Measurements, Sensors and Data Logging Course

Week 3

Upcoming Weeks

- Office Hours
  - Monday Nov 15 @ 7:00 PM

- Weekly Session
  - Thursday Nov 11 @ 7:00 PM
  - Thursday Nov 18 @ 7:00 PM

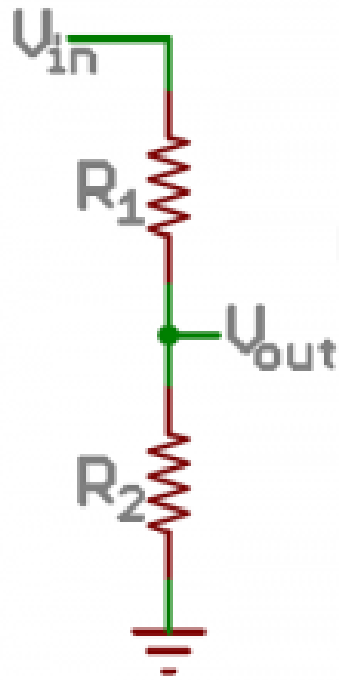
Lesson 3: Potentiometer

Use a potentiometer to change the brightness of the LED

Voltage Divider

Lesson 3: Pot

- What is a voltage divider?
  - Simple circuit which turns a large voltage into a smaller one.
    - **Vout = Vin** $* \frac{R2}{R1+R2}$
    - Vin = 5V, R1 = 50, R2 = 50
      - Vout = $5V * \frac{50}{50+50}$ = 2.5V
    - Vin = 5V, R1 = 20, R2 = 80
      - Vout = $5V * \frac{80}{20+80}$ = 4V
  - More Info:
    - https://learn.sparkfun.com/tutorials/voltage-dividers/all#:~:text=A%20voltage%20divider%20is%20a,most%20fundamental%20circuits%20in%20electronics



Voltage Divider

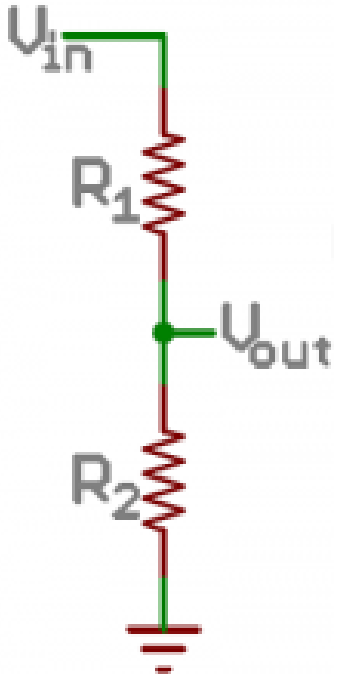
Lesson 3: Pot

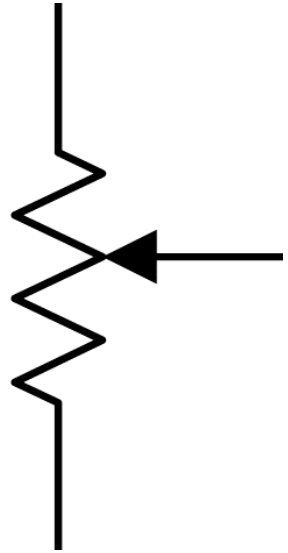
- What is a voltage divider?
  - Simple circuit which turns a large voltage into a smaller one.
    - $\mathbf{Vout = Vin * \frac{R2}{R1+R2}}$
    - Vin = 5V, R1 = 10, R2 = 90
      - Vout = ?
    - Vin = 5V, R1 = 180, R2 = 20
      - Vout = ?
  - More Info:
    - https://learn.sparkfun.com/tutorials/voltage-dividers/all#:~:text=A%20voltage%20divider%20is%20a,most%20fundamental%20circuits%20in%20electronics

Potentiometer Introduction

Lesson 3: Pot

- Potentiometers are commonly used as adjustable voltage dividers.



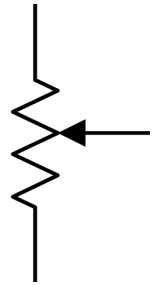


Potentiometer Introduction

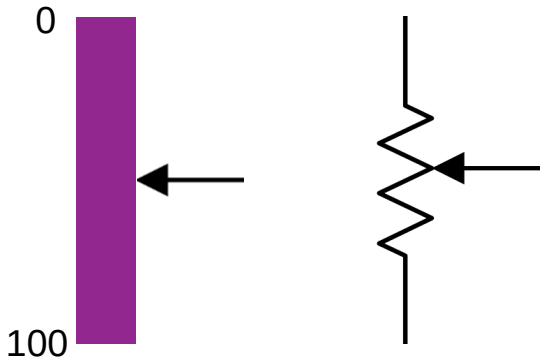
Lesson 3: Pot

- What is a potentiometer (pot)?
  - A pot is a type of variable resistor that has 3 terminals, two end terminals and a moveable wiper terminal.
  - Commonly used as position sensors.

Potentiometer Symbol



By Potentiometer with load.png: OmegatronDerivative work: DesbWit - This file was derived from: Potentiometer with load.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20737313



Potentiometer Introduction

Lesson 3: Pot

- Where are pots used?
  - Pots are used in many devices, from volume knobs, industrial equipment, servos, home appliances, vehicles, and much, much more.
  - Activity: find a specific device that uses a pot.

Example Potentiometers

By Junkyardsparkle - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=39291275

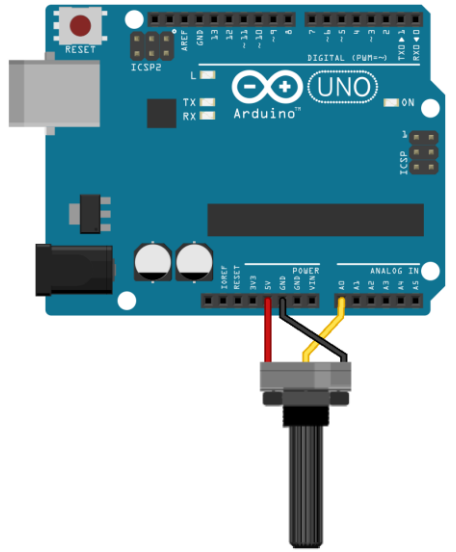
Potentiometer Introduction

Lesson 3: Pot

- How do I use a potentiometer?
  - Follow the connection diagram to the right. Your Grove Beginner's Kit has already done this for you.
  - We then read the state of the input using the analogRead function.

- More Info:
  - https://en.wikipedia.org/wiki/Potentiometer
  - https://www.allaboutcircuits.com/textbook/direct-current/chpt-6/voltage-divider-circuits/

Example Potentiometer Connection



Modified from https://www.arduino.cc/en/Tutorial/BuiltInExamples/AnalogInput

Potentiometer Introduction

Lesson 3: Pot

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Combining Analog, PWM, and LEDs

Lesson 3: Pot

- We can use the MCU on our Arduino to read the value of the pot and output a PWM signal to the LED to control the brightness.
  - Outputting a higher value is a larger duty cycle which means a brighter LED.
- What hardware will we need for this Lesson?
  - Grove LED Module on pin D4
  - Grove Rotary Potentiometer Module on pin A0
  - Seeeduino Lotus (Arduino Uno compatible board)

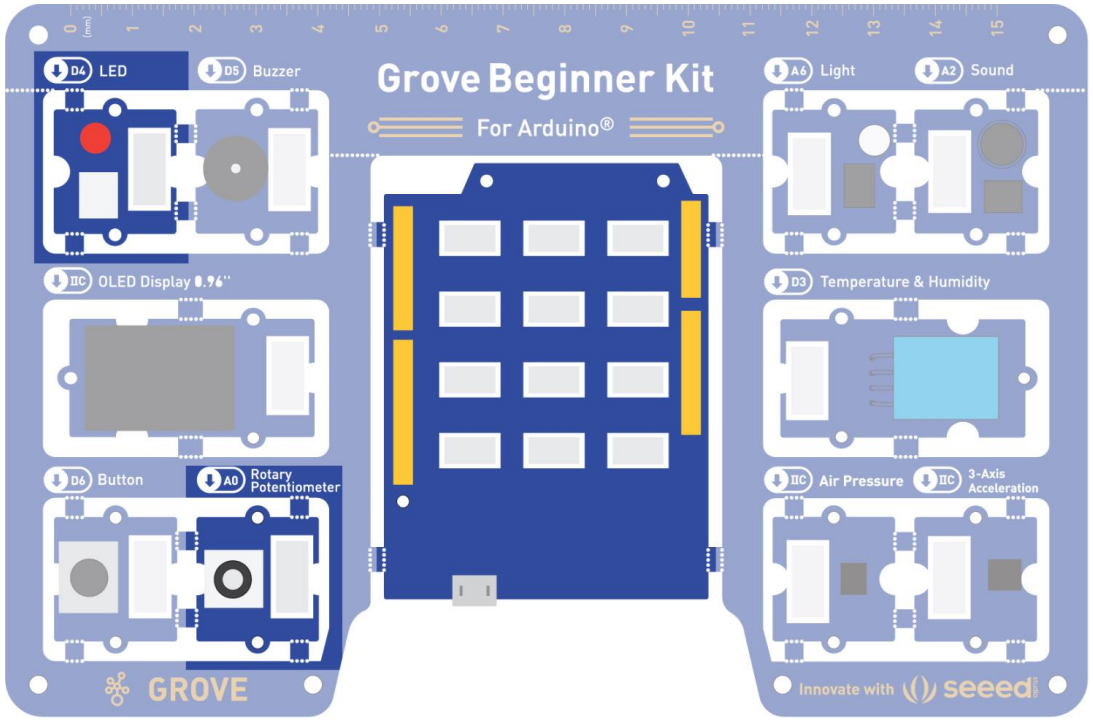


Image from https://files.seeedstudio.com/wiki/Grove-Beginner-Kit-For-Arduino/res/Grove-Beginner-Kit-For-ArduinoPDF.pdf

Open and Upload Sketch

Lesson 3: Pot

1. Open Pot Sketch
   a. **File → Sketchbook → CrashCourse_Jan → L3_Pot**
2. Verify the sketch by clicking the Verify Button.
   a. The sketch should compile with no errors.
3. Upload the sketch to your Arduino by clicking the Upload Button.
   a. The sketch should re-compile, and then upload to your Arduino.
4. Watch the LED as you rotate the potentiometer.

Code Analysis – delayMicroseconds Function

Lesson 3: Pot

```
delayMicroseconds(potValue);
```

- Wait for the number of microseconds (µs) stored in potValue.

- This function is similar to the delay function from Lesson 1, except it pauses by microseconds instead if milliseconds.
- There are 1000µs in 1ms and 1,000,000µs in 1s.
- Syntax:

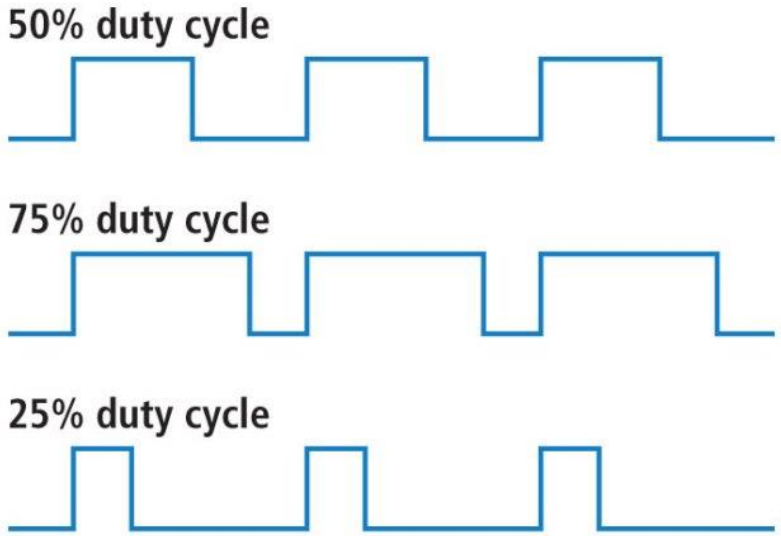
```
delayMicroseconds(µs);
```

  - µs: number of microseconds (µs) to pause.
    - Data type is unsigned int with a range of 0 to 16,383µs (about 16 ms)
- More information:
  - https://www.arduino.cc/reference/en/language/functions/time/delaymicroseconds/

Pulse Width Modulation (PWM) Introduction

Lesson 3: Pot

- What is Pulse Width Modulation?
  - PWM is a type of digital signal that varies its value using the width of the pulse.



- It is easy to convert a PWM signal back to an analog signal with a low pass filter.
- We can use this to control the brightness of the LED.
- More Info:
  - https://en.wikipedia.org/wiki/Pulse-width_modulation
  - https://www.allaboutcircuits.com/textbook/semiconductors/chpt-11/pulse-width-modulation/
  - https://learn.sparkfun.com/tutorials/pulse-width-modulation/all

Pulse Width Modulation (PWM) Introduction

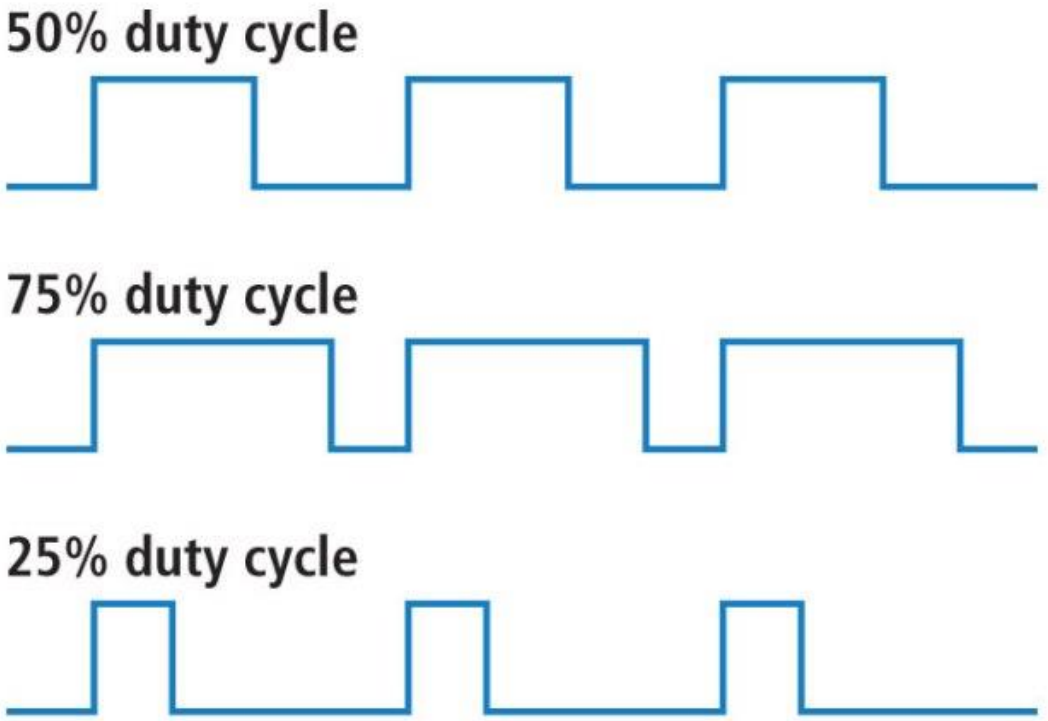
Lesson 3: Pot

- Two parts to Pulse Width Modulation
  - Duty Cycle (D), can can be calculated as follows:
    - $\mathrm{D} = \frac{t_H}{t_H + t_L}$
    - Where t_H is the time the signal is high,
    - And t_L is the time the signal is low.
    - Is measured as %
  - Frequency (Hz), how many times the cycle can occur in 1 second
    - $\mathrm{F} = \frac{1}{t_H + t_L}$

Pulse Width Modulation (PWM) Introduction

Lesson 3: Pot

- $\mathrm{D} = \frac{t_H}{t_H + t_L}$, $\mathrm{F} = \frac{1}{t_H + t_L}$
- t_H = 50ms, t_L = 50ms
  - $\mathrm{D} = \frac{50ms}{50ms+50ms}$ = 50%
  - $\mathrm{F} = \frac{1}{0.050s+0.050s}$ = 10Hz
- t_H = 25ms, t_L = 75ms
  - $\mathrm{D} = \frac{25ms}{25ms+75ms}$ = 25%
  - $\mathrm{F} = \frac{1}{0.025s+0.075s}$ = 10Hz
- t_H = 150ms, t_L = 50ms
  - $\mathrm{D} = \frac{ms}{ms+ms}$ = %
  - $\mathrm{F} = \frac{1}{s+s}$ = Hz



Pot Activities

Lesson 3: Pot

- Activity 1
  - Change the LED PWM to get brighter with a clockwise rotation of the potentiometer.
- Activity 2 (Bonus / Homework)
  - If the light sensor is on pin A6, modify the sketch to use the light sensor instead of the potentiometer.

Lesson 4: Light Sensor

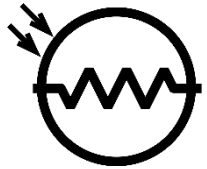
See the output of the light sensor in the Serial Monitor

Light Sensor Introduction

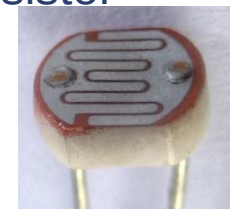
Lesson 4: Light Sensor

- What is a Light Sensor?
  - A light sensor is a type of device that changes a measurable electrical property based on the number (and type) of photons hitting it.
  - They come in many types but the main three for sensing applications are
    - **Photoresistors**: Resistance changes with light
    - **Photodiodes**: Photocurrent increases with light (this is also how a solar cell works)
    - **Phototransistors**: Amplified version of a photodiode.
- Where are light sensors used?
  - Occupancy sensors, daylight sensors, fiber optic communications, TVs (remote control receiver), cell phones, range finders, camera image sensors, etc.
  - Activity: Find a device not listed above that uses a light sensor.
- More information:
  - https://en.wikipedia.org/wiki/Photodetector
  - https://en.wikipedia.org/wiki/Photodiode
  - https://en.wikipedia.org/wiki/Photoresistor
  - https://www.seeedstudio.com/blog/2020/01/08/what-is-a-light-sensor-types-uses-arduino-guide/

Photoresistor



By User:FDominec et al. - File:Electrical_symbols_library.svg, CC0, https://commons.wikimedia.org/w/index.php?curid=49516462



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Photodiode

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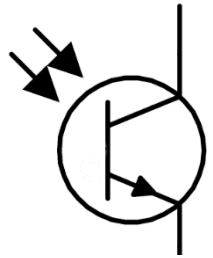
Copied from https://www.digikey.com/en/products/detail/w%C3%BCrth-elektronik/1540031EA4590/12366192

Phototransistor



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Lesson 4 Hardware

Lesson 4: Light Sensor

- What hardware will we need for this Lesson?
  - Grove Light Sensor Module on pin A6
  - Seeeduino Lotus (Arduino Uno compatible board)
    - The Arduino has the serial port hardware built into the device

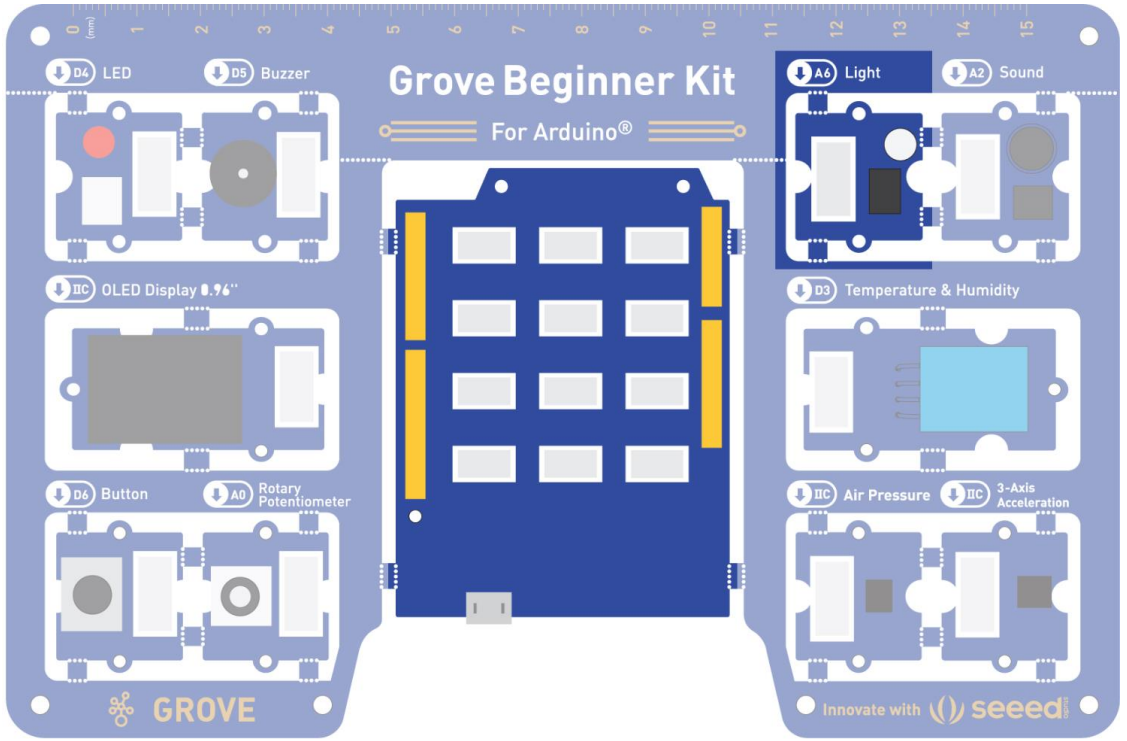


Image modified from https://files.seeedstudio.com/wiki/Grove-Beginner-Kit-For-Arduino/res/Grove-Beginner-Kit-For-ArduinoPDF.pdf

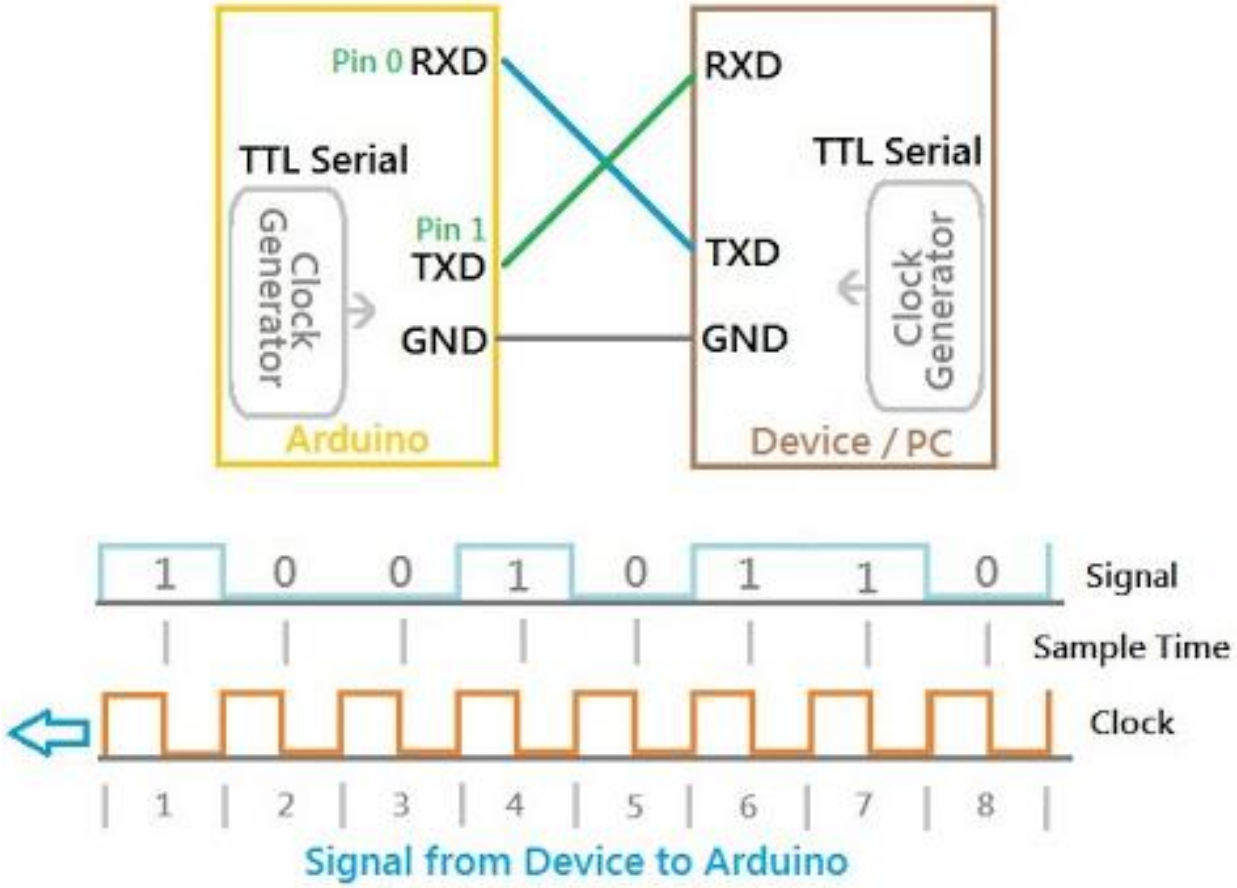
Serial Introduction

Lesson 4: Light Sensor

- What is Serial Communication?
  - A digital signal where data is sent one bit at a time over a single channel.
  - Serial communications include RS232, RS485, UART, USART, USB, Ethernet, CAN, I^2C, SPI, SATA, etc.
  - Serial (without descriptors) typically refers to RS-232 and related communication signaling standards (UART or USART for a microcontroller).
- Where are serial communications used?
  - Internet, computers, cell
- More information:
  - https://en.wikipedia.org/wiki/Serial_communication
  - https://www.codrey.com/embedded-systems/uart-serial-communication-rs232/

Serial Introduction

Lesson 4: Light Sensor

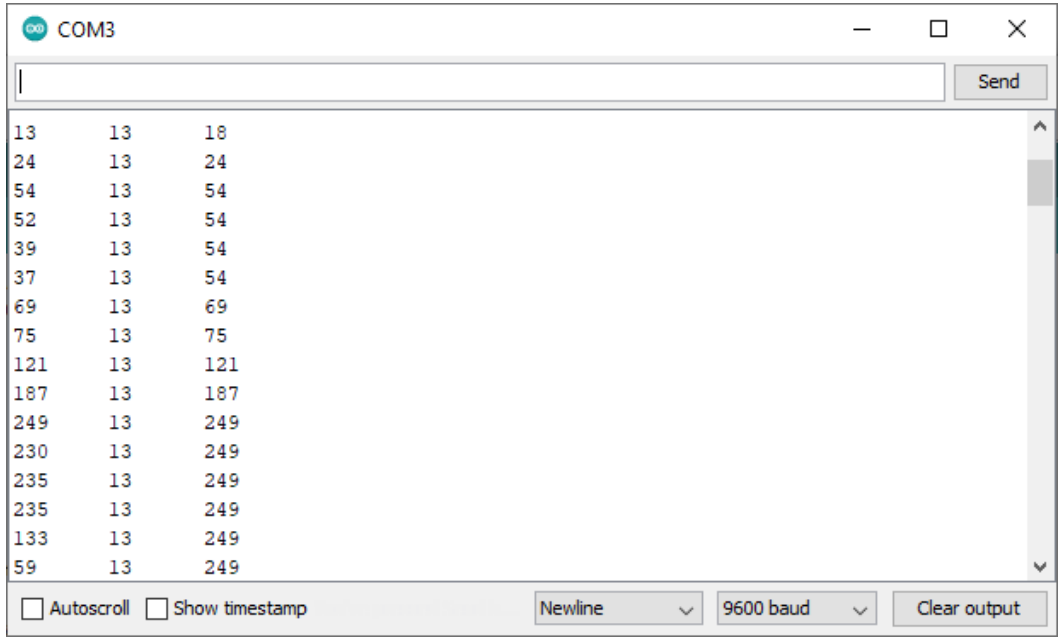


- More information:
  - http://elextutorial.com/learn-arduino/arduino-serial-communication-write-port-example-test-begin/

Open and Upload Sketch

Lesson 4: Light Sensor

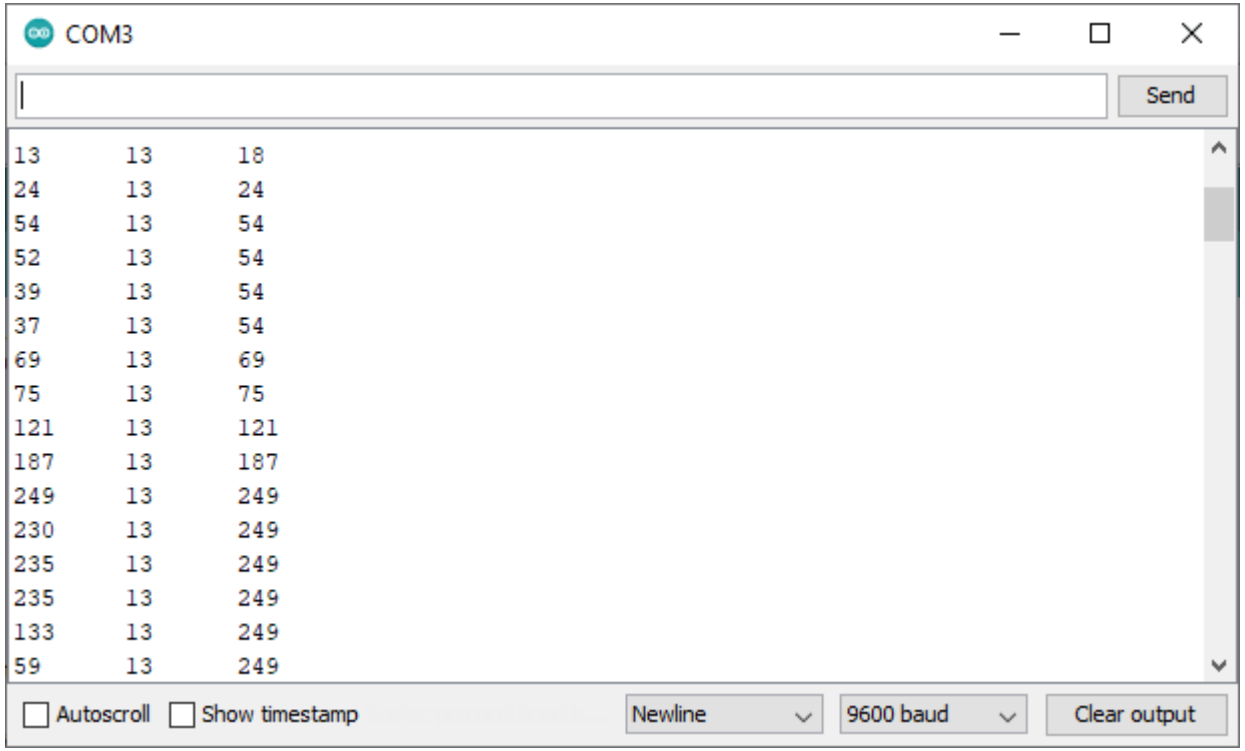
1. Open Light_Serial Sketch
   a. **File → Sketchbook → CrashCourse_Jan → L4_Light_Serial.ino**
2. Verify the sketch by clicking the Verify Button.
   a. The sketch should compile with no errors.
3. Upload the sketch to your Arduino by clicking the Upload Button.
   a. The sketch should re-compile, and then upload to your Arduino.
4. Open the serial monitor.
   a. **Tools → Serial Monitor** (Ctrl+Shift+M)
5. Observe the output in the Serial Monitor



Serial Monitor

Lesson 4: Light Sensor

- What is the Serial Monitor?
  - The Serial Monitor is a feature of the Arduino IDE that gives you a serial terminal to see what is being sent to the COM port and allows you to send stuff out of the COM port.
  - We use this for receiving data from the Arduino.
  - We can also use this to help us debug our sketches.



Code Analysis – `Serial` Functions

Lesson 4: Light Sensor

- **`Serial.begin(9600);`**
  - Start the Serial port at a 9600 baud
  - Put this function in the setup() function
  - Must call this function before using any other serial function
- **`Serial.print("string");`**
  - print a string or value to the serial port
- **`Serial.println("string");`**
  - same as print but add a new line character at the end of the string or value
- Special characters:
  - `'\t'` is a Tab character
  - `'\n'` is a New Line (some operating systems [⊞] use `"\r\n"`)
- More Information:
  - https://www.arduino.cc/reference/en/language/functions/communication/serial/
  - https://en.wikipedia.org/wiki/Control_character

Code Analysis – `min()` and `max()` Functions

Lesson 4: Light Sensor

`min(valueA, valueB);`

- Returns whichever value is lower

`max(valueA, valueB);`

- Returns whichever value is higher

- More information:
  - https://www.arduino.cc/reference/en/language/functions/math/max/
  - https://www.arduino.cc/reference/en/language/functions/math/min/