BUILD THE CIRCUIT

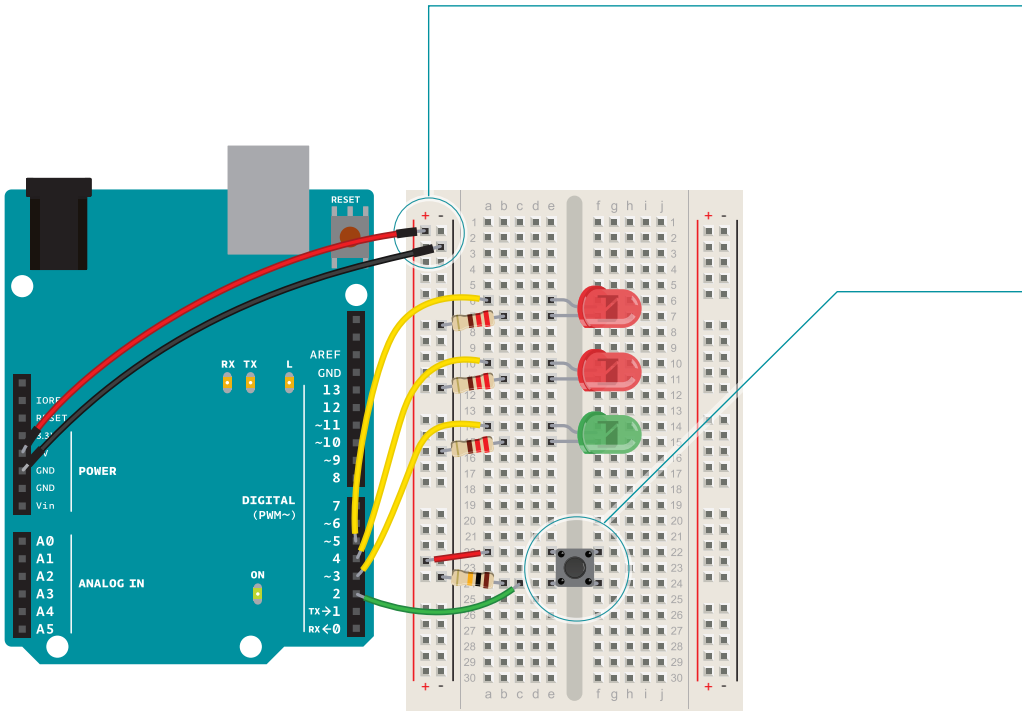


Fig. 1

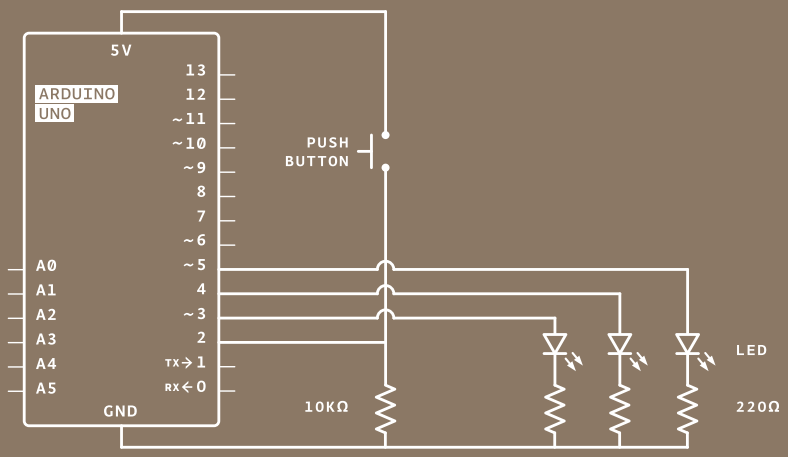
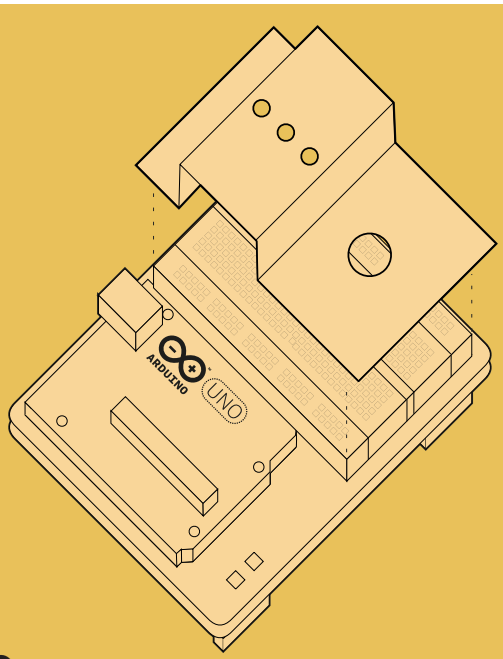


Fig. 2

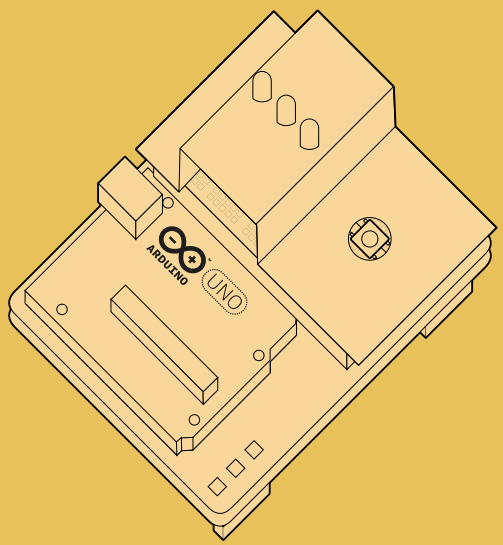
1. Wire up your breadboard to the Arduino's 5V and ground connections, just like the previous project. Place the two red LEDs and one green LED on the breadboard. Attach the cathode (short leg) of each LED to ground through a 220-ohm resistor. Connect the anode (long leg) of the green LED to pin 3. Connect the red LEDs' anodes to pins 4 and 5, respectively.

2. Place the switch on the breadboard just as you did in the previous project. Attach one side to power, and the other side to digital pin 2 on the Arduino. You'll also need to add a 10k-ohm resistor from ground to the switch pin that connects to the Arduino. That pull-down resistor connects the pin to ground when the switch is open, so it reads `LOW` when there is no voltage coming in through the switch.

You can cover the breadboard the template provided in the kit. Or you can decorate it to make your own launch system. The lights turning on and off mean nothing by themselves, but when you put them in a control panel and give them labels, they gain meaning. What do you want the green LED to mean? What do the flashing red LEDs mean? You decide!



1. Fold the pre-cut paper as shown.



2. Place the folded paper over the breadboard. The three LEDs and pushbutton will help keep it in place.

THE CODE

Some notes before you start

Every Arduino program has two main functions. Functions are parts of a computer program that run specific commands. Functions have unique names, and are "called" when needed. The necessary functions in an Arduino program are called `setup()` and `loop()`. These functions need to be declared, which means that you need to tell the Arduino what these functions will do. `setup()` and `loop()` are declared as you see on the right.

In this program, you're going to create a variable before you get into the main part of the program. Variables are names you give to places in the Arduino's memory so you can keep track of what is happening. These values can change depending on your program's instructions.

Variable names should be descriptive of whatever value they are storing. For example, a variable named `switchState` tells you what it stores: the state of a switch. On the other hand, a variable named `"x"` doesn't tell you much about what it stores.

Let's start coding

To create a variable, you need to declare what *type* it is. The *data type* `int` will hold a whole number (also called an *integer*); that's any number without a decimal point. When you declare a variable, you usually give it an initial value as well. The declaration of the variable as every statement must end with a semicolon (;).

Configure pin functionality

The `setup()` runs once, when the Arduino is first powered on. This is where you configure the digital pins to be either inputs or outputs using a function named `pinMode()`. The pins connected to LEDs will be OUTPUTs and the switch pin will be an `INPUT`.

Create the loop function

The `loop()` runs continuously after the `setup()` has completed. The `loop()` is where you'll check for voltage on the inputs, and turn outputs on and off. To check the voltage level on a digital input, you use the function `digitalRead()` that checks the chosen pin for voltage. To know what pin to check, `digitalRead()` expects an *argument*.

Arguments are information that you pass to functions, telling them how they should do their job. For example, `digitalRead()` needs one argument: what pin to check. In your program, `digitalRead()` is going to check the state of

```
void setup(){
}

void loop(){
}
```

{ Curly brackets }
Any code you write inside the curly brackets will be executed when the function is called.

```
1 int switchState = 0;
```

```
2 void setup(){
3   pinMode(3,OUTPUT);
4   pinMode(4,OUTPUT);
5   pinMode(5,OUTPUT);
6   pinMode(2,INPUT);
7 }
```

Case sensitivity
Pay attention to the `case sensitivity` in your code.
For example, `pinMode` is the name of a command, but pinmode will produce an error.

```
8 void loop(){
9   switchState = digitalRead(2);
10  // this is a comment
```

Comments
If you ever want to include natural language in your program, you can leave a comment.
Comments are notes you leave for yourself that the computer ignores. To write a comment, add two slashes `//`
The computer will ignore anything on the line after those slashes.

pin 2 and store the value in the switchState variable.
If there's voltage on the pin when `digitalRead()` is called, the `switchState` variable will get the value `HIGH` (or 1). If there is no voltage on the pin, switchState will get the value `LOW` (or 0).

The if statement

Above, you used the word if to check the state of something (namely, the switch position). An `if()` statement in programming compares two things, and determines whether the comparison is true or false. Then it performs actions you tell it to do. When comparing two things in programming, you use two equal signs ==. If you use only one sign, you will be setting a value instead of comparing it.

Build up your spaceship

`digitalWrite()` is the command that allows you to send 5V or 0V to an output pin. `digitalWrite()` takes two arguments: what pin to control, and what value to set that pin, `HIGH` or `LOW`. If you want to turn the red LEDs on and the green LED off inside your `if()` statement, your code would look like this .

If you run your program now, the lights will change when you press the switch. That's pretty neat, but you can add a little more complexity to the program for a more interesting output.

You've told the Arduino what to do when the switch is open. Now define what happens when the switch is closed. The `if()` statement has an optional `else` component that allows for something to happen if the original condition is not met. In this `case`, since you checked to see if the switch was `LOW`, write code for the `HIGH` condition after the `else` statement.

To get the red LEDs to blink when the button is pressed, you'll need to turn the lights off and on in the `else` statement you just wrote. To do this, change the code to look like this.

Now your program will flash the red LEDs when the switch button is pressed.

After setting the LEDs to a certain state, you'll want the Arduino to pause for a moment before changing them back. If you don't wait, the lights will go back and forth so fast that it will appear as if they are just a little dim, not on and off. This is because the Arduino goes through its `loop()` thousands of times each second, and the LED will be turned on and off quicker than we can perceive. The `delay()` function lets you stop the Arduino from executing anything for a period of time. `delay()` takes an argument that determines the number of milliseconds before it executes the next set of code. There are 1000 milliseconds in one second. `delay(250)` will pause for a quarter second.

```
  if (switchState == LOW) {
  // the button is not pressed
    digitalWrite(3, HIGH); // green LED
    digitalWrite(4, LOW);  // red LED
    digitalWrite(5, LOW);  // red LED
  }
```

```
  else {  // the button is pressed
    digitalWrite(3, LOW);
    digitalWrite(4, LOW);
    digitalWrite(5, HIGH);

    delay(250);  // wait for a quarter second
    // toggle the LEDs
    digitalWrite(4, HIGH);
    digitalWrite(5, LOW);
    delay(250); // wait for a quarter second

  }
} // go back to the beginning of the loop
```

It can be helpful to write out the flow of your program in pseudocode: a way of describing what you want the program to do in plain language, but structured in a way that makes it easy to write a real program from it. In this case you're going to determine if `switchState` is `HIGH` (meaning the button is pressed) or not. If the switch is pressed, you'll turn the green LED off and the red ones on. In pseudocode, the statement could look like this:

```
if the switchState is LOW:
  turn the green LED on
  turn the red LEDs off

if the switchState is HIGH:
  turn the green LED off
  turn the red LEDs on
```

USE IT

Once your Arduino is programmed, you should see the green light turn on. When you press the switch, the red lights will start flashing, and the green light will turn off. Try changing the time of the two `delay()` functions; notice what happens to the lights and how the response of the system changes depending on the speed of the flashing. When you call a `delay()` in your program, it stops all other functionality. No sensor readings will happen until that time period has passed. While delays are often useful, when designing your own projects make sure they are not unnecessarily interfering with your interface.

How would you get the red LEDs to be blinking when your program starts? How could you make a larger, or more complex interface for your interstellar adventures with LEDs and switches?

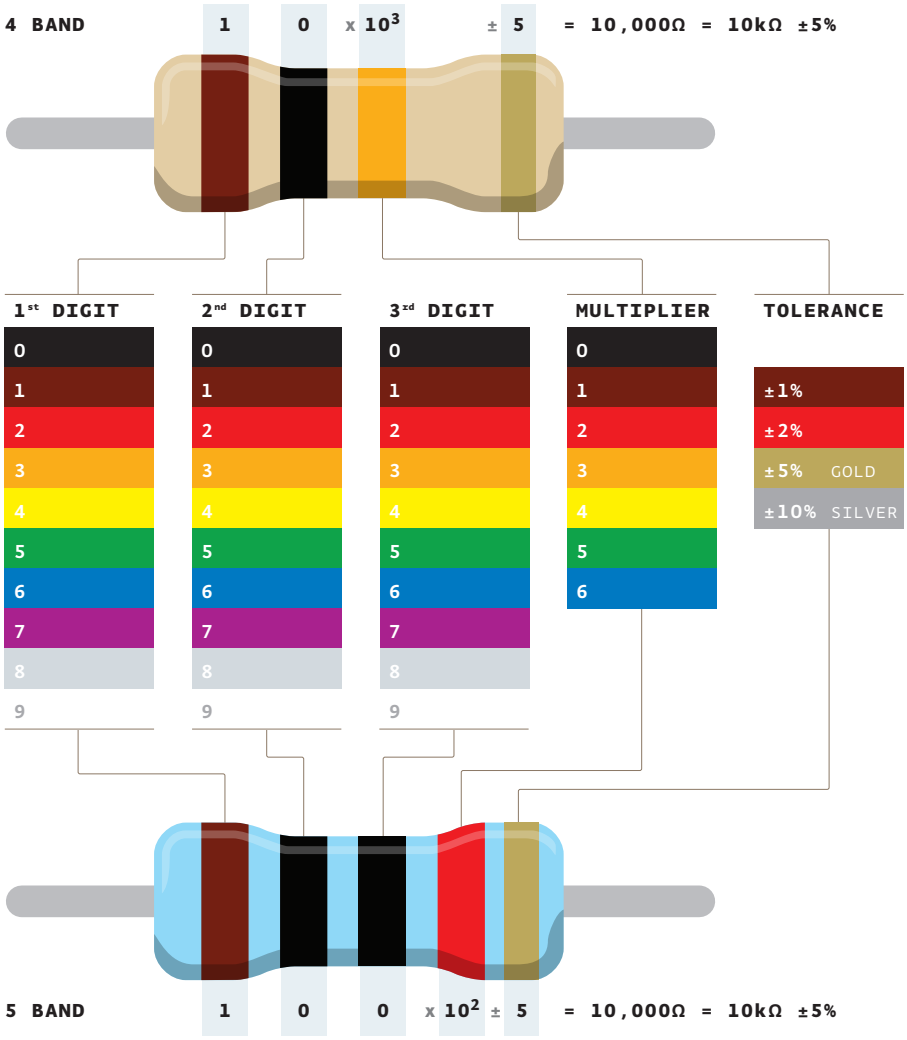
When you start creating an interface for your project, think about what people's expectations are while using it. When they press a button, will they want immediate feedback? Should there be a delay between their action and what the Arduino does? Try and place yourself in the shoes of a different user while you design, and see if your expectations match up to the reality of your project.

In this project, you created your first Arduino program to control the behavior of some LEDs based on a switch. You've used variables, an if()...else statement, and functions to read the state of an input and control outputs.

HOW TO READ RESISTOR COLOR CODES

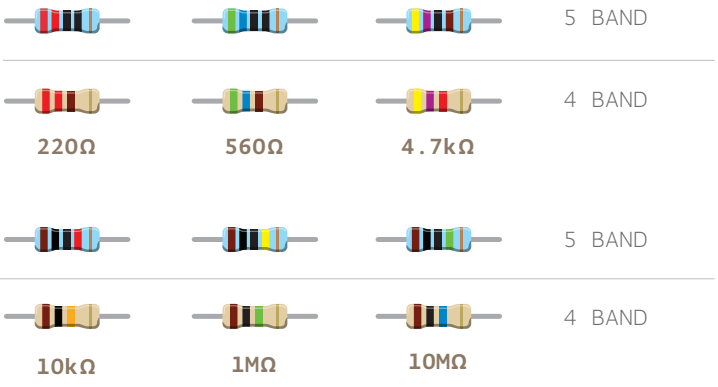
Resistor values are marked using colored bands, according to a code developed in the 1920s, when it was too difficult to write numbers on such tiny objects.

Each color corresponds to a number, like you see in the table below. Each resistor has either 4 or 5 bands. In the 4-band type, the first two bands indicate the first two digits of the value while the third one indicates the number of zeroes that follow (technically it reprents the power of ten). The last band specifies the tolerance: in the example below, gold indicates that the resistor value can be 10k ohm plus or minus 5%.



RESISTORS INCLUDED IN THE STARTER KIT

You'll find either a 4 band or a 5 band version.



03

LED

220 OHM RESISTOR

TEMPERATURE SENSOR

INGREDIENTS

LOVE-O-METER

TURN THE ARDUINO INTO A LOVE MACHINE. USING AN ANALOG INPUT, YOU'RE GOING TO REGISTER JUST HOW HOT YOU REALLY ARE!

Discover: analog Input, using the serial monitor

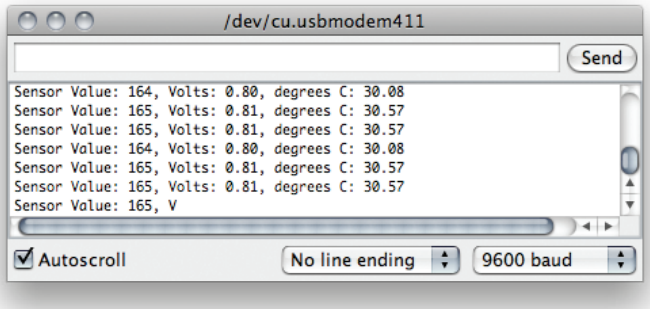
Time: **45 MINUTES**
Level: ■ □ □ □ □

Builds on projects: **1, 2**

While switches and buttons are great, there's a lot more to the physical world than on and off. Even though the Arduino is a digital tool, it's possible for it to get information from analog sensors to measure things like temperature or light. To do this, you'll take advantage of the Arduino's built-in Analog-to-Digital Converter (ADC). Analog in pins A0-A5 can report back a value between 0-1023, which maps to a range from 0 volts to 5 volts.

You'll be using a ***temperature sensor*** to measure how warm your skin is. This component outputs a changing voltage depending on the temperature it senses. It has three pins: one that connects to ground, another that connects to power, and a third that outputs a variable voltage to your Arduino. In the sketch for this project, you'll read the sensor's output and use it to turn LEDs on and off, indicating how warm you are. There are several different models of temperature sensor. This model, the TMP36, is convenient because it outputs a voltage that changes directly proportional to the temperature in degrees Celsius.

The Arduino IDE comes with a tool called the ***serial monitor*** that enables you to report back results from the microcontroller. Using the serial monitor, you can get information about the status of sensors, and get an idea about what is happening in your circuit and code as it runs.



Serial monitor

Fig. 1

BUILD THE CIRCUIT

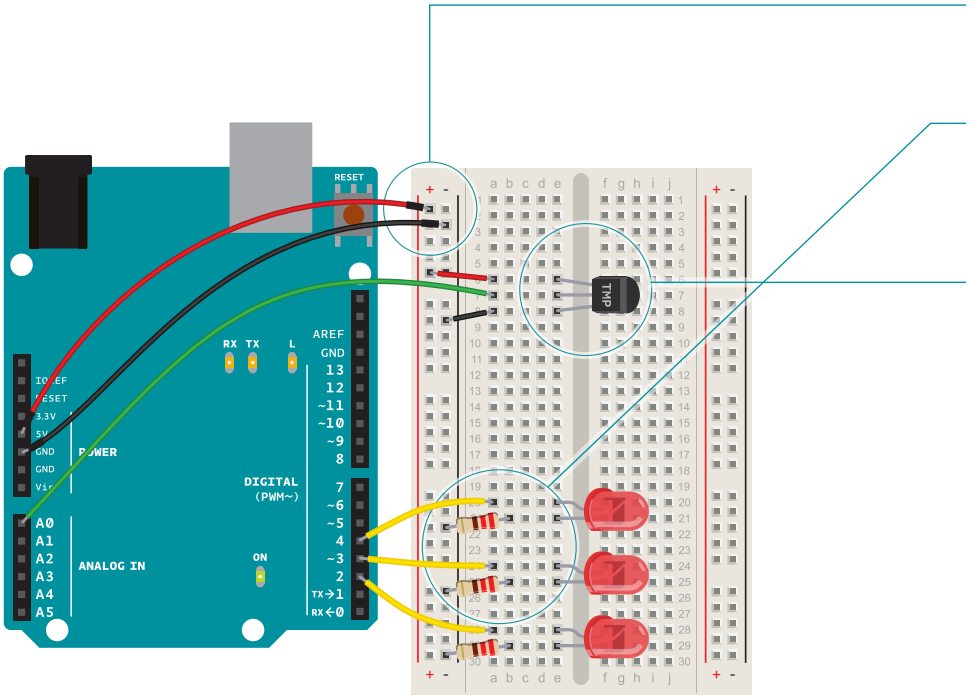


Fig. 2

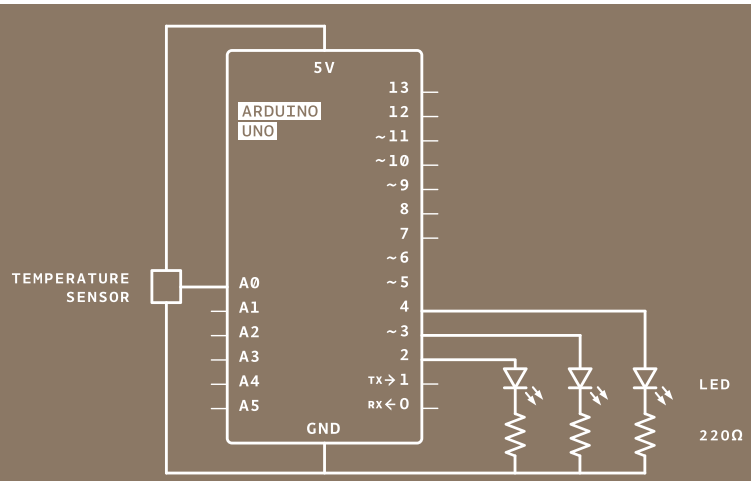


Fig. 3

In this project, you need to check the ambient temperature of the room before proceeding. You're checking things manually right now, but this can also be accomplished through calibration. It's possible to use a button to set the baseline temperature, or to have the Arduino take a sample before starting the `loop()` and use that as the reference point. Project 6 gets into details about this, or you can look at the Calibration example that comes bundled with the Arduino software:

arduino.cc/calibration

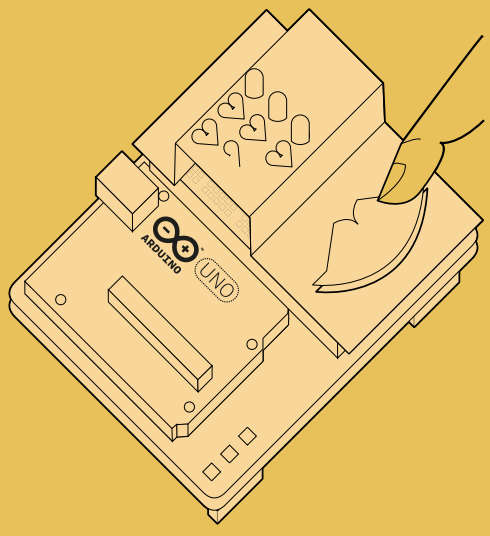
1. Just as you've been doing in the earlier projects, wire up your breadboard so you have power and ground.

2. Attach the cathode (short leg) of each of the LEDs you're using to ground through a 220-ohm resistor. Connect the anodes of the LEDs to pins 2 through 4. These will be the indicators for the project.

3. Place the TMP36 on the breadboard with the rounded part facing away from the Arduino (the order of the pins is important!) as shown in Fig. 2. Connect the left pin of the flat facing side to power, and the right pin to ground. Connect the center pin to pin A0 on your Arduino. This is analog input pin 0.

Create an interface for your sensor for people interact with. A paper cutout in the shape of a hand is a good indicator. If you're feeling lucky, create a set of lips for someone to kiss, see how well that lights things up! You might also want to label the LEDs to give them some meaning. Maybe one LED means you're a cold fish, two LEDs means you're warm and friendly, and three LEDs means you're too hot to handle!

1. Cut out a piece of paper that will fit over the breadboard. Draw a set of lips where the sensor will be, and cut some circles for the LEDs to pass through.



2. Place the cutout over the breadboard so that the lips cover the sensor and the LEDs fit into the holes. Press the lips to see how hot you are!

THE CODE

A pair of useful constants

Constants are similar to variables in that they allow you to uniquely name things in the program, but unlike variables they cannot change. Name the analog input for easy reference, and create another named constant to hold the baseline temperature. For every 2 degrees above this baseline, an LED will turn on.
You've already seen the int datatype, used here to identify which pin the sensor is on. The temperature is being stored as a *float*, or floating-point number. This type of number has a decimal point, and is used for numbers that can be expressed as fractions.

Initialize the serial port to the desired speed

In the setup you're going to use a new command, `Serial.begin()`. This opens up a connection between the Arduino and the computer, so you can see the values from the analog input on your computer screen.
The argument `9600` is the speed at which the Arduino will communicate, 9600 bits per second. You will use the Arduino IDE's serial monitor to view the information you choose to send from your microcontroller. When you open the IDE's serial monitor verify that the baud rate is 9600.

Initialize the digital pin directions and turn off

Next up is a `for()` loop to set some pins as outputs. These are the pins that you attached LEDs to earlier. Instead of giving them unique names and typing out the `pinMode()` function for each one, you can use a `for()` loop to go through them all quickly. This is a handy trick if you have a large number of similar things you wish to iterate through in a program. Tell the `for()` loop to run through pins 2 to 4 sequentially.

Read the temperature sensor

In the `loop()`, you'll use a local variable named `sensorVal` to store the reading from your sensor. To get the value from the sensor, you call `analogRead()` that takes one argument: what pin it should take a voltage reading on. The value, which is between 0 and 1023, is a representation of the voltage on the pin.

Send the temperature sensor values to the computer

The function `Serial.print()` sends information from the Arduino to a connected computer. You can see this information in your serial monitor. If you give `Serial.print()` an argument in quotation marks, it will print out the text you typed. If you give it a variable as an argument, it will print out the value of that variable.

```
1 const int sensorPin = A0;
2 const float baselineTemp = 20.0;
```

```
3 void setup(){
4   Serial.begin(9600); // open a serial port
```

```
5   for(int pinNumber = 2; pinNumber<5; pinNumber++){
6     pinMode(pinNumber,OUTPUT);
7     digitalWrite(pinNumber, LOW);
8   }
9 }
```

for() loop tutorial
arduino.cc/for

```
10 void loop(){
11   int sensorVal = analogRead(sensorPin);
```

```
12   Serial.print("Sensor Value: ");
13   Serial.print(sensorVal);
```

Convert sensor reading to voltage

With a little math, it's possible to figure out what the real voltage on the pin is. The voltage will be a value between 0 and 5 volts, and it will have a fractional part (for example, it might be 2.5 volts), so you'll need to store it inside a `float`. Create a variable named voltage to hold this number. Divide `sensorVal` by 1024.0 and multiply by 5.0. The new number represents the voltage on the pin.

Just like with the sensor value, you'll print this out to the serial monitor.

Convert the voltage to temperature and send the value to the computer

If you examine the sensor's *datasheet*, there is information about the range of the output voltage. Datasheets are like manuals for electronic components. They are written by engineers, for other engineers. The datasheet for this sensor explains that every 10 millivolts of change from the sensor is equivalent to a temperature change of 1 degree Celsius. It also indicates that the sensor can read temperatures below 0 degrees. Because of this, you'll need to create an offset for values below freezing (0 degrees). If you take the voltage, subtract 0.5, and multiply by 100, you get the accurate temperature in degrees Celsius. Store this new number in a floating point variable called temperature.

Now that you have the real temperature, print that out to the serial monitor too. Since the temperature variable is the last thing you're going to be printing out in this loop, you're going to use a slightly different command: `Serial.println()`. This command will create a new line in the serial monitor after it sends the value. This helps make things easier to read in when they are being printed out.

Turn off LEDs for a low temperature

With the real temperature, you can set up an `if()...else` statement to light the LEDs. Using the baseline temperature as a starting point, you'll turn on one LED on for every 2 degrees of temperature increase above that baseline. You're going to be looking for a range of values as you move through the temperature scale.

```
14   // convert the ADC reading to voltage
15   float voltage = (sensorVal/1024.0) * 5.0;
```

```
16   Serial.print(", Volts: ");
17   Serial.print(voltage);
```

```
18   Serial.print(", degrees C: ");
19   // convert the voltage to temperature in degrees
20   float temperature = (voltage - .5) * 100;
21   Serial.println(temperature);
```

```
22   if(temperature < baselineTemp){
23     digitalWrite(2, LOW);
24     digitalWrite(3, LOW);
25     digitalWrite(4, LOW);
```

Starter Kit datasheets
arduino.cc/kitdatasheets

Turn on one LED for a low temperature

The && operator means "`and`", in a logical sense. You can check for multiple conditions: "if the temperature is 2 degrees greater than the baseline, and it is less than 4 degrees above the baseline."

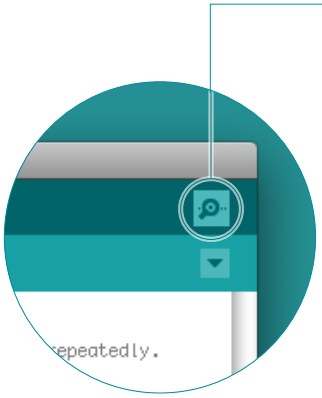
Turn on two LEDs for a medium temperature

If the temperature is between two and four degrees above the baseline, this block of code turns on the LED on pin 3 as well.

Turn on three LEDs for a high temperature

The Analog-to-Digital Converter can only read so fast, so you should put a small delay at the very end of your `loop()`. If you read from it too frequently, your values will appear erratic.

USE IT



With the code uploaded to the Arduino, click the serial monitor icon. You should see a stream of values coming out, formatted like this : `Sensor: 200, Volts: .70, degrees C: 17`

Try putting your fingers around the sensor while it is plugged into the breadboard and see what happens to the values in the serial monitor. Make a note of what the temperature is when the sensor is left in the open air.

Close the serial monitor and change the baselineTemp constant in your program to the value you observed the temperature to be. Upload your code again, and try holding the sensor in your fingers. As the temperature rises, you should see the LEDs turn on one by one. Congratulations, hot stuff!

```
  }else if(temperature >= baselineTemp+2 &&
    temperature < baselineTemp+4){
    digitalWrite(2, HIGH);
    digitalWrite(3, LOW);
    digitalWrite(4, LOW);

  }else if(temperature >= baselineTemp+4 &&
    temperature < baselineTemp+6){
    digitalWrite(2, HIGH);
    digitalWrite(3, HIGH);
    digitalWrite(4, LOW);

  }else if(temperature >= baselineTemp+6){
    digitalWrite(2, HIGH);
    digitalWrite(3, HIGH);
    digitalWrite(4, HIGH);

  }
  delay(1);
}
```

Create an interface for two people to test their compatibility with each other. You get to decide what compatibility means, and how you'll sense it. Perhaps they have to hold hands and generate heat? Maybe they have to hug? What do you think?

Expanding the types of inputs you can read, you've used analogRead() and the serial monitor to track changes inside your Arduino. Now it's possible to read a large number of analog sensors and inputs.

04

LED

220 OHM RESISTOR

10 KILOHM RESISTOR

PHOTORESISTOR

GEL

INGREDIENTS