TI Designs
Low-Power Flow Meter Design Using GMR Sensors

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

TIDM-GMR-WATERMTR	Design Page
MSP430FR6989	Product Folder
EVM430-FR6989	Tool Folder

TI E2E™ Community

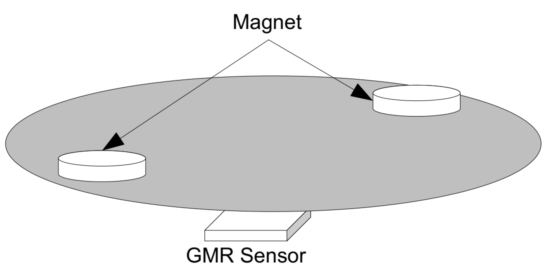
ASK Our E2E Experts
WEBENCH® Calculator Tools

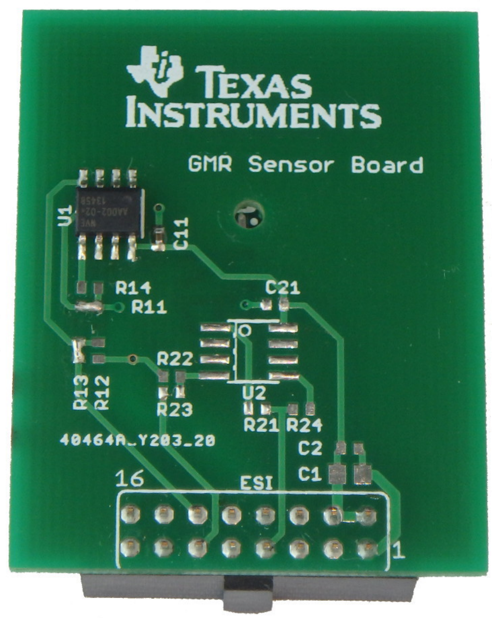
Design Features

- Daughter GMR Sensor Board for EVM430-FR6989
- Detects Rotation using GMR Sensors
- Example for Calibration
- Ultra-Low Power with ESI

Featured Applications

- Flow Meter
- Gas Meter
- Heat Meter
- Other Applications for Detecting Rotation





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Description

In conventional designs for mechanical flow meters, the flow measurement is performed by spinning a wheel by the flow. A mechanical register is coupled with the spinning wheel using magnets. To convert the mechanical register into an electronic one, a simple way is to detect the magnetic field of the spinning wheel.

GMR can detect magnetic field. The structure of GMR sensors is similar to a resistor ladder. The output signal of a GMR sensor can be measured by an MCU, and the MCU can find the rotation of the mechanical wheel (Figure 1).

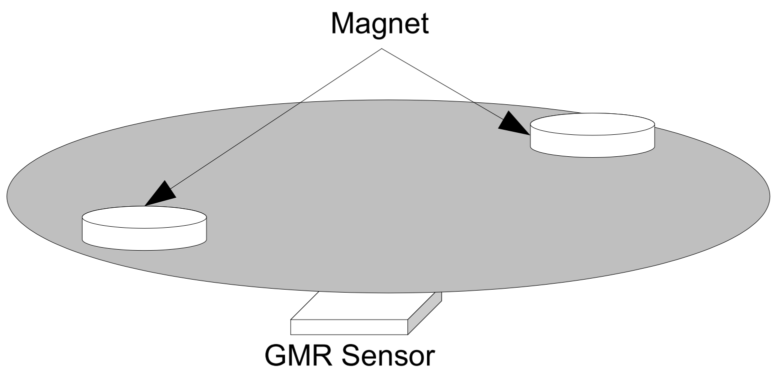


Figure 1. GMR Detects the Rotation of the Spinning Wheel by Measuring the Magnetic Field

Some flow meter designs are battery powered. These designs are typically required to operate for several years to over a decade. Therefore, lowering the system's power consumption is critical for extending the battery life of the system.

By using an extended scan interface (ESI), the system automates the measurement process and reduces CPU involvement, which helps reduce power consumption of the MCU. The characteristic of the ESI analog front-end (AFE) structure also helps reduce the power consumption of the sensor circuits.

This sensor board is designed for the EVM430-FR6989 as a daughter board to detect rotation using GMR sensors. The sensor board is attached to the main board of the EVM430-FR6989. The GMR sensors are connected to the ESI module of the MSP430FR6989.

2 Design Features

The GMR structure is similar to a resistor ladder. When voltage is applied on the GMR sensor, a direct current (DC) generates. The magnetic field changes the resistance inside the GMR sensor. The MCU measures the output voltage of the GMR sensor. Because the measurement requires only a short time, the DC current wastes energy when the system is idled. The ESI helps to overcome this issue.

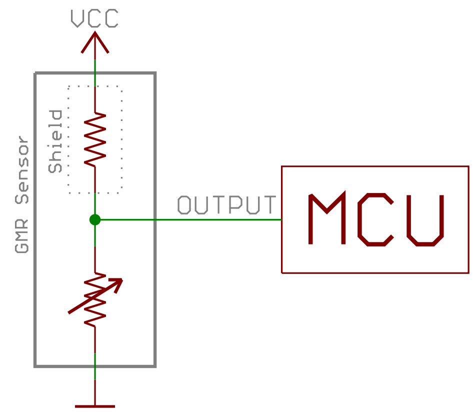


Figure 2. Simple GMR Connection

Figure 3 shows the connection of the GMR sensor and the ESI with the excitation circuit as an enable pin. During the measurement, the excitation circuit is triggered. The ESICHx pin is connected to the ground. The circuit is completed and a voltage is generated on the ESICIx. The voltage on the ESICIx is then measured using the ESI comparator (ESICA) and the reference voltage generated by the ESIDAC. After getting the output of the ESICA, the excitation circuit is set to a floating state. The circuit of the GMR sensor is opened, stopping the current flow. This process takes a short time and is controlled by the timing state machine (TSM) of the ESI.

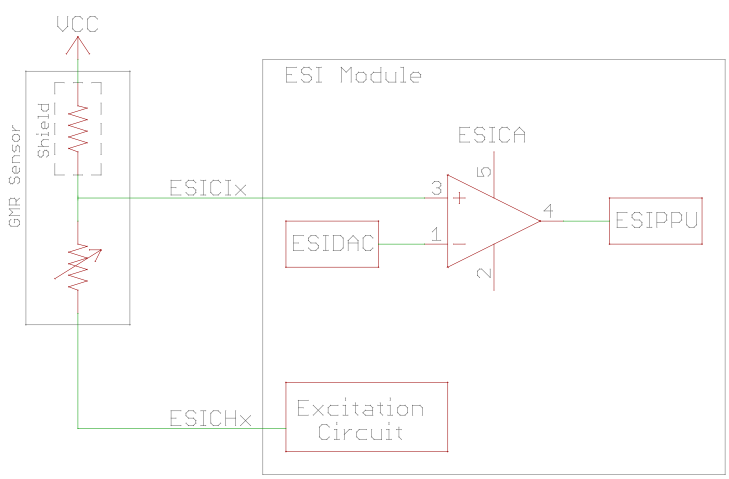


Figure 3. GMR Sensor with ESI

3 Software Description

Due to component tolerance and environmental conditions, the analog signal slightly differs from device to device. Therefore, calibration is required before normal operation.

The calibration requires the mechanical wheel to rotate for several cycles to find the maximum and minimum signals of the GMR sensor. Two pseudo-thresholds are set dynamically based on the maximum and minimum signals. Two thresholds are then calculated for detecting the signal state.

After calibration, the system goes to sleep mode to save power. The ESI takes full control of the rotation detection. The ESI triggers the CPU and displays the counter value on the LCD whenever it detects a rotation.

The software uses one GMR sensor and assumes the mechanical wheel rotates in one direction.

The power consumption depends on the sampling rate and the turn-on time of the sensor circuit set by the ESITSM register.

4 Test Setup

The test uses a GMR sensor board, a spinning wheel attached to the sensor board, and a magnet glued onto the spinning wheel. The sensor board is connected to the EVM430-FR6989 main board. One GMR sensor is used for measurement. With all other peripherals of the MCU disabled, the system power consumption is measured at different sampling rates of the ESI.

The actual connection between the GMR sensors and the MSP430FR6989 is shown in Figure 4.

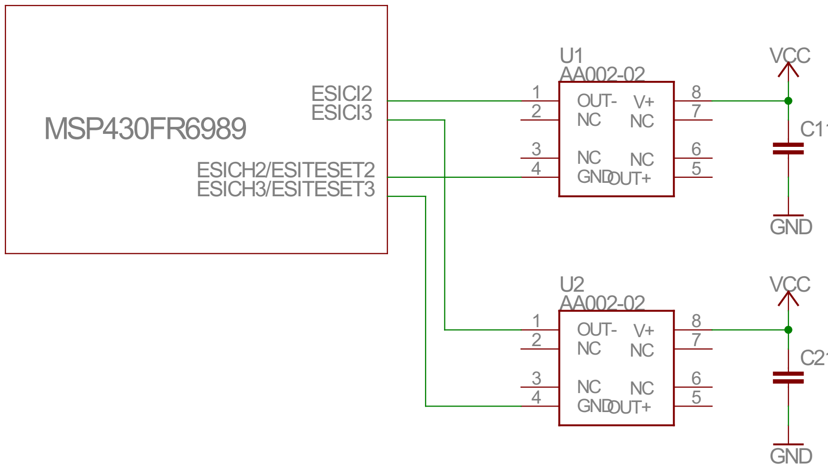


Figure 4. Connection between GMR Sensors and MSP430FR6989

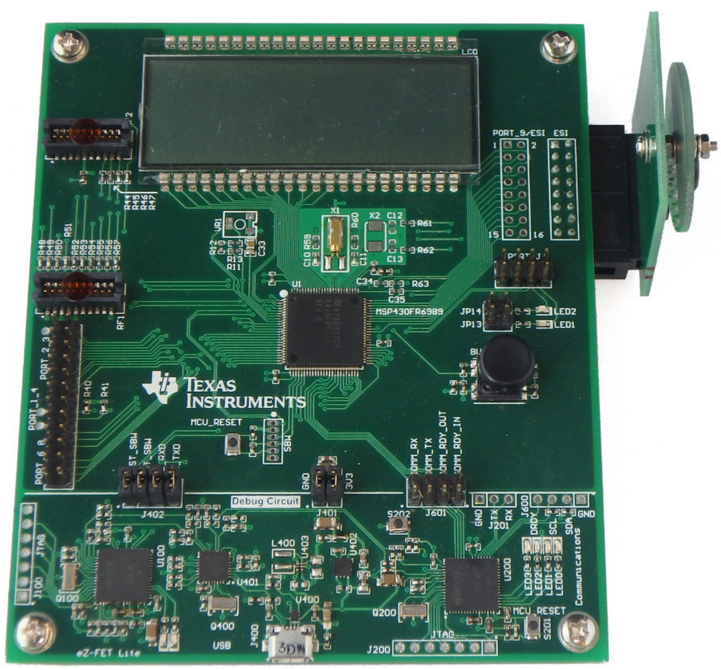


Figure 5. EVM430-FR6989 Main Board with GMR Sensor Board Attached

5 Test Results

Table 1 shows the power consumption of the system based on different sampling rates. The ESIDIV2 and ESIDIV3 are the register values of ESITSM. The sampling rate is calculated based on the 32.768-kHz crystal and the ESIDIV2 and ESIDIV3 settings.

Table 1. Power Consumption Rates

ESIDIV2	ESIDIV3	SAMPLING RATE	SYSTEM CURRENT (LCD OFF)
8	90	46	3.44
1	330	99	3.59
1	162	202	3.87
1	110	298	4.13
1	78	420	4.46
1	66	496	4.66
1	54	607	4.97
1	42	780	5.45
1	30	1092	6.3
1	26	1260	6.76
1	22	1489	7.4
1	18	1820	8.3

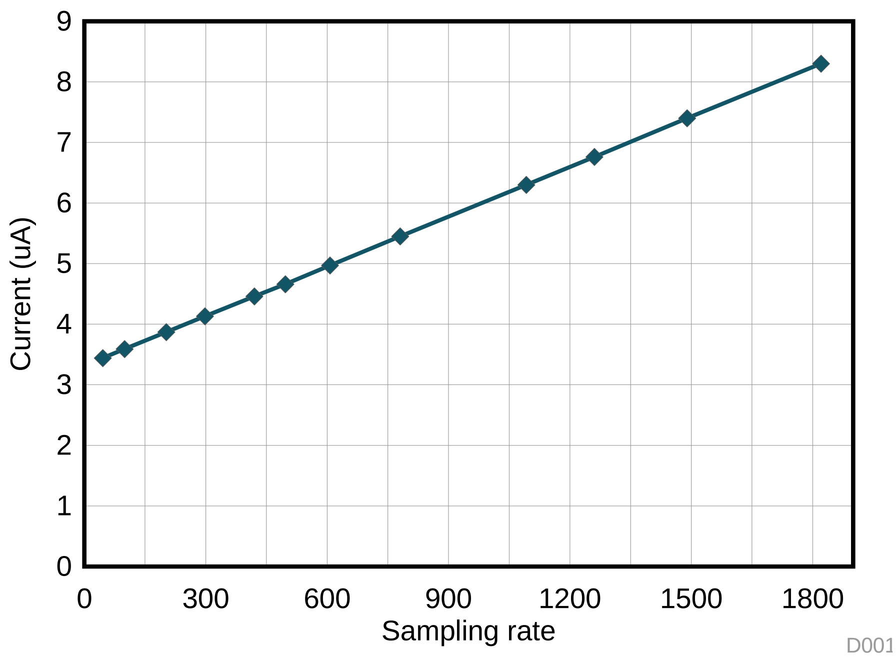


Figure 6. Sampling Rate versus Power Consumption

6 Design Files

6.1 Schematics

To download the schematics, see the design files at TIDM-GMR-WATERMTR.

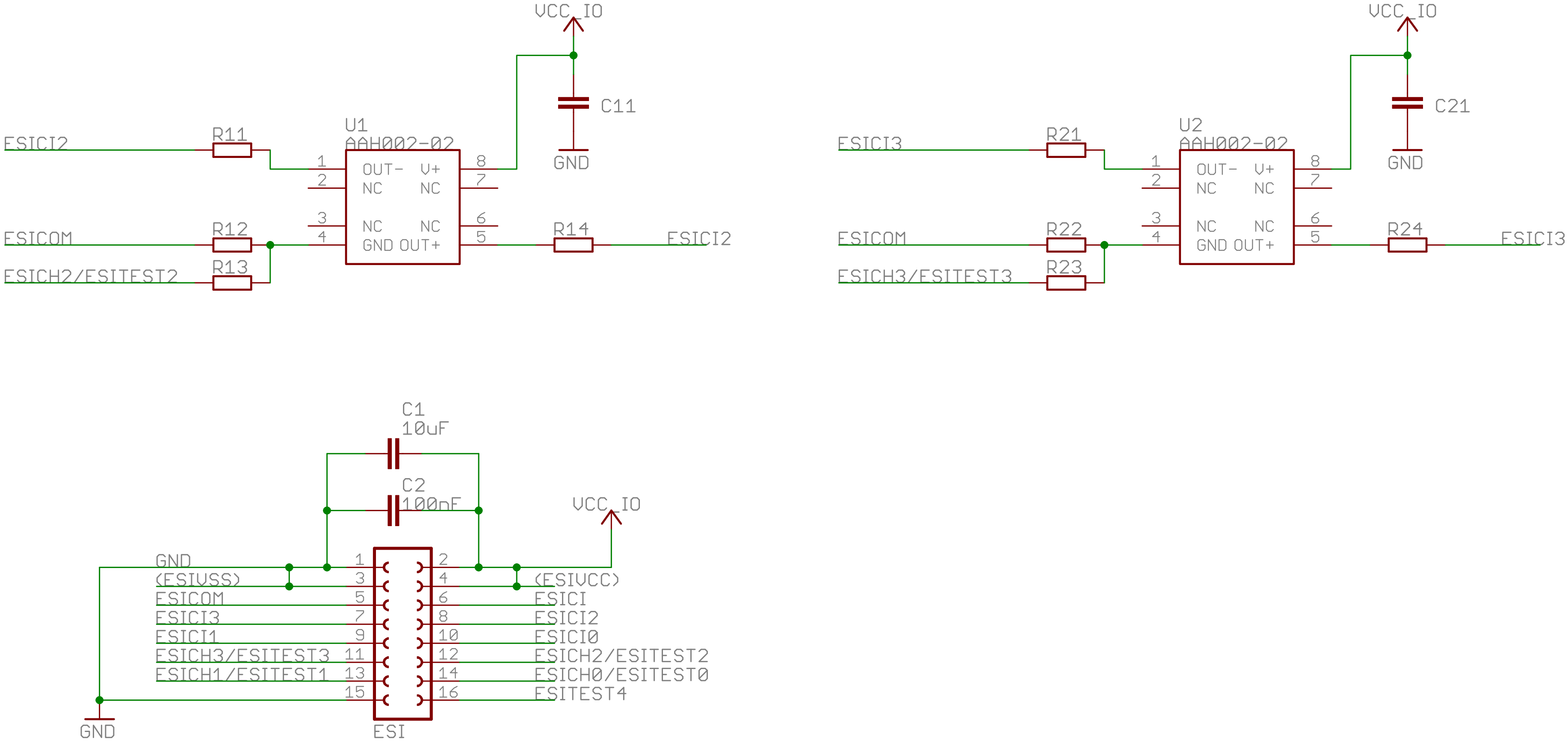


Figure 7. TIDM-GMR-WATERMTR Schematic

6.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-GMR-WATERMTR.

Table 2. BOM

DESIGNATOR	VALUE	QUANTITY	DESCRIPTION	DIGIKEY PN
R11, R13	0 R	2	0402 SMD Chip Resistor	311-0.0JRCT-ND
C1	10 µF	1	0805 SMD Chip Capacitor	490-3886-1-ND
C11, C2	100 nF	2	0402 SMD Chip Capacitor	490-3261-1-ND
U1	AA002-02	1	GMR Sensor	391-1045-5-ND
ESI	SFH11-PBPC-D08-ST-BK	1	Connector	S9196-ND
C21	DNP	0	0402 SMD Chip Capacitor	
U2	DNP	0	GMR Sensor	
R12, R14, R21, R22, R23, R24	DNP	0	0402 SMD Chip Resistor	

6.3 PCB Layout

To download the layer plots, see the design files at TIDM-GMR-WATERMTR.

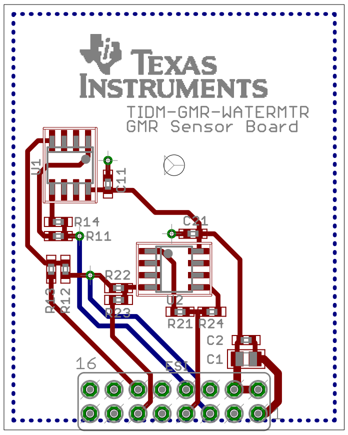


Figure 8. Layer Plot 1

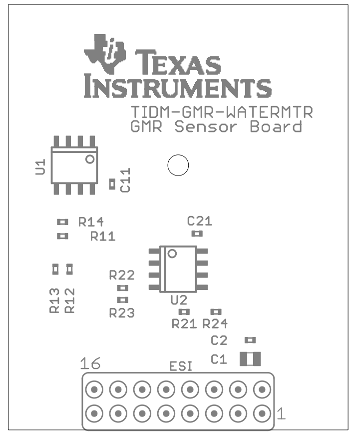


Figure 9. Layer Plot 2

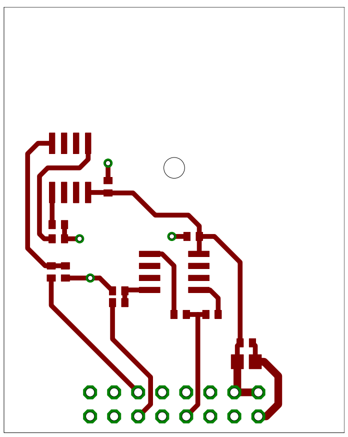


Figure 10. Layer Plot 3

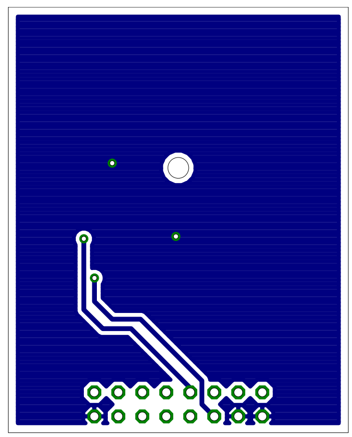


Figure 11. Layer Plot 4

6.4 Gerber Files

To download the Gerber files, see the design files at TIDM-GMR-WATERMTR.

7 Software Files

To download the software files, see the design files at TIDM-GMR-WATERMTR.

8 About the Author

ZACK MAK is a system application engineer at Texas Instruments where he is responsible for developing reference design solutions for the industrial segment. Zack earned his bachelor of electronic and communication engineering from City University of Hong Kong.

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Texas Instruments Incorporated ("TI") reference designs are solely intended to assist designers (“Buyers”) who are developing systems that incorporate TI semiconductor products (also referred to herein as “components”). Buyer understands and agrees that Buyer remains responsible for using its independent analysis, evaluation and judgment in designing Buyer’s systems and products.

TI reference designs have been created using standard laboratory conditions and engineering practices. **TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.** TI may make corrections, enhancements, improvements and other changes to its reference designs.

Buyers are authorized to use TI reference designs with the TI component(s) identified in each particular reference design and to modify the reference design in the development of their end products. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY THIRD PARTY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT, IS GRANTED HEREIN, including but not limited to 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.

TI REFERENCE DESIGNS ARE PROVIDED "AS IS". TI MAKES NO WARRANTIES OR REPRESENTATIONS WITH REGARD TO THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ACCURACY OR COMPLETENESS. TI DISCLAIMS ANY WARRANTY OF TITLE AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, QUIET POSSESSION, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS WITH REGARD TO TI REFERENCE DESIGNS OR USE THEREOF. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY BUYERS AGAINST ANY THIRD PARTY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON A COMBINATION OF COMPONENTS PROVIDED IN A TI REFERENCE DESIGN. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY AND WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING IN ANY WAY OUT OF TI REFERENCE DESIGNS OR BUYER’S USE OF TI REFERENCE DESIGNS.

TI reserves 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 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 for TI components 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.

Reproduction of significant portions of TI information in TI data books, data sheets or reference designs 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.

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 that anticipate dangerous failures, monitor failures and their consequences, lessen the likelihood of dangerous failures 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 Buyer’s 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 an agreement specifically governing such use.

Only those TI components that 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 that have ***not*** been so designated is solely at Buyer's risk, and 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265