TI Designs

Low-Power Flow Meter Design Using Optical Sensors

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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-OPTICALWATERMTR	Design Page
MSP430FR6989	Product Folder
EVM430-FR6989	Tool Folder

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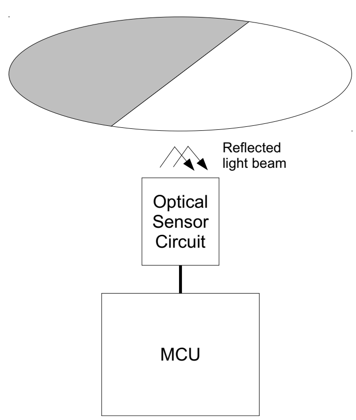
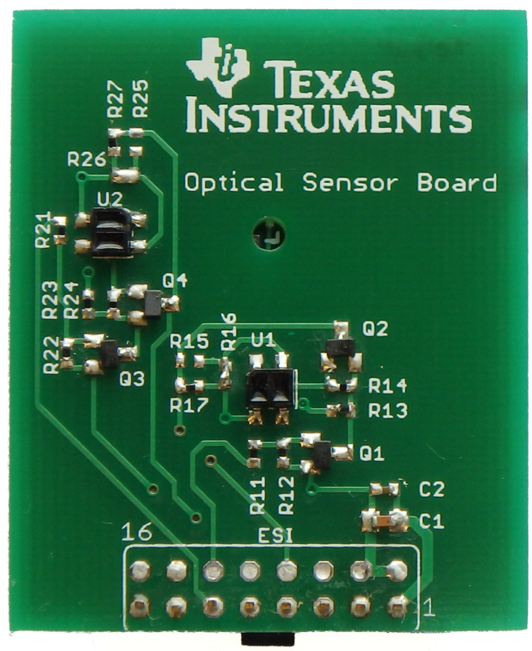
Design Features

- Daughter Optical Sensor Board for EVM430-FR6989
- Detects Rotation using Optical Sensors
- Supports Two Optical Sensors for Detecting Rotation Movement
- 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

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

An optical sensor is an example of a flow meter design that consists of two elements: an emitter (such as an IR LED) and a receiver (such as a photo diode).The receiver receives the light beam generated by the emitter. This design also uses a coded wheel to detect the rotation of the wheel driven by the flow inside the meter. Figure 1 shows an example of a coding wheel when one half has a more reflective surface while the other half is less reflective.

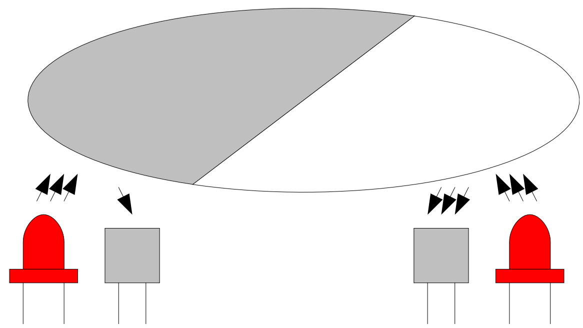

Figure 1. Optical Sensor using Coding Wheel for Rotation Detection

The emitter of the optical sensor usually consumes high current, which limits the lifetime of the system if it is battery powered. Other sub-systems, such as communication, are usually active on demand. Even if the power consumption of those sub-systems are higher, the system will not greatly increase the overall power consumption because they are idled when not in use. However, the sensor circuit needs to be active continuously to monitor the flow inside the meter over the system's lifetime. Therefore, lowering the power consumption of the sensor circuit could benefit the overall power consumption.

One of the techniques is to measure the signal of the optical sensor by measuring in samples. The emitter sends short pulses of light, and then the MCU measures the signal from the receiver. This process reduces the time to turn on the emitter, which reduces power consumption.

By using an extended scan interface (ESI), the system automates the measurement process and reduces CPU intervention, 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 by automating the turn on time of the emitter without CPU intervention.

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

2 Design Features

Figure 2 shows the connection of the optical sensor and the ESI with the excitation circuit as an enable pin. When the ESI is in an idle state, the ESICHx floats. The R_{bias} pulls the base of the PNP transistor T_{SW} to VCC. The T_{SW} turns off, halting the current flow through the optical sensor circuit. When the excitation circuit is triggered, the ESICHx pin is pulled down to the ground. The T_{SW}, as well as the optical sensor circuit, then turns on, and the T_{amp} amplifies the current signal of the receiver of the optical sensor. The output voltage is measured on R_{L2} at ESICIx. After measuring the comparator output, the excitation circuit floats again, and the optical sensor circuit turns off. This process takes a short time and is controlled by the setting of the timing state machine (TSM) of the ESI.

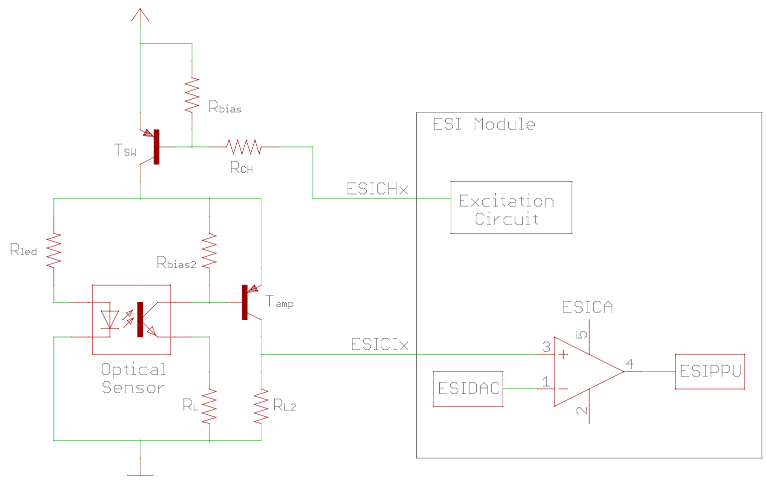

Figure 2. Optical Sensor with ESI

3 Software Description

The amount of light entering the optical receiver is translated into an analog signal. 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 coding wheel to rotate for several cycles to find out the maximum and minimum signals of the optical sensor. Two pseudo-thresholds are set dynamically based on these maximum and minimum signals. Two thresholds are then calculated for detecting the state: the bright side and the dark side of the rotating object.

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

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

4 Test Setup

An optical sensor board is plugged onto the EVM430-FR6989 main board. Two optical sensors are used for the measurement. Cover the test setup to prevent ambient light from entering the receiver of the sensor that may increase the current. 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 optical sensors and the MSP430FR6989 is shown in Figure 3.

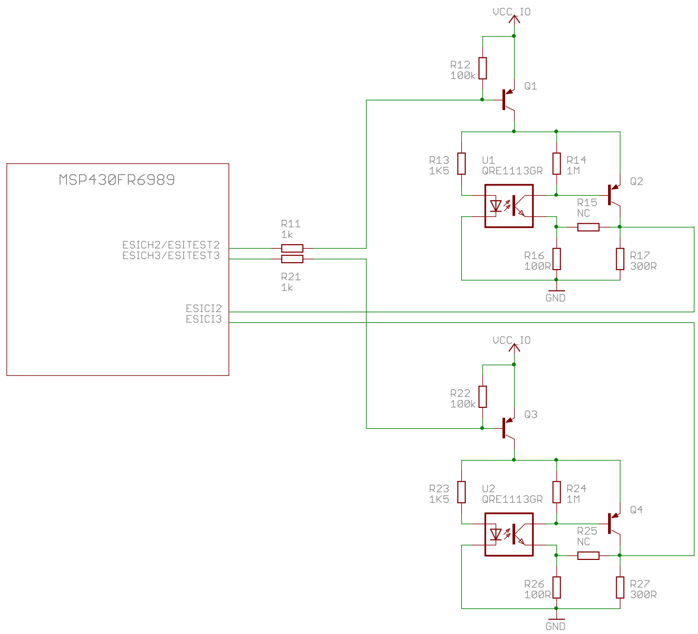

Figure 3. Connection Between Optical Sensors and the MSP430FR6989

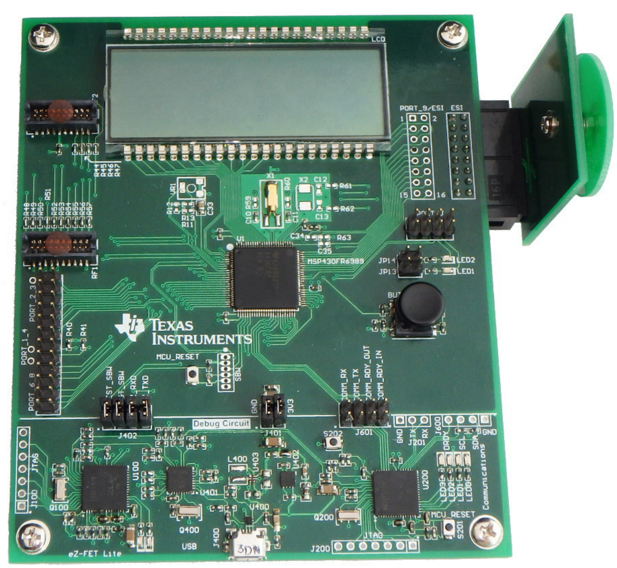

Figure 4. EVM430-FR6989 Main Board with Optical Sensor Board Attached

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 (µA) (BOTH SENSOR STATE = 0)
8	210	20	3
8	98	42	4.2
8	66	62	5.2
1	390	84	6.4
1	286	115	8
1	242	135	9.2
1	210	156	10.2
1	182	180	11.4
1	162	202	12.6
1	150	218	13.5
1	130	252	15.3
1	110	298	17.6
1	98	334	19.5
1	90	364	21.1
1	78	420	24.1
1	70	468	26.7
1	66	496	28.2

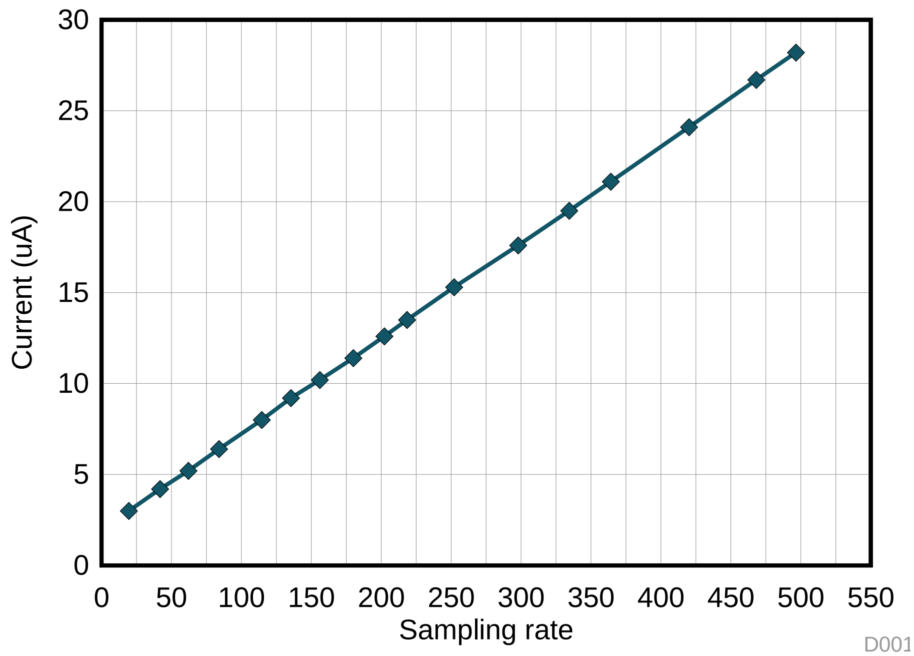

Figure 5. Sampling Rate versus Power Consumption

6 Design Files

6.1 Schematics

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

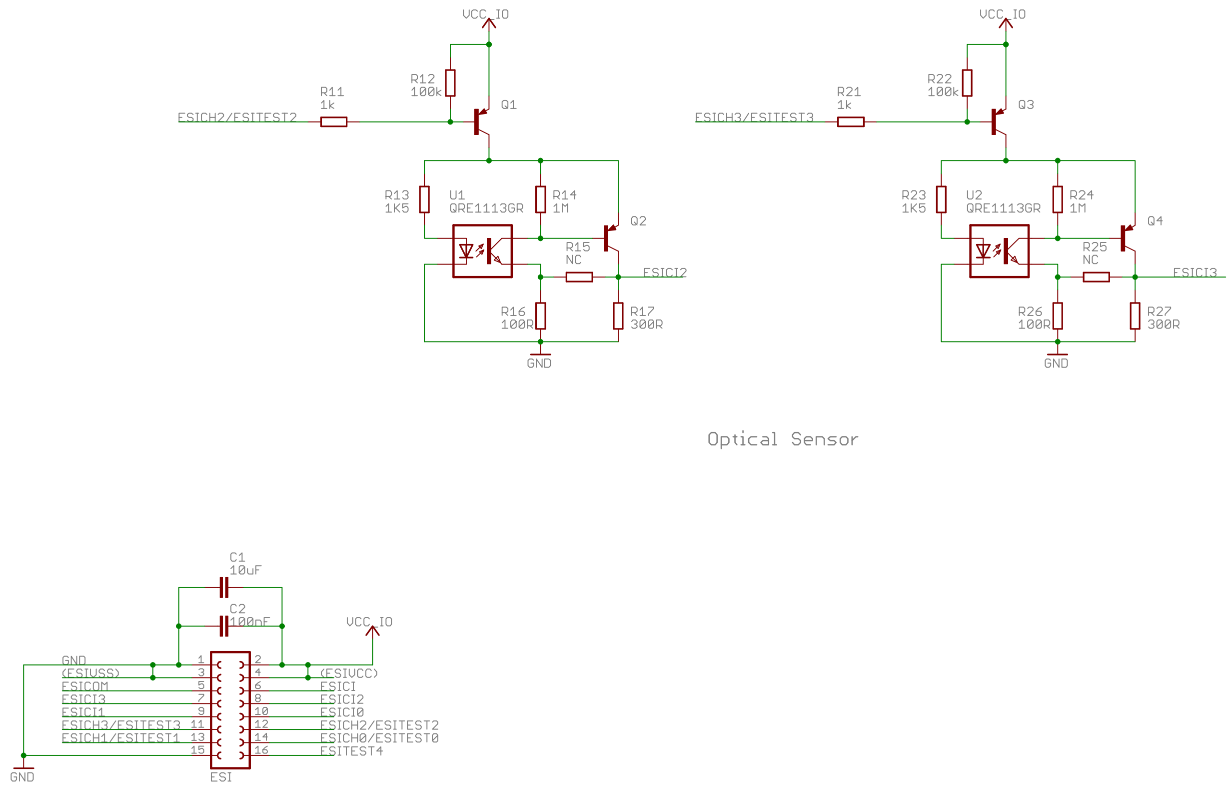

Figure 6. TIDM-OPTICALWATERMTR Schematic

6.2 Bill of Materials

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

Table 2. BOM

DESIGNATOR	VALUE	QUANTITY	DESCRIPTION
R11, R21	1 k	2	0402 SMD Chip Resistor
R12, R22	100 k	2	0402 SMD Chip Resistor
R13, R23	1K5	2	0402 SMD Chip Resistor
R14, R24	1 M	2	0402 SMD Chip Resistor
R16, R26	100 R	2	0402 SMD Chip Resistor
R17, R27	300 R	2	0402 SMD Chip Resistor
R15, R25	NC	0	Not Connected
C1	100 nF	1	0402 SMD Chip Capacitor
C2	10 µF	1	0805 SMD Chip Capacitor
Q1, Q2, Q3, Q4	MMBT3906	4	PNP BJT Transistor
U1, U2	QRE1113GR	2	Reflective Optical Sensor
ESI		1	Connector

6.3 Layer Plots

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

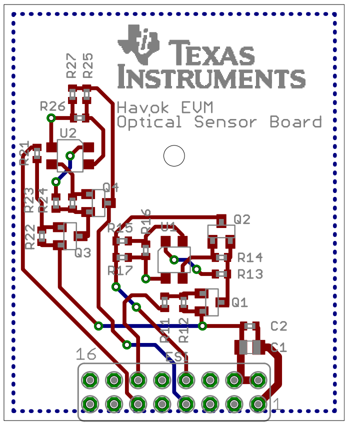

Figure 7. Layer Plot 1

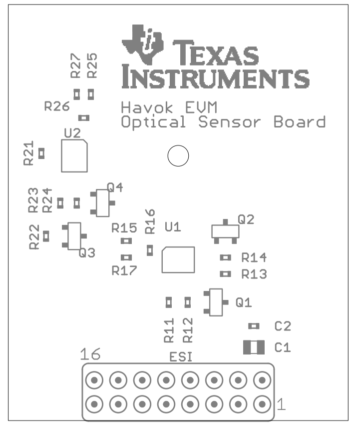

Figure 8. Layer Plot 2

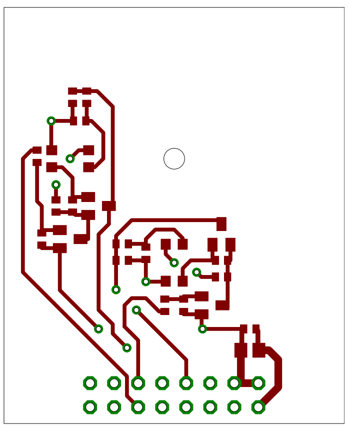

Figure 9. Layer Plot 3

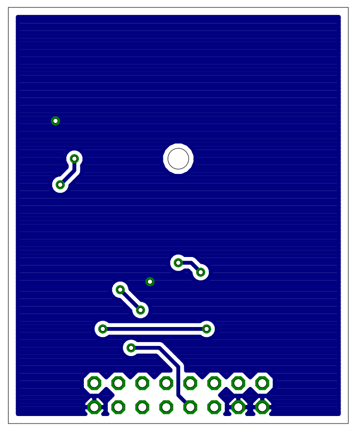

Figure 10. Layer Plot 4

6.4 Gerber Files

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

7 Software Files

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

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.