Lab: Serial Output from an Arduino to Processing

last edited 30 August 2015 by Tom Igoe

Introduction

In this lab, you'll send data from a single sensor to a program on a personal computer. The program, written in Processing, will graph the output of the sensor onscreen. This is a common way to find out how a sensor's output corresponds to the physical events that it senses.

Asynchronous serial communication, which you'll see demonstrated in this lab, is one of the most common means of communication between a microcontroller and another computer. You'll use it in nearly every project, for debugging purposes if nothing else.

The Processing sketch in this exercise graphs the incoming bytes. Graphing a sensor's value like this is a useful way to get a sense of its behavior.

These videos will help to understand this lab:

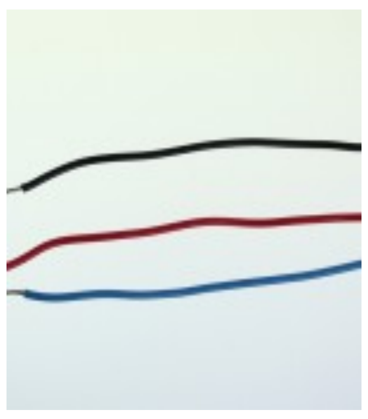
- Video: Introduction to Serial Communication
- Video: Serial Under the Hood: Interpreting Serial Data
- Video: Reading Serial Input in Arduino
- Video: Serial From Arduino to Processing

What You'll Need to Know

To get the most out of this Lab, you should be familiar with the basics of programming an Arduino microcontroller. If you're not, review the Digital Input and Output Lab, and perhaps the Getting Started with Arduino guide.

Things You'll Need

For this lab you'll need:

		
22-AWG hookup wire	*Arduino module*	*10Kohm potentiometer (or a different form of analog sensor)*

Connect the sensor

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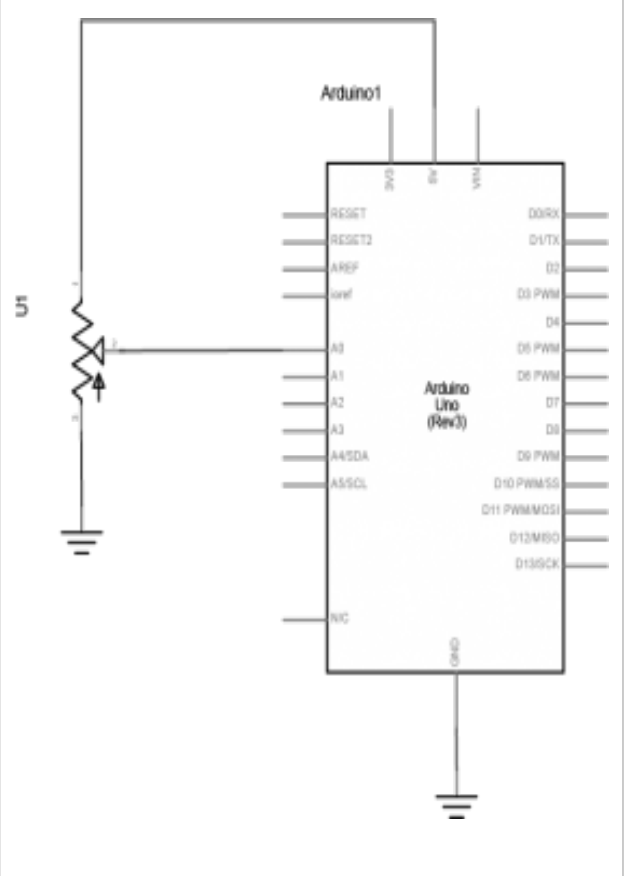
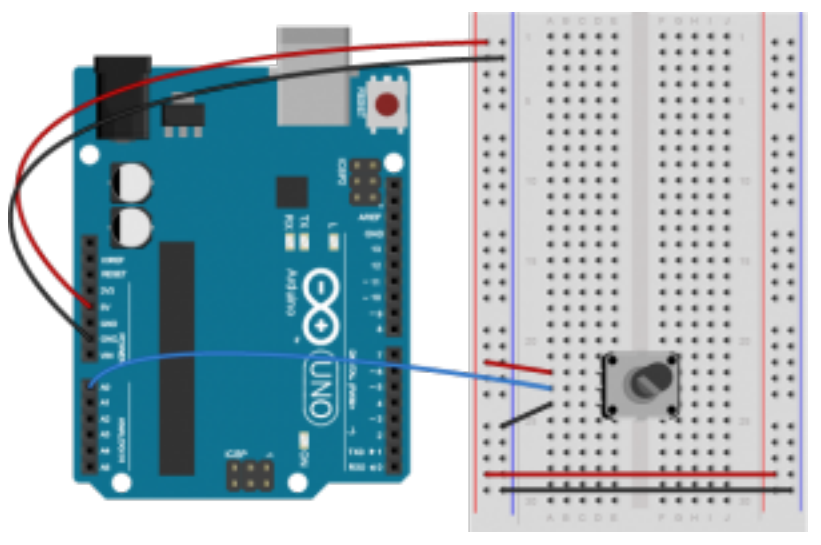
Connect your analog sensor to analog pin 0 like you did in the analog lab. A potentiometer is shown there because it's easy, but you might want to pick a sensor that's more interesting. IR distance rangers are fun for this exercise, for example. Force-sensing resistors are good as well.

 Arduino1 3V3 5V VIN RESET RESET2 AREF ioref A0 A1 A2 A3 A4/SDA A5/SCL N/C D0/RX D1/TX D2 D3 PWM D4 D5 PWM D6 PWM D7 D8 D9 PWM D10 PWM/SS D11 PWM/MOSI D12/MISO D13/SCK Arduino Uno (Rev3) GND U1	
Schematic of a potentiometer connected to an Arduino	*A potentiometer connected to an Arduino will work for this lab, but you might want to try a more exciting analog sensor instead.*

Read the Sensor Value and Send the Data Serially

Program the Arduino module to read the analog sensor and print the results to the Serial monitor. To do this, you'll use the Arduino serial commands. You've been using these in the digital and analog labs to send data to the Serial Monitor. Instead of using the `Serial.println()` command as you did in those labs, however, use `Serial.write()`. This will send the sensor value as a raw binary value rather than as a string:

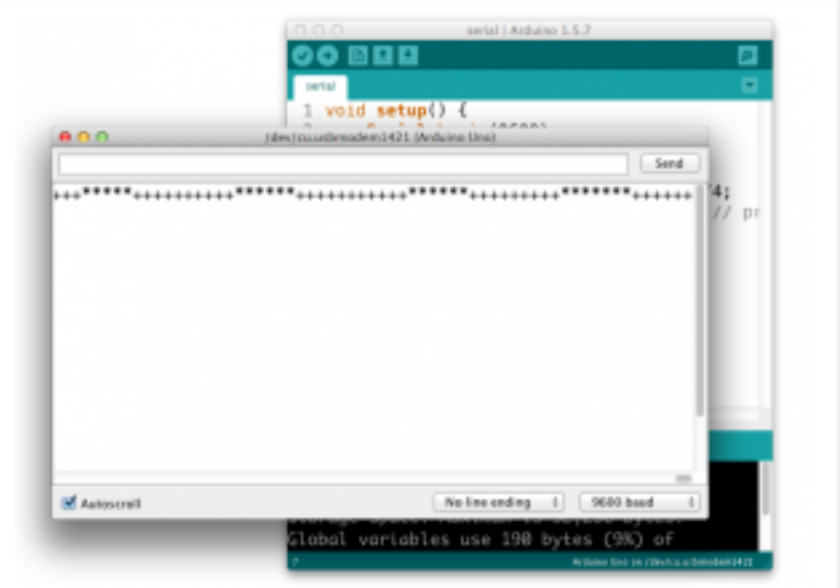
```
void setup() {
 Serial.begin(9600);
}

void loop() {
 int analogValue = analogRead(A0)/4; // read the sensor value
 Serial.write(analogValue);          // send the value serially
                                     // as a binary value
}
```

Note: Why divide the sensor value by 4?

Dividing the sensor value by 4 reduces the range to 0 to 255, the range that can fit in a single byte.

When you open the serial monitor, you will see garbage characters. What's going on? The `Serial.write()` command doesn't format the bytes as ASCII characters. It sends out the binary value of the sensor reading. Each sensor reading can range from 0 to 1023; in other words, it has a 10-bit range, since 2^{10} = 1024 possible values. Since that's more than the eight bits that can fit in a byte, you're dividing the value by 4 in the code above, to get a range from 0 to 255, or 2^{8} bits. For more background on this, see the notes on variables.



```
1 void setup() {
```

```
+++*****++++++++++******++++++++++******+++++++++*******++++++
```

```
Global variables use 198 bytes (9%) of
```

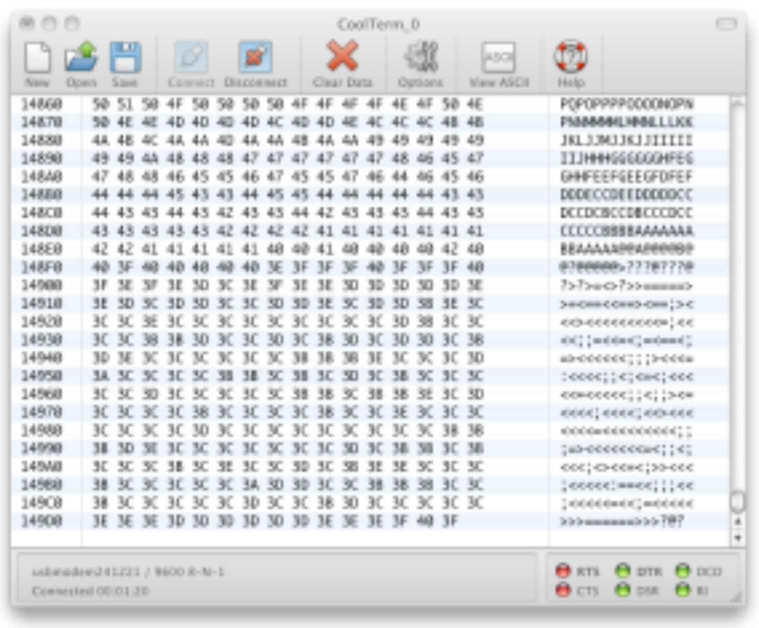
Autoscroll ✓ · No line ending · 9600 baud

Serial monitor screenshot, showing garbage. What is happening?

So, for example, if the sensor reading's value is 234, then the `Serial.write()` command sends the binary value 11101010. If the reading is 255, then `Serial.write()` sends 11111111. If it's 157, then the command sends 10011101. For more decimal-to-binary conversions, open your computer's calculator and choose the Programmer view (press apple-3 on a mac, and Alt-3 on Windows).

When the Serial Monitor receives a byte, it and assumes it should show you the ASCII character corresponding to that byte's value. The garbage characters are characters corresponding to the ASCII values the Monitor is receiving. You'll learn more about that in the two-way serial lab.

Sending data using `Serial.write()` is efficient for the computer, but it's difficult to read. However, there are other ways to see the serial data. The serial terminal program CoolTerm is available for Mac, Windows, and Linux. It gives you both an ASCII view of incoming bytes and a hexadecimal view. Download it and install it, and open the Options tab. From there, pick your serial port in the menu, then close the Options tab. Then click the Connect button to open the serial port. Related Video: Using CoolTerm



```
14860   50 51 50 4F 50 50 50 50 4F 4F 4F 4F 4E 4F 50 4E   PQPOPPPPOOOONOPN
14870   50 4E 4E 4D 4D 4D 4D 4C 4D 4D 4E 4C 4C 4C 4B 4B   PNNMMMMLMMNLLLKK
14880   4A 4B 4C 4A 4A 4D 4A 4A 4B 4A 4A 49 49 49 49 49   JKLJJMJJKJJIIIII
14890   49 49 4A 48 48 48 47 47 47 47 47 47 48 46 45 47   IIJHHHGGGGGGHFEG
148A0   47 48 48 46 45 45 46 47 45 45 47 46 44 46 45 46   GHHFEEFGEEGFDFEF
148B0   44 44 44 45 43 43 44 45 45 44 44 44 44 44 43 43   DDDECCDEEDDDDDCC
148C0   44 43 43 44 43 42 43 43 44 42 43 43 43 44 43 43   DCCDCBCCDBCCCDCC
148D0   43 43 43 43 43 42 42 42 42 41 41 41 41 41 41 41   CCCCCBBBBAAAAAAA
148E0   42 42 41 41 41 41 41 40 40 41 40 40 40 40 42 40   BBAAAAA@@A@@@@B@
148F0   40 3F 40 40 40 40 40 3E 3F 3F 3F 40 3F 3F 3F 40   @?@@@@@>???@???@
14900   3F 3E 3F 3E 3D 3C 3E 3F 3E 3E 3D 3D 3D 3D 3D 3E   ?>?>=<>?>>=====>
14910   3E 3D 3C 3D 3D 3C 3C 3D 3D 3E 3C 3D 3D 3B 3E 3C   >=<==<<==><==;><
14920   3C 3C 3E 3C 3C 3C 3C 3C 3C 3C 3C 3C 3D 3B 3C 3C   <<><<<<<<<<<=;<<
14930   3C 3C 3B 3B 3D 3C 3C 3D 3C 3B 3D 3C 3D 3D 3C 3B   <<;;=<<=<;=<==<;
14940   3D 3E 3C 3C 3C 3C 3C 3C 3B 3B 3B 3E 3C 3C 3C 3D   =><<<<<<;;;><<<=
14950   3A 3C 3C 3C 3C 3B 3B 3C 3B 3C 3D 3C 3B 3C 3C 3C   :<<<<;;<;<=<;<<<
14960   3C 3C 3D 3C 3C 3C 3C 3C 3B 3B 3C 3B 3B 3E 3C 3D   <<=<<<<<;;<;;><=
14970   3C 3C 3C 3C 3B 3C 3C 3C 3C 3B 3C 3C 3E 3C 3C 3C   <<<<;<<<<;<<><<<
14980   3C 3C 3C 3C 3D 3C 3C 3C 3C 3C 3C 3C 3C 3C 3B 3B   <<<<=<<<<<<<<<;;
14990   3B 3D 3E 3C 3C 3C 3C 3C 3C 3C 3D 3C 3B 3B 3C 3B   ;=><<<<<<<=<;;<;
149A0   3C 3C 3C 3B 3C 3E 3C 3C 3D 3C 3B 3E 3E 3C 3C 3C   <<<;<><<=<;>><<<
149B0   3B 3C 3C 3C 3C 3C 3A 3D 3D 3C 3C 3B 3B 3B 3C 3C   ;<<<<<:==<<;;;<<
149C0   3B 3C 3C 3C 3C 3C 3D 3C 3C 3B 3D 3C 3C 3C 3C 3C   ;<<<<<=<<;=<<<<<
149D0   3E 3E 3E 3D 3D 3D 3D 3D 3D 3E 3E 3E 3F 40 3F      >>>======>>>?@?
```

```
usbmodem241221 / 9600 8-N-1
Connected 00:01:20
```

CoolTerm screenshot showing incoming bytes as hexadecimal values

NOTE: only one program can control a serial port at a time. When you're not using a given program, remember to close the serial port. You won't be able to re-program the Arduino module if you don't, because the serial terminal program will have control of the serial port.

Once you have data coming into CoolTerm, click the Hex button. Instead of seeing the ASCII representation of the byte, you'll see its hexadecimal value, with the ASCII characters down the side. As you change the sensor's value, you'll see the values change.

Remember, the microcontroller is just sending a series of electrical pulses. How those pulses are interpreted is up to the program that reads them. In CoolTerm, you see two different interpretations, the hexadecimal value and the ASCII character corresponding to the value.
For most projects, you'll set the port settings to 9600 bits per second, 8 data bits, no parity, one stop bit, and no hardware flow control. This will be set in the Preferences or Settings or Connection Options of whatever program you're using. Once you've applied those settings, open the serial port by clicking. Any bytes you type in the window will be sent out the serial port you opened. They won't show up on the screen, however. Any bytes received in the serial port will be displayed in the window. Click the Disconnect button to close the serial port.

Read the Data in Processing

Related video: Basic Processing

The serial monitor in Arduino and CoolTerm aren't the only programs on your computer that can read data in from the microcontroller. Any program that can access the computer's serial ports can do it. Processing is an excellent tool for reading serial data because you can program it to interpret the data any way you want. Write a program to take in serial bytes and graph them.

The first thing you need to do is to import the Processing Serial Library. This is a code library that adds functionality to Processing so it can read from and write to the computer's serial ports. You can do this by choosing the Sketch menu, then `Import Library...-->serial`, or you can type:

Processing code:

```
import processing.serial.*;
```

To use the serial library, create an instance of the library in a global variable as shown below:

Processing code:

```
Serial myPort;
```

Note: you might get an error message when trying to use the Processing Serial Library for the first time. Here are instructions on what to do if this happens.

In the `setup()` method, set the window size, and use the serial library to get a list of the serial ports:

Processing code:

```
void setup () {
  size(800, 600);        // window size

  // List all the available serial ports
  println(Serial.list());
}
```

If you run what you've typed so far, you should get a list of the serial ports in the monitor pane that looks a bit like this on a mac. On a Windows machine, the port list will have names like COM3, COM4, COM5, and so forth:

/dev/cu.Bluetooth-Incoming-Port /dev/cu.Bluetooth-Modem /dev/cu.usbmodem13 /dev/cu.usbmodem15 /dev/cu.usbmodem17 /dev/cu.usbmodem1421 /dev/cu

One of these ports is the same as the serial port name you use in the Arduino programming environment. That's the one you want. In this case, it's "/dev/tty.usbmodem1421" or the 13th item in the list. But since arrays start counting at zero, that item is counted as the 12th item. So to open that port, add the following lines at the end of the setup:

Processing code:

```
// change the number below to match your port:
String portName = Serial.list()[12];
myPort = new Serial(this, portName, 9600);
```

Finally, set the background color. Pick a nice color, don't just use primary colors. You'll be looking at it a long time, so you might as well like it. If you can't think of a nice color combination, try kuler.adobe.com. Add this to the end of the setup:

Processing code:

```
background(#081640);
```

The serial library has a special method called `serialEvent()`. Every time a new byte arrives in the serial port, `serialEvent()` is called. So you can use it to read bytes coming in the serial port from the microcontroller. Write a serialEvent method that reads the incoming byte and prints it out:

Processing code:

```
void serialEvent (Serial myPort) {
  // get the byte:
  int inByte = myPort.read();
  // print it:
  println(inByte);
}
```

`myPort.read()` tells the program to read a byte from the serial port `myPort`. Bytes are read like peas coming out of a peashooter. Every time you read a byte, it's removed from the serial buffer. So it's good practice to read the byte into a variable as shown above, then never read again until you want another byte. If you want to do something with the byte you read (like graphing it), use the variable in which you saved the incoming byte.

Graph the Sensor Value

Now it's time to draw a graph with the bytes you read. To do this, you'll pick a point whose distance from the bottom of the window corresponds to the byte's value. In other words, the vertical position (call it `yPos`) equals the height minus the byte's value (`yPos = height - inByte`). Add global variables called `xPos` and `yPos` and set them to 0. Then in the `draw()`, set the stroke color to a nice color, and draw a line at xPos, from the bottom of the screen to the vertical position you just calculated.

Add this at the top of the program:

Processing code:

```
// at the top of the program:
float xPos = 0; // horizontal position of the graph
float yPos = 0; // vertical position of the graph
```

Add this to the end of the `serialEvent()` method. it will change yPos based on the last byte you read from the serial port:

```
yPos = height - inByte;
```

Then add this `draw()` method:

Processing code:

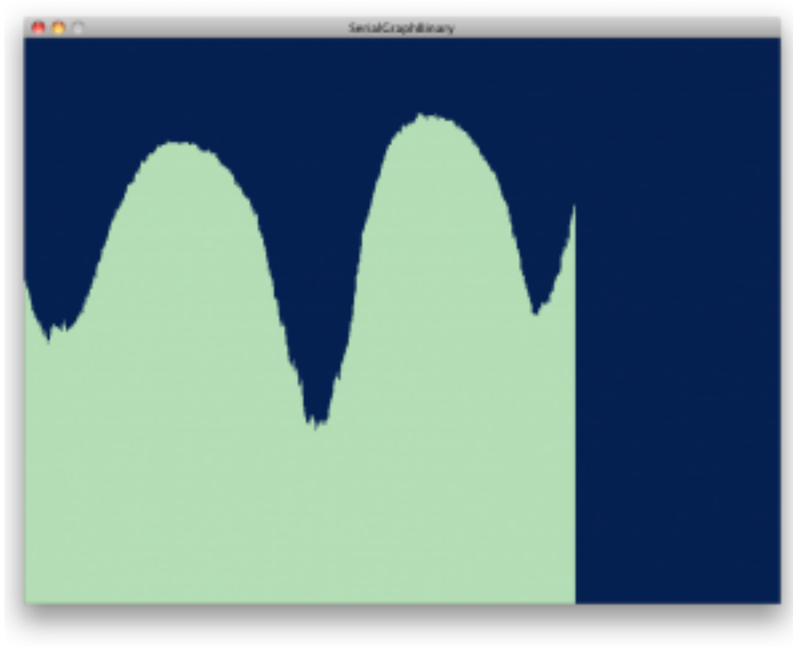
```
void draw () {
   // draw the line in a pretty color:
  stroke(#A8D9A7);
  line(xPos, height, xPos, yPos);
}
```

Finally you need to increment the horizontal position after you draw the line, so that the next byte's line is further along on the graph. If you reach the edge of the screen, set the horizontal position back to 0. Do this at the end of the `draw()`:

Processing code:

```
// at the edge of the screen, go back to the beginning:
  if (xPos >= width) {
    xPos = 0;
    // clear the screen by resetting the background:
    background(#081640);
  } else {
    // increment the horizontal position for the next reading:
    xPos++;
  }
```

That's it! When you run this sketch, you'll see the sensor's value graphed on the screen like so:



Graphing a sensor in Processing