



# Module 6

Introduction: General Purpose Input Output



# Introduction: General Purpose Input Output

## Educational Objectives:

**REVIEW** C programming

**UNDERSTAND** direction registers, input, and output

**EXPLORE** conversion from light to voltage, and voltage to binary

**LEARN** how to write software to initialize GPIO pins

**DESIGN, BUILD & TEST A SYSTEM**

Detect position relative to a black line on a white field

**Prerequisites** (Modules 1, 2, and 4)

- Running code on the LaunchPad using CCS (Module 1)
- Voltage, current, resistance, capacitance (Module 2)
- Basic C programming (Module 4)

**Recommended reading materials for students:**

- Volume 1 Sections 4.1 and 4.2  
**Embedded Systems: Introduction to the MSP432 Microcontroller**  
**OR**  
**ISBN: 978-1512185676, Jonathan Valvano, copyright (c) 2017**
- Volume 2 Sections 2.2 and 2.4  
**Embedded Systems: Real-Time Interfacing to the MSP432 Microcontroller, ISBN: 978-1514676585, Jonathan Valvano, copyright (c) 2017**

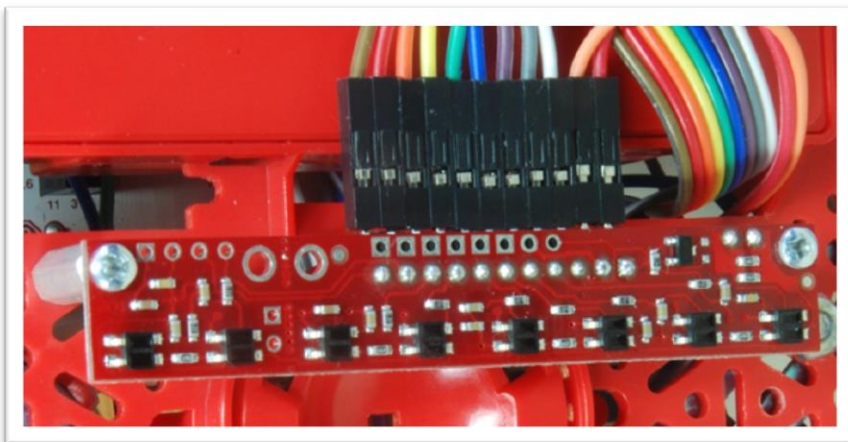


Figure 1. QTR-1RC line sensor, positioned on the bottom of the robot.

The simplest I/O port on a microcontroller is the parallel port, or **general purpose input output** (GPIO). A parallel I/O port is a mechanism that allows the software to interact with external devices. It is called parallel because multiple signals can be accessed all at once. Ports 1 – 10 are 8 bits wide meaning we read and write port pins 8 bits at time. Not every port on the MSP432 LaunchPad has all 8 pins.

An **input port** allows the software to read external digital signals. That means a read cycle access from **P1->IN** returns the values existing on the inputs of Port 1 at that time. To make a pin input, we write a 0 to its direction register. A write cycle access to an input port usually produces no effect. Input pins on some microcontrollers are 5V-tolerant, meaning input voltages can vary from 0 to 5.0 V. However, pins on the MSP432 are not 5-V tolerant, meaning the input voltages must be between 0 and 3.3 V.

While an input device usually just involves the software reading the port, an **output port** can participate in both the read and write cycles very much like a regular memory. A write cycle to **P1->OUT** will affect the values on the output pins of Port 1. To make a pin output, we write a 1 to its direction register. Since it is a readable output, a read cycle access from the port address returns the current values existing on the port pins. We can either read from **P1->OUT**, returning the values previously written, or read from the pins themselves to see the pin values, **P1->IN**.

To make the microcontroller more marketable, the ports on most microcontrollers can be software-specified to be either inputs or outputs. Microcontrollers use the concept of a **direction register** to determine whether a pin is an input (direction register bit is 0) or an output (direction register bit is 1). We define an initialization ritual as a program executed once during start up that initializes hardware and software. If the ritual makes the direction bit zero, the port pin behaves like a simple input, and if it makes the direction bit one, the port pin becomes a readable output. Each digital port pin has its own direction bit. This means some pins on a port may be inputs while others are outputs.



## Introduction: General Purpose Input Output

In the lab associated with this module, you will interface a line sensor to the microcontroller, see Figure 1. Proper function of the sensor will require you to fully understand the direction register and how to perform input and output. This lab does provide an opportunity to improve your C programming skills including debugging with CCS and with an oscilloscope. Since there are measurements in this lab, you will be able to discover performance metrics such as accuracy, monotonicity, specificity, standard deviation (noise), and coefficient of variation. In previous modules, you developed code on the MSP432 using CCS, but in this module you will create a major component required to build the robot explorer. Other labs will provide additional sensors for the robot controller. In **10. Debugging** you will add bumper switches, and implement this line sensor interface using interrupts.

The basic approach to system development is to create components and then piece the components together to create the system. In this module, you will design develop and test the line sensor measurement required for the for robot explorer.

## IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY 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 products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources 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 RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2018, Texas Instruments Incorporated