOUT. When the ENA voltage reaches the enable-threshold voltage of 1.06 V, the start-up sequence begins as described above.

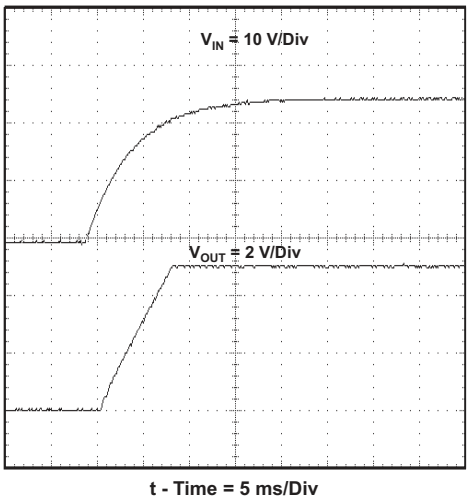


**Figure 8. Power Up, VOUT Relative to VIN**

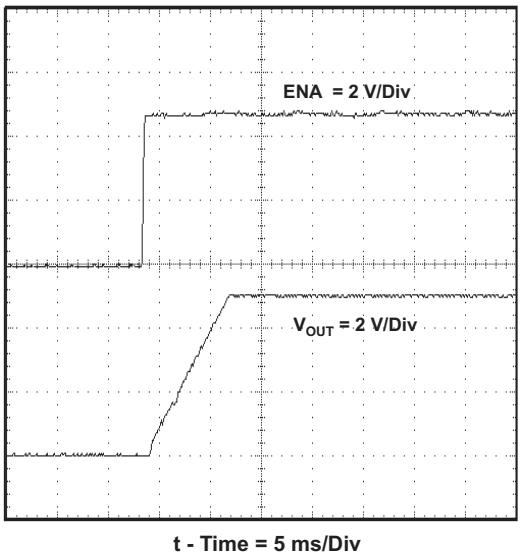


**Figure 9. Start-Up Waveform, VOUT Relative to ENA**

# 3 Board Layout

This section provides a description of the TPS5420EVM-175 board layout and layer illustrations.

## *3.1 Layout*

The board layout for the TPS5420EVM-175 is shown in Figure 10 through Figure 12. The top-side layer of the TPS5420EVM-175 is laid out in a manner typical of a user application. The top and bottom layers are 2-oz. copper.

The top layer contains the main power traces for VIN, OUT, and VPHASE. Also on the top layer are connections for the remaining pins of the TPS5420 and a large area filled with ground. The bottom layer contains ground and some signal routing. The top and bottom and internal ground traces are connected with multiple vias placed around the board including four vias directly under the TPS5420 device to provide a thermal path from the PowerPAD™ land to ground.

The input decoupling capacitors (C1 and C4) and bootstrap capacitor (C3) are all located as close to the IC as possible. In addition, the voltage set-point resistor divider components are also kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, adjacent to the output capacitor C3.

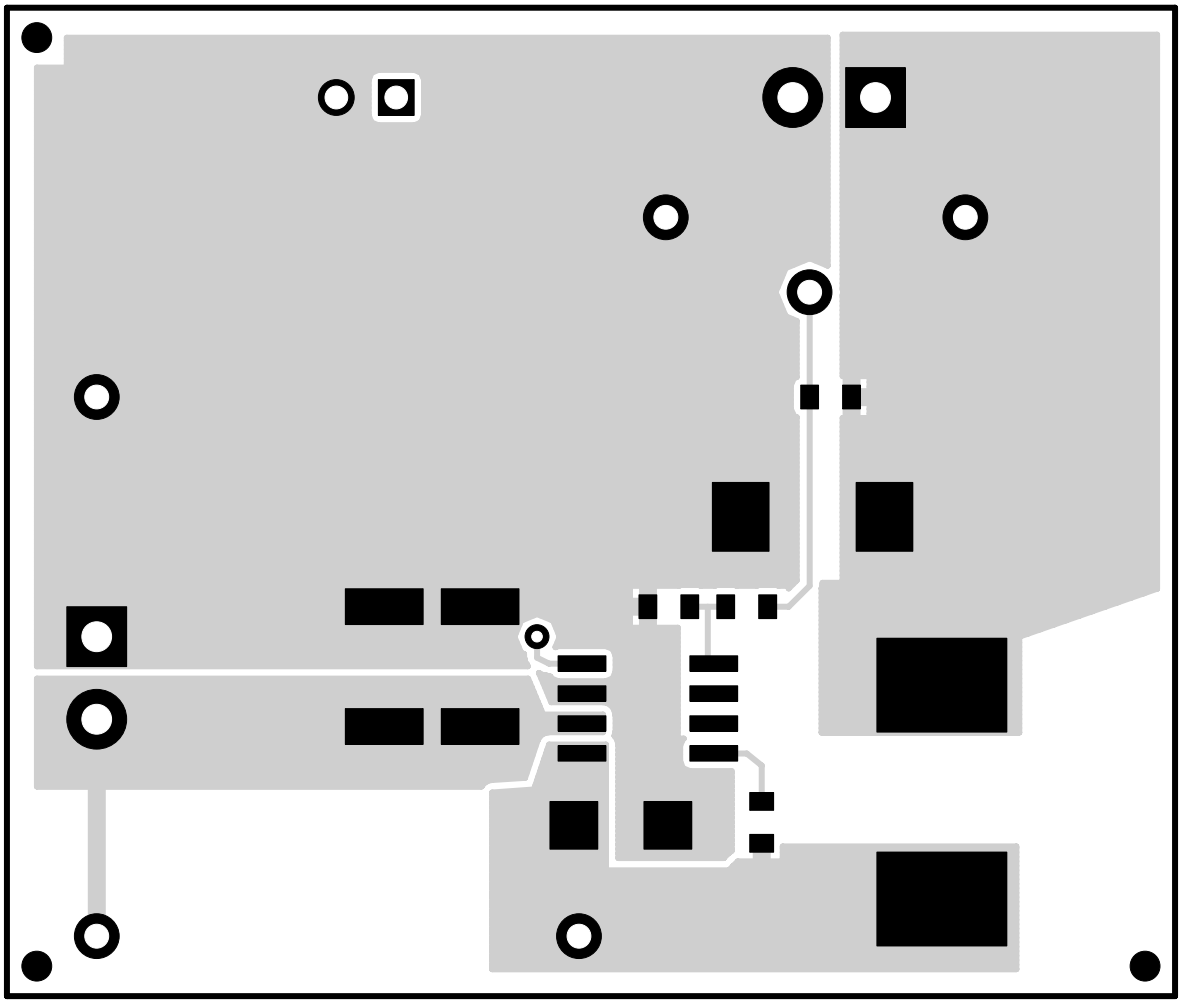

**Figure 10. Top-Side Layout**

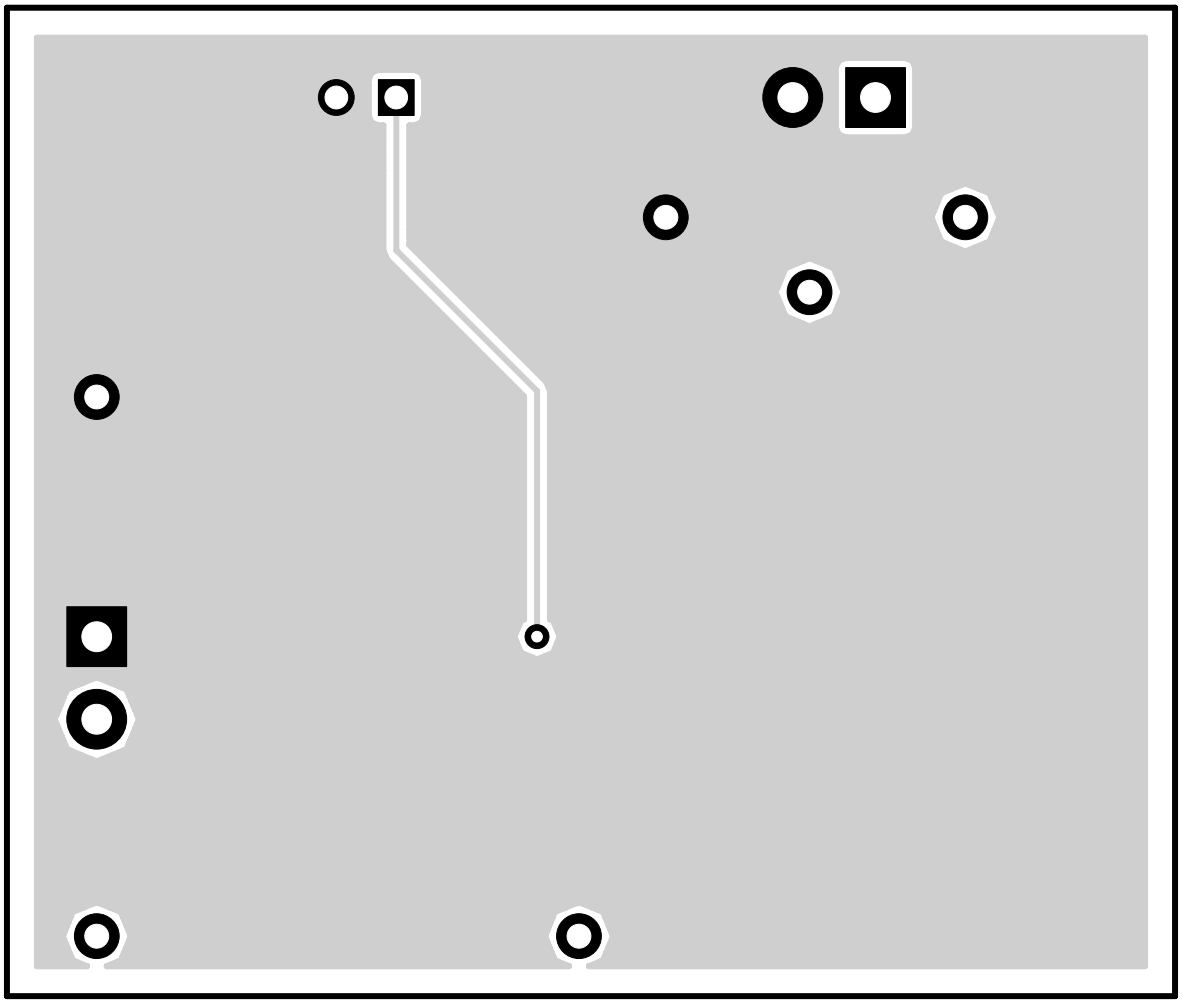

**Figure 11. Bottom-Side Layout (Looking From Top Side)**

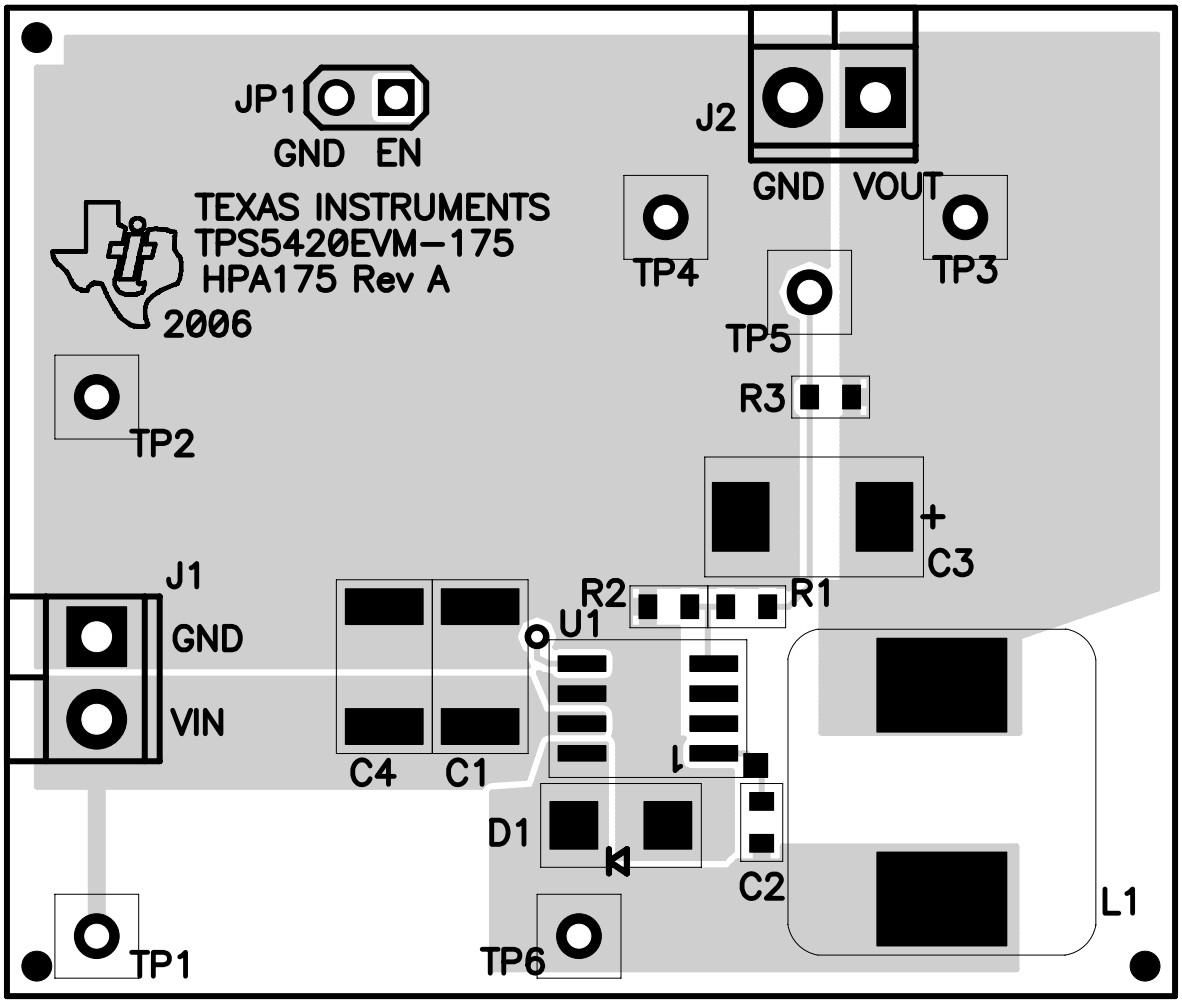


**Figure 12. Top-Side Assembly**

## 4 Schematic and Bill of Materials

The TPS5420EVM-175 schematic and bill of materials are presented in this section.

## 4.1 Schematic

The schematic for the TPS5420EVM-175 is shown in Figure 13.

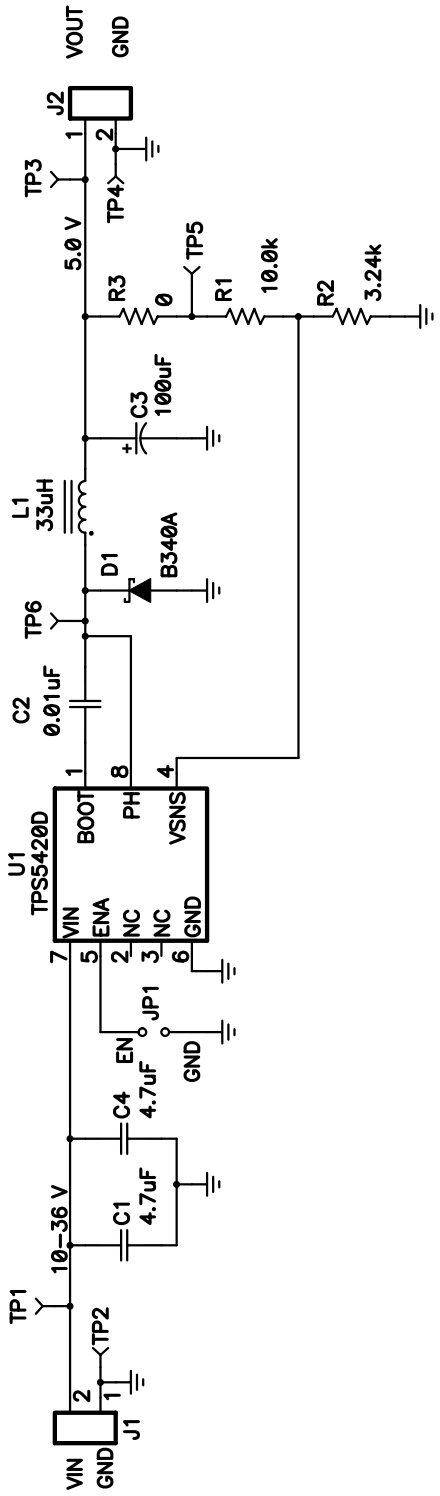


**Figure 13. TPS5420EVM-175 Schematic**

## 4.2 Bill of Materials

The bill of materials for the TPS5420EVM-175 is given by Table 5.

**Table 5. TPS5420EVM-175 Bill of Materials**

| Count | REF DES | Value | Description | Size | Part Number | MFR |
|---|---|---|---|---|---|---|
| 2 | C1, C4 | 4.7 µF | Capacitor, Ceramic, 50V, X7R, 20% | 1812 | C4532X5R1H475MT | TDK |
| 1 | C2 | 0.01 µF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | C1608X7R1H103K | TDK |
| 1 | C3 | 100 µF | Capacitor, Tantalum, 10V, 20% | 7343(D) | TPSD107M010R0080 | AVX |
| 1 | D1 | | Diode, Schottky, 3A, 40V | SMA | B340A | Diodes Inc |
| 2 | J1, J2 | | Terminal Block, 2 pin, 6A, 3,5mm | 0.27 x 0.25 | ED1514 | OST |
| 1 | JP1 | | Header, 2-pin, 100mil spacing, (36-pin strip) | 0.100 x 2 | PTC36SAAN | Sullins |
| 1 | L1 | 33 µH | Inductor, SMT, 2.2A, 75milliohm | 0.484 x 0.484 | MSS1260-333 | Coilcraft |
| 1 | R1 | 10.0 k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R2 | 3.24 k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R3 | 0 | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 4 | TP1, TP3, TP5, TP6 | | Test Point, Red, Thru Hole Color Keyed | 0.100 x 0.100 | 5000 | Keystone |
| 2 | TP2, TP4 | | Test Point, Black, Thru Hole Color Keyed | 0.100 x 0.100 | 5001 | Keystone |
| 1 | U1 | | IC, Switching Step-Down Regulator, 36V, 2A | SO8 | TPS5420D | TI |
| 1 | – | | PCB, 1.95 In x 1.95 In x 0.062 In | | HPA175 | Any |
| 1 | – | | Shunt, 100-mil, Black | 0.100 | 929950-00 | 3M |

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**General Statement for EVMs including a radio**

*User Power/Frequency Use Obligations*: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

**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**

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**

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.

**For EVMs annotated as IC – INDUSTRY CANADA Compliant**

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

**Concerning EVMs including radio transmitters**

This device complies with Industry Canada licence-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.

**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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

**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.

**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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2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

**Certain Instructions**. It is important to operate this EVM within TI’s recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

**Agreement to Defend, Indemnify and Hold Harmless.** You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

**Safety-Critical or Life-Critical Applications.** If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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