



CODES & CONTROLLERS | EDUCATOR

Module 1: Sensor Technology Series

Links to Next

Generations Science Standards |

MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success

MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Links to Common Core Standards |

CCSS.ELA-LITERACY.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments or performing technical tasks.

STEM

Contributing Author | Dennis (DJ) Pevey, Science Communication Fellow

Pacing | 1-3 class periods

Background Needed | Basic understanding of technological tools

Assessment | Rubric provided

Materials/Resources |

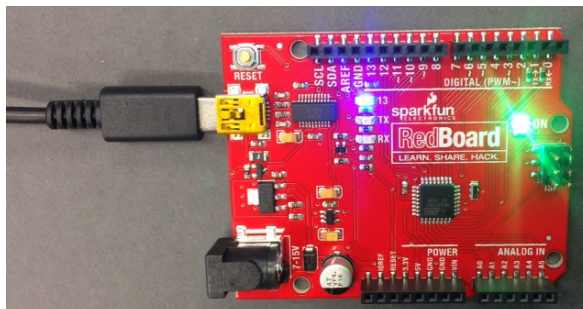
- ▶ Each group will need the following:
 - ▶ Any non-chromebook computer or laptop
 - ▶ 1 mini USB cable (<http://nautl.us/2v1zbTH>)
 - ▶ 1 Arduino Uno/Genuino (<http://nautl.us/2uBQw4x>)
 - ▶ 1 Breadboard (<http://nautl.us/2u2uWml>)
 - ▶ A few 20AWG jumper wires (<https://nautl.us/2ukbiYc>) (5-10 per group)
 - ▶ Assorted LEDs (<http://nautl.us/2eRHcEl>) (light emitting diode)
 - ▶ A few 10 ohm Resistors (<http://nautl.us/2wpb9lk>) (1-5 per group)
- ▶ Optional (per group):
 - ▶ Plastic mounting plate for Arduino and breadboard (<http://nautl.us/2vQO3Aw>)
 - ▶ Small wire clippers
 - ▶ Magnifying glasses
- ▶ **For additional reference please see our suggested budget (<http://nautl.us/2gZ72ag>) for all modules in this series.**

Overview

This module will introduce students to the basic concepts of coding and microcontrollers using Arduino Uno hardware. Students will learn the basic components of hardware, software and breadboards to construct simple single and multiple LED circuits. They will analyze basic coding language, manipulate pre-written codes to change the variables of an output device, set up a basic LED circuit using a breadboard, and finally write their own SOS code. They will work with their classmates to compare codes and witness that there are many ways to code for the same results.

Objectives & Learning Outcomes

- ▶ Students will identify practical applications of microcontrollers.
- ▶ Students will identify practical applications of breadboards.
- ▶ Students will learn and apply basic programming technology to set up and





Links to Common Core Standards |

CCSS.ELA-

LITERACY.RST.6-8.4:

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

Set The Stage!

Have an Arduino/LED light display set up and running (this link <http://nautl.us/2i6Wfe9> has one example). Ask students to discuss what they think is happening to make the lights to turn on in that pattern. Encourage a class discussion to gauge students' background knowledge and prior experience with this topic.

Warm-Up Activity

✓ **Answers:**

- 1 D `int LED_BuiltIn = 13;`
- 2 E `void setup() {`
- 3 C `pinMode(LED_BuiltIn, OUTPUT);`
`}`
- 4 G `void loop() {`
- 5 A `digitalWrite(LED_BuiltIn,HIGH);`
- 6 F `delay(1000);`
- 7 B `digitalWrite(LED_BuiltIn, LOW);`
- 8 H `delay(1000);`

Choice Bank

- A. Turns the LED on
- B. Turns the LED off
- C. Declares the LED as an output pin
- D. Assigns a name to the LED connected to pin 13 on the Arduino to be used throughout the sketch
- E. Designates which functions will be performed in the setup portion of the sketch
- F. Tells LED to remain "on" for 1 second
- G. Designates which functions will be repeated (looped)
- H. Tells the LED to remain "off" for 1 second

Guiding Questions

1. Provide some examples of input and output devices used in communication with a computer.
✓ **Possible answers: both:** cell phones, microcontroller; **input:** human scanner, mouse, temperature sensor, multibeam sonar, cameras; **output:** speaker, 3D printer, monitor, ROV manipulator arm, lights, motors.
2. What are the advantages of using a microcontroller in various STEM applications?
✓ **Possible answers:** affordable, easy to use, can be used to program sensors for a variety of research and practical uses; testing circuits before finalizing products or projects.
3. Why are resistors used in circuits?
✓ **Possible answers:** to limit the current to various components such as an LED to maintain proper functioning.



Extensions & Adaptations

Introductory I

Use this [presentation](http://nautl.us/2ljSoaE) (<http://nautl.us/2ljSoaE>) to lead all students through the lesson at the same pace.

Advanced I

Encourage students to create their own LED display or another circuit project by writing their own code or searching online for project guides. Students can share their examples with the class. Associated websites/tutorials could be compiled into a class resource list.

Activity/Tasks

Students will:

- ▶ Determine work group arrangements and group roles (suggestions: team manager, materials manager, reader, engineer, team advocate if in need of assistance, etc.).
- ▶ Read through the lesson introduction and complete guiding questions.
- ▶ Gather all materials.
- ▶ Work through the all parts of the procedure and complete all associated tasks.

Educator: Lesson Procedure/Directions

- ✓ **LESSON SET-UP** | It is suggested that students work in small groups to complete this module.
- ☐ Helpful tips:
 - ✓ Set up required student materials ahead of time at each student work station. It may be beneficial to establish group roles (such as materials manager, timekeeper, engineer, etc. to ensure efficiency in collaboration)
 - ✓ Arduino troubleshooting guide: <https://www.arduino.cc/en/Guide/Troubleshooting>
 - ✓ In part 4 of the procedure, if students' LEDs do not blink when plugged in, have them unplug the USB, double check the orientation of the wires on the LED and/or resistor connections and replug the USB back in.
- ☐ Going Further Answers:
 - ✓ How did this device get its name?
Kitchen breadboards were commonly used many years ago when electronics were still of a large size as a platform for experimenting with circuits on.
 - ✓ What are two benefits of using a breadboard?
Allows people to prototype or test out circuits to see how it will react under a certain set of parameters. Can be used for testing out new parts such as integrated circuits (ICs).
 - ✓ What is another name for the conductive rows and what are they used for?
Terminal strips, they are used for the attachment of wires or other components and conduction of electricity through items in the same row.
 - ✓ What is the purpose of having power rails run vertically along both sides of the breadboard?
Lots of easy access to power where it's needed in a circuit.



Student Applications Answer Key

Part 1: Proofreading Code:

```
int led = 9;           // the PWM pin the LED is attached to
int brightness = 0;    // how bright the LED is
int fadeAmount = 5;    // how many points to fade the LED by

// the setup routine runs once when you press reset:
void setup() {
  // declare pin 9 to be an output:
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  // set the brightness of pin 9:
  analogWrite(led, brightness);

  // change the brightness for next time through the loop:
  brightness = brightness + fadeAmount;

  // reverse the direction of the fading at the ends of the fade:
  if (brightness <= 0 || brightness >= 255) {
    fadeAmount = -fadeAmount;
  }
  // wait for 30 milliseconds to see the dimming effect
  delay(30);
}
```

Part 2: Write an SOS Code: Create your own code to get the LED to blink in an SOS pattern (3 short pulses followed by 3 long pulses followed by 3 short pulses). Take a screenshot or record your code below.

```
int ledPin = 9; // LED connected to digital pin 9

int s = 300; // 0,3 second delay for 'S' letter
int o = 800; // 0,8 second delay for 'O' letter
int pause = 100; // 0,1 second delay between letters

void setup() {
  // put your setup code here, to run once:
  pinMode(ledPin, OUTPUT);
}

void character(int speed, int pause) {
  for (int i = 1; i <= 3; i++) {
    digitalWrite(ledPin, HIGH);
    delay(speed);
    digitalWrite(ledPin, LOW);
    delay(300);
  }
  delay(pause); //delay between letters
}

void loop() {
  character(s,pause);
  character(o,pause);
  character(s,pause);
  delay(2000); //2 seconds delay for after the word SOS
}
```

Discussion Question: Compare your group's code with others. Can different codes produce the same results?

Yes, codes can be written differently to produce the same results.



Learning Goals

- Identify practical applications of microcontrollers in daily life.
- Learn and apply basic programming terms and skills.
- Use basic coding skills to program a microcontroller.

Think, Pair, Share

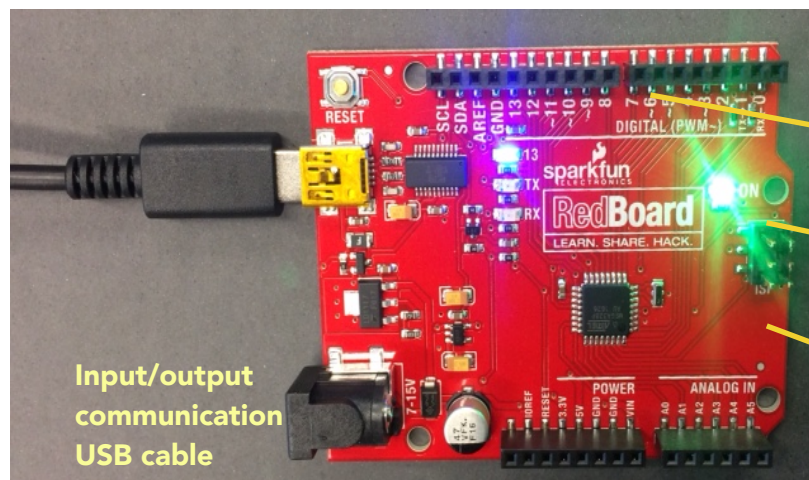
Draw a diagram showing the connection between the following terms: **microcontroller**, **circuit board**, **processing system**, **input**, **output**. Share your diagram with a classmate.

Introduction | Want to program a computer to do your bidding? Microcontrollers, such as Arduino, provide the key to creating custom-built electronics projects. In this module series, you will learn how to program a microcontroller to use a sensor to collect scientific data. You can apply your new skills to design your very own project within your school or community.

The activities in this lesson will get you started with basics of setting up a microcontroller and writing code to make an LED blink in a pattern that you determine.

Background | In their most basic form, **microcontrollers** contain a tiny processor core, memory, and programmable input and output portions that give a computer the power to detect information from its surrounding environment. Microcontrollers are used in many common electronic products from kitchen appliances, power tools, and toys to medical devices and science equipment.

Developed in the early 2000's by Italian researchers, Arduino has become one of the most commonly-used microcontrollers on the market. Their small profile, low cost, and ease of use by engineers and non-engineers alike open up possibilities for innovation in a range of STEM fields.



Input/output
communication
USB cable

Pins for connecting
circuits

LED (Output)

Arduino Uno
Microcontroller
Hardware



CODES & CONTROLLERS | STUDENT

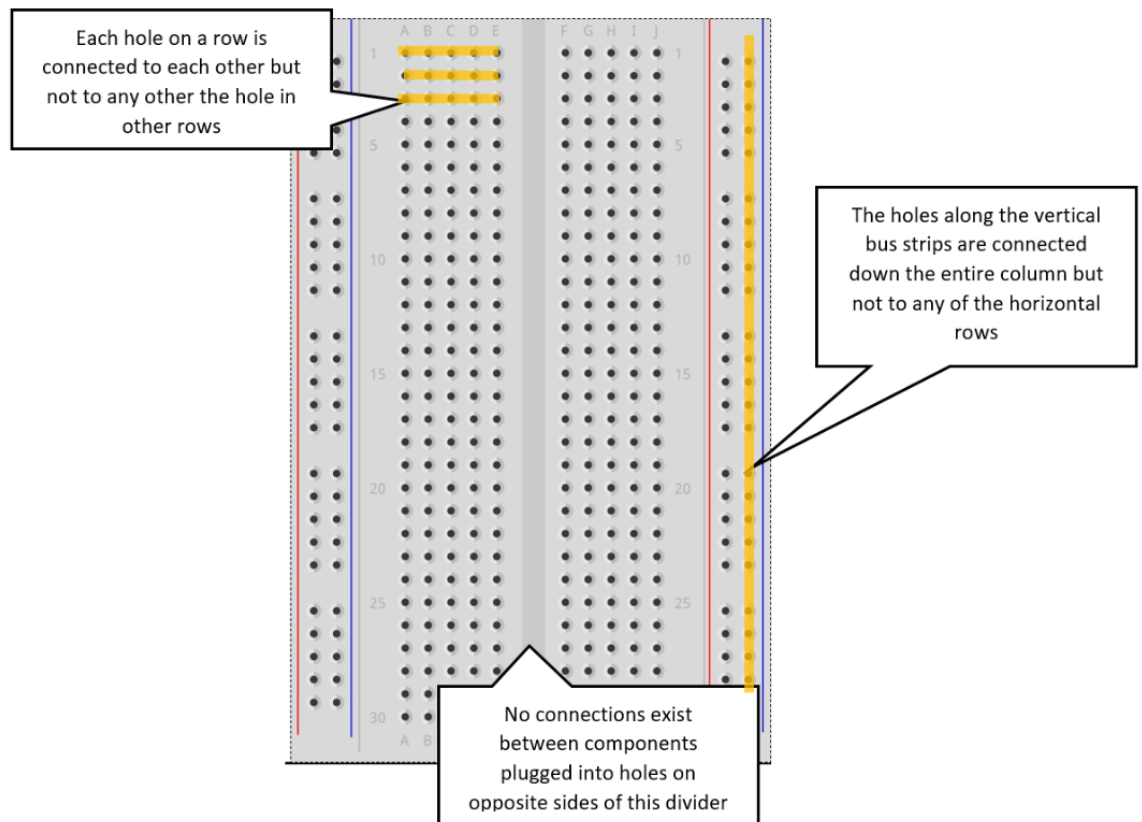
Module 1: Sensor Technology Series

Going Further:

Use the following website <https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard> to learn more about breadboards and answer the following questions:

- ▶ How did this device get its name?
- ▶ What are two benefits of using a breadboard?
- ▶ What is another name for the conductive rows and what are they used for?
- ▶ What is the purpose of having power rails run vertically along both sides of the board?

When working on electronics projects, the process of **soldering** (pronounced saw-terr-ing) is often required to fuse together two or more components by melting a filler metal (called solder) into the connected joints. Once soldered together, it is very difficult to separate individual components. **Breadboards** (shown below) provide us with an alternative. Conductive internal parts of the breadboard allow electrons to flow through components plugged into multiple holes on the board without being soldered together. Breadboards can be used over and over again and are a great option for building prototype circuits.

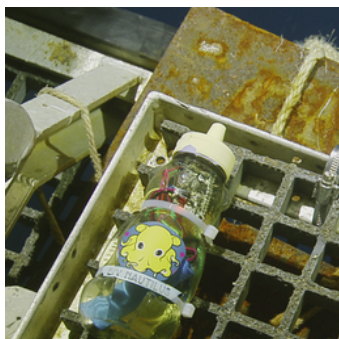


For these activities, you will use a breadboard, Arduino, and a few other components to build a simple LED circuit.



On Exploration Vessel *Nautilus*, Data Engineers use micro controllers called Raspberry Pi's (imagine an Arduino with built-in ethernet plug), to run data kiosks for science tools, to sense temperature and humidity around the sonar computers, and to track climate conditions in the computer server room where equipment directs the live video transmission off the ship to satellites to viewers around the world. Microcontrollers are used in the underwater vehicle industry to collect and process seafloor images and environmental data.

During a 2016 expedition, scientists built their own temperature sensor using a microcontroller and a recycled honey container.



3. Arduino code is referred to as a **sketch**. Sketches are written in a programming language called C which is CASE SENSITIVE (check your caps lock) and require a semi-colon (;) at the end of each line. Sketches are uploaded to an Arduino board to direct a specific task. Here are some links to help you learn the basics of writing code for Arduino: <http://nautl.us/2ile93V>, <http://nautl.us/2ifvBM4>, <http://nautl.us/2wtERnR>

Warm-Up Activity: Check out the example sketch below (listed in the correct order). See if you can match each line of code with its function in the choice bank:

```

1 ____  int LED_BuiltIn = 13;
2 ____  void setup( ) {
3 ____  pinMode(LED_BuiltIn, OUTPUT);
        }
4 ____  void loop( ) {
5 ____  digitalWrite(LED_BuiltIn,HIGH);
6 ____  delay(1000);
7 ____  digitalWrite(LED_BuiltIn, LOW);
8 ____  delay(1000);
    
```

Choice Bank

- A. Turns the LED on
- B. Turns the LED off
- C. Declares the LED as an output pin
- D. Assigns a name to the LED connected to pin 13 on the Arduino to be used throughout the sketch
- E. Designates which functions will be performed in the setup portion of the sketch
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Guiding Questions |

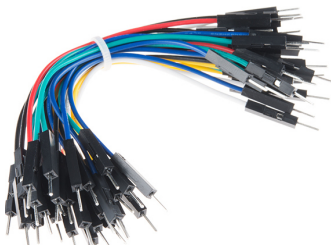
1. Provide some examples of input and output devices used in communication with a computer.
2. What are some advantages of using a microcontroller?
3. Why are resistors used in circuits?



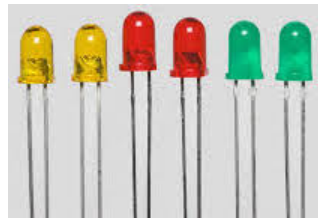
Materials |

Each group will need the following:

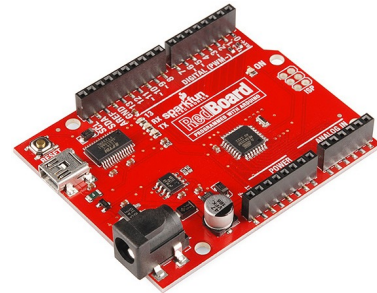
- ▶ Any non-chromebook computer or laptop



Handful of 20AWG jumper wires



Assorted LED bulbs (light emitting diode)



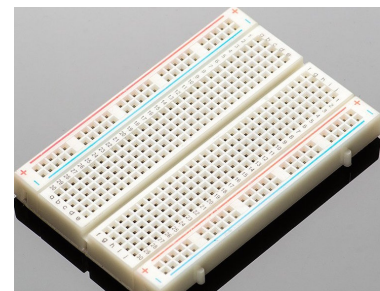
Arduino Uno/Genuino



Mini USB Cable



A few 10 ohm Resistors



Breadboard

Procedure |

Part 1: Board Set-Up

1. Download Arduino from www.arduino.cc/download.
2. Install the FTDI Driver
3. Follow onscreen directions to complete the installation.

Part 2: Connecting Hardware

1. Double-click on the Arduino Icon to open the program where it is saved.
2. Use the mini USB cable to connect the Arduino board to the computer. Once plugged in, the green LED should turn on, and the other LED should start blinking.
3. In the program menu, go to 'Tools' and select 'Board', then select 'Arduino Uno'.

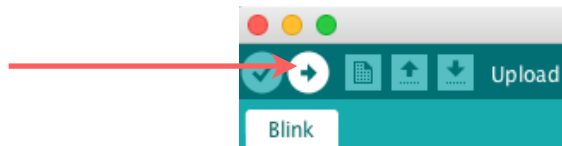


4. Under 'Tools', select the serial port (whichever port is labeled Arduino/Genuino Uno).

If you're not sure which port is your device, unplug the board, check the menu, then replug in the board and check the menu again. On Windows laptops, the port is often labeled "COM3" or higher numbers. On OSX it's named similarly to "/dev/cu.usbmodem1461". Installation procedure will vary depending on your operating system. On Windows, run the installer, which will also install the necessary drivers. On OS X, drag the Arduino app into the applications folder. No drivers need to be installed. For Windows troubleshooting, you can refer to <https://www.arduino.cc/en/Guide/ArduinoUno>. For Mac troubleshooting: <https://learn.sparkfun.com/tutorials/how-to-install-ftdi-drivers/mac>

Part 3: Practice With Code

1. From the Arduino application, load an example sketch by selecting File → Examples → 01.Basics → Blink.
2. Examine the code in the Blink example. Notice there are notes after the //. This text is a comment and will not be compiled by the program or affect its size. It's a good practice to add comments to code for reference and troubleshooting later on.
3. Click the Upload button (shown below) to transfer the Blink sketch to the board. The LEDs labeled RX and TX will flash, and the software will show a message "Done uploading" at the bottom of the window. A few seconds later the LED on the board will begin to blink to the pattern stated in the sketch.



4. Give yourself a pat on the back! You have just sent your first code to an Arduino. Using these same basic skills, you can launch any number of other awesome electronics projects!

Skills Check!

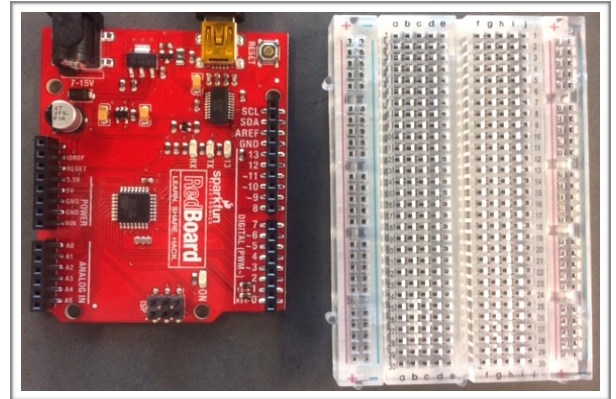
Manipulate the code in the Blink example to make the LED blink faster or slower. Remember to click the Upload button to transfer the new code to the Arduino board. Were you successful? If so, record what you did to change the blinking rate here:



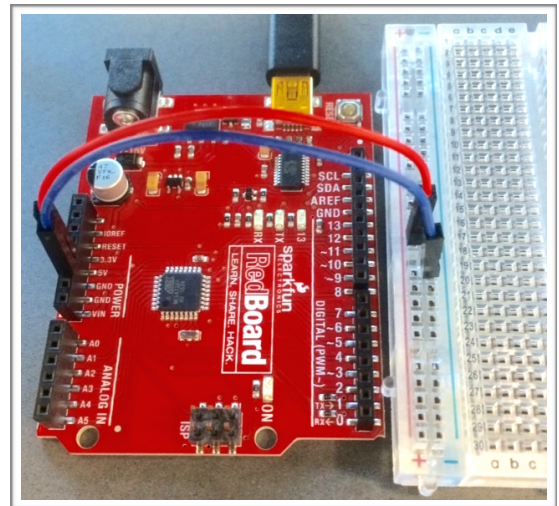
CONGRATULATIONS! You have completed the the first steps in using and programming Arduino. In the next steps, you will learn how to connect a breadboard LED circuit.

Part 4: Breadboard LED Circuit

1. Disconnect the USB cable before wiring your Arduino to the breadboard.
2. Set the Arduino Uno and breadboard side by side as shown.

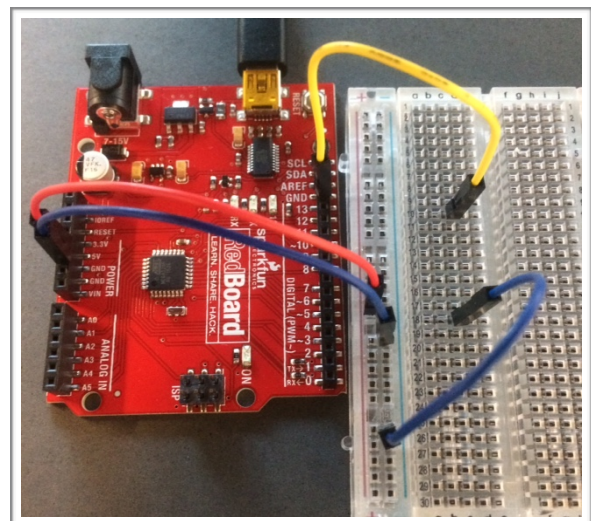


3. Plug one end of a red wire into the pin marked 5V on the Arduino board. Plug the other end into the breadboard rail marked with a red line (red power rail).
4. Plug a blue wire into one of the pins marked GND. (Note: there are 3 GND ground pins. They're all wired to the same ground chip, so it doesn't matter which one you choose). Plug the other end of the blue wire into the blue power rail on the breadboard.



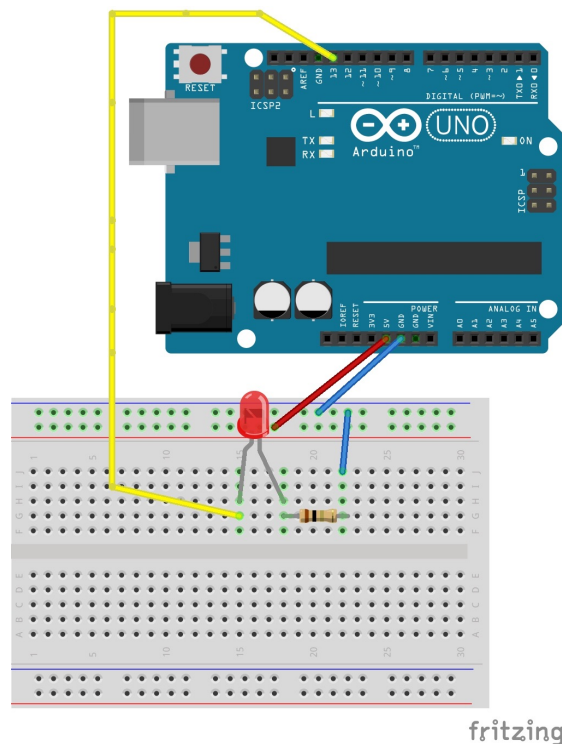
****Important note: wires are all the same; the various colors are used to easily differentiate various connections and circuits when following schematics, diagrams or written instructions.**

5. Plug a yellow wire into Arduino pin 13. This will be used to complete a circuit (connects to the ground pin/rail) with the LED. Plug the other end into any horizontal row within the breadboard rows closest to the Arduino.
6. Connect a blue wire from the blue power rail into any breadboard row (columns a - e).





7. Find a 1K resistor within your supplies- they have brown, black, and gold bands. Plug one wire lead from the resistor into the same row as one of the blue wires. Plug the other end into the same column beside the yellow wire. ***Note: A resistor must follow the path of the circuit, the shorter end (-) of the LED must be in the same row as one end of the resistor, and the other end needs to be in the same row as the ground wire.*
8. Grab a red LED and connect the longer wire lead (positive anode) in the same row as the



yellow wire and the shorter wire lead (negative cathode) in the same row next to the resistor.

In this circuit, a positive charge streams from the Arduino pin through the LED and resistor to ground. A resistor helps limit the current of electricity flowing to the LED light bulb.

9. Plug your Arduino into the computer using the USB cable and the LED should start to blink. Upload the "Blink" file from the 'Arduino Examples—>Basics' menu and edit the sketch to watch the LED blink faster or slower.
10. Ready for another challenge? Try connecting multiple LEDs following these [diagram instructions \(http://nautl.us/2kASED3\)](http://nautl.us/2kASED3).
11. When you are ready to move on, unplug the USB cable and remove all but the first LED and its yellow wire from the breadboard.
12. Move the yellow wire to Arduino pin 9.
13. Complete the two applications on the next page.



Student Applications |

Part 1: Proofreading Code: Examine the following sketch and fix any errors. If done correctly, the code should make the LED fade in and out when uploaded to Arduino. Type your corrected code into a blank sketch to see if it works.

```
int led = 9;           // the PWM pin the LED is attached to
int brightness = 0;    // how bright the LED is
int fadeAmount = 5     // how many points to fade the LED by

// the setup routine runs once when you press reset:
void setup() {
  // declare pin 5 to be an output:

}

// the loop routine runs over and over again forever:
void loop() {
  // set the brightness of pin 5:
  analogWrite( led, brightness);

  // change the brightness for next time through the loop:
  brightness = brightness + fadeAmount;

  // reverse the direction of the fading at the ends of the fade:
  if (brightness <= 255 || brightness >= 0) {
    fadeAmount = -fadeAmount;
  }
  // wait for 30 milliseconds to see the dimming effect
  delay(10);
}
```

Part 2: Write an SOS Code: Create your own code to get the LED to blink in an SOS pattern (3 short pulses followed by 3 long pulses followed by 3 short pulses). Take a screenshot or record your code below.

Discussion Question: Compare your group's code with others. Can different codes produce the same results?



CODES & CONTROLLERS | ASSESSMENT

Module 1: Sensor Technology Series

OBJECTIVE	CRITERIA			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Knowledge & Understanding 	Student consistently, correctly and thoroughly answers all questions. Uses an abundance of relevant vocabulary and is able to explain relationships within the content using examples. Can apply the content to other topics or real life.	Student is able to consistently answer most questions correctly. Uses an adequate amount of relevant vocabulary. Can explain relationships within the content and can apply content to other topics or real life.	Student is able to answer some questions correctly. Uses some relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.	Student is able to answer a few questions correctly. Inconsistently uses relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.
Content Organization, Methodology & Analysis 	Student effectively organizes complex ideas, concepts, and information to make important connections and distinctions. This may include detailed, labeled and thorough procedures, data tables, graphs, diagrams and/or analyses.	Student is able to organize ideas, concepts, and information to make connections and distinctions. This may include mostly detailed, labeled and thorough procedures, data tables, graphs, diagrams and/or analyses.	Student attempts to organize ideas, concepts and information to make some connections and distinctions. Student is able to provide basic procedures, data tables, graphs, diagrams and/or analyses.	Student has difficulty organizing ideas, concepts and information to make connections and distinctions. Student is unable to provide basic procedures, data tables, graphs, diagrams and/or analyses.
Self-Directed Learner 	Student is actively engaged in the learning process; consistently contributes to class discussions and asks clarifying questions. Seeks out and shares additional resources with the class or teacher. Advocates for his/her learning needs.	Student is engaged in the learning process. Often contributes to class discussions and asks clarifying questions. Advocates for his/her learning needs.	Student is inconsistently engaged in the learning process. Sometimes contributes to class discussions or asks clarifying questions. Inconsistently advocates for his/her learning needs.	Student is weakly engaged in the learning process. Rarely contributes to class discussions or asks clarifying questions. Rarely advocates for his/her learning needs.
Technological Tools 	Use of digital resources is always appropriate for the task. Willing to learn and use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is appropriate for the task. Willing to use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is sometimes appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is rarely appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.
Collaboration Skills 	Consistently works effectively and respectfully with a diverse group of learners. Actively checks with others for understanding and how he or she may be of help. Student listens when others speak and incorporates or builds off of the ideas of others.	Works effectively and respectfully with a diverse group of learners. Checks with others for understanding and how he or she may be of help. Student listens when others speak.	Sometimes works effectively and respectfully with a diverse group of learners. Sometimes checks with others for understanding and how he or she may be of help. Student listens when others speak.	Has difficulty working effectively and respectfully with a diverse group of learners. Rarely checks with others for understanding and how he or she may be of help. Student may talk over other students or does not listen when others speak.
Total Score: <hr/>	Comments:			

HOW LARGE IS NAUTILUS NATION?

Tracking the reach of Ocean Exploration Trust's education programs is essential in ensuring we are funded to continue making discoveries and inspiring the next generation of explorers.

Name: _____ **My Community (City, State):** _____

Email Address: _____

School's Name: _____

Instruction date: _____ **Grade level instructed:** _____

Subject area: _____

My education space is a...	Who did you engage in your teaching?
<input type="checkbox"/> Classroom	# Students
<input type="checkbox"/> After school program / Club meeting	
<input type="checkbox"/> Fair / Festival / Event	
<input type="checkbox"/> Museum / Science Center	# Community Members
<input type="checkbox"/> Other. Tell us more: _____	

Select all the OET materials you used in your instruction:

- ☐ STEM Learning Modules. Which ones? _____
- ☐ Digital Resource Library materials. Which ones? _____
- ☐ Nautilus Live website: photo albums ☐ highlight videos ☐ live stream
- ☐ Meet the Team STEM mentor profiles
- ☐ Facebook (NautilusLive) ☐ Twitter (@EVNautilus) ☐ Instagram (@nautiluslive)
- ☐ Other. Tell us more: _____

What made working with OET resources valuable to your instruction (select all that apply)?

- ☐ Hands-on activities ☐ STEM career connections
- ☐ Easy to use lessons ☐ Standards-based lessons
- ☐ Website resource access ☐ Real world application of curricula topics
- ☐ Excitement of cutting-edge discoveries / Unfamiliarity of deep ocean
- ☐ Another reason. Tell us more: _____

Using OET resources increased my confidence in teaching my science, technology, engineering, or math subjects.	<input type="checkbox"/> Yes	<input type="checkbox"/> No
OET provided me with helpful and relevant teaching resources.	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Using OET resources increased my awareness of STEM careers.	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, how so? How can we improve?		

Please scan this document or snap a picture of it with your phone. Email the feedback or questions to education@oet.org. You can also submit feedback online: <http://nautl.us/2cp3PNu>

THANK YOU FOR ALL YOU DO!