LESSON B-13

LEVEL SHIFTING & INFRARED SENSORS

In this lesson you will learn about shifting the voltage level of signals, when it is necessary, as well as working with infrared obstacle and line sensors.

Signal Level Shifting

In previous lessons you learned that digital signals can be either high or low. The voltage level of a low is always zero volts, but the voltage level of a high signal can depend on the piece of equipment you are working with.

The GPIO pins on a Raspberry Pi operate in the range of 0 to 3.3 volts, with 3.3V representing a high signal. Another popular microcontroller board is called the Arduino and its GPIO pins are based on a system with a range of 0 to 5 volts. In the case of the Arduino, a high signal will be 5V.

Many devices, such as infrared sensors or RFID readers, are specifically designed to communicate using either 3.3V or 5V signals, but you must ensure they are compatible with your device. An Arduino can accept 5V signals and can generally interface with 3.3V devices as well. The Raspberry Pi, with its lower 3.3V GPIO voltage, will be damaged if connected to a device that sends out signals at a 5V level. Therefore, it is extremely important to understand what signal levels a device will be outputting before connecting it to your Raspberry Pi.

Generally, devices will use their supply voltage to determine the voltage level used for communication. If an RFID reader is powered by 3.3V, then it will likely communicate using 3.3V as a high signal. If an infrared obstacle sensor is powered by 5V then it will likely communicate using 5V as a high signal. These are only general rules, so always confirm that a device will not communicate using voltages above 3.3V if you plan to connect it directly to the GPIO pins of your Raspberry Pi.

Hardware Level Shifting

What if you find a really interesting sensor that was designed to communicate with an Arduino using 5V, but you want to use it in your Raspberry Pi? For that, you can use hardware level shifting to convert the signal from 5V down to 3.3V.

A hardware level shifter is an IC or circuit board that converts one voltage level to another. They are available in many voltage levels, but for these lessons you will be focusing on 3.3V and 5V. These level shifters can come in a few different varieties:

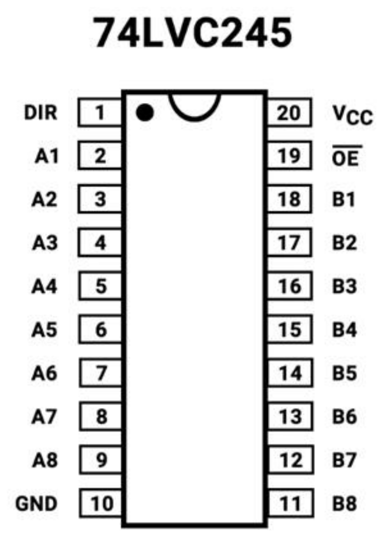
3.3V to 5V – converts a 3.3V input signal to a 5V output signal

5V to 3.3V – converts a 5V input signal to a 3.3V output signal

3.3V/5V Bidirectional – converts both 3.3V and 5V inputs into the opposite output

Bidirectional level shifters are generally more costly since they can convert between 3.3V and 5V in both directions. These devices are used to enable two-way communication between two devices, one using 3.3V signals and one using 5V signals.

If two-way communication is not required, then a standard, or unidirectional level shifter can be used to shift the voltage level of signals coming from a 5V sensor, into signals that are safe for Raspberry Pi GPIO pins. One model of IC used for this purpose is the 74LVC245.



The 74LVC245 is an 8-channel level shifter that is capable of level shifting 8 signals at once. By varying its input voltage, this IC has the ability to shift 3.3V inputs to 5V outputs, or shift 5V inputs to 3.3V outputs. To the right is the pinout of the 74LVC245 IC.

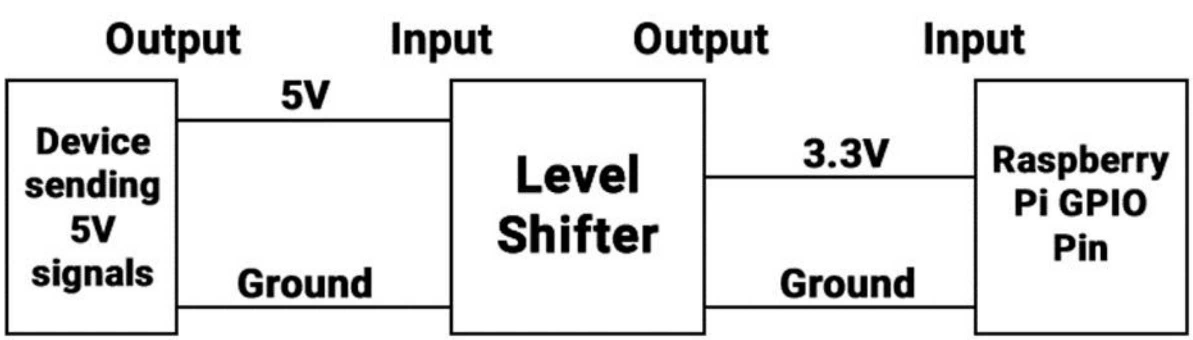
The VCC and GND pins will be connected to 3.3V and Ground. A1 through A8 and B1 through B8 are the configurable input or output pins. Applying 3.3V or Ground to the DIR and OE pins determines whether As or Bs will be used as inputs. We will be using A as the inputs and B as the outputs. The datasheet for this part states that to enable communication in this direction, OE must be low or grounded, and DIR must be high or 3.3V. This is the way we will configure the IC in the activities section so that the A side can be used as 5V inputs, and the B side will be the 3.3V outputs.

A channel is made up of A and B pins sharing the same number. This means that A1 and B1 are one channel, with A being the input, and B being the output. If a 5V high is seen at input A1 then the IC will make B1 go to 3.3V to represent a high. A2 feeds to B2, A3 feeds to B3, and so on.

Important Note:

Take notice of the location of each input and output channel. THEY DO NOT LINE UP. On many of these level shifting ICs, the inputs and outputs are directly opposite, but this is not the case on the 74LVC245. The OE next to VCC pin forces all of the pins on the B side to shift down by one, causing a slight misalignment of inputs and outputs. This means that if you're feeding in a 5V sensor on A6 (pin 7), do not expect the 3.3V output to be present on across from it on pin 14, as that is actually the output for channel 5. The output for channel 6 is B6 on pin 13. Keeping this small offset in mind when you're wiring inputs and outputs on this IC will help minimize troubleshooting due to outputs not behaving as expected.

When shifting signals from 5V down to 3.3V, the IC should be powered by 3.3V. Below is a diagram of a 74LVC245 being used to connect a 5V sensor to a GPIO pin of the Raspberry Pi:

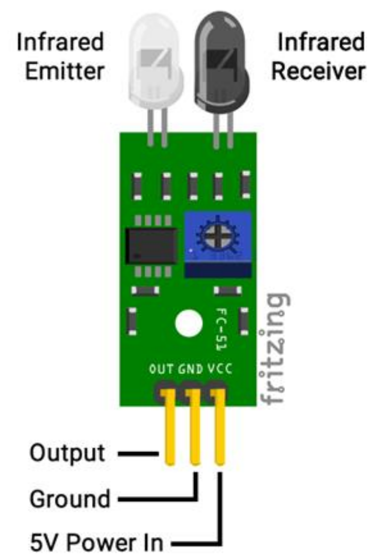


The sensor outputs a 5V signal that would damage the Pi if connected directly. The 5V signal is instead connected to the input of the level shifter. The level shifter takes the 5V input and converts it to 3.3V. This 3.3V output can then be connected directly to a GPIO pin of the Raspberry Pi. If the sensor outputs a 5V high, the Pi will see a 3.3V high, and your program can use this data in any way that you like.

Infrared Obstacle Sensor

An infrared or IR obstacle sensor is a device that uses infrared waves to determine if an object or surface is near the sensor. A 5V output line is used to report whether or not an object is near the sensor. This output line can be level shifted down to 3.3V and connected to an input on your Raspberry Pi, allowing a program to know if something has come close to the sensor.

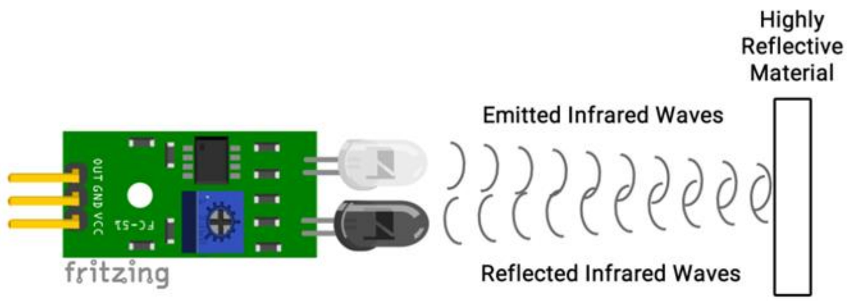
The obstacle sensor included in your kit has an active low output, which means that when no object is detected the output line will have a high or 5V present. When an obstacle is detected this output line will go to ground or 0V. Your program must be coded to understand that high means no object has been detected, and that low represents that an object is near the sensor.

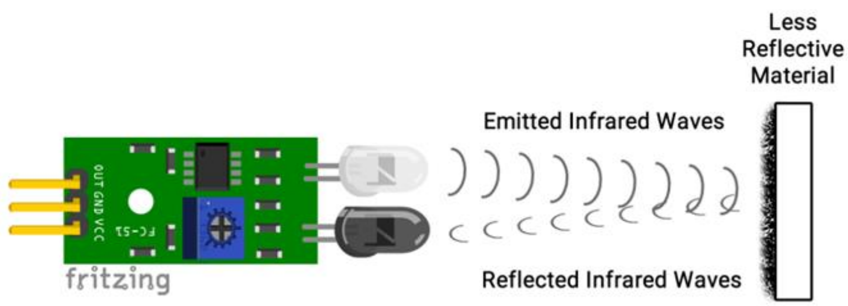


The sensor contains an infrared emitter and receiver, located next to each other.

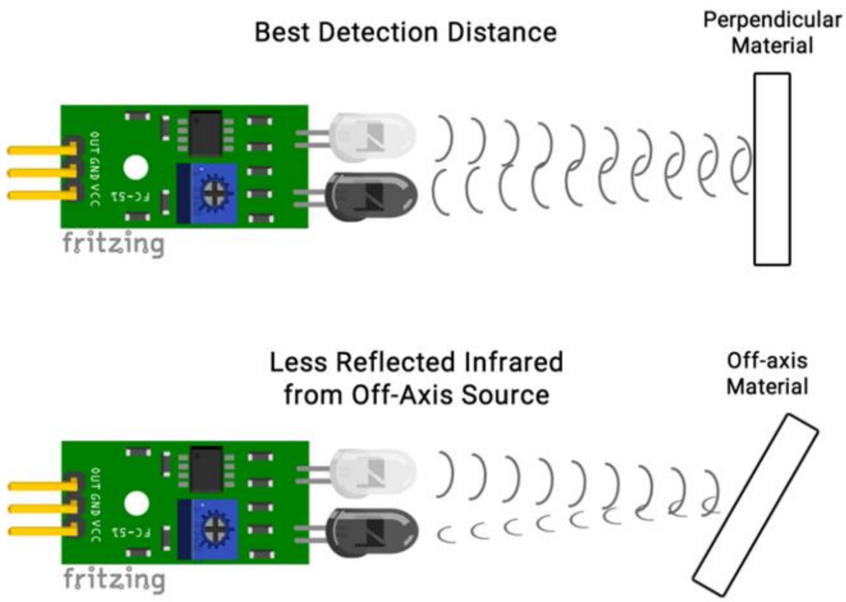
The infrared emitter constantly sends out infrared signals, and receiver is constantly waiting to receive those signals back. If an object is close enough to the sensor, the emitter signals will bounce off the object and reflect back to the receiver. The sensor then knows that something is close, and the circuitry on the sensor board will pull the output pin low, indicating an object is near. If an object is not close enough to reflect the emitted signals back to the receiver, then the sensor will know that no object is near the sensor, and the output pin will remain high.

The infrared reflectance of an object is its ability to reflect infrared energy. This reflectance will determine how far away a sensor will see infrared reflected from that surface. A wall in your house will have a fairly high level of reflectance, so the sensor will likely be able to detect it from 4-6 inches away. A furry blanket or pet will have very low infrared reflectance, which will likely lower the detection distance down to 2 inches or less.





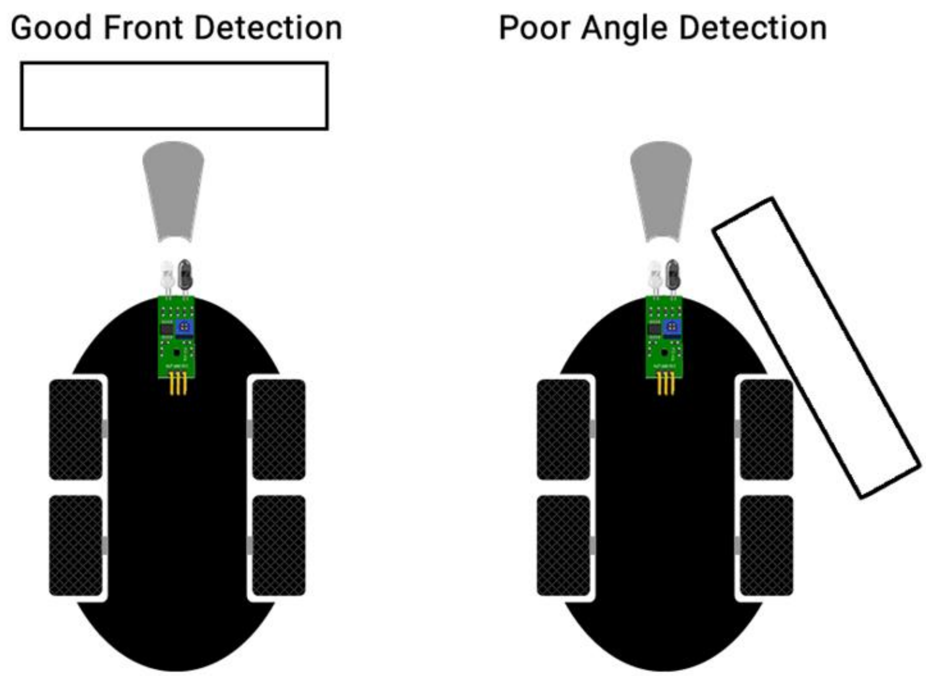
The detection distance will also be affected by the angle at which the emitted infrared contacts the surface of the object. An object reflecting perpendicular to the sensor will offer the highest level of reflectance, allowing for the greatest possible detection distance. The further an angle is from 90-degrees, the lower the amount of reflectance that surface will offer, which will lower the detection range:



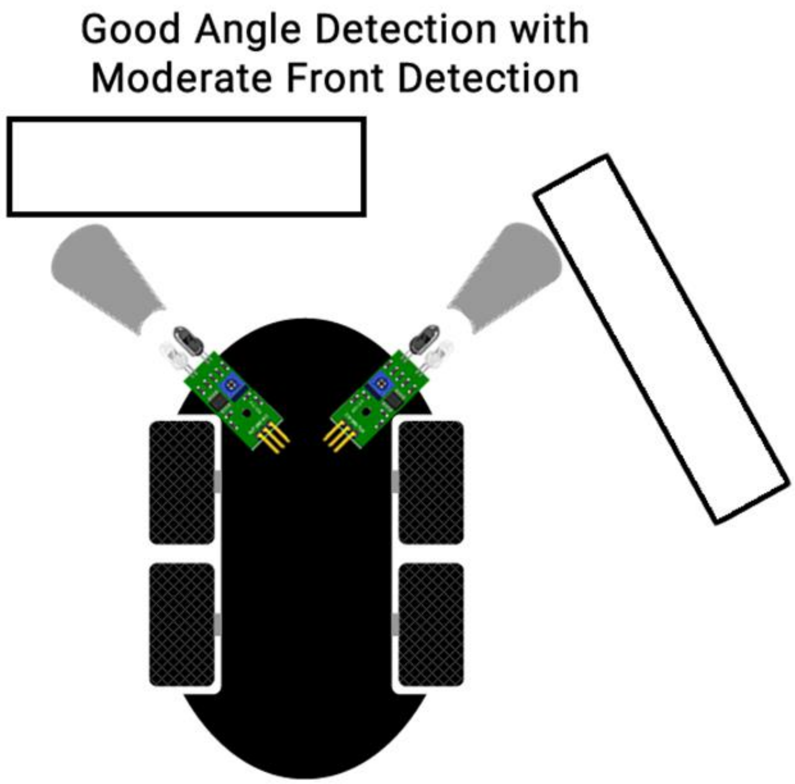
The type of infrared obstacle sensor in your kit is good for sensing objects that are fairly close to the sensor. This type of sensor will not tell you how far away an object is, only that something is near the sensor, making it a good option for keeping a robot from running into walls or other objects. If measuring the distance to objects or sensing objects at distances greater than 10 inches are required, there are other, slightly more complex sensors available for that task.

Alignment of Obstacle Sensors

An IR obstacle sensor can be added anywhere that touchless object sensing is needed. They might be used for obstacle avoidance on a robot, or to sense the presence of your hand to run part of a program. These sensors will only detect objects in a narrow area in front of the sensor, so their alignment may need to be adjusted to ensure they cover the desired area:



In order to get coverage for the tire area, sensors can be mounted at a 45-degree angle. This will allow for angle detection while still providing some front detection:

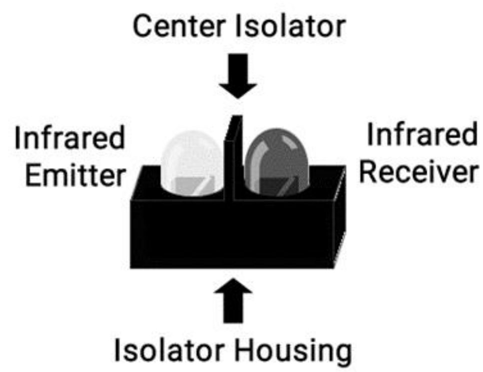


A different type of long-range distance sensor can then be mounted on the front of the robot to provide additional obstacle information. This type of sensor will be discussed in an upcoming lesson.

Infrared Line Sensor

An infrared line sensor can be used to detect the difference between dark colors and light colors using infrared waves. This can allow a robot to perform an activity referred to as “line following” where it can follow a black line, often created by using black electrical tape, on any light-colored surface. The robot can follow the path created by the tape without any intervention from the user, using only the IR line sensor input and the program.

The infrared line sensor operates almost exactly like the infrared obstacle sensor. The only difference is that the emitter/receiver have been relocated from the front to the bottom of the board. Since the line sensor is always close to the surfaces it’s detecting, a plastic shroud is installed around and between the emitter and receiver, to limit emission and detection to just the ends of those components, enhancing accuracy.

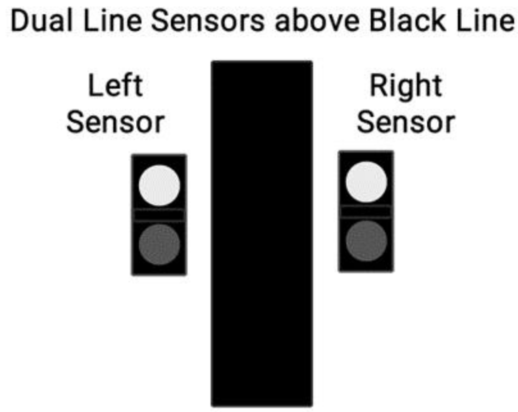


The line sensor operates using the infrared properties of different colored objects. Black objects absorb most of the infrared waves they receive, so they have a low level of infrared reflectance. White objects reflect almost all the infrared energy they receive, so they have a high level of infrared reflectance. As colors vary between white and black, so will their infrared reflectance, lighter colors having higher reflectance, and darker having lower.

The sensor uses this difference in reflectance to determine if it’s positioned above a black or white surface. The 5V output pin is then updated to match the color that is currently being sensed, with low or 0V indicating black and high or 5V indicating white. If no object is close enough to reflect the infrared, the output will also stay low.

Alignment of Line Sensors

You could follow a black line using only one IR line sensor. The sensor would need to be positioned directly above the line, and your robot would have to be programmed to drive one motor at a time. If white was sensed by the line sensor, the current motor has driven you off the line, and the other motor needs to drive until you are back on the line.



While this would technically work, your robot would have to move extremely slowly to avoid getting away from the line too quickly and getting lost. Adding a second sensor allows you to watch both sensors, and if either sees black, then turn away from the line. This allows you to sense a larger area, so your robot can follow the line faster without getting lost:

Using two sensors is the most cost-effective way to make a robot reliably follow a line but continuing to add sensors can enhance the robot's ability to follow a line quickly. Some line sensing packages, like the one pictured below made by SunFounder, have as many 8 infrared sensors:

This can greatly increase your robot's ability to know the exact position of the line, however your program will have to be much more complex to process and act on the data from all 8 sensors. To keep your programming as simple as possible, you will only be using two line sensors on the robot in Level D.

Important Note:

The pinouts between the IR Obstacle and the IR Line sensors are not the same. Even though they are both three pins with 5V, GND, and Output, these are located in a different order on both devices. It's critical to ensure that 5V, GND, and Output are connected properly prior to applying power to your sensor. Reversing any of these connections will likely result in damaging the sensor and possibly your Raspberry Pi.