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**Low-Power Flow Meter Design Using GMR Sensors**

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**Design Resources**

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

**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

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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).

![GMR Sensor and Magnet Diagram](image)

**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](image)

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 ESIC x pin is connected to the ground. The circuit is completed and a voltage is generated on the ESIC x. The voltage on the ESIC x 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](image)

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

<table>
<thead>
<tr>
<th>ESIDIV2</th>
<th>ESIDIV3</th>
<th>SAMPLING RATE</th>
<th>SYSTEM CURRENT (LCD OFF)</th>
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<tr>
<td>8</td>
<td>90</td>
<td>46</td>
<td>3.44</td>
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<tr>
<td>1</td>
<td>330</td>
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<td>1</td>
<td>18</td>
<td>1820</td>
<td>8.3</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>DESIGNATOR</th>
<th>VALUE</th>
<th>QUANTITY</th>
<th>DESCRIPTION</th>
<th>DIGIKEY PN</th>
</tr>
</thead>
<tbody>
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<td>R11, R13</td>
<td>0 R</td>
<td>2</td>
<td>0402 SMD Chip Resistor</td>
<td>311-0.0JRCT-ND</td>
</tr>
<tr>
<td>C1</td>
<td>10 µF</td>
<td>1</td>
<td>0805 SMD Chip Capacitor</td>
<td>490-3886-1-ND</td>
</tr>
<tr>
<td>C11, C2</td>
<td>100 nF</td>
<td>2</td>
<td>0402 SMD Chip Capacitor</td>
<td>490-3261-1-ND</td>
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<tr>
<td>U1</td>
<td>AA002-02</td>
<td>1</td>
<td>GMR Sensor</td>
<td>391-1045-5-ND</td>
</tr>
<tr>
<td>ESI</td>
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<td>Connector</td>
<td>S9196-ND</td>
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<td>0402 SMD Chip Capacitor</td>
<td></td>
</tr>
<tr>
<td>U2</td>
<td>DNP</td>
<td>0</td>
<td>GMR Sensor</td>
<td></td>
</tr>
<tr>
<td>R12, R14, R21, R22, R23, R24</td>
<td>DNP</td>
<td>0</td>
<td>0402 SMD Chip Resistor</td>
<td></td>
</tr>
</tbody>
</table>
6.3 **PCB Layout**

To download the layer plots, see the design files at [TIDM-GMR-WATERMTR](#).

![Layer Plot 1](#)

**Figure 8. Layer Plot 1**

![Layer Plot 2](#)

**Figure 9. Layer Plot 2**

![Layer Plot 3](#)

**Figure 10. Layer Plot 3**

![Layer Plot 4](#)

**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**

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