Interfacing Electronic Devices

Objectives

In this lab, you will build simple circuits using electronic devices and interface it with the VEX microcontroller.

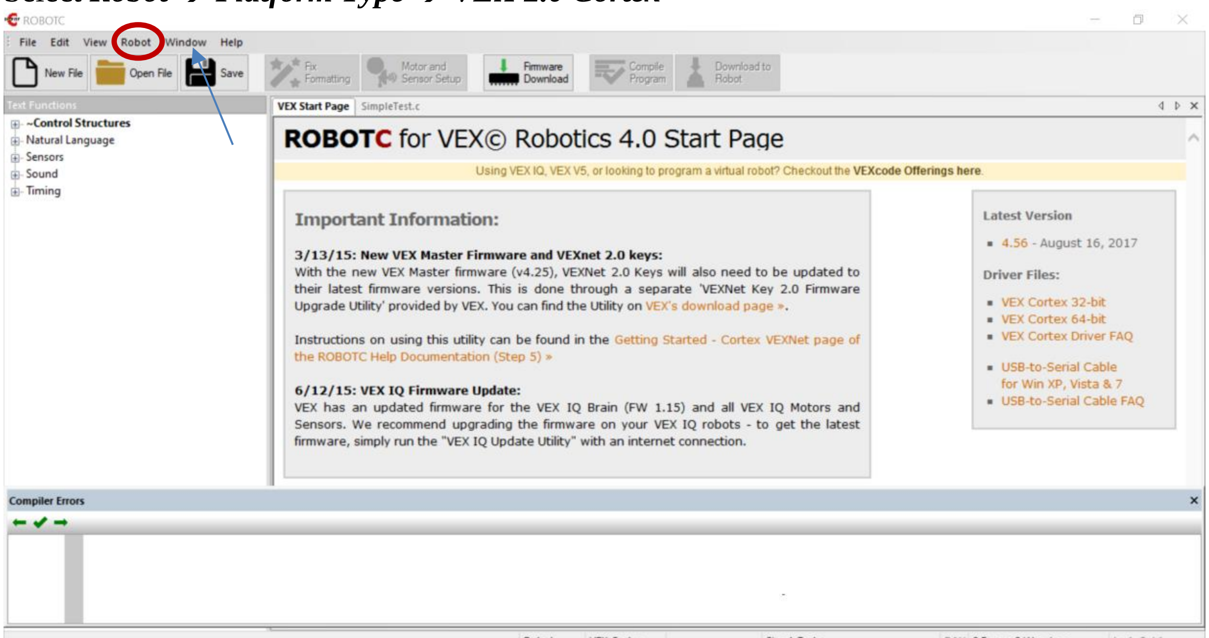
Overview

In this lab, you will learn to build and interface circuits comprising of electronic devices. The circuit can sense environmental variable (example: IR light) and share it with the microcontroller for further actions.

Note: Since RobotC comes with a fairly good debugger, and you have your VEX kits already, feel free to test your code outside of lab time. You can refer to the videos given here:
https://www.robotc.net/teaching_rc_cortex_v2/lesson/index_reference.html

Getting Started

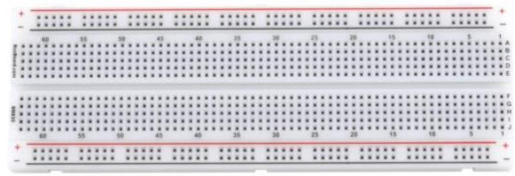
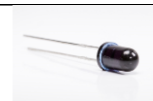
1) Connect your VEX microcontroller to a lab computer using the USB cable
2) Connect the battery to the VEX microcontroller and turn-on the power button
3) Open *RobotC for VEX* in the computer
4) Select ***Robot → Platform Type → VEX 2.0 Cortex***



5) Select ***Robot → VEX Cortex Communication Mode → VEXnet or USB***
6) Select ***Robot → Download Firmware → Automatically Update VEX Cortex***
7) Select ***Window → Menu level → Super User***
8) Turn-off the power to the microcontroller.

Exercise 1 – Familiarizing with the components

Parts list:

Component	**Quantity**	**Image**
Breadboard	**1**	
Resistor	**1**	
LED (*image corresponds to a red LED*)	**1**	
Infrared (IR) sensor	**1**	

1. **<u>Breadboard</u>**:
In this lab, you will be using the breadboard from your kit. This breadboard consists of grids and lines of sockets which can hold the ends of wires, VEX connector pins, and any component leads. The breadboard electrically connects the sockets as shown in Figure 1, where an orange line indicates an electrical connection between the sockets under the line.

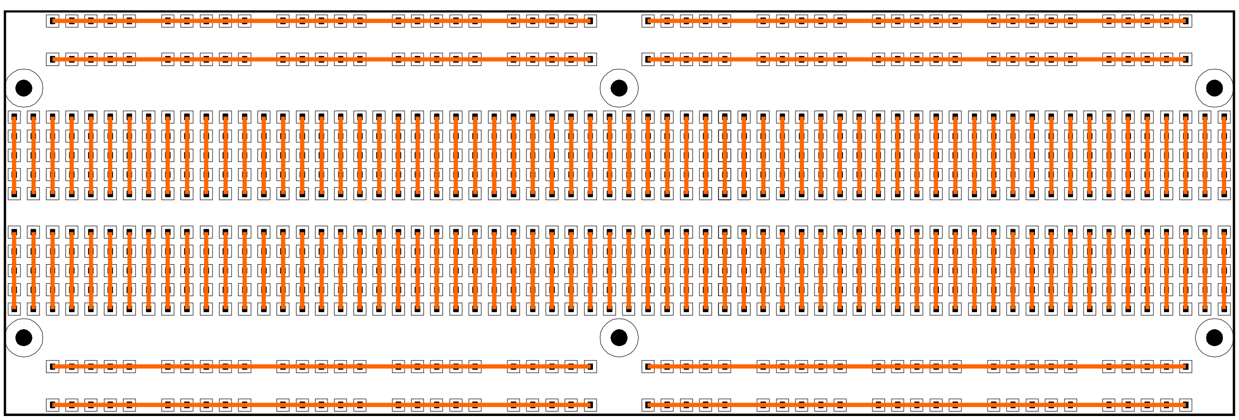


Figure 1: Breadboard Connectivity (lines indicate ports which are electrically connected)

2. **<u>Resistor</u>**:
A resistor is an electrical component that has two terminals. A resistor is not polarized, so flipping its terminal will not have any impact. A resistor will limit current flowing in a circuit. This property is defined as resistance. Moreover, when current flows through it, a resistor will have voltage across the two ends of it. To build a circuit with two resistors as given below, one could use the wiring shown in Figure 2.

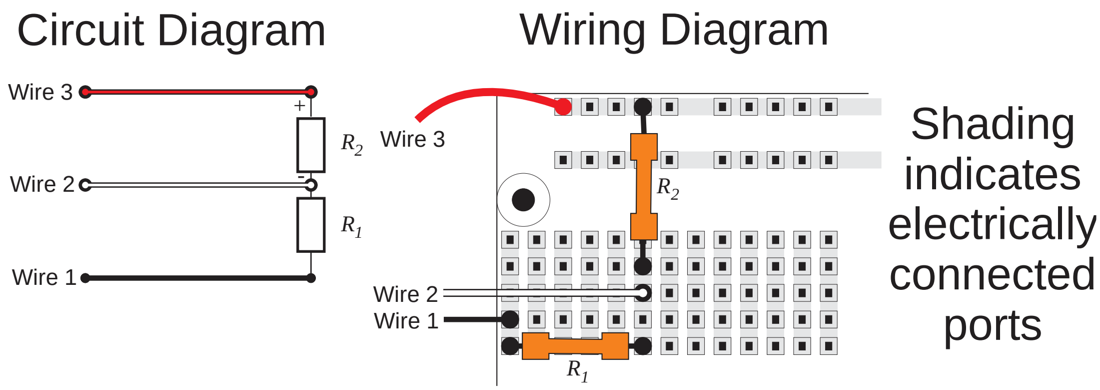


Figure 2: Circuit diagram and breadboard wiring for two resistors

3. **<u>LED (Light Emitting Diode)</u>**:
   An LED is a two terminal device. An LED is a polarized device. One of the terminals is called Anode (A) and the other terminal is called Cathode (K). An LED will emit light when its Anode is connected to the positive terminal of a battery and its Cathode is connected to the negative terminal of the battery. LEDs can only carry a finite amount of current. Therefore, it is common practice to place a resistor in between the battery and the LED as shown in Figure 3 to limit the current flowing through the LED.

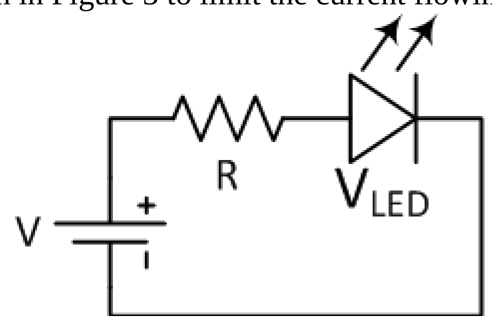


Figure 3: Circuit schematic of a battery powering an LED. A resistor is connected in the circuit to limit the current through the LED.

   An LED emits light of a particular wavelength (colour). A red LED emits visible red colored light whereas an infrared LED emits invisible light (although one can see it using the mobile phone's camera).

4. **<u>Infrared (IR) sensor</u>**:
   An IR sensor is also a polarized two terminal device. One of the terminals is the Collector (C) and the other terminal is the Emitter (E). For the best operation, the IR sensor should be inserted such that there is a positive voltage applied to the Collector terminal relative to the Emitter terminal. If it is inserted backwards, the sensitivity of your sensor will be severely reduced.
   The IR sensor has a resistance R(X) which is a function of X, an environment parameter of interest. In this case, the environment parameter of interest is the intensity of infrared light. The resistance of the IR sensor is 0 (zero) when it is illuminated by intense infrared light. When there is no infrared light illuminating the IR sensor, its resistance tends to be infinite.
   Typically, IR sensors are connected to microcontrollers as shown in Figure 4. The circuit for interfacing IR sensor with the VEX controller (as shown in Figure 4) is called the voltage divider circuit. The output voltage, V_1, is given by

$$V_1 = \frac{\mathrm{R}(X)}{R(X)+R_1} V_{source} \tag{1}$$

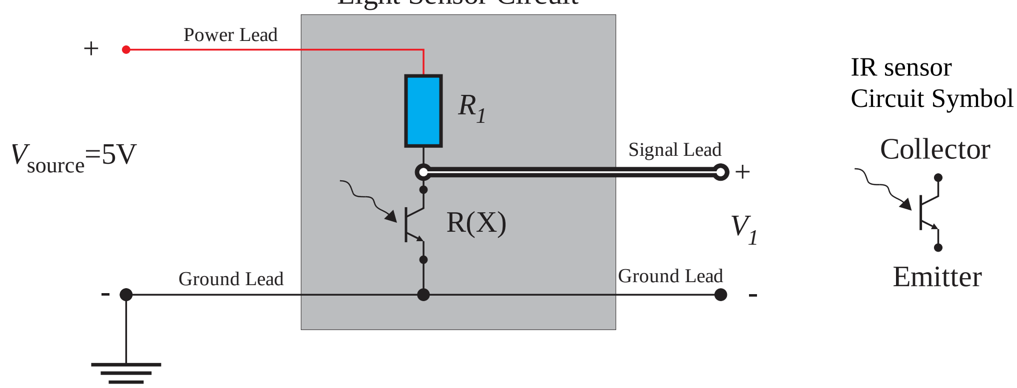


Figure 4: Circuit schematic of a typical IR sensing circuit.

Referring to Equation (1), if the IR sensor is placed in the voltage divider, V_1=0 indicates intense light of the proper wavelength is detected as $R(X) \rightarrow 0\ \Omega$. On the other hand, $V_1 \approx V_{source}$ indicates the presence of no light at the proper wavelength as $R(X) \rightarrow \infty\ \Omega$. Any value of voltage in between these two extremes indicates a proportional change in intensity of the detected light.

To convert the sensor voltages to a digital value that can be processed by the microcontroller, a device known as an Analog-to-Digital Convertor (ADC) is employed. The VEX controller has ADC units connected to each of its ANALOG ports to measure the voltage between the "Signal" connector and "Ground" connector. The ANALOG ports are capable of giving quantitative measurements, which indicate the level of the voltage applied to each port. The ANALOG port values can be read as value between 0 and 4095, which maps to an input voltage from zero to five Volts respectively.

For the voltage divider circuit of Figure 4, the Collector terminal of the IR sensor is connected to the Signal lead of an ANALOG port in the VEX and the Emitter terminal of the IR sensor is connected to a ground lead of an ANALOG port. When this is done, one can read a value proportional to the voltage V_1 with a function call within the RobotC program.

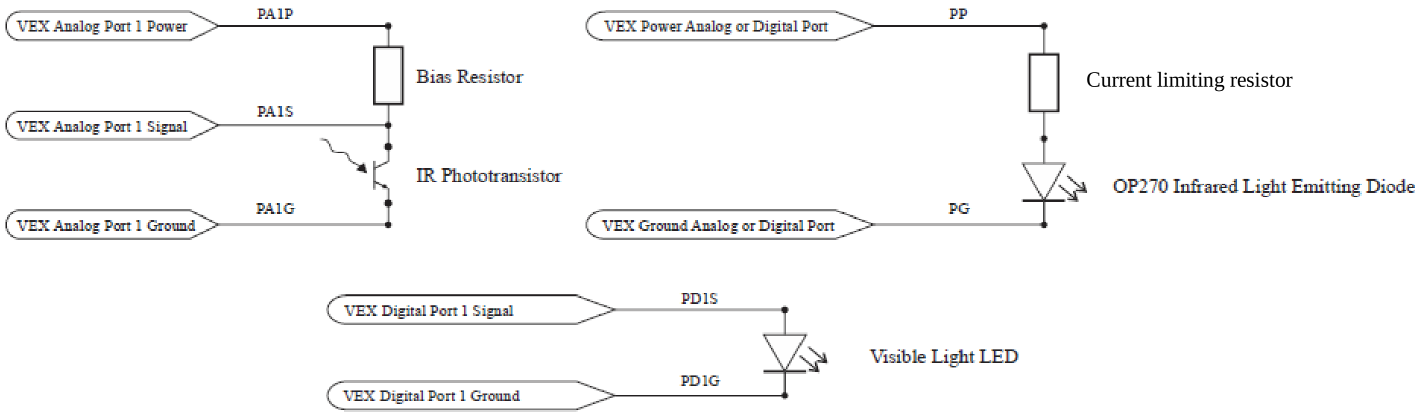
Exercise 2 – Building the circuit

Parts list:

Component	Quantity
Breadboard	**1**
Bias resistor to be used with the voltage divider circuit of the IR sensor	**1**
Current limiting resistor to be used with the IR LED circuit	**1**
Infrared (IR) sensor to detect IR light *(IR phototransistor)*	**1**
Red LED	**1**
Infrared (IR) LED to emit IR light	**1**
Connecting wires of different colours	**As required**
Battery powered VEX microcontroller	**1**

Wiring:

Using the schematic diagram shown below, build the circuits and interface them with the VEX microcontroller.



Circuit Notes:
- Signals for Power Ports Pins at 5 Volts whenever VEX controller is powered.
- Signals for Ground Ports Pins are at 0 Volts (ground) whenever VEX is powered.
- Infrared LED should be continuously on when VEX is powered.
  * The circuit for the OP270 Infrared LED can be hooked up the Power and Ground lines of any VEX Analog or Digital Port.
- Voltage of signal PA1S decreases when phototransistor is exposed to infrared beam from LED.
- VEX Analog Port 1 is configured for Reflection Sensor.
- VEX Digital Port 1 is configured for Digital Output.
  * VEX Digital Port 1 outputs 3.3 V on signal line when 1 is written to port.
  * VEX Digital Port 1 outputs 0 V on signal line when 0 is written to port.

Notes:

a. *Ensure that your VEX controller is powered down before you make any connections.*

b. *Use Red color wire for POWER port, black color wire for GROUND port and a different color wire for SIGNAL port.*

c. *Build the circuits for the VEX ports ANALOG 1, DIGITAL 1, and the IR LED in order. Initially use a 1000-ohms resistor for the bias resistor of the IR sensor circuit on ANALOG 1. Do not change the ports used, or the circuit will not communicate with the controller using the RobotC code supplied for this lab.*

d. *It is important that the LEDs and phototransistor are inserted in the correct directions. The infrared LED package base is rounded on the side with the wire lead for the anode and has a flattened portion on the side with the wire lead for its cathode.*

e. *The phototransistor package's base has a flat side for its collector lead and a rounded side for its emitter lead.*

f. *Gently bend the phototransistor and IR LED lead wires about 90 degrees so the top part of the phototransistor and IR LED can face each other when they are aligned on the breadboard. Place them in the breadboard so that the IR LED and IR Phototransistor are 10 cm apart and facing each other. Make sure that the direct path between the active ends of the IR LED and phototransistor device is not obstructed.*

Your TA will demonstrate/help with the wiring and/or will check the wiring before you can proceed.

Exercise 3 – Familiarizing with the code

Step 1: Loading the supplied code

Connect the VEX microcontroller to the computer. Load the supplied code *IR-sensor.c* (available in Brightspace) and

a. Check the type of sensors configured for ports in1 and dgtl1. This can be done by selecting the ***Robot→Motors and Sensors Setup*** and then clicking on the ***VEX 2.0 Analog Sensors 1-8*** and the ***VEX Cortex Digital Sensors 1-12*** tabs in the ***Motors and Sensors Setup*** window. Make sure the sensors are set up as below:

Port	Port Number	Name	Sensor Type	Purpose
in1	Analog Port 1	InfraCollector	Light Sensor	IR detector (Input)
dgtl1	Digital Port 1	RedLED	Digital Output	Visible Light LED (Output)

b. You will see the program listing show up in the main RobotC window and two additional windows pop up. The additional windows are the ***Program Debug Window*** and the ***Sensors*** window. If these windows do not open, you can find and open them by selecting the ***Robot→Debugger Window*** options. In this lab, you will be using the ***Sensors*** window to track the value the VEX controller is currently reading from or writing to each of the controller's ANALOG/DIGITAL ports.

c. Start the program on the VEX controller.

d. As soon as the program starts, the IR LED should be activated. Check that your IR LED is lit. The IR LED does not emit enough visible light for you to see with your eyes if it is on. Fortunately, most semiconductor-based imaging devices, such as the camera on some cellular telephones, are somewhat sensitive to IR light. If you set the camera to view finding mode, where the current image from the camera is shown on the phone screen, and aim the camera at the IR LED, you will see a blue light coming from the LED in the camera's viewfinder when the IR LED is on. Some cellular telephone cameras have filters to block this IR light so don't worry if you cannot see this light. You can also measure the voltage between the IR LED's leads as well to detect if the LED is on; if the voltage over the LED is in the range of 0.5 to 2.0 volts then the LED is probably operating.

Please ask your TA to check the work before you proceed.

Step 2: Check the sensors and program operation.

a. The program is designed to turn the red LED ON when the value on the *InfraCollector* sensor port drops below the constant IR_SENSOR_THRESHOLD, which should be set to the value of 1000.

b. Save your code. Recompile the program and download the code to the VEX controller.

c. Make sure that the VEX sensor port states are being updated continuously in the ***Sensors*** window. This can be done by clicking the ***Continuous*** button under the ***Refresh Rate*** heading in the ***Program Debug*** window.

d. Stop the program execution with the ***Step Into*** button in the ***Program Debug*** window.

e. Set the phototransistor to face the IR LED so that the *InfraCollector* sensor reads below the IR_SENSOR_THRESHOLD in the ***Sensors*** window.

f. Step through the program and confirm that the red LED is turned on by the controller.

g. Block the direct path between the IR LED and phototransistor so the *InfraCollector* sensor reads above the IR_SENSOR_THRESHOLD value.

h. Step through the program and confirm that the red LED is now turned off properly by the controller.

Please ask your TA to check the work before you proceed.

Step 3: Confirm that the IR LED and IR photodetector interact correctly.

a. Find the sensor port values when the direct path between the IR LED and phototransistor between are not blocked and when they are unobstructed. Measure the voltage between the signal line and the ground line on Analog port 1 for the two conditions. Measure the voltage the multi meter in your kit. Record the port values and the voltages in the table below.

b. Change the bias resistor to 100 Ω. Repeat the port and voltage measurements from part (a) above with the new bias resistor value.

c. Change the bias resistor to 1MΩ. Repeat the port and voltage measurements from part (a) above with the new resistor value.

Bias Resistor Value	Low Port Value	Low Port Voltage	High Port Value	High Port Voltage
100 Ω				
1000 Ω				
1 MΩ				

Questions to ponder:

1. What is the effect of changing the current limiting resistor connected to the IR LED?
2. What changes will you make to the circuit/program so that your robot can detect IR light flashing at 10 Hz?

END OF LAB