

TPS7A4700EVM-094 Evaluation Module

This User's Guide describes the functional operation of the TPS7A4700EVM-094 Evaluation Module (EVM) for use as a design reference and as a general engineering demonstration for the TPS7A4700 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.

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1 Introduction

The TI TPS7A4700-094 Evaluation Module is designed to help engineers evaluate the operation and performance of the TPS7A4700 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.

PowerPad is a trademark of Texas Instruments.

2 Setup

This section describes the connectors and headers on the EVM as well as how to properly connect, setup and use the TPS7A4700EVM-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 Amp)
- J4 GND – Ground return from the load (up to 1 Amp)
- J5 (S+) – V_{OUT} , Kelvin connection V_{OUT}
- J5 (S–) – GRD, Kelvin connection Ground
- J6 & J7 – Extra GRD connections
- J8 – Enable jumper for external resistor divider
- J9 – Enable jumper for the TPS7A4700-094 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 TPS7A4700 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.

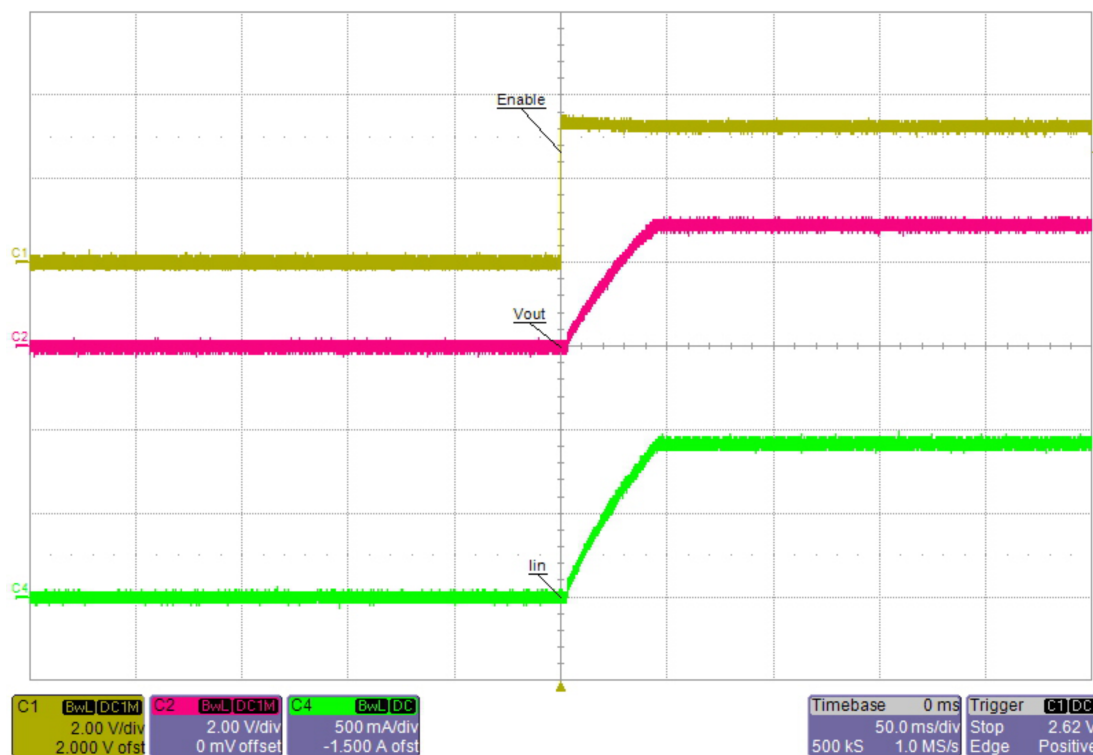


Figure 1. Turn On Sequence

4.2 Output Load Transient

Figure 2 shows the V_{OUT} transient response

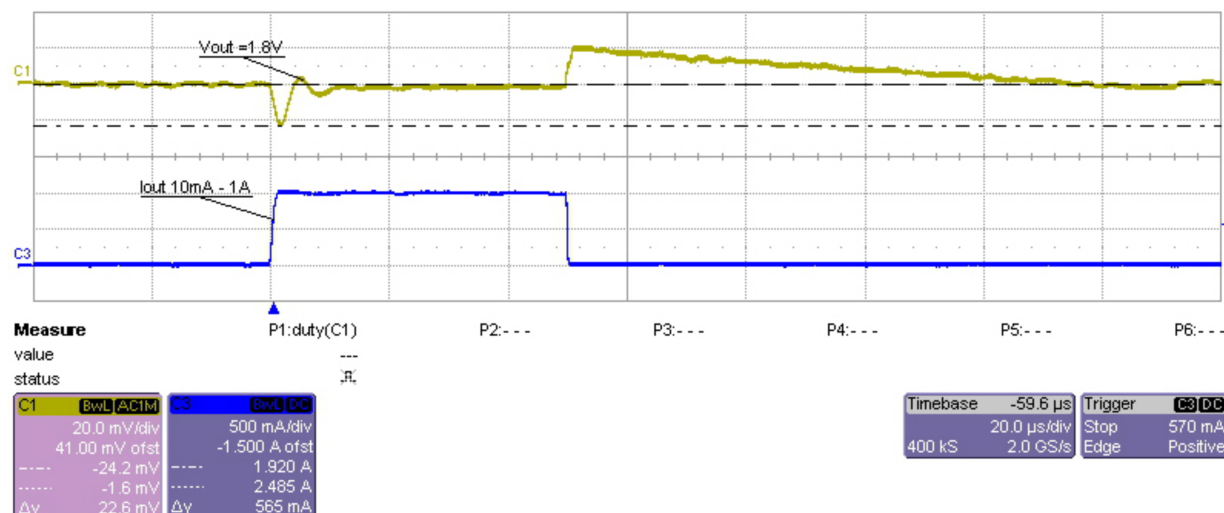


Figure 2. Step Load and Output Voltage Transient Response

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 ($^{\circ}$ C), T_A is the ambient temperature ($^{\circ}$ C), P_d is the power dissipation in the device (Watts), and θ_{JA} is the thermal resistance from junction to ambient ($^{\circ}$ C/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.

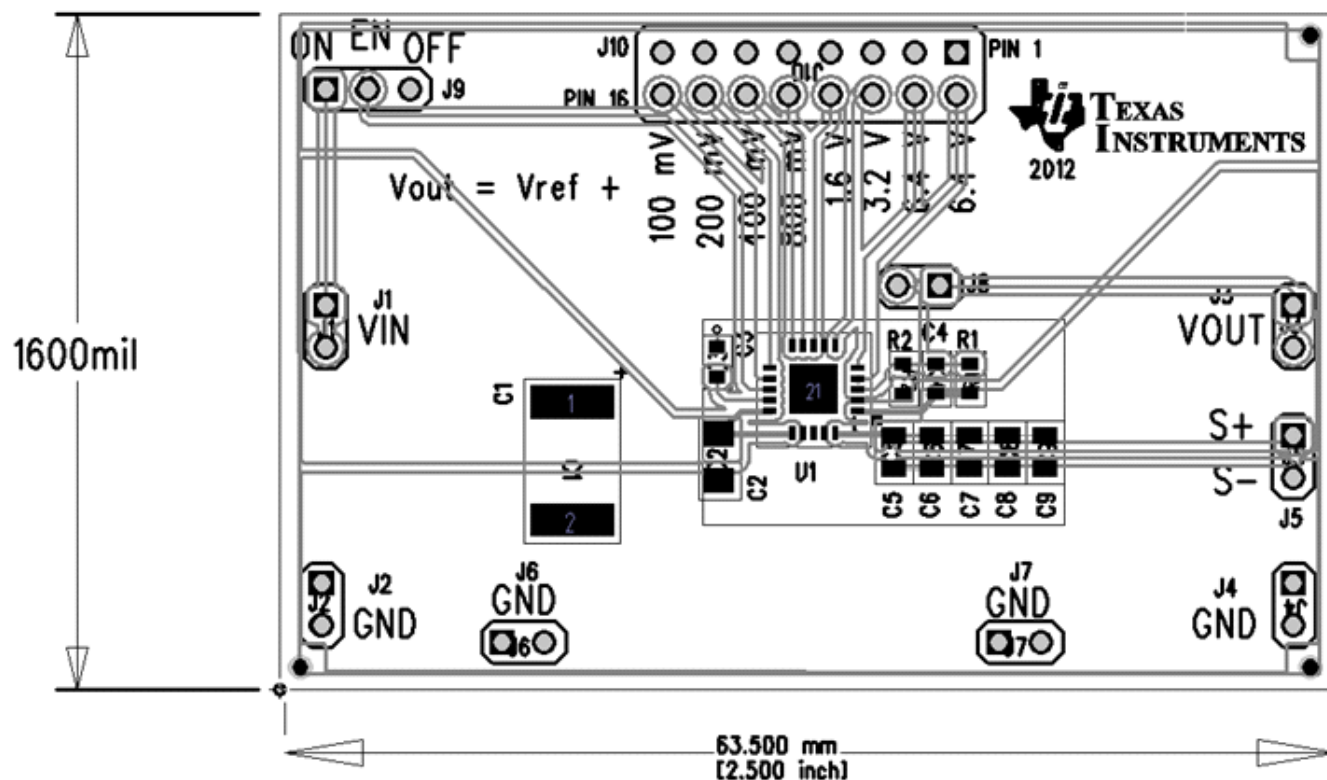
Table 2 relies on thermal resistance information from the Thermal Information Table of the TPS7A4700 data sheet for comparison with the approximate thermal resistance, θ_{JA} , calculated for this EVM layout to show the variation in junction-ambient thermal resistances for varying copper areas. The High-K 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 ($T_A = 25^{\circ}$ C)	Max Dissipation without Derating ($T_A = 70^{\circ}$ C)
High-K	RGW	30.5° C/W	3.27 W	1.8 W
TPS7A4700EVM-094	RGW	21° C/W	4.76 W	2.6 W

The thermal resistance for the TPS7A4700EVM-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





7 Schematic and Bill of Materials

7.1 Schematic

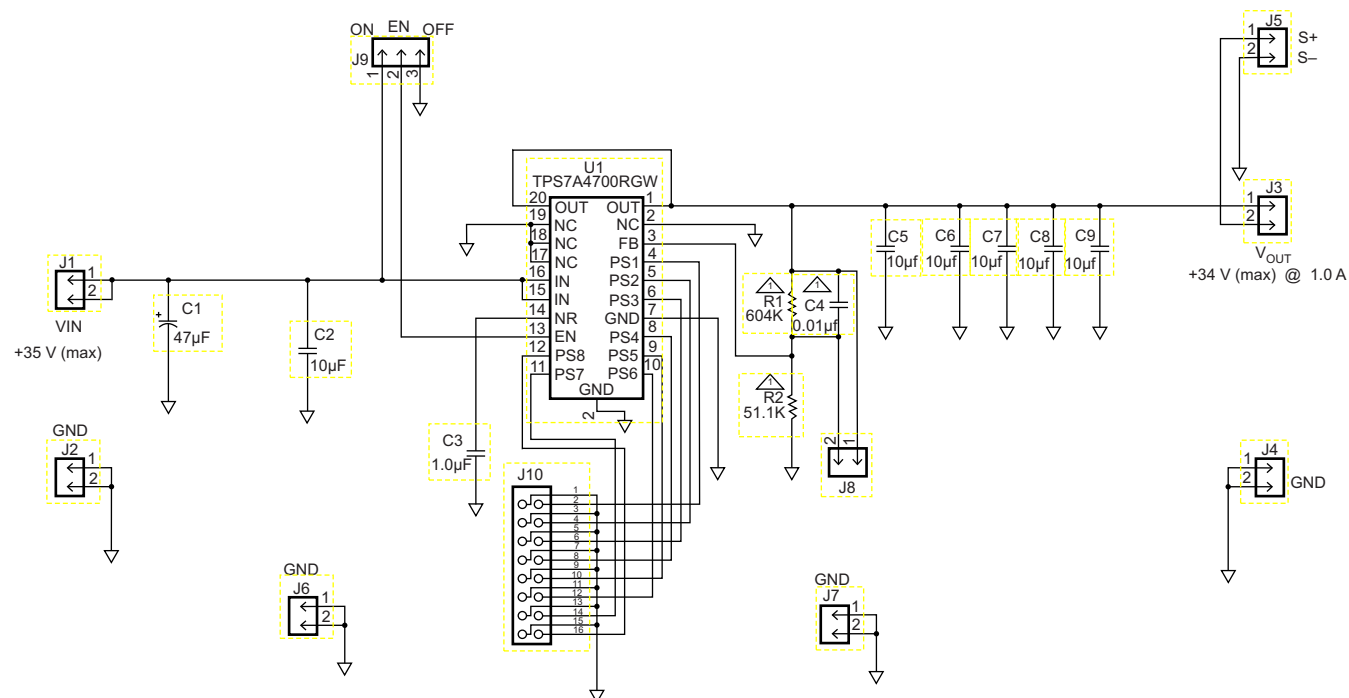


Figure 6. TPS7A4700EVM-094 Schematic

7.2 Bill of Materials

Table 3. TPS7A4700EVM-094 Bill of Materials

QTY	RefDes	Value	Description	Size	Part Number	MFR
1	C1	47 μ F	Capacitor, tantalum, 35 V, X5R, 20%	7343	TAJE476M035RNJ	AVX
1	C2	10 μ F	Capacitor, ceramic, 50 V, X5R, 10%	1206	C3216X5R1H106K	TDK
1	C3	1.0 μ F	Capacitor, ceramic, 50 V, X5R,10%	0603	STD	TDK
0	C4	0.01 μ F	Capacitor, ceramic, 25 V, X5R,10%	0603	STD	STD
5	C5-9	10 μ F	Capacitor, ceramic, 25 V, X5R,10%	0805	STD	STD
8	J1- J8	PEC02SAAN	Header, Male 2-pin, 100 mil spacing	0.100 in $\times$ 2	PEC02SAAN	Sullins
1	J9	PEC03SAAN	Header, Male 3-pin, 100 mil spacing	0.100 in $\times$ 3	PEC03SAAN	Sullins
1	J10	PEC08DAAN	Header, Male 2 $\times$ 8 pin, 100 mil spacing	0.100 in $\times$ 2 $\times$ 8	PEC08DAAN	Sullins
0	R1	604 k Ω	Resistor, chip, 1/16W, 1%	0603	STD	STD
0	R2	51.1 k Ω	Resistor, chip, 1/16W, 1%	0603	STD	STD
1	U1	TPS7A4700RGW	IC, Low Noise Power Solution For High Performance Signal Chain Applications	QFN-20	TPS7A4700RGW	TI
5			Shunt, Black	100-mil	929950-00	3M
1	--	PCB	PCB, 1.60 in $\times$ 2.50 in $\times$ 0.062 in	1.6 $\times$ 2.5 $\times$ 0.062 in	PWR094	Any
1	--		Label (See note 5)	1.25 $\times$ 0.25 in	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. Use of no clean flux is not acceptable.						
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 is 8 pt. font, as shown: Assembly Number: PWR094-001, Text: TPS7A4700EVM-094						

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For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

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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.

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.

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

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For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

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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 this Product 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.

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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. 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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