HDC2010METER-EVM User's Guide

The HDC2010METER-EVM provides the user with an easy-to-read module to measure ambient air temperature and relative humidity. This Evaluation Module (EVM) demonstrates the key considerations in developing a low-power system for devices with integrated temperature and humidity sense capability. The EVM measures 1.83 in × 1.45 in, so the system is fitted to a small form factor for further convenience in space-constrained environments. The onboard microcontroller (MCU) communicates with the humidity sensor using I2C communication protocol and displays the measurement onto an LCD through SPI protocol.

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1 Introduction

The HDC2010METER-EVM comes pre-loaded with firmware that ensures successful operation upon connection of the coin cell battery. Because the MCU is flashed using JTAG protocol, the test, reset, and ground pins are broken out to a three-pin header for the user to have the option to flash the MSP430FR5969 MCU. The device features three push-buttons. Button S1 functions to perform RESET, S2 switches the temperature display format on the display (Celsius or Fahrenheit), and another button (S3) can be programmed by the user. Test points are provided for the user to probe the clock and data signal lines corresponding to I2C data transfer, in addition to power and ground probe locations.

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Figure 1. HDC2010METER-EVM Front View

Figure 2. HDC2010METER-EVM Back View

1.1 Features

Low-power, high-accuracy humidity and temperature sensor: The HDC2010 offers a Relative Humidity (RH) accuracy of ±2% with an average current consumption of 550 nA.

Ultra-low-power MCU: The MSP430FR5969 can operate from 1.8V to 3.6V while consuming 0.4 µA in standby and 0.02 µA in shutdown.

Coin Cell Operation: CR2032 supplies 3V with a nominal capacity of 225 mAh

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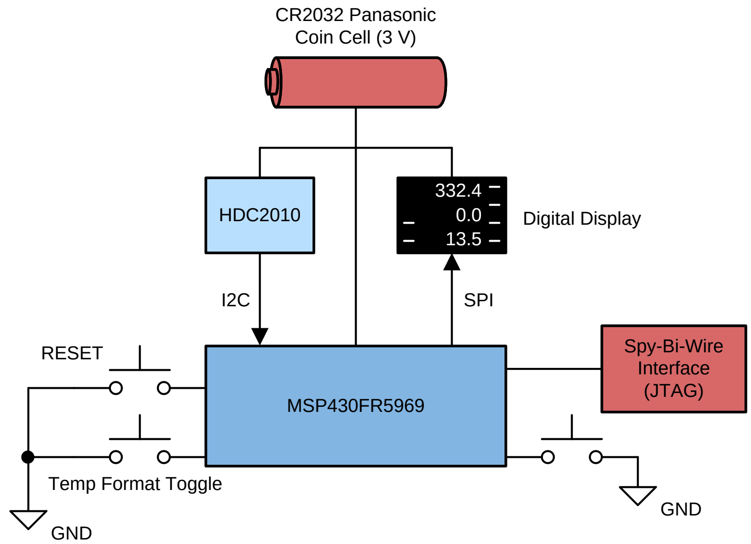

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Figure 3. HDC2010METER-EVM Block Diagram

1.1.1 HDC2010 Humidity and Temperature Sensor

The HDC2010 sensor measures the ambient air temperature and humidity with very low power consumption. The sensor comes in an ultra-compact Wafer Level Chip Scale Package (WLCSP) with the sensing element placed on the bottom part of the device, making it more robust against dirt, dust, and other environmental contaminants. One of the key features of the HDC2010 is its low power consumption, a key requirement for this coin cell based design. The device consumes a mere 50 nA of current in sleep mode, which is the default mode upon startup and is the mode it immediately returns to following a measurement.

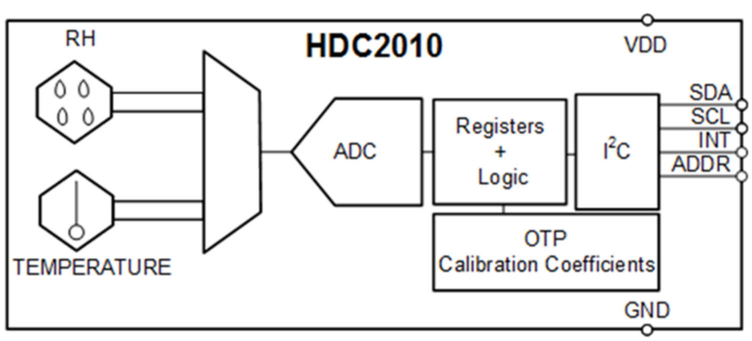

Figure 4. HDC2010 Block Diagram

1.1.2 MSP430FR5969 Mixed-Signal Microcontroller

The MSP430FR5969 is an ultra-low-power MCU that is optimized for lowered energy budgets in end equipment.

The device is a member of the MSP430FR59xx family of ultra-low-power mixed-signal MCUs featuring generous FRAM capabilities to enhance low-power designs in addition to intelligent peripherals to allow for varied application implementation. Updating FRAM takes 100× less time than DRAM, and there is no pre-erase required. In addition, FRAM includes faster write speeds, unified memory, and low-energy writes. Unified memory refers to program, data, and storage registers in one single place, which expedites the software run. Because of its fast write speeds, FRAM has near infinite endurance. In a remote sensor, data could be written more often for improved data accuracy, or it could collect data for longer. Due to the lack of a charge pump, FRAM enables lower average and peak power during writes. FRAM is also

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nonvolatile (that is, retains its contents upon power loss). Using the MSP430 MCU with FRAM allows for on-the-fly writes, as opposed to buffered in RAM. The bitwise programmable memory can be used at the programmer's convenience for data or program storage. FRAM also offers advantages in security and is inherently more secure due to its makeup. Also, de-layering is not effective. In comparison to MCUs with flash, FRAM:

- Is very easy to use
- Requires no setup or preparation such as unlocking of control registers
- Is not segmented and each bit is individually erasable, writable, and addressable
- Does not require an erase before a write
- Allows low-power write accesses (does not require a charge pump)
- Can be written to across the full voltage range (1.8 V to 3.6 V)
- Can be written to at speeds close to 8MBps (maximum flash write speed including the erase time is approximately 14 kBps)
- Does not require additional power to write to FRAM when compared to reading from FRAM

1.2 Applications

The primary application of this EVM is to showcase a low power solution for humidity and temperature monitoring by utilizing low power-consumption devices.

A battery voltage monitoring system allows the user to implement in firmware. A potential divider serves to feed an ADC-enabled GPIO of the MSP430 MCU. That way, voltage sags intrinsic to battery operation over time can be monitored and optionally displayed along with temperature measurement results; however, this requires firmware modification. VCCMonitor is calculated as follows:

$$\text{VCCMonitor} = \text{R5} \times \text{VCCR4} + \text{R5} \quad (1)$$

Select R4 and R5 to provide appropriate drive current to the ADC. In addition, the system features a reverse polarity protection FET applied to the battery terminals. This FET acts as a load switch in the system. Looking at the schematic, the body diode of Q1 sits connected between the drain and source of Q1. The anode is connected to the drain, while the cathode is connected to the gate. When the battery is connected correctly, the body diode is forward biased and conducts current from the drain to the source. Because Q1 is a P-channel MOSFET, the gate voltage is brought below the source voltage, providing the correct turnon condition. When the battery is connected in reverse, the gate of Q1 is receiving a voltage above the source voltage. Therefore, Q1 does not turn on and current is not passed to the load through conduction of the body diode.

2 Setup and Test Results

2.1 Hardware

NOTE: The HDC2010METER-EVM requires a Panasonic CR2032 coin cell battery which is not included.

The HDC2010METER-EVM includes:

- MSP430FR5969 MCU
- Three push-button switches
- HDC2010 humidity and temperature sensor
- LSO13B7DH03 LCD
- 32-kHz FC-135 32.7680KA-A3 crystal
- Associated discrete components

For a comprehensive list of all parts, see Table 1.

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2.2 Software

The HDC2010METER-EVM ships pre-loaded with software for its MSP430FR5969 MCU. When the battery is loaded, the display shows a Texas Instruments splash screen and then proceeds to display the current temperature and humidity. The rest of this section details the operation of the software.

Included with this reference design is a software package that contains a Code Composer Studio (CCS) project designed for the MSP430FR5969 mCU. For proper evaluation, import the CCS project into CCS v7.3 or later with TI Compiler v16.9.4.LTS or later.

After reset or power-on, several hardware initializations take place. All GPIO pins are configured as outputs and driven to logic low to save power. The pins that are used are then reconfigured for their intended purpose. The MSP430 MCU's internal oscillator, known as DCO, is configured for 8 MHz and connected to the internal signals SMCLK and MCLK. The external 32-kHz real-time crystal (RTC) is connected to the low-frequency clock inputs (LFXT), so the LFXT is configured as the source of the internal signal ACLK (Aux Clock). TIMER A is configured as a counter with ACLK as the source. Conveniently, a count of 32768 (215) is equivalent to 1 second, a count of 16384 (214) is equivalent to a half second, and so on. The eUSCI B0 peripheral is configured for I2C communication with the HDC2010 device. Finally, the eUSCI A1 peripheral is configured for SPI use with the TM display, and the Sharp display is initialized. The next step in the software is to begin the loop.

On each iteration, the MSP430 MCU begins by checking the state of the button S1 and setting the Celsius and Fahrenheit variable. An I2C Write transaction is then performed to instruct the HDC2010 to begin a temperature and humidity measurement. This measurement takes a few milliseconds (for conversion time, see HDC2010 Low Power Humidity and Temperature Digital Sensors), so the MSP430FR5969 is configured for LPM4 during the down time. After TIMER A interrupts and resumes, the temperature and humidity data is retrieved from the HDC2010. The values for temperature and humidity are converted to characters using the tmpdecode.c library. This library is designed to provide string conversion without loss of 16-bit precision, but it can be adjusted for less precision. Finally, the temperature and humidity strings update the display, and the MSP430FR5969 returns to LPM4 for 2 seconds before looping.

2.2.1 Programming

The HDC2010 meter can be flashed or debugged using the Spy-By-Wire (SBW) interface. The MSP430FR5969's SBW interface is available at header J1 pins TEST and RST. Connect these pins, and GND/VCC as appropriate, to an MSP430 TM or a standalone debugger such as MSP-FET.

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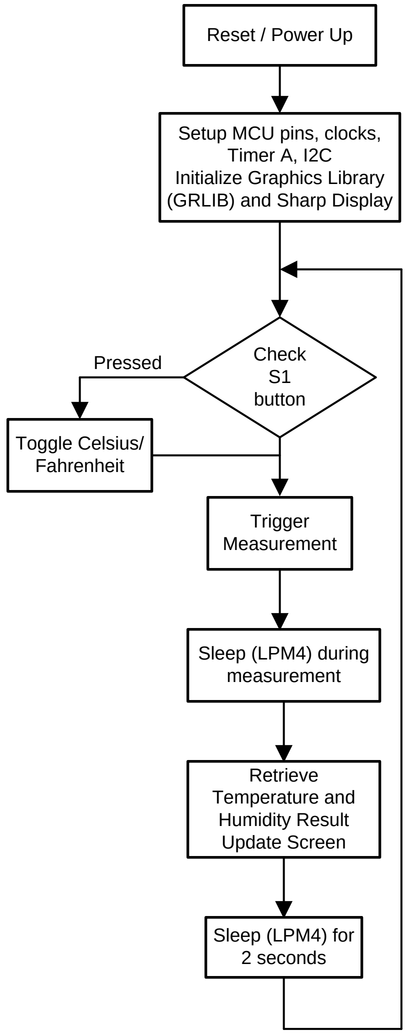

Figure 5. System Flow Chart

2.3 Current Consumption Test

2.3.1 Test Setup

Although the current consumption of the system in its inactive mode is clearly defined by summing each inactive mode current specification in device data sheets, it is not so clear when the devices are active. Therefore, this test is set up to measure the current consumption of the system in active mode. The measurement is taken using a small series resistor connected to a simple instrumentation amplifier to perform a differential measurement across the resistor. This arrangement is used because the standard probes of an oscilloscope can only take single-ended measurements.

2.3.2 Test Results

Because the gain of the instrumentation amplifier is programmed to 1000, the 1.07-V measurement highlighted by cursor A corresponds to 1.07 mA consumed by the system.

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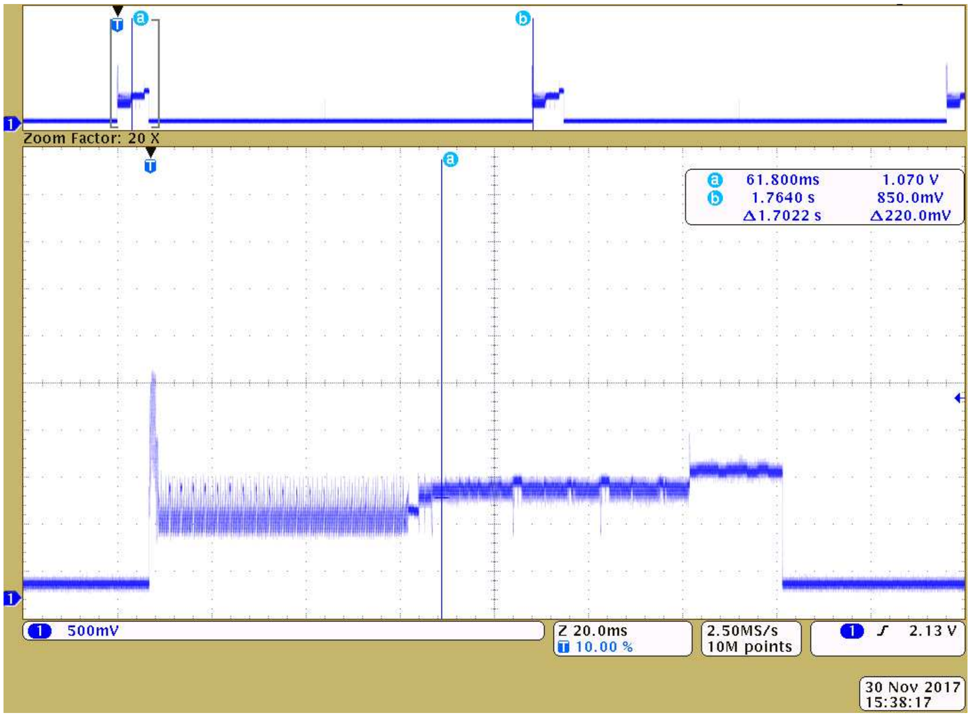

Figure 6. System Current Consumption

The transactions taking place during the system's active mode cycle are as follows:

- MSP430 MCU wakes up due to interrupt from Timer A.
- MSP430 MCU communicates with the HDC2010 through I2C.
- MSP430 MCU decodes information provided by HDC2010.
- MSP430 MCU communicates with the LCD through SPI to update the display.

These transactions are reflected in the oscilloscope capture whenever the voltage signal steps up. After these operations take place, the MSP430 MCU returns to standby mode (LPM4), the HDC2010 returns to sleep mode, and the LCD returns to its low power consumption mode. During the active mode transactions, the system consumes between 0.80 mA to 1.40 mA. Because the active mode cycle is occurring about every 2 seconds, this active mode occurs 1800 times per hour. The active mode transactions each take about 100 ms to perform, so for 6.65% of an hour, the system is in active mode. The blue arrow indicates the system current consumption in LPM4 (shutdown). Shutdown current consumption includes the MSP430 MCU, HDC2010, and LCD in shutdown modes. The current consumption of a typical system shutdown is about 130 µA. The below equation yields an estimate for the expected battery life of the CR2032:

Battery Life (hours) = Nominal Battery Capacity (mAh)*% of the hour spent activeActive Mode Current Consumption (mA)+Nominal Battery Capacity (mAh)*% of the hour spent inactiveInactive Current Consumption (mA) (2)

3 Schematic and Bill of Materials

To download the full design package, see the TI Design Guide .

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3.1 Schematic

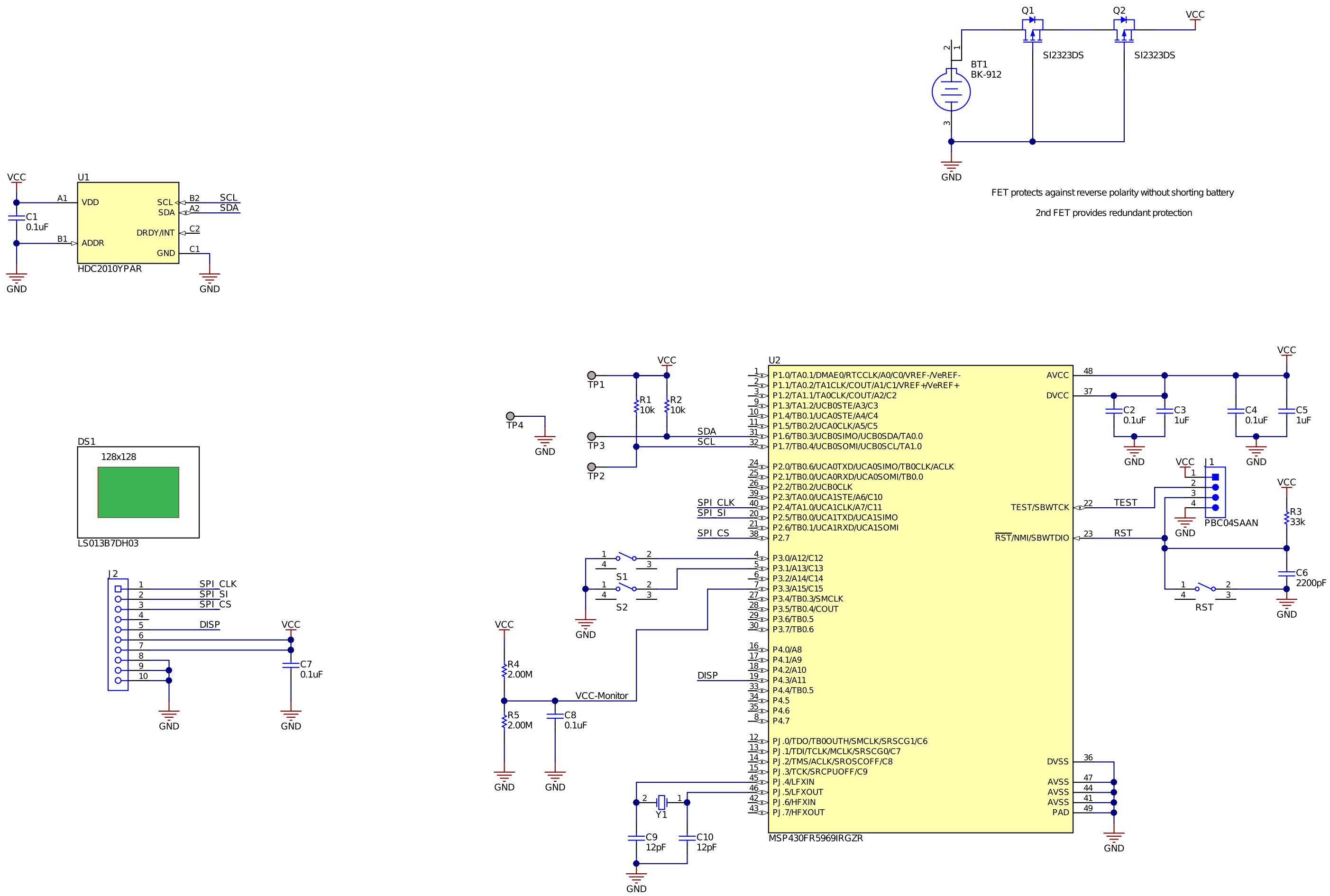

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Figure 7. HDC2010METER-EVM Schematic

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3.2 Bill of Materials

Table 1. BOM

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		SENS020	Any
BT1	1		Battery Holder for CR2032, SMT	Battery Holder for CR2032, SMT	BK-912	Memory Protection Devices
C1	1	0.1uF	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X5R, 0201	0201	GRM033R61C104KE84D	MuRata
C2, C4, C7	3	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A104KA01D	MuRata
C3, C5	2	1uF	CAP, CERM, 1 uF, 6.3 V, +/- 10%, X5R, 0402	0402	GRM155R60J105KE19D	MuRata
C6	1	2200pF	CAP, CERM, 2200 pF, 6.3 V, +/- 10%, X5R, 0402	0402	GRM155R60J222KA01D	MuRata
C9, C10	2	12pF	CAP, CERM, 12 pF, 50 V, +/- 5%, C0G/NP0, 0201	0201	GRM0335C1H120JA01D	MuRata
DS1	1		LCD Display Dot Pixels 128x128	LCD Display Dot Pixels 128x128	LS013B7DH03	Sharp Microelectronics
H1, H2, H3, H4	4		Bumpon, Cylindrical, 0.312 X 0.200, Black	Black Bumpon	SJ61A1	3M
J2	1		Connector, FPC 10 Pos. 9.1x2.0x5.6 mm	Connector PFC, 9.1x2.0x5.6mm	FH12-10S-0.5SH(55)	Hirose Electric Co. Ltd.
Q1	1	-20V	MOSFET, P-CH, -20 V, -3.7 A, SOT-23	SOT-23	SI2323DS	Vishay-Siliconix
R1, R2	2	10k	RES, 10 k, 5%, 0.063 W, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R3	1	33k	RES, 33 k, 5%, 0.063 W, 0402	0402	CRCW040233K0JNED	Vishay-Dale
RST, S1, S2	3		Switch, SPST-NO, 1 Pos, 0.05A, 12VDC, SMD	7.8x3.5mm	TL3330AF260QG	E-Switch
TP1, TP2, TP3, TP4	4		Natural PC Test Point Brass, SMT	Natural PC Test Point Brass, SMT	S2761-46R	Harwin
U1	1		HDC2010 Low Power Humidity and Temperature Digital Sensor, YPA0006ABAB (DSBGA-6)	YPA0006ABAB	HDC2010YPAR	Texas Instruments
U2	1		MSP430FR5969 16 MHz Ultra-Low-Power Microcontroller featuring 64 KB FRAM, 2 KB SRAM, 40 IO, RGZ0048B (VQFN-48)	RGZ0048B	MSP430FR5969IRGZR	Texas Instruments
Y1	1		CRYSTAL, 32.768KHz, 12.5PF, SMD	3.2x0.9x1.5mm	ABS07-32.768KHZ-T	Abracon Corporation
C8	0	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A104KA01D	MuRata
J1	0		Header, 2.54 mm, 4x1, Gold, TH	Header, 2.54 mm, 4x1, TH	PBC04SAAN	Sullins Connector Solutions
R4, R5	0	2.00Meg	RES, 2.00 M, 1%, 0.063 W, 0402	0402	CRCW04022M00FKED	Vishay-Dale

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

   CAUTION

   This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

   FCC Interference Statement for Class A EVM devices

   NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

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3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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