TEXAS INSTRUMENTS

User's Guide
SLVU602–November 2011

TPS7A3301EVM-061

This User's Guide describes operational use of the TPS7A3301EVM-061 Evaluation Module (EVM) as a reference design for engineering demonstration and evaluation of the TPS7A3301, low-dropout negative-voltage linear regulator (LDO). Included in this user's guide are setup instructions, a schematic diagram, layout and thermal guidelines, a bill of materials, and test results.

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1 Introduction

The Texas Instruments TPS7A3301EVM-061 EVM helps design engineers to evaluate the operation and performance of the TPS7A33xx family of linear regulators for possible use in their own circuit applications. This particular EVM is preconfigured to output –15 V and contains a single linear regulator (LDO) with internal current limit and thermal shutdown protection. The TPS7A33xx family of low-dropout regulators allows input voltages from –3 V to –36 V and can be adjusted to any output voltage between –1.2 V and –20 V by only changing a resistor value in accord with the given equation. The regulator, including external components, is capable of delivering up to 1 A to the load depending on the input-output power dissipation across the part. The TPS7A33xx has been optimized for ac performance, including PSRR and load transient response, using capacitors rated over the full voltage range of the regulator. The TPS7A33xx family is available in a TO220-7 KVT bent-lead package.

2 Setup

This section describes the jumpers and connectors on the EVM as well as how to properly connect, set up, and use the TPS7A3301EVM.

2.1 *Input/Output Connectors and Jumper Descriptions*

2.1.1 J1 — (–)Vin

Negative input power supply voltage connector. The negative input lead and ground return lead from the input power supply should be twisted and kept as short as possible to minimize EMI transmission. Additional bulk capacitance should be added between J1 and J3 if the supply leads are greater than six inches. For example, an additional 47-µF electrolytic capacitor connected from J1 to ground can improve the transient response of the TPS7A3301 while eliminating unwanted ringing on the input due to long wire connections. A (+) power supply may be used if the (+) lead is connected to J2 (GND) and the GND lead is connected to J1 (–VIN).

2.1.2 J2 — GND

Ground-return connector for the input power supply

2.1.3 J3 — (–)Vout

Regulated (–) output voltage connector

2.1.4 J4 — GND

Output ground-return connector

2.1.5 JP1 — EN

Output enable. To enable the output, connect a jumper to short the ON pin 1 to the EN center pin 2. To disable the output, connect a jumper to short EN pin 2 to OFF pin 3.

2.2 *Equipment Setup*

- Turn off the input power supply after verifying that its output voltage is set to greater than –15 V (–18 V recommended; –36 V maximum). Connect the negative voltage lead from the input power supply to –VIN, at the J1 connector of the EVM. Connect the ground lead from the input power supply to GND at the J2 connector of the EVM. If using a (+) power supply, connect the (+) lead is to J2 (GND) and the GND lead J1 (–VIN).
- Connect desired (≤1 A) load between the –VOUT pin at connector J3, and the GND pin at connector J4. Be careful to calculate the power dissipation across the part for the desired –VIN level.

3 Operation

- Turn on the input power supply. For initial operation, it is recommended that the input power supply, –VIN on J1, be set to –18 V.
- Vary the load and –VIN voltage as necessary for test purposes.

4 Adjustable Operation

The nominal output voltage for the typical LDO circuit employing the TPS7A3301 is set by two external resistors, R1and R2, as illustrated in Figure 1. R1 and R2 can be calculated for any output voltage using Equation 1 and the Vref voltage found in the device data sheet under the Electrical Characteristics.

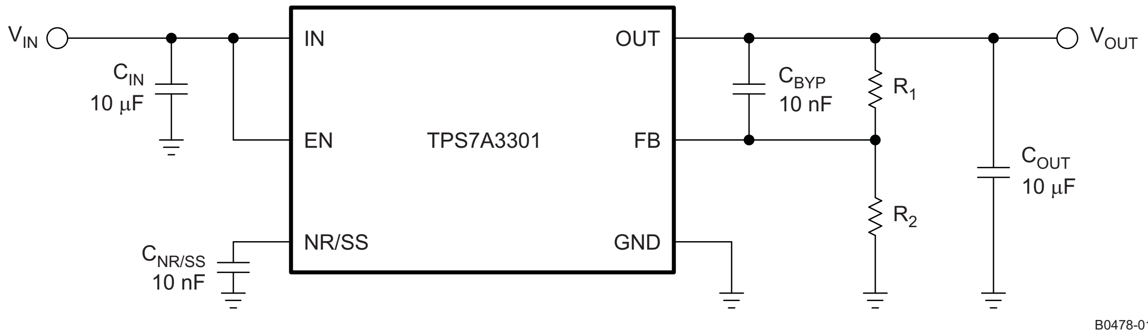

Figure 1. TPS7A3301 LDO Schematic Showing Adjustment Resistors

$$R_2 = R_1 \div ((V_{OUT}/V_{FB}) - 1), \quad \text{where} \quad V_{OUT} / (R_1 + R_2) \geq 5\ \mu A \tag{1}$$

Once the resistor values have been calculated, the new resistors can be installed appropriately in the correct place using the PCB and schematic diagrams of Figure 4 5 through Figure 7.

Suggestion: When recalculating the resistor values for a particular desired output voltage, change only the R2 value in order to maintain the frequency-domain zero formed by R1 and C_{BYP} in accord with Equation 2.

$$F_Z = 1/(2 \times \pi \times R_1 \times C_{BYP}) \tag{2}$$

For additional information on adjustable operation, see the TPS7A3301 data sheet (SBVS169).

5 Test Results

This section provides typical performance waveforms for the TPS7A3301EVM-061 printed circuit board.

5.1 Turnon Sequence

Figure 2 shows the hard turnon characteristic where –VIN is –18 V, EN (C1, yellow) is switched on to –18 V and the output drives a 1-A load (C4, green). The output (C3, blue) shows a fairly monotonic rise time of approximately 800 ms.

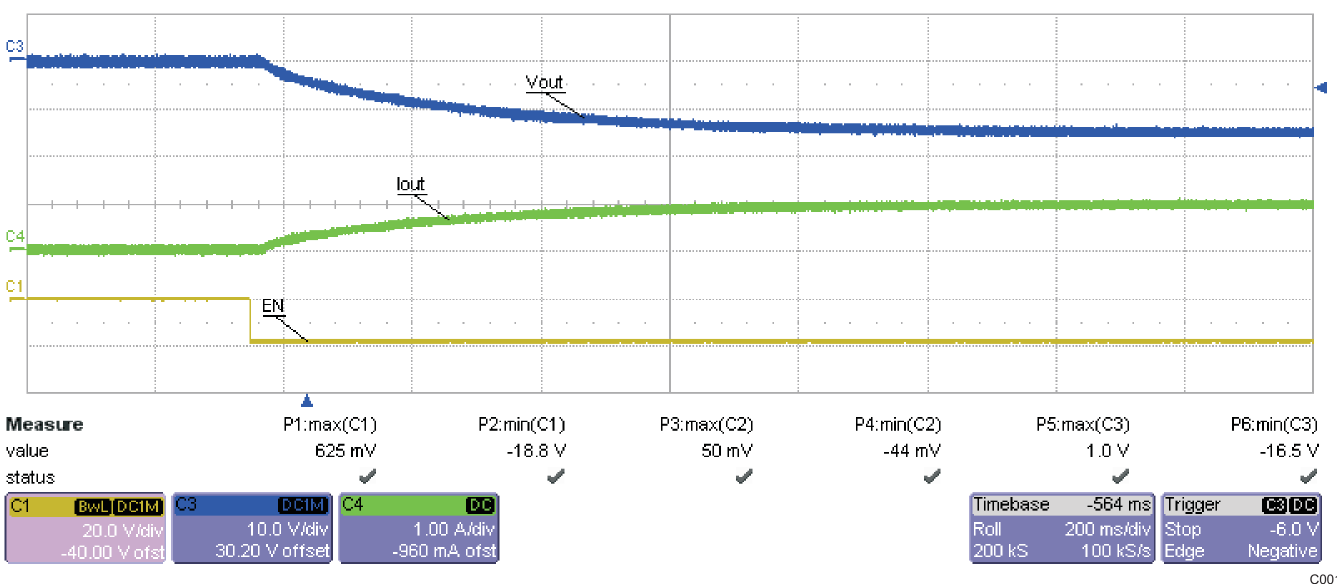

Figure 2. Turnon Sequence

5.2 Output Load Transient

Figure 3 shows the load transient response (Vout - C1, yellow) for a full-load step transient from 100 mA to 1 A (C3, blue). This test was run with the EVM set up for –5-V –VOUT and –VIN was set at –8 V.

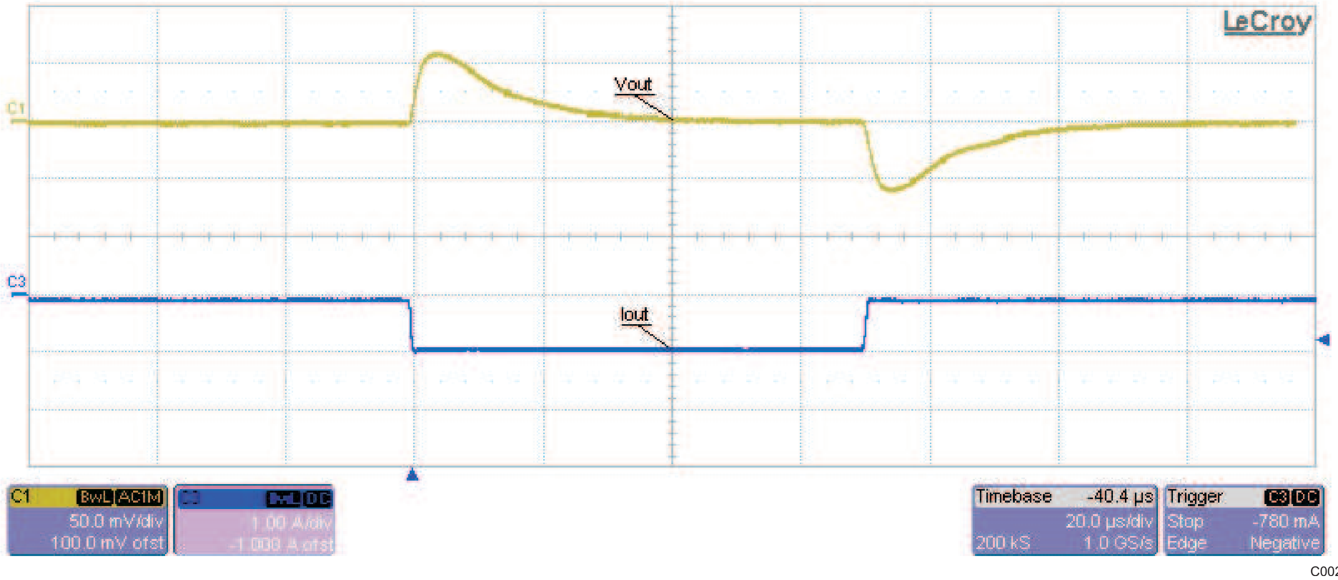

Figure 3. Load Step and Transient Response

6 Thermal Guidelines and Layout Recommendations

Thermal management is a key component of the design of any power converter and is especially important when the power dissipation in the LDO is high. Use the following formula to approximate the maximum power dissipation for the particular ambient temperature:

$$T_J = T_A + P_D \times \theta_{JA} \tag{3}$$

where T_J is the junction temperature, T_A is the ambient temperature, P_D is the power dissipation in the device (watts), and θ_{JA} is the thermal resistance from junction to ambient. All temperatures are in degrees Celsius. The maximum silicon junction temperature, T_J, must not be allowed to exceed 150°C. The layout design must use copper trace and plane areas smartly, as thermal sinks, in order not to allow T_J to exceed the absolute maximum rating under all temperature conditions and voltage conditions across the part. The designer must consider carefully the thermal design of the PCB for optimal performance over temperature. The actual allowable power dissipation on a PCB is a strong function of its layout.

Heat flows from the device to the ambient air through many paths, each of which represents resistance to the heat flow; this resistance is called thermal resistance.

The total thermal resistance of a system is defined by Equation 4:

$$\theta_{JA} = \frac{(T_J - T_A)}{P_D} \tag{4}$$

where θ_{JA} is the thermal resistance (in °C/W), T_J is the allowable junction temperature of the device (in °C), T_A is the maximum temperature of the ambient cooling air (in °C), and P_D is the amount of power (heat) generated by the device (in W).

Whenever a heatsink is installed, the total thermal resistance (θ_{JA}) is the sum of all the individual resistances from the device, going through its case and heatsink to the ambient cooling air.

$$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA} \tag{5}$$

Realistically, the user can only control two resistances, θ_{CS} and θ_{SA}. Therefore, for a device with a known θ_{JC}, θ_{CS} and θ_{SA} become the main design variables in selecting a heat sink.

The thermal interface between the case and the heat sink, θ_{CS}, is controlled by selecting the right heat conducting material. Once the θ_{CS} is selected, the required thermal resistance from the heatsink to ambient is calculated by Equation 6:

$$\theta_{SA}\left[\frac{(T_J - T_A)}{P_D}\right] - (\theta_{JC} + \theta_{CS}) \quad (6)$$

This information allows the user to select the most appropriate heatsink for any particular application.

The heat sink chosen for the TPS7A3301EVM-061 (507302B00000G from Aavid) has a specified thermal resistance (θ_{SA}) of 24°C/W. There is also an option of using the two large mounting holes (13 and 14 – see Figure 4) to mount a heat sink with a smaller thermal resistance. The mounting holes are sized for the use of any heat sink with solderable mounting tab spacing of 1 inch (25.4 mm). The 5310 series from Aavid is one example and has a specified thermal resistance (θ_{SA}) of 13.4°C/W.

7 Board Layout

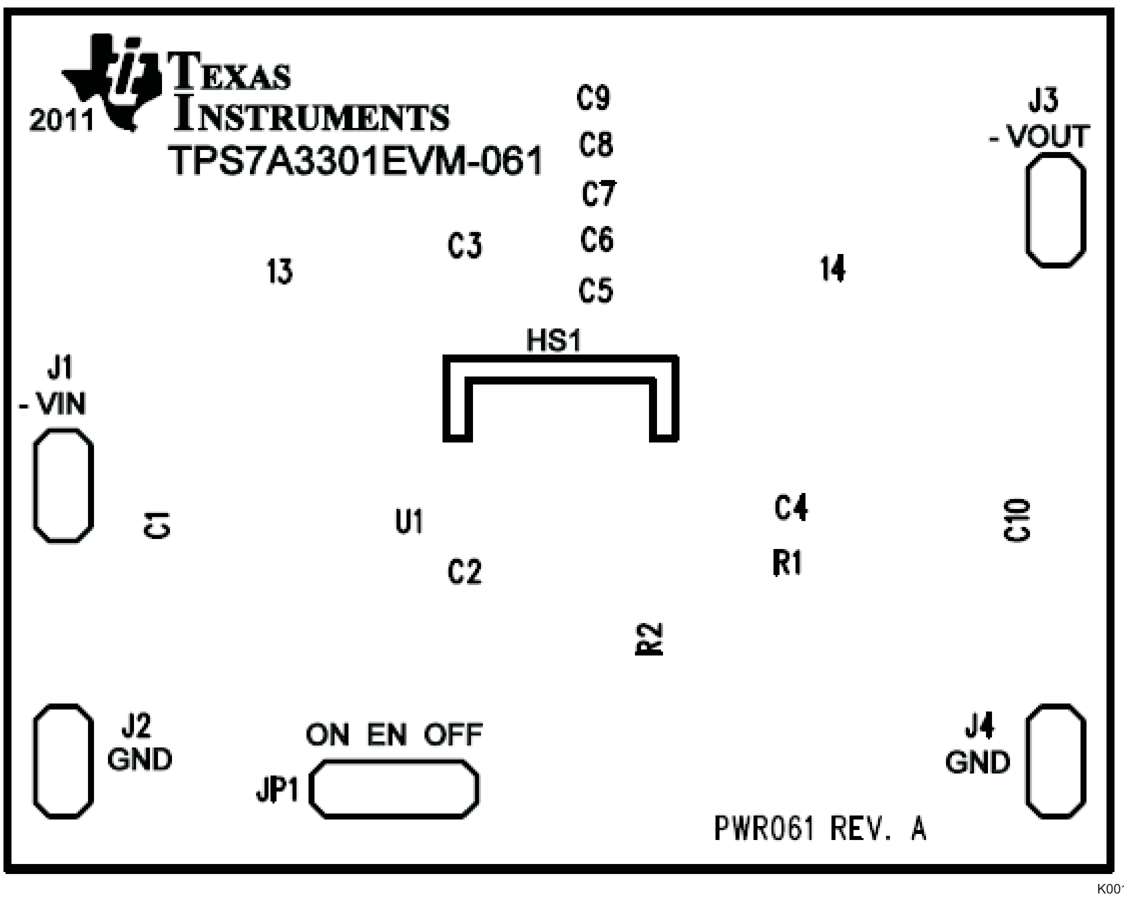

Figure 4. Top Layer Silkscreen

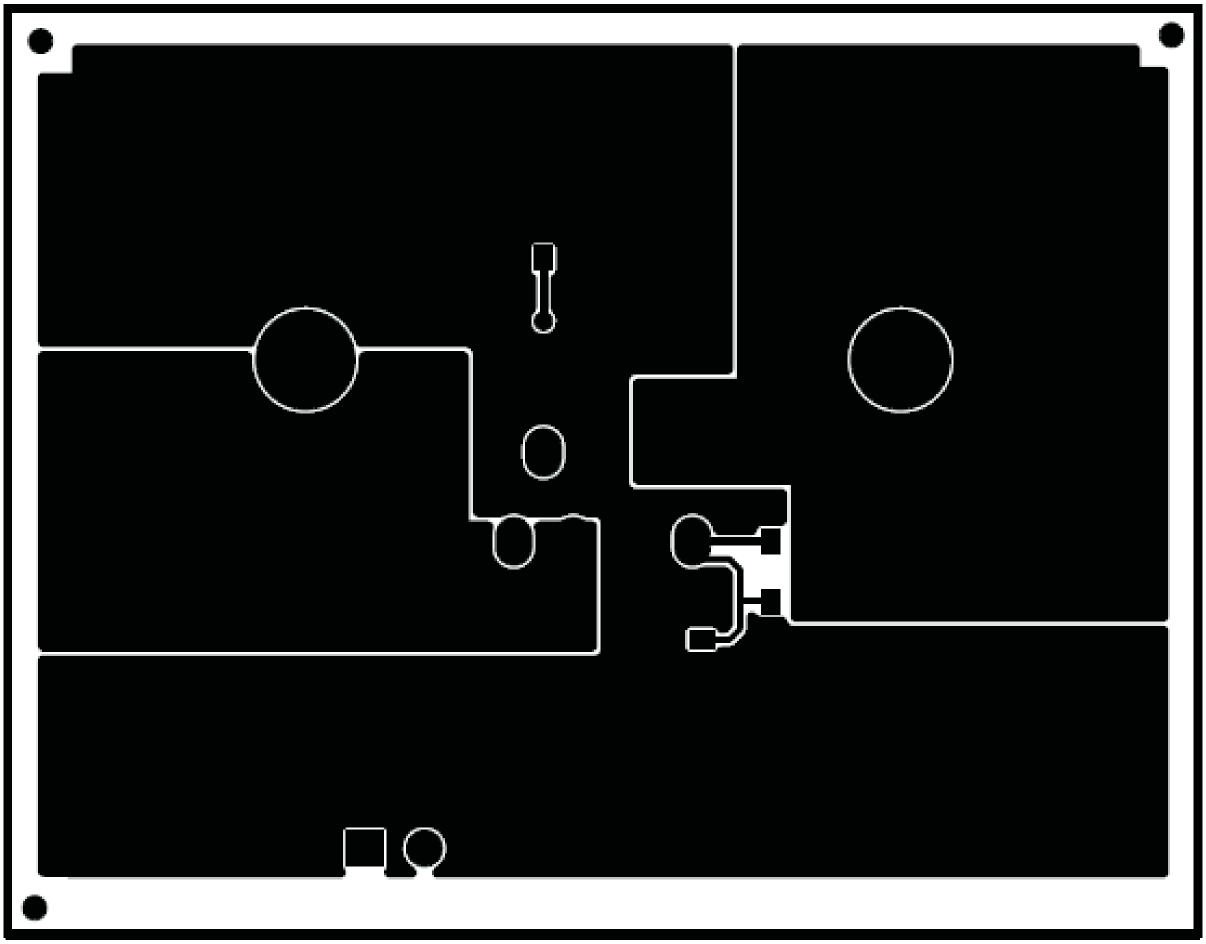

Figure 5. Top Layer Routing

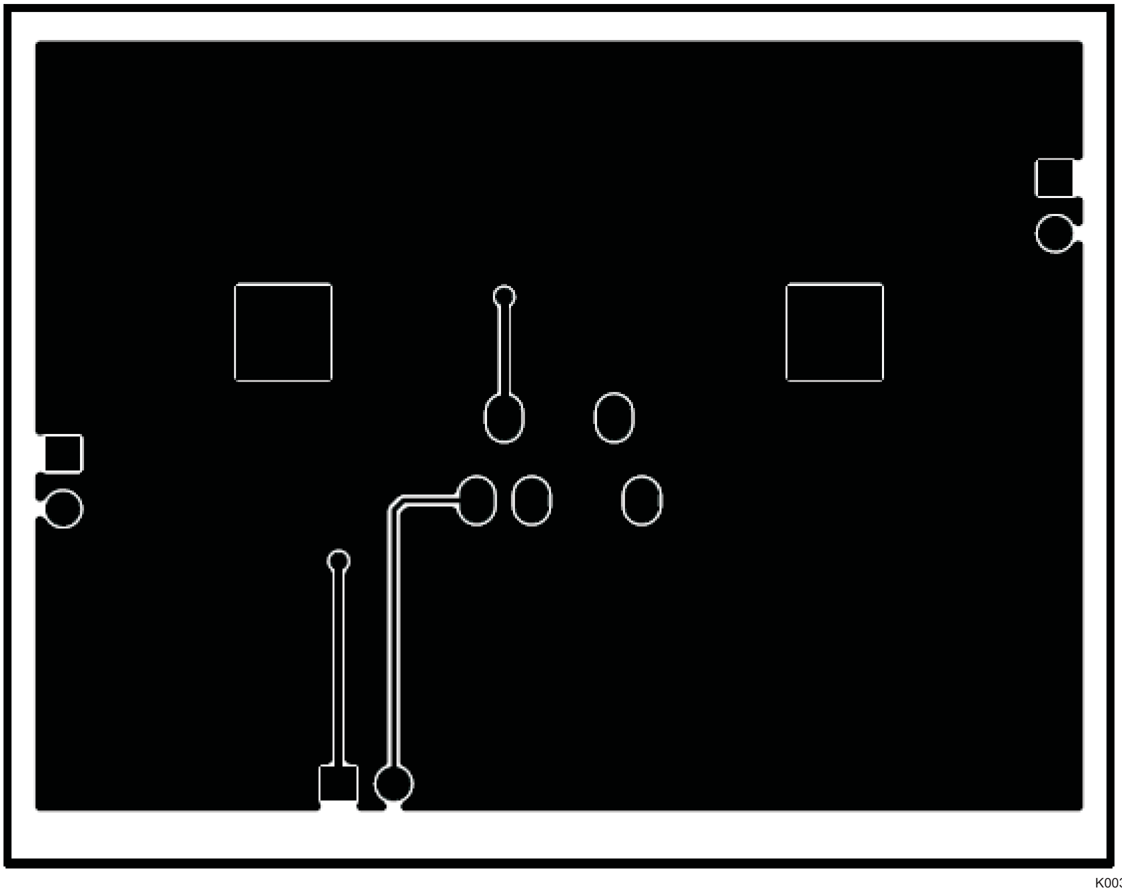

Figure 6. Bottom Layer Routing

8 Schematic and Bill of Materials

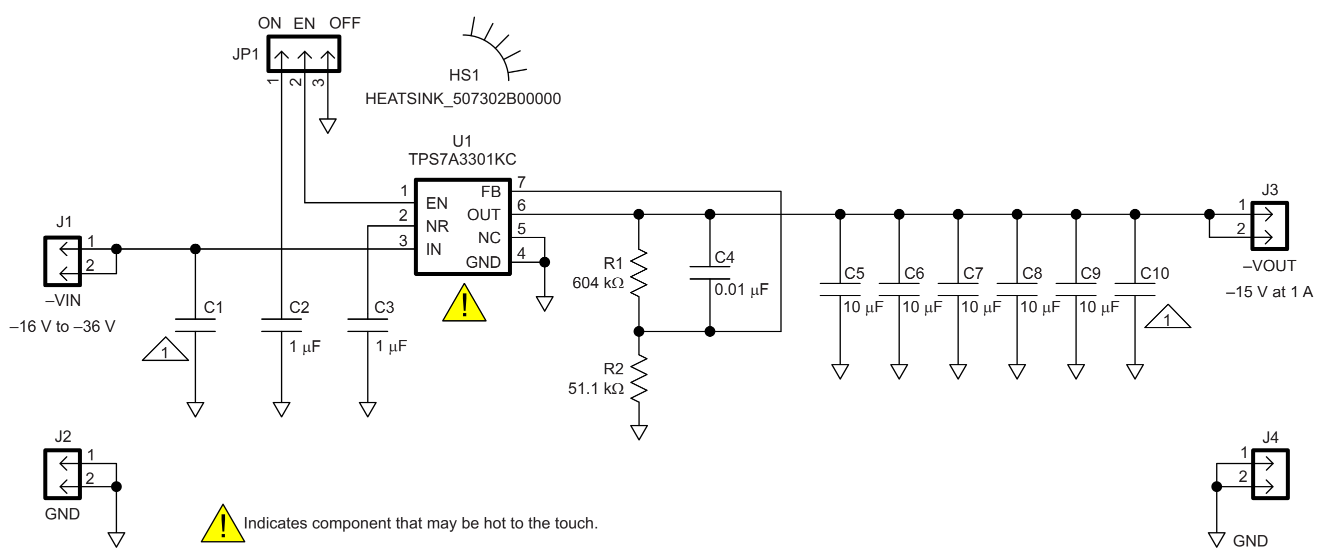

Figure 7. TPS7A3301EVM-061 Schematic

Table 1. TPS7A3301EVM-061 Bill of Materials

RefDes	COUNT	Value	Description	Size	Part Number	MFR
C1	0	47 µF	Capacitor, ceramic, 50 V, X5R, 10%	2220	STD	STD
C2	1	1 µF	Capacitor, ceramic, 50 V, X5R, 10%	0805	STD	STD
C3	1	1 µF	Capacitor, ceramic, 50 V, X5R, 10%	0603	STD	STD
C4	1	0.01 µF	Capacitor, ceramic, 25 V, X5R, 10%	0603	STD	STD
C5–C9	5	10 µF	Capacitor, ceramic, 25 V, X5R, 10%	0805	STD	STD
C10	0	47 µF	Capacitor, ceramic, 16 V, X5R, 10%	2220	STD	STD
HS1	1	13.4°C/W	Heatsink, TO-220, vertical-mount	1 inch × 1.375 inch (2.54 cm × 2.49 cm)	507302B00000G	Aavid
J1–J4	4	PEC02SAAN	Header, male 2-pin, 100-mil (2.54-mm) spacing	0.1 inch (2.54 mm) × 2	PEC02SAAN	Sullins
JP1	1	PEC03SAAN	Header, male 3-pin, 100-mil (2.54-mm) spacing	0.1 inch (2.54 mm) × 3	PEC03SAAN	Sullins
R1	1	604 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
R2	1	51.1 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
U1	1	TPS7A3301KC	IC, –36-V, –1-A, ultralow-noise negative linear regulator	TO-220	TPS7A3301KC	TI
–	1	–	Shunt, black	100 mil (2.54 cm)	929950-00	3M
–	1	–	Screw, hex mach. 4-40 × 1/2 S/S	4-40 × 1/2 S/S	HMSSS 440 0050	STD
–	1	–	Hdwr. mtg. nut, 0.062-inch × 0.184-inch (1.59-mm × 4.67-mm)	0.062 inch × 0.184 inch (1.59 mm × 4.67 mm)	7248-3	STD
–	1	PCB	PCB, 1.555-inch × 2-inch × 0.062-inch (3.95-cm × 5.08-cm × 1.59-mm)	1.5 inch × 2 inch × 0.062 -inch (3.81 cm × 5.08 cm × 1.59 mm)	PWR061	Any

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of –3 V to –36 V and the output voltage range of –1.2 V to –20 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. 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 100 °C. The EVM is designed to operate properly with certain components above 100 °C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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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.

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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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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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This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 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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3. 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.

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