CE211301 – Interfacing the PSoC® Analog Coprocessor with a PIR Motion Sensor

Objective

This code example demonstrates how to implement an analog front end (AFE) for a Pyroelectric Infrared (PIR) motion sensor, using the PSoC Analog Coprocessor.

Overview

This code example demonstrates how to measure the voltage signal from a PIR motion sensor and detect the movement of an infrared (IR) emitting object. The measured PIR motion sensor signal and the motion detection status are sent over I^2C to a host PC running the Cypress's Bridge Control Panel (BCP) software. The RGB LED turns ON whenever motion is detected.

Requirements

Tool: PSoC Creator™ 3.3 CP3 or later versions

Programming Language: C (ARM® GCC 4.9.3)

Associated Parts: All PSoC Analog Coprocessor parts

Related Hardware: CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit

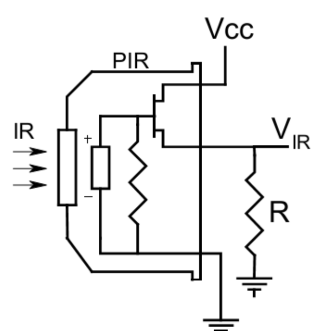
Design

PIR Motion Sensing – Theory of Operation

The PIR motion sensor is based on the pyroelectric effect, where certain materials generate a voltage when exposed to infrared radiation. This radiation is the portion of the electromagnetic spectrum that falls between microwaves and visible light. Infrared radiation has wavelengths longer than the visible light but shorter than microwaves. Humans at normal body temperature radiate strongest in the infrared at an approximate wavelength of 10 µm.

The PIR motion sensor uses infrared sensitive materials as the sensing elements. It is packaged with a field effect transistor (FET) in the source follower mode, as Figure 1 shows. FET is required to buffer the high-impedance output of the sensor element. When the sensor element is exposed to infrared radiation, a voltage is generated across the element.

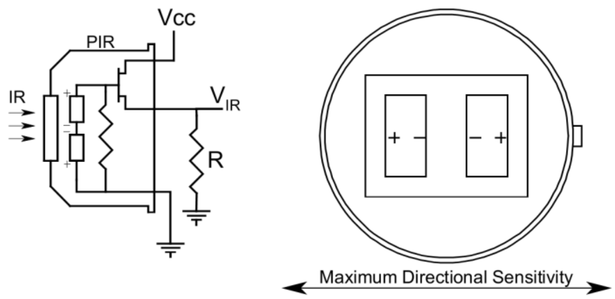
Figure 1. PIR Motion Sensor – Single-Element



Most of the common PIR motion sensors have two or four sensing elements. These elements are arranged such that the voltage generated by one is subtracted by the other. This arrangement cancels the common signal and generates a voltage only when there is a difference in the incident infrared radiation level on the sensing elements.

Figure 2 shows the dual element PIR motion sensor with the elements connected in series but with an opposite phase, because of which it has maximum sensitivity along a particular axis.

Figure 2. PIR Motion Sensor Dual-Element



The sensor package is designed to have a unique field-of-view for each element. When an IR radiating source moves across the fields of view, the sensor generates a differential signal (see Figure 3). For a 90° field-of-view or more, a Fresnel lens is mounted on the PIR motion sensor. It improves the sensitivity and thus the detection distance.

Figure 3. PIR Motion Sensor Output Response

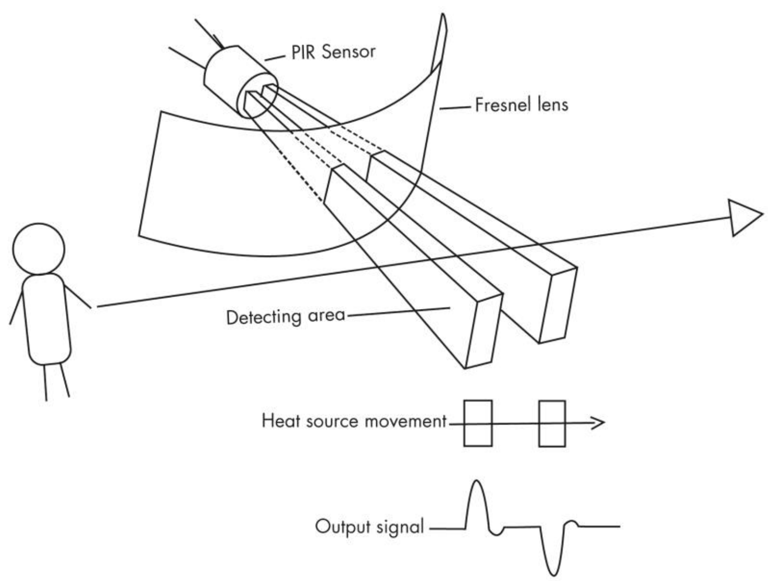
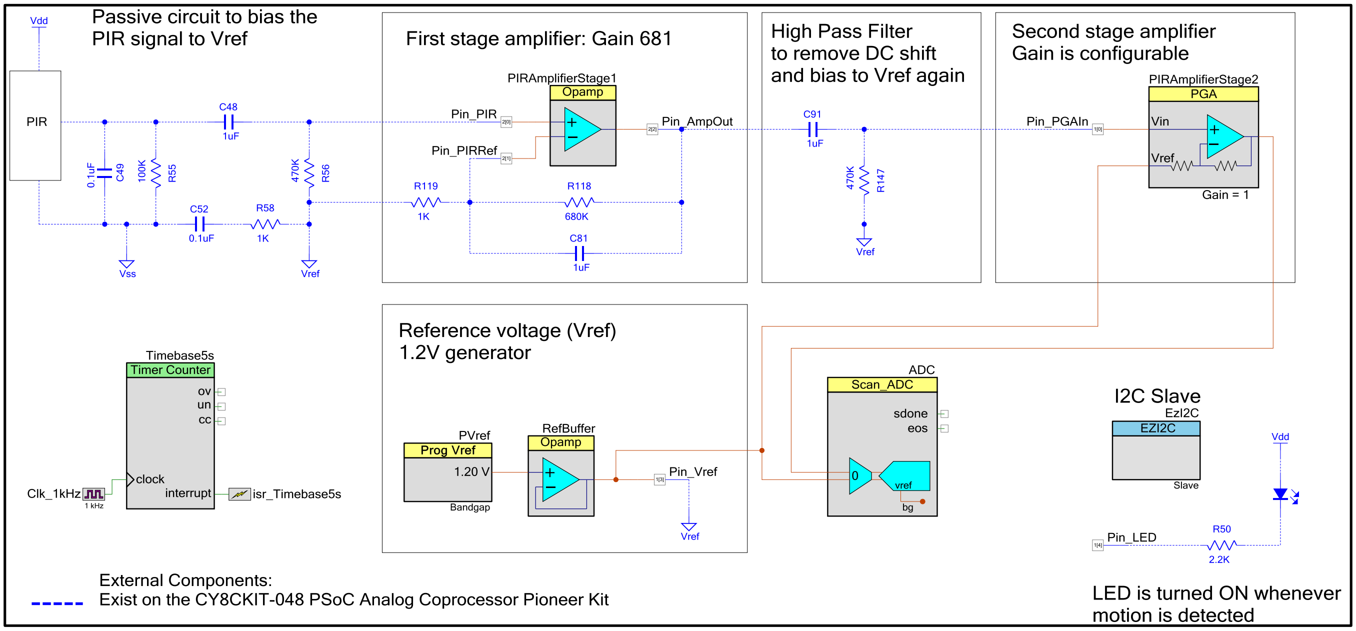


Figure 4 shows the PSoC Creator schematic for interfacing a PIR motion sensor with the PSoC Analog Coprocessor.

Figure 4. PIR Motion Sensing Schematic



The PIR motion sensor implementation on the CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit consists of five stages: a bias circuit for the PIR motion sensor, a first-stage amplifier, a high-pass filter (HPF), a second-stage amplifier, and an ADC. In the main stages of the PIR motion sensor implementation, the two amplifiers are implemented in the PSoC Analog Coprocessor.

The PSoC Analog Coprocessor Pioneer Kit has a dual-element PIR motion sensor (ZRE200GE). The voltage signal generated by the sensor is AC-coupled (using C48) and clamped to the internal reference voltage V_{REF}. The typical sensor output voltage is in the order of several millivolts and varies depending on the strength of the incident infrared radiation. To detect the motion of a human body at a distance of 10 feet, a gain of >1000 is required. A single-stage amplifier with such a high gain causes the amplifier output to saturate due to the amplification of the input offset voltage. Thus, a two-stage amplifier is best suited for amplifying with high gain.

The total gain is split between two stages. The first-stage amplifier uses a non-inverting amplifier configuration using an internal Opamp and external gain setting resistors – R118 and R119. The second-stage amplifier uses a PGA Component. The first stage amplifier gain is set to 681 and the PGA gain is set to 1 on startup. However, the second-stage amplifier gain changes depending on the detection distance required – 3 feet, 10 feet, or 20 feet.

A HPF, made using external passive components C91 and R147, is introduced between the first and the second amplifier stages to eliminate the offset voltage.

The PIR motion sensor and gain stages use a 1.2-V bandgap voltage as the reference voltage. The bandgap voltage is independent of supply voltage fluctuations and hence provides a stable voltage reference. This voltage is generated using a programmable reference component, PVref, and is buffered using an Opamp.

The output of the second-stage PGA is connected to the Scanning SAR ADC Component. The Scanning SAR ADC results are compared against threshold values to detect the motion of an IR emitting object. When motion is detected, the LED turns ON for 5 seconds.

In addition to indicating the status on an LED, multiple data such as PIR raw count, detection thresholds, and detection status are sent to a host PC using I^2C. The host PC sets the desired detection distance over I^2C.

Design Considerations

This design can be adapted for other PIR motion sensors. You may need to change amplifier gains depending on the sensor characteristics.

This code example is designed for the PSoC Analog Coprocessor Pioneer Kit. The design is easily portable to other kits and PCBs, typically by just changing the sensor, I^2C, or LED pin assignments.

Hardware Setup

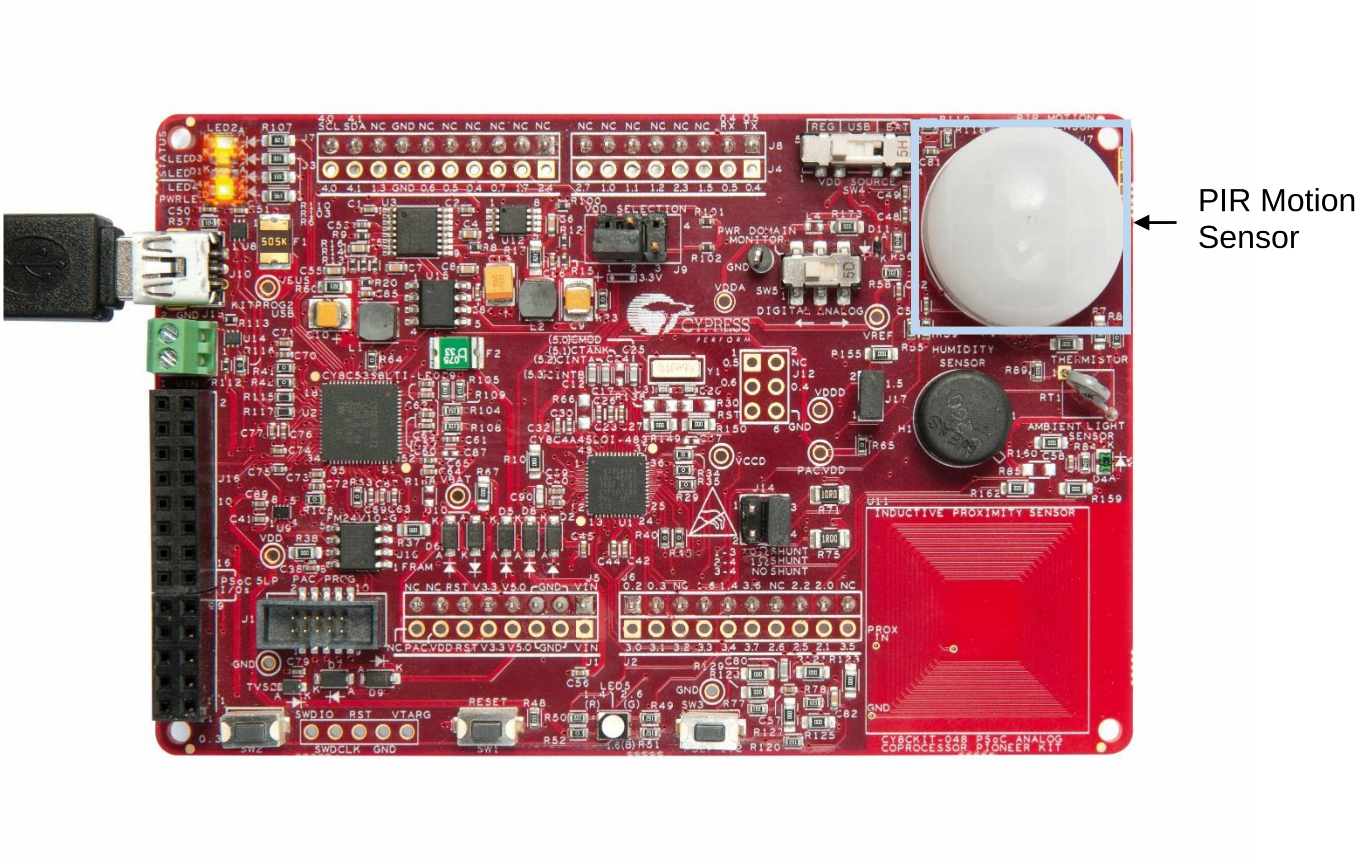
Set the SW4 switch on the PSoC Analog Coprocessor Pioneer Kit to ‘REG’ position, to select the regulator as the V_{DD} source. Set the jumper J9 to 1-2 for 3.3-V device operation. If you want to use a different power source or a different V_{DD} value, select the SW4 and J9 settings based on Table 1.

Table 1. PSoC Analog Coprocessor Pioneer Kit Power Supply Source and V_{DD} Selection

Power Supply Source	V_{DD} (volts)	SW4 (switch position)	J9 (jumper position)
USB	1.8	REG	open
	3.3	REG	1-2
	5.0	USB	Any position except 2-3
	1.8 - 3.3	REG	4-2
External VIN	1.8	REG	open
	3.3	REG	1-2
	5.0	REG	2-3
Arduino baseboard	1.8	REG	open
	3.3	REG	1-2
Coin Cell	3.0	BAT	NA

Connect the PSoC Analog Coprocessor Pioneer Kit to your computer’s USB port, using the USB cable provided with the kit, as Figure 5 shows. Ensure that the Fresnel lens is mounted on the sensor.

Figure 5. Hardware Connection



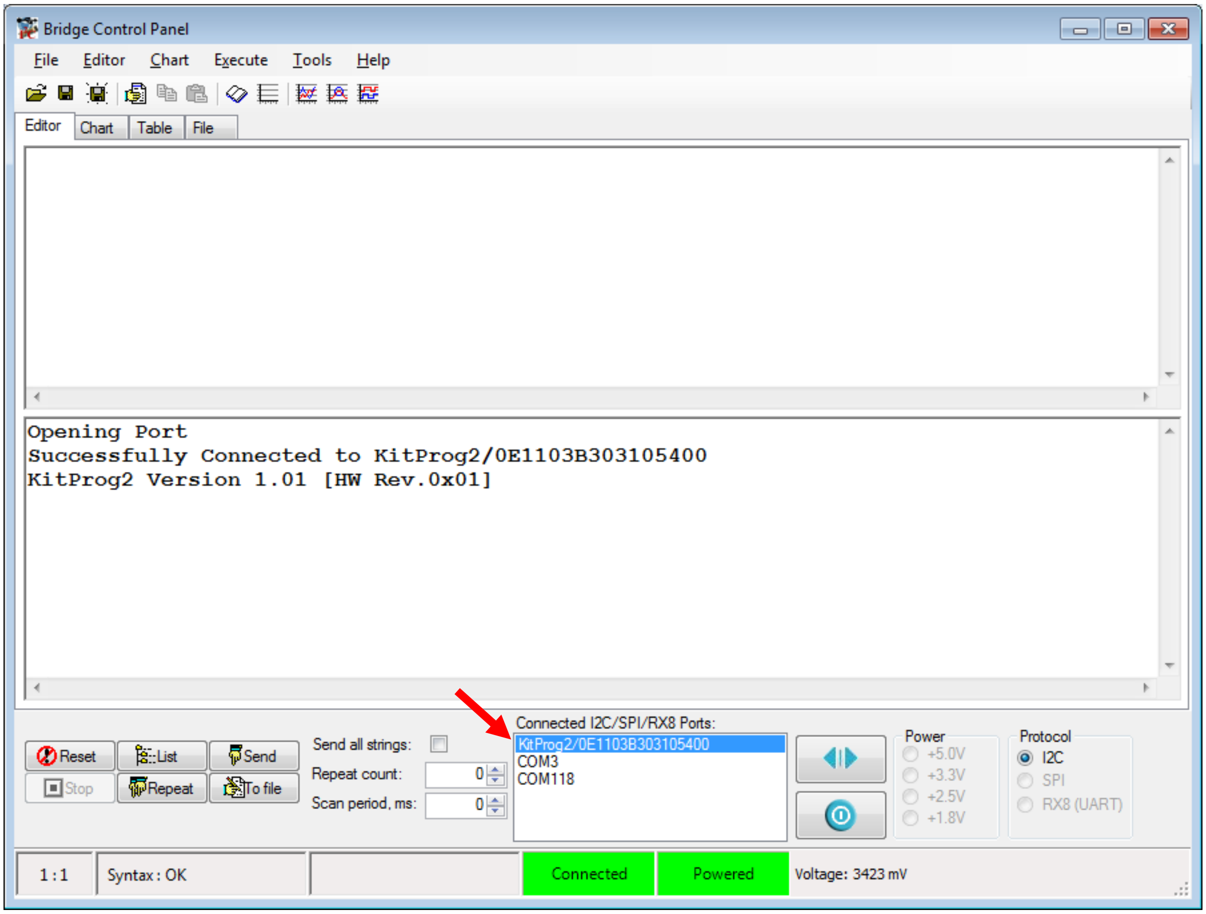
Software Setup

This section describes how to set up the Cypress Bridge Control Panel (BCP) software for viewing sensor data sent over I^2C.

The BCP is installed automatically as part of the kit software installation. Follow these steps to configure the BCP:

1. Open the BCP from: **Start** > **All Programs** > **Cypress** > **Bridge Control Panel <version>** > **Bridge Control Panel <version>.**
2. Select **KitProg2/<serial number>** under **Connected I2C/SPI/RX8 Ports** (see Figure 6). Note that the PSoC Analog Coprocessor Pioneer Kit must be connected to the USB port of your computer.

Figure 6. Bridge Control Panel

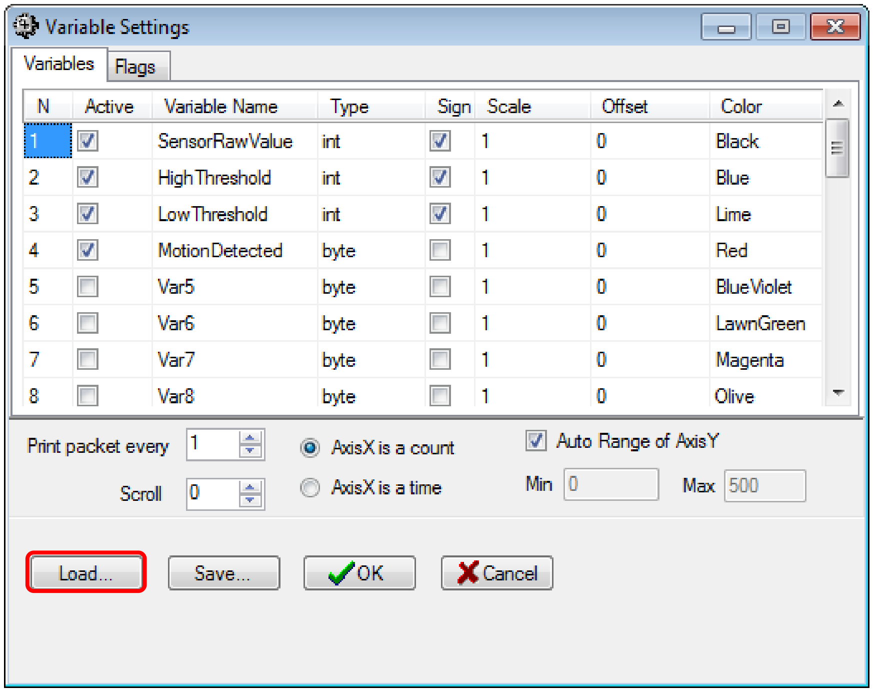


3. Select menu item **Tools** > **Protocol Configuration**, navigate to the **I2C** tab, and set the **I2C speed** to ‘100 kHz’. Click **OK**.

4. Select menu item **Chart** > **Variable Settings** and **Load** the *CE211301_PIR_Motion_Sensing.ini* file from the following path: <Install_Directory>\CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit\<version>\Firmware\PSoC Analog Coprocessor\BCP Command\. Click **OK**. See Figure 7.

   This file includes the variable names, their data type, and their signs, to represent the data sent over I^2C.

Figure 7. Variable Settings in Bridge Control Panel Software



The BCP is now ready for reading and displaying the sensor data. Refer to the Operation for the testing procedure.

Components

Table 2 lists the PSoC Creator Components used in this example and the hardware resources used by each Component.

Table 2. List of PSoC Creator Components

Component	Instance Name	Version	Hardware Resources
Scanning SAR ADC	ADC	v1.10	SAR ADC
Opamp	RefBuffer	v1.20	Continuous Time Block (CTB)
Opamp	PIRAmplifierStage1	v1.20	Continuous Time Block (CTB)
PGA	PIRAmplifierStage2	v1.0	Continuous Time Block (CTB)
PVref	PVref	v1.0	Programmable Reference Block (PRB)
Clock	Clk_1kHz	v2.20	Clock
Timer Counter (TCPWM Mode)	Timebase5s	v2.10	Timer Counter Pulse Width Modulator (TCPWM)
EZI2C Slave (SCB mode)	EZI2C	v3.20	Serial Communication Block (SCB)
Analog Pin	Pin_Vref, Pin_PGAIn, Pin_AmpOut, Pin_PIR, Pin_PIRRef	v2.20	I/O
Digital Output	Pin_LED	v2.20	I/O

Parameter Settings

Table 3 lists the non-default settings of all the components used in the design.

Table 3. Component Parameters

Component Instance Name	Settings (Non-Default)
ADC	Free-run scan rate (SPS): 10000 Number of Channels: 1
RefBuffer	Mode: Follower Output: Output to pin Power/Bandwidth: High
PIRAmplifierStage1	Output: Output to pin Power/Bandwidth: High
PIRAmplifierStage2	-
PVref	-
Clk_1kHz	Frequency: 1 kHz
Timebase5s	Compare/Capture: Compare Period: 4999 Compare: 2500
EZI2C	-
Pin_PIR , Pin_PGAIn, Pin_AmpOut, Pin_PIRRef, Pin_Vref	External terminal: Enabled
Pin_LED	Digital output > HW connection: Disabled External terminal: Enabled

Note EZI2C pins are embedded within the Component.

Design-Wide Resources

Table 4 shows the physical pins used.

Table 4. Pin Names and Locations

Pin Name	Location
EZI2C: SCL	P4[0]
EZI2C: SDA	P4[1]
Pin_LED	P1[4]
Pin_PIR	P2[0]
Pin_PIRRef	P2[1]
Pin_AmpOut	P2[2]
Pin_PGAIn	P1[0]
Pin_Vref	P1[3]

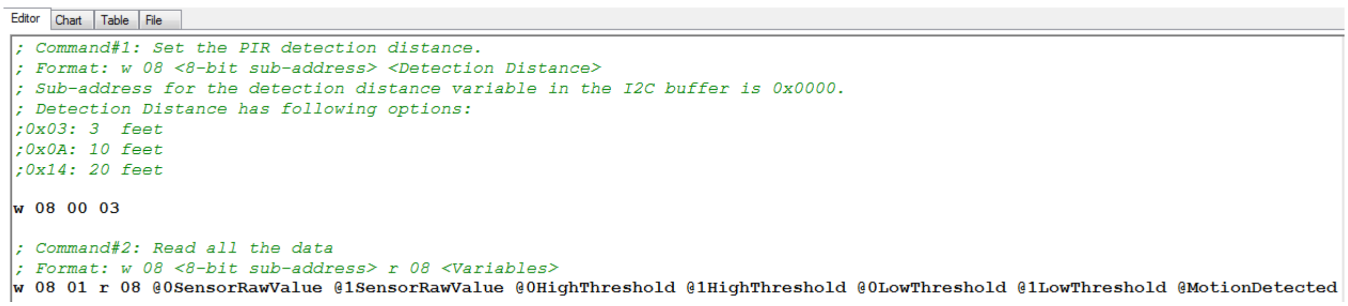
Operation

Follow these steps:

1. Select the *CE211301_PIR_Motion_Sensing.cywrk* file in the PSoC Creator Start page, under **Examples and Kits** > **Kits** > **CY8CKIT-048**. Select a location to save the code example.
2. Build the project; select the PSoC Creator menu item **Build** > **Build CE211301_PIR_Motion_Sensing**.
3. Connect the PSoC Analog Coprocessor Pioneer Kit to your computer's USB port, as described in the section Hardware Setup.
4. Program the PSoC Analog Coprocessor device; select **Debug** > **Program**.
5. Configure the BCP software as described in the section Software Setup.
6. Select **File** > **Open File**. Open the *CE211301_PIR_Motion_Sensing.iic* file, from the following path: `<Install_Directory>\CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit\<version>\Firmware\PSoC Analog Coprocessor\BCP Command\`

   This file contains the read and write commands to be executed by the BCP. The commands appear on the panel, as Figure 8 shows.

   Figure 8. Read and Write Command in the Bridge Control Panel

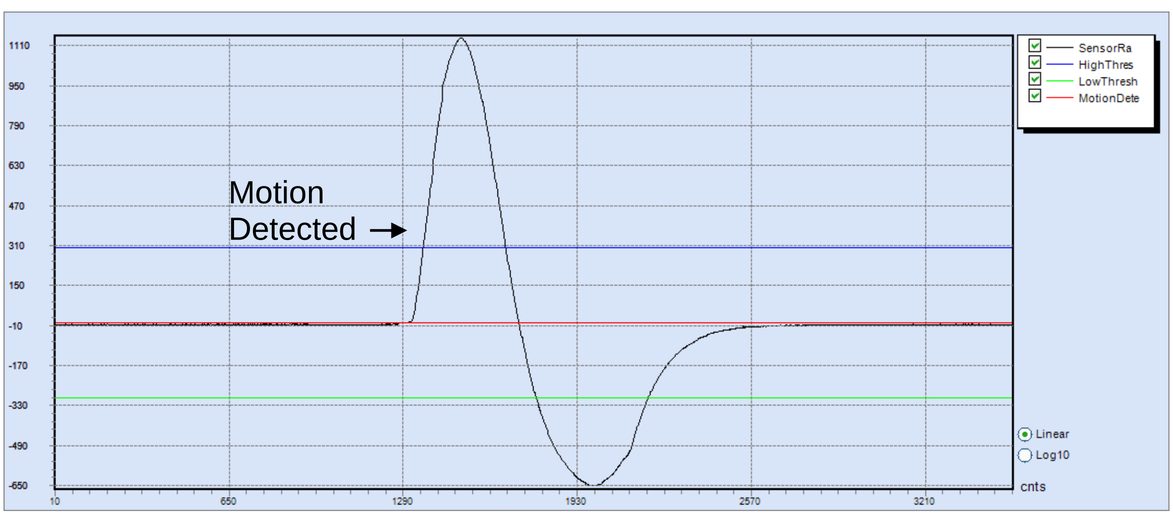
   

   ```
   Editor | Chart | Table | File
   ; Command#1: Set the PIR detection distance.
   ; Format: w 08 <8-bit sub-address> <Detection Distance>
   ; Sub-address for the detection distance variable in the I2C buffer is 0x0000.
   ; Detection Distance has following options:
   ;0x03: 3  feet
   ;0x0A: 10 feet
   ;0x14: 20 feet

   w 08 00 03

   ; Command#2: Read all the data
   ; Format: w 08 <8-bit sub-address> r 08 <Variables>
   w 08 01 r 08 @0SensorRawValue @1SensorRawValue @0HighThreshold @1HighThreshold @0LowThreshold @1LowThreshold @MotionDetected
   ```

   To set the detection distance, use command #1 - "w 08 00 03". To execute the command, click on the instruction and then click the **Send** button. See the comments in the BCP for more details on the instruction.
7. To read the sensor data, click on command #2 and then click the **Repeat** button. This reads the data continuously.

   Go to the **Chart** tab and observe the plot of the four values – PIR Motion Sensor raw data, high threshold, low threshold, and motion detection status – that are read from the PSoC Analog Coprocessor device. See Figure 9.

   Figure 9. PIR Motion Sensor Data on the Bridge Control Panel Chart

8. Move across the PIR Motion Sensor within the range specified using Command #1. Observe that the red LED turns ON for 5 seconds when the motion is detected. Note that because of the higher sensitivity of the 20-feet mode, the LED may be ON continuously if you are close to the sensor. Make sure the red LED is OFF before making any movement.

Related Documents

Table 5 lists all relevant application notes, code examples, knowledge base articles, device datasheets, and Component datasheets.

Table 5. Related Documents

Application Notes		
AN211293	Getting Started with PSoC Analog Coprocessor	Describes the PSoC Analog Coprocessor.
PSoC Creator Component Datasheets		
Scanning SAR ADC	Supports multiple channel hardware scan with single ended and differential input modes	
PGA	Support configurable gain of 2 to 32	
PVref	Generates configurable voltage references using internal bandgap voltage or supply voltage VDDA	
Opamp	Supports voltage follower mode and the Opamp mode with configurable power	
EZI2C Slave	Simplified I2C slave implementation	
Pins	Supports connection of hardware resources to physical pins	
Timer Counter	Supports Timer, Counter, PWM functions	
Device Documentation		
PSoC Analog Coprocessor Datasheets		
PSoC Analog Coprocessor Architecture Technical Reference Manual		
PSoC Analog Coprocessor Register Technical Reference Manual		
Development Kit (DVK) Documentation		
CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit		

Document History

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Document Number: 002-11301

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	5301267	DIMA	06/08/2016	New code example.

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Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709

Phone : +1-408-943-2600
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