

TPS7A47xxEVM-094 Evaluation Module

This user's guide describes the functional operation of the TPS7A47xxEVM-094 Evaluation Module (EVM) for use as a design reference and as a general engineering demonstration for the TPS7A47xx low dropout linear (LDO) regulator. Included in this User's Guide are setup instructions, a schematic diagram, layout and thermal guidelines, a bill of materials, and test results.

Contents

1	Introduction	1
2	Setup	2
	2.1 Input/Output Connector-Headers and Jumper Descriptions	2
	2.2 Soldering Guidelines	2
	2.3 Initial Setup and Equipment Interconnect	3
3	Operation	3
4	Test Results	3
	4.1 Turn On Characteristic	3
	4.2 Output Load Transient	4
5	Thermal Guidelines and Layout Recommendations	4
6	Board Layout	5
7	Schematic and Bill of Materials	7
	7.1 Schematic	7
	7.2 Bill of Materials	8

List of Figures

1	Turn On Sequence	3
2	Step Load and Output Voltage Transient Response	4
3	Assembly Layer	5
4	Top Layer Routing	6
5	Bottom Layer Routing	6
6	TPS7A47xxEVM-094 Schematic.....	7

List of Tables

1	J10 Jumper Voltages	2
2	Thermal Resistance, θ_{JA} , and Maximum Power Dissipation.....	4
3	TPS7A47xxEVM-094 Bill of Materials.....	8

1 Introduction

This EVM is designed to help engineers evaluate the operation and performance of the TPS7A47xx linear regulator for possible use in their own circuit application. Notable features of this LDO regulator include thermal and current limit shutdown protection, pin selectable output voltage, low dropout, and low noise ($\sim 3.5 \mu\text{V} / \sqrt{\text{Hz}}$). The EVM contains a single linear regulator in a 5 mm × 5 mm, QFN (RGW), thermally enhanced (PowerPad™) package. This regulator, including external components, is capable of delivering up to 1.0 A to a dynamic load across the full recommended input and output voltage range of the LDO. A multi-pin header with jumpers is provided to enable easy manual selection of the output voltage.

2 Setup

This section describes the connectors and headers on the EVM as well as how to properly connect, setup and use the TPS7A47xxEVM-094. See the assembly layer diagram, [Figure 5](#), for the location and orientation of referenced components.

2.1 Input/Output Connector-Headers and Jumper Descriptions

- J1 V_{IN} – Positive (+) input power supply voltage test and measurement header
- J2 GND – Ground and measurement header
- J3 V_{OUT} – Regulator output (up to 1 A)
- J4 GND – Ground return from the load (up to 1 A)
- J5 (S+) – V_{OUT} , Kelvin connection V_{OUT}
- J5 (S–) – GRD, Kelvin connection Ground
- J6 and J7 – Extra GRD connections
- J8 – Enable jumper for external resistor divider
- J9 – Enable jumper for the EVM
- J10 – Header for selecting the appropriate output voltage

NOTE: The positive input lead and ground return lead from the input power supply should be twisted and kept as short as possible to minimize EMI and source inductance. Additional bulk capacitance in the form of a Tantalum cap (47 μ F; 35 V) has been added to the EVM at C1 to counter source inductances that may cause ringing on the load transient waveform during higher current transients. This bulk capacitance should not be necessary in a typical application circuit.

Output Voltage Set Note: Set the output voltage by connecting J10 header pins, each assigned to a given voltage level, to ground where $V_{OUT} = V_{REF} + (\text{Sum of the jumper voltages})$. J10 header pins are numbered sequentially, odd pins (1, 3, 5...15) ascending leftward of pin 1 on the top row. All odd pins are connected to ground. Each even pin is numbered right to left sequentially (2, 4, 6...16) on the bottom row and each even pin is assigned a unique voltage level. See the pin-to-pin output voltage assignments in [Table 1](#).

Table 1. J10 Jumper Voltages

$V_{OUT} = V_{REF}^{(1)} + \text{Sum of Voltage Levels}$		
Voltage Level	Voltage Set Pins	Ground Pins
100 mV	16	15
200 mV	14	13
400 mV	12	11
800 mV	10	9
1.6 V	8	7
3.2 V	6	5
6.4 V	4	3
6.4 V	2	1

⁽¹⁾ See the data sheet for V_{REF} value. Publication: SBVS204

Example: Set V_{OUT} to 3.0 V by connecting a shorting jumper from pin 8 to pin 7.

$$V_{OUT} = V_{REF} + 1.6 \text{ V} = 3.0 \text{ V}$$

2.2 Soldering Guidelines

Any solder rework to modify the EVM for the purpose of repair or other application reasons must be performed using a hot-air system to avoid damaging the integrated circuit (IC).

2.3 Initial Setup and Equipment Interconnect

- Select the desired V_{OUT} by programming the output voltage according to the instructions listed above in the **Output Voltage Set Note** in [Section 2.1](#).
- Disable the EVM by adding a shorting jumper to J9 from EN (Pin 2) to OFF (Pin3).
- Before connecting the input power supply to the EVM, verify that the output voltage is set to the desired supply voltage (+3 V to +35 V range) and that it is current limited to 2 A. With the input power supply turned off, connect the positive voltage lead (+) from the power supply to V_{IN} (J1, Pin 1) of the EVM. Next, connect the ground lead (-) from the power supply to GND (J2, Pin 1).
- Connect a 0- to 1-A load between V_{OUT} (J3, Pin 1) and GND (J4, Pin 1).

3 Operation

1. Turn on the input power supply and verify that the output voltage, V_{OUT} , is near 0 V.
2. Enable the output by reconnecting the jumper on J9 to short the EN (Pin 2) to the ON (Pin 1).
3. Vary the load current and V_{IN} voltage as necessary for test purposes.

NOTE: Power dissipation (P_{DISP}) across the TPS7A47xx is dependent on the V_{IN} to V_{OUT} voltage drop and the output load current, I_{LOAD} ($P_{DISP} = (V_{IN} - V_{OUT}) \times I_{LOAD}$). If the power dissipation is high, the output voltage may continuously transition on-off-on, due to the shutdown effect of the thermal limit shutdown circuit.

4 Test Results

This section provides typical performance waveforms for the EVM, characteristic of this design.

4.1 Turn On Characteristic

Figure 1 shows the V_{OUT} ramp-up waveform at turn-on (ENable) as well as the input surge current into the IN pin of the LDO itself when the LDO starts-up into a fully loaded output.

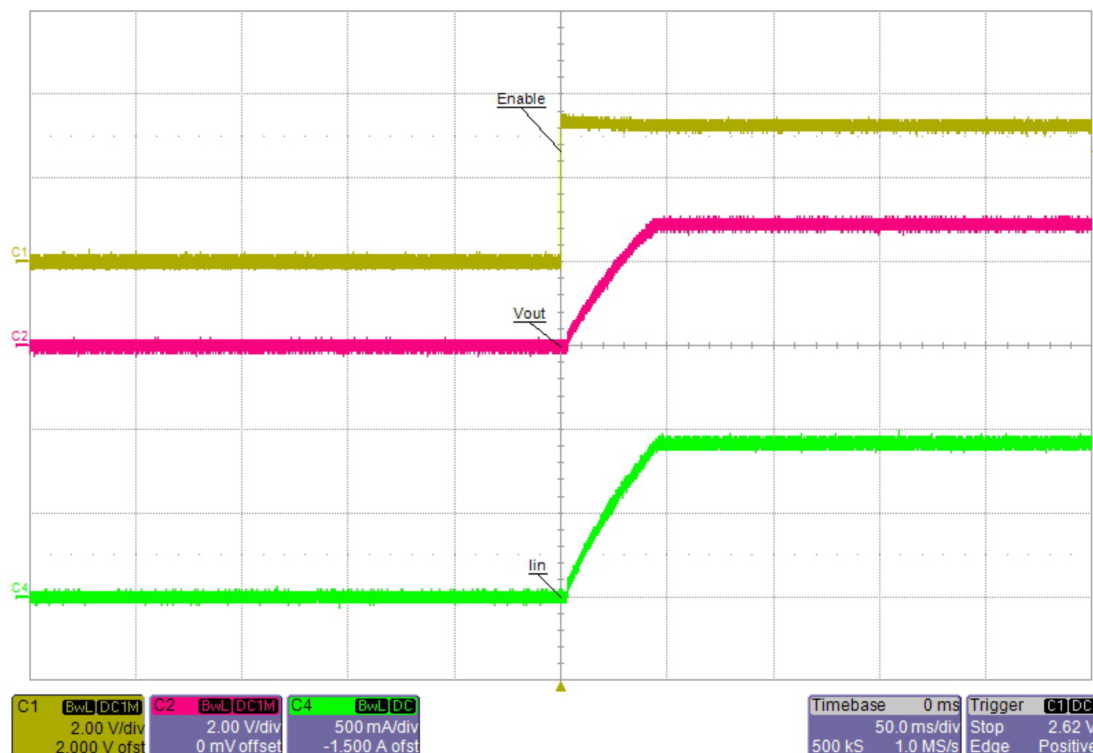


Figure 1. Turn On Sequence

4.2 Output Load Transient

Figure 2 shows the V_{OUT} transient response

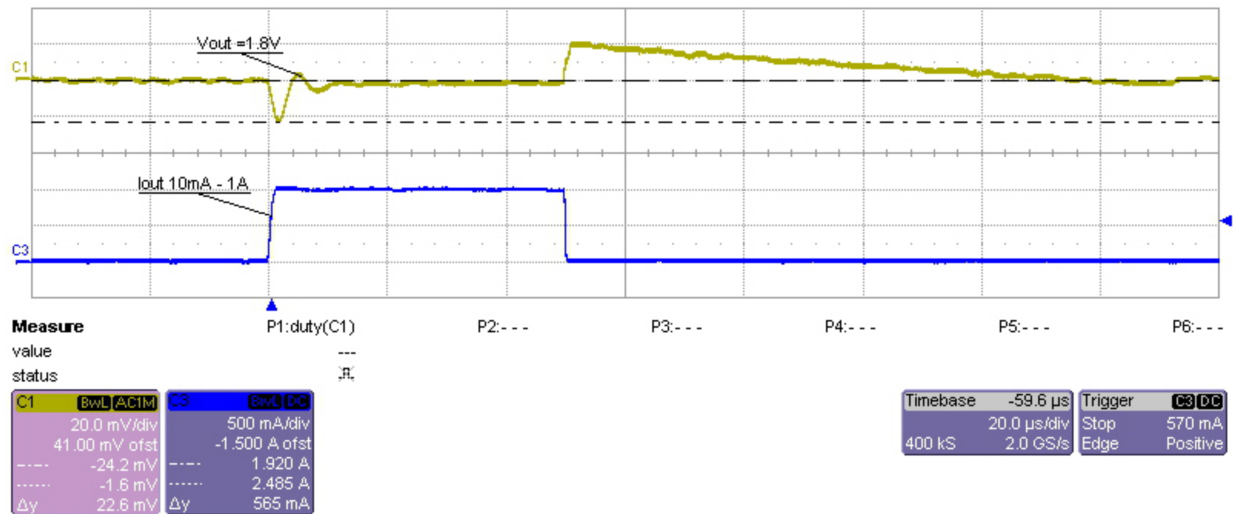


Figure 2. Step Load and Output Voltage Transient Response

5 Thermal Guidelines and Layout Recommendations

Thermal management is a key consideration in the design of any dc-dc converter but is especially important for an LDO when the power dissipation is high. Use the equation below to approximate the worst case junction temperature for the application:

$$T_J = T_A + P_d \times \theta_{JA} \quad (1)$$

where T_J is the junction temperature ($^{\circ}\text{C}$), T_A is the ambient temperature ($^{\circ}\text{C}$), P_d is the power dissipation in the device (Watts), and θ_{JA} is the thermal resistance from junction to ambient ($^{\circ}\text{C}/\text{W}$). The maximum silicon junction temperature should not be allowed to exceed 125°C for reliable operation. The layout design must use copper traces and plane areas smartly, as thermal sinks, so as to not allow T_J to exceed the absolute maximum rating under all load, voltage, and temperature conditions for a given application.

The layout should consider carefully the thermal design of the PCB for optimal performance over temperature. For this EVM, Figure 4 shows that the RGW package footprint employs a square thermal pad, centered under the part, for conducting heat to the copper spreading layers of the PCB. The thermal pad is soldered directly to a pad on the PCB containing a 5×5 pattern of 10.mil vias for conducting heat to the bottom side ground plane copper. Approximately 4.0 in^2 of 2 ounce copper is used on the bottom side of the EVM for dissipating heat generated by the LDO.

Table 2 relies on thermal resistance information from the thermal information table of the TPS7A47xx data sheet for comparison with the approximate thermal resistance, θ_{JA} , calculated for this EVM layout to show the variation in junction-ambient thermal resistances for varying copper areas. The High-K thermal resistance, θ_{JA} , is determined using a standard JEDEC high-k (2s2p) board having dimensions of $3 \text{ in} \times 3 \text{ in}$ with two 1-ounce internal power and ground planes and one 2-ounce copper bottom plane for spreading/sinking heat from the IC component.

Table 2. Thermal Resistance, θ_{JA} , and Maximum Power Dissipation

Board	Package	θ_{JA}	Max Dissipation without Derating ($T_A = 25^{\circ}\text{C}$)	Max Dissipation without Derating ($T_A = 70^{\circ}\text{C}$)
High-K	RGW	$30.5^{\circ}\text{C}/\text{W}$	3.27 W	1.8 W
TPS7A47xxEVM-094	RGW	$21^{\circ}\text{C}/\text{W}$	4.76 W	2.6 W

The thermal resistance for the TPS7A47xxEVM-094 is the measured value for this particular layout scheme. The maximum power dissipation is proportional to the volume of copper volume connected to the package.

6 Board Layout

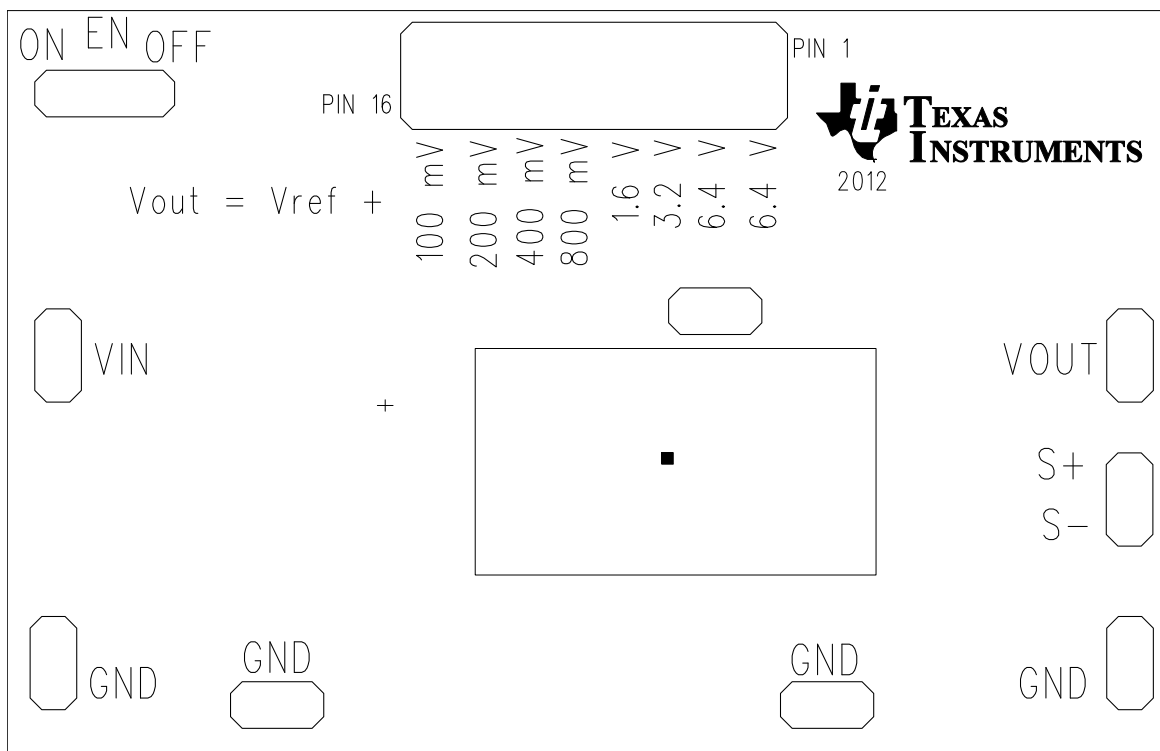


Figure 3. Assembly Layer

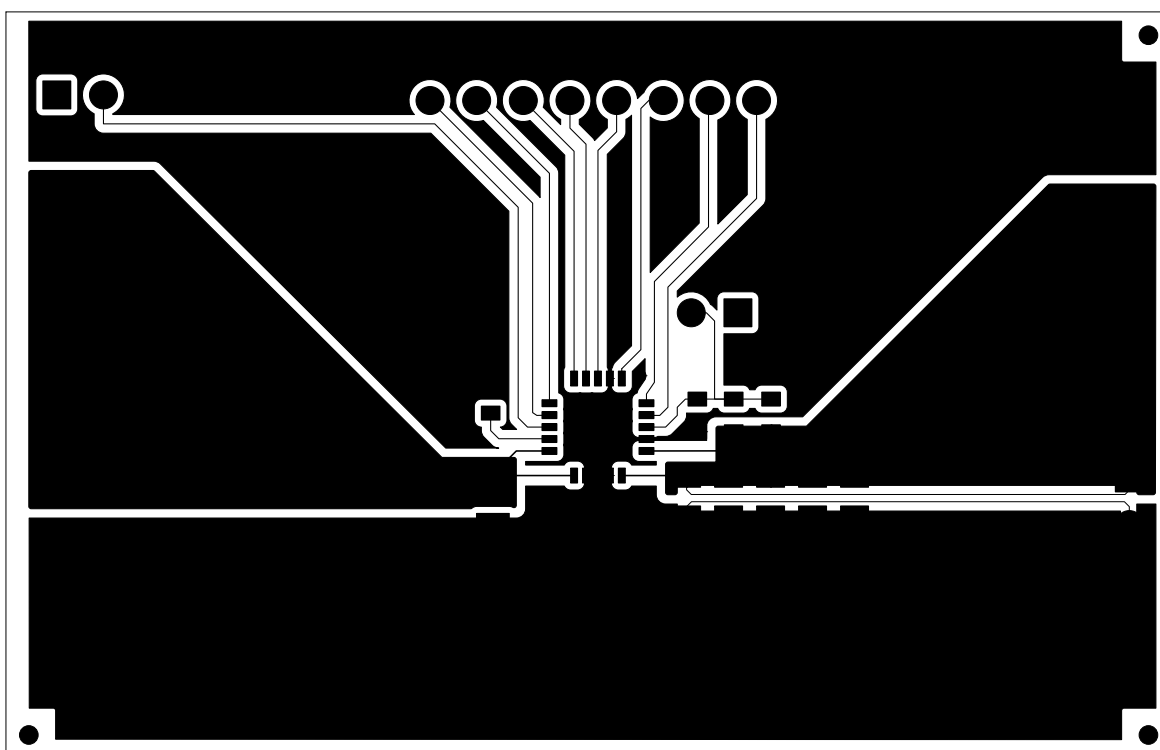


Figure 4. Top Layer Routing

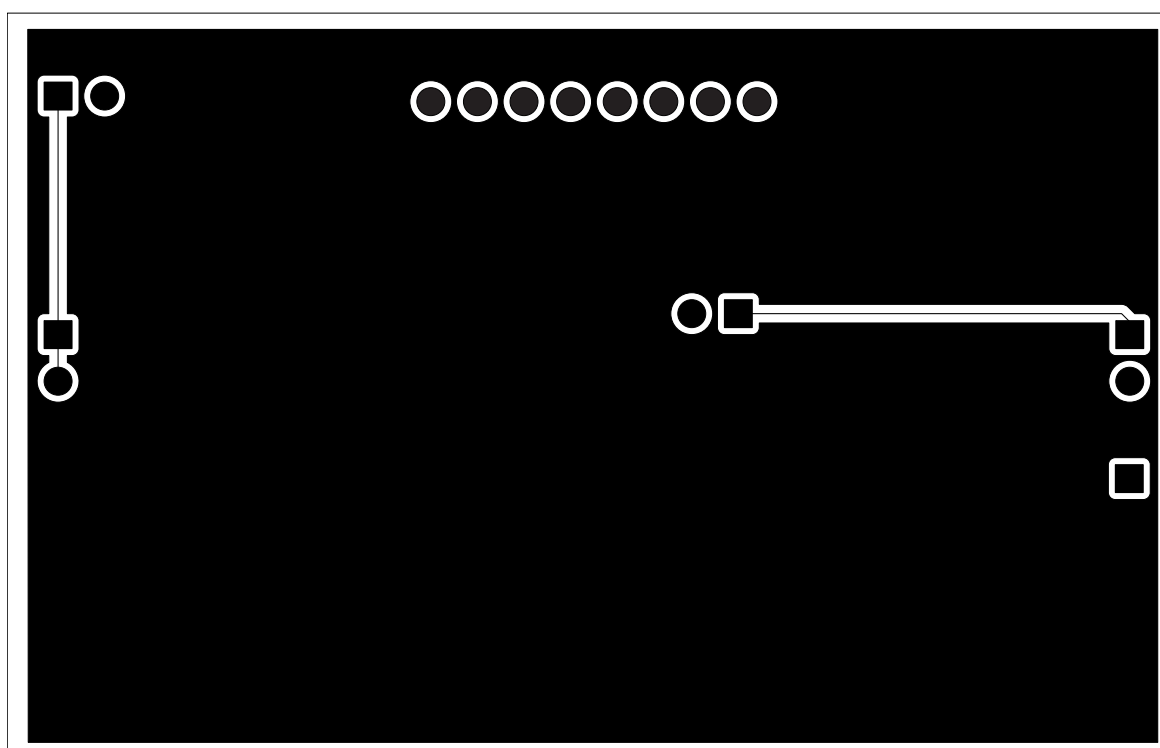


Figure 5. Bottom Layer Routing

7 Schematic and Bill of Materials

7.1 Schematic

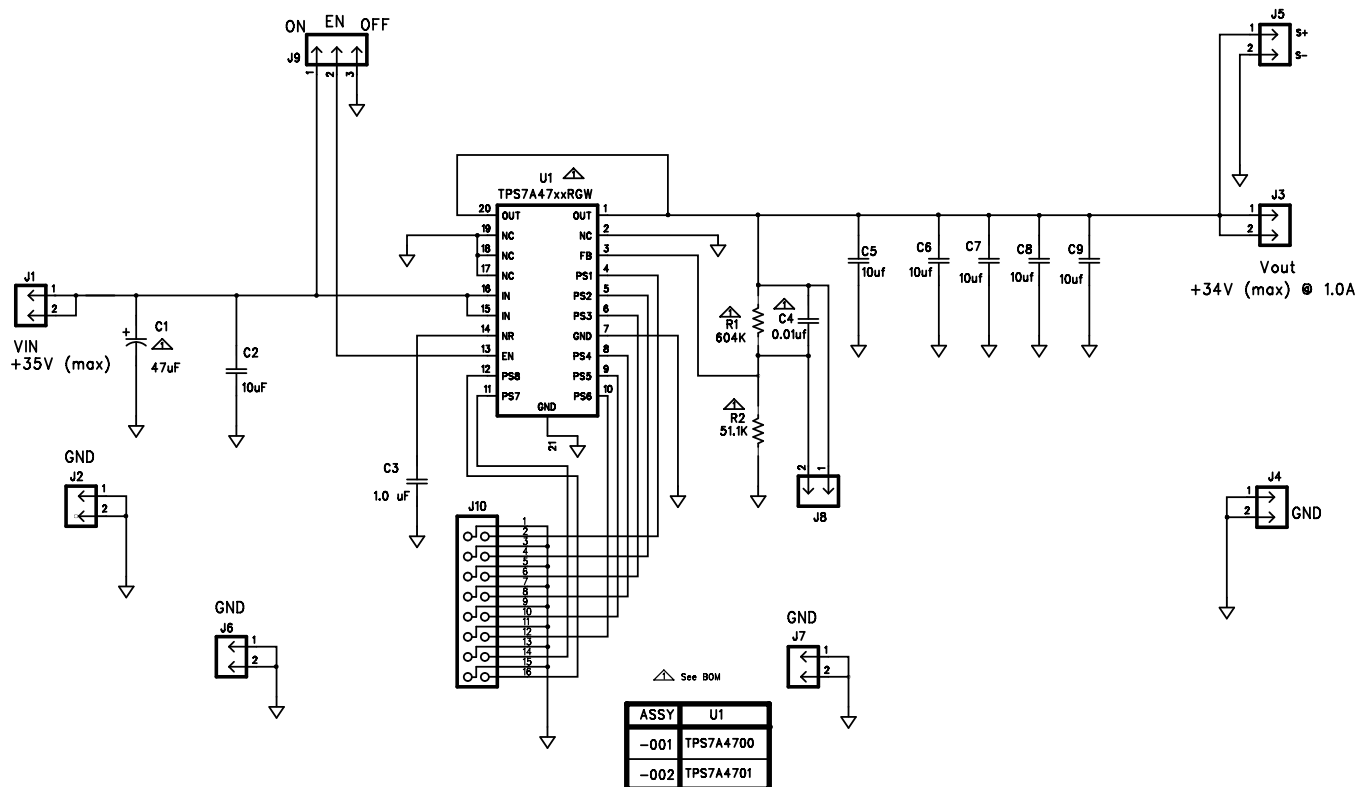


Figure 6. TPS7A47xxEVM-094 Schematic

7.2 Bill of Materials

Table 3. TPS7A47xxEVM-094 Bill of Materials

-001	-002						
CO UNT	COUN T	RefDes	Value	Description	Size	Part Number	MFR
0	0	C1	47uF	Capacitor, Tantalum, 35V, X5R, 20%	7343	TAJE476M035 RNJ	AVX
1	1	C2	10uF	Capacitor, Ceramic, 50V, X5R, 10%	1206	C3216X5R1H1 06K	TDK
1	1	C3	1.0 uF	Capacitor, Ceramic, 50V, X5R,10%	0603	C1608X5R1H1 05K080AB	TDK
0	1	C4	0.01uF	Capacitor, Ceramic, 25V, X7R,10%	0603	GRM188R71E 103KA01D	Murata
5	5	C5-9	10uf	Capacitor, Ceramic, 35V, X5R,10%	0805	C2012X5R1V1 06K085AC	TDK
8	8	J1- J8	PEC02SAAN	Header, Male 2-pin, 100mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
1	1	J9	PEC03SAAN	Header, Male 3-pin, 100mil spacing	0.100 inch x 3	PEC03SAAN	Sullins
1	1	J10	PEC08DAAN	Header, Male 2 x 8 pin, 100mil spacing	0.100 inch X 2 X 8	PEC08DAAN	Sullins
0	1	R1	604K	Resistor, Chip, 1/10W, 1%	0603	CRCW060360 4KFKEA	Vishay-Dale
0	1	R2	51.1K	Resistor, Chip, 1/10W, 1%	0603	CRCW060351 K1FKEA	Vishay-Dale
1	0	U1	TPS7A4700RGW	IC, Low Noise Power Solution For High Performance Signal Chain Applications	QFN-20	TPS7A4700R GW	TI
0	1	U1	TPS7A4701RGW	IC, Low Noise Power Solution For High Performance Signal Chain Applications	QFN-20	TPS7A4701R GW	TI
5	5			Shunt, Black	100-mil	929950-00	3M
1	1	--	PCB	PCB, 1.60 In x 2.50 In x 0.062 In	1.6 x 2.5 x0.062 in.	PWR094	Any
1		--		Label (See note 5)	1.25 x 0.25 inch	THT-13-457-10	Brady
Notes:		1. These assemblies are ESD sensitive, ESD precautions shall be observed.					
		2. These assemblies must be clean and free from flux and all contaminants. Do not use no clean flux.					
		3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.					
		4. Ref designators marked with an asterisk ("**") cannot be substituted. All other components can be substituted with equivalent MFG's components.					
		5. Install label in silkscreened box after final wash. Text shall be 8 pt font. Text shall be per Table 1.					
			Table 1				
			Assembly Number	Text			
			PWR094-001	TPS7A4700EVM-094			
			PWR094-002	TPS7A4701EVM-094			

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used. TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

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.

【Important Notice for Users of EVMs for RF Products in Japan】

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.

Texas Instruments Japan Limited
(address) 24-1, Nishi-Shinjuku 6 chome, Shinjuku-ku, Tokyo, Japan

<http://www.tij.co.jp>

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】

本開発キットは技術基準適合証明を受けておりません。

本製品のご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。

日本テキサス・インスツルメンツ株式会社
東京都新宿区西新宿 6 丁目 2 4 番 1 号
西新宿三井ビル

<http://www.tij.co.jp>

EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
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.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com