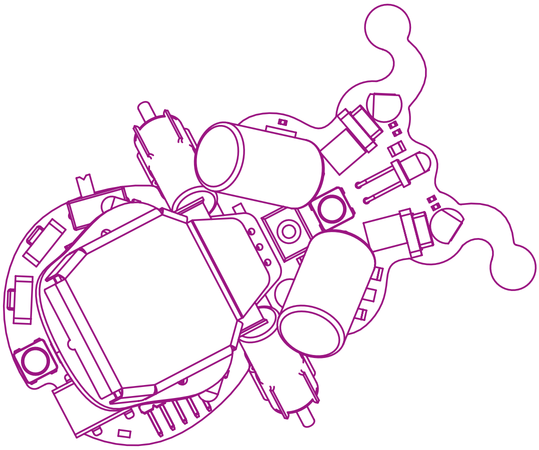
Ringo Educational Guide



Overview

Thank you!!

Thank you for your support in purchasing a Ringo robot. Ringo began as a project I started with my son and daughter. We wanted to design a robot together as a fun family project and only planned to make a couple of them. The idea evolved into a Kickstarter campaign which became very successful. We have been overwhelmed with the incredible community support and encouragement we received along the way. We are very hopeful to continue designing and producing many more robots in the future.

Your Ringo robot was assembled with love and care near Portland, Oregon. We had most of the components sent from over seas, but we actually populate all the parts on the board, as well as program and test right here in our own little shop. Most of the assembly was performed by students we hired from our local Clark Community Collage. We thank you for supporting a small business run by people of the Maker movement, and we hope Ringo will provide you a fun learning experience and many hours of entertainment. Cheers!

Acknowledgements

This guide will give you a quick orientation of the Ringo robot and how to program him, but first we want to give a few acknowledgements. Ringo is Open Source Hardware, which means his design is open to study and learn from. He wouldn't have been possible without others before us sharing their own open source creations with the world.

We have produced several of Ringo's primary systems based on open designs from SparkFun and AdaFruit, and Ringo's brain and programming environment were brought to the world by Massimo Banzi and the other fine people behind the Arduino project. Arduino has grown to become one of the most popular open source development platforms in history thanks to the wonderful user community which sprang up around the platform. Ringo's motor design was inspired by the Solar Popper robot produced by Solarbotics. Solarbotics is known for producing BEAM robotics kits, which are robots that carry out rather complex behaviors yet are based on very simple analog circuitry. Robotics physicist Mark Tilden is largely credited for the creation of the BEAM robot movement. I guess what we're saying is that creations like Ringo are possible thanks to the open sharing of knowledge between creative people. These fine people and many more we haven't mentioned have their fingerprints on Ringo as much as the people at Plum Geek. We hope you will join us and continue in this spirit as you write interesting software and create behaviors for Ringo that can be shared and built upon in the community. We're very excited to have you along for the ride!

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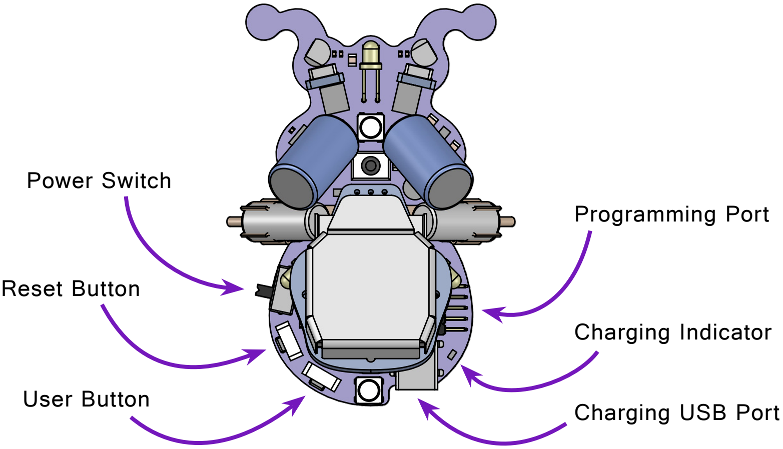
Overview



Overview of Ringo's Parts:

Power Switch: This turns Ringo on and off. Click it forward to turn Ringo ON, click it rearward to turn Ringo OFF.

Battery: Ringo contains a 240 mAh Lithium Polymer battery, sometimes called a "LiPo" battery. LiPo batteries are awesome for a few reasons, but they do have a down side. If the battery is discharged too far, it becomes permanently damaged. Lucky for you, Ringo has a part onboard called a "voltage monitor". It's a little part that looks at battery voltage all the time, and if that voltage drops below 3.0 volts, it will immediate turn Ringo off, and will allow him to turn back on once the voltage is increased by charging the battery. All this to say, you don't have to worry about discharging Ringo too far. He will take care of himself if he is left on or run too long without a charge. If you notice Ringo is tending to reset on his own, it is likely because the battery voltage is getting low. Turn him off and plug him into a charging source for a while and he'll be happy again.

Charging Ringo: Ringo has a self contained battery charging circuit. Whenever he is plugged into a power source via either the Charging USB Port or the Programming Port, he will automatically charge his battery. This happens whether the Power Switch is turned on or off. It is okay to run Ringo while charging. The charger will automatically turn off when Ringo's battery is full (about 4.2 volts), so you cannot over charge him. Just plug him in and let him handle it. Whenever Ringo is charging, the RED Charging Indicator will be lit.

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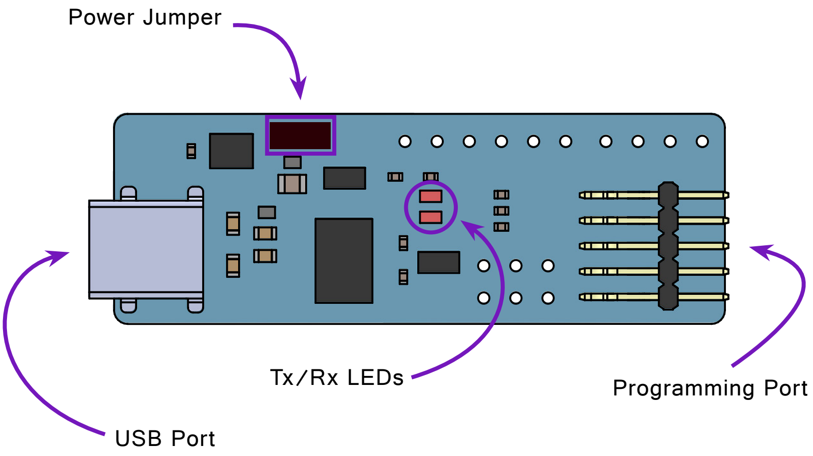
Charging USB Port: The USB port present on Ringo does not allow for programming him. However, it is useful for charging his battery. USB cables provide a 5 volt power source which is used for charging. Feel free to plug him into a USB power source via this port for charging without the programming adaptor. (When the Programming Adaptor is plugged into a USB power source, it will pass this 5 volt power along the programming cable to Ringo's Programming Port, and Ringo will use this source whenever available to automatically begin charging his battery).

Reset Button: This button connects to a special pin on Ringo's brain. Whenever pressed, it will halt Ringo's processing, and when released, Ringo will startup fresh from the beginning of his program. This button does the same thing as turning the power switch off then back on.

User Button: This is a button you can use for your own purposes. Ringo can be programmed to look at this button and determine if it is being pressed, and if it is being pressed, to carry out some action, to change his behavior in some way, whatever you can think of. We'll cover the use of this button later in this guide.

Programming Port: This port connects Ringo to the Plum Geek Programming Adaptor. It is used to load Ringo with his programming. It can also charge Ringo's battery when the Programming Adaptor is plugged into a USB power source.

Overview



The Programming Adaptor is used to communicate between your computer and Ringo's brain. We'll go into more detail later in the installation section, but wanted to provide a quick overview of the programmer here.

USB Port: Connect this to your computer. This requires a USB A to Mini-B cable.

Programming Port: This connects to Ringo via the programming cable.

Tx/Rx LEDs: These LEDs blink whenever data travels between Ringo and your computer through the programmer.

Power Jumper: This jumper connects the power supplied by your computer via the USB Port to the Programming Port, which allows Ringo to charge through the Programming Adaptor. Normally this should be left in place. It is however occasionally useful to remove this jumper. As the battery in Ringo reaches its maximum charge level, the charging circuit will continue to cycle on and off while Ringo is running, which causes minor voltage fluctuations in Ringo's power system. This is okay and normal, except that while taking readings from Ringo's sensors (like the light sensors), you'll see these readings spiking a lot more while charging is allowed. In this case, it may be useful to prevent Ringo from charging while still allowing Ringo to communicate with your computer. Remove the jumper to suspend charging. If you do remove the jumper, place it back on one of the pins so the little jumper connector is not lost on your desk.

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Software Installation

Install the Arduino IDE (Integrated Development Environment)

Access the Internet

In order to program your Ringo, you'll need to download the newest version of the Arduino software first from www.arduino.cc. (it's free!). This software, known as the Arduino IDE, will allow you to program your Ringo to do exactly what you want. It's like a word processor for writing programs. With an internet-capable computer, open up your favorite browser and type in the following URL into the address bar:

arduino.cc/en/main/software

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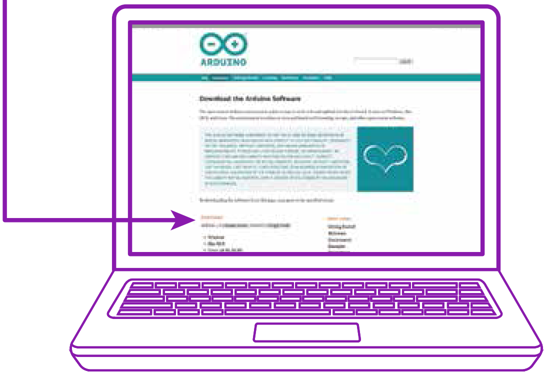
Download | **Click on your appropriate computer operating system next to the " + " sign.**

- + **Windows**
- + **Mac OS X**
- + **Linux: 32 bit, 64 bit**
- + **source**



! *Choose the appropriate Operating System installation package for your computer.*

This section has been largely reproduced from the SIK Guide for the SparkFun Inventor's Kit.

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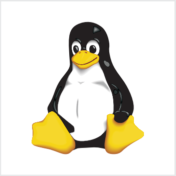
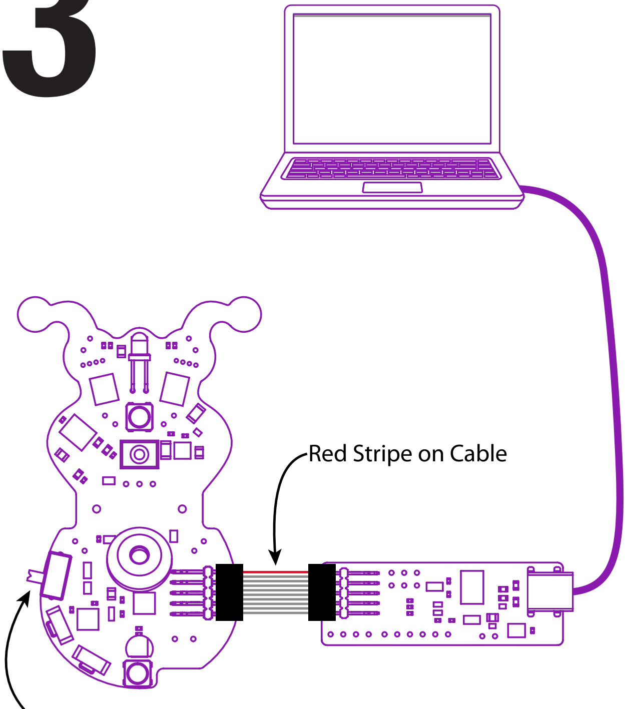
Visit www.plumgeek.com and follow the instructions to install the required driver for the programming adaptor. It is super important that you do this before connecting the programmer to your computer.



Connect a USB cable between your computer and the Plum Geek Programming Adaptor. Then connect the Programming Adaptor to your Ringo robot using the supplied cable.

You will require a USB A to Mini B cable (commonly supplied with digital cameras and the like).

3



Red Stripe on Cable

Turn switch ON before programming (ON is toward the front, OFF is toward the back)

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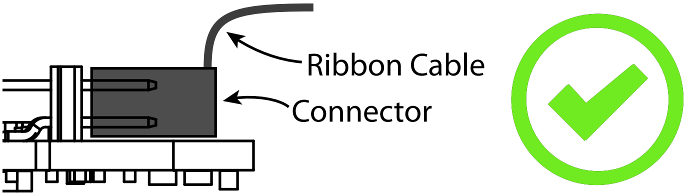
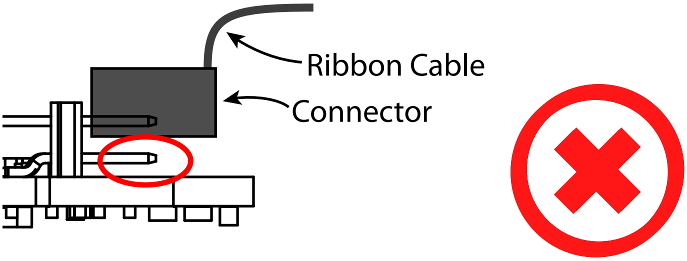
Software Installation

Warning! It is rather easy to attach the programming connector to the top row of pins only which is incorrect. Please look closely as you are attaching the programming connector to be sure it engages both the upper and lower set of pins at the same time.

Warning! Take care to not bend the pins when handling Ringo or attaching the programming cable.

TIP: You don't need to press the ribbon cable all the way onto Ringo's programming pins. Normally it'll work fine if pressed on only half way. This makes the ribbon cable easier to remove and is less likely to stress the cable. Try not to pull the ribbon cable off of Ringo by the cable - try to use the black plastic ends if possible. This again will help reduce stresses on the cable.





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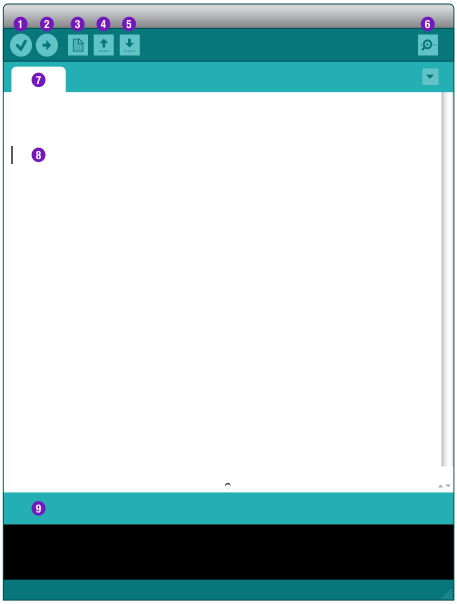
Software Installation

Open the Arduino IDE:

Open the Arduino IDE software on your computer. Look around and get to know the interface. We aren't going to code right away, this is just an introduction. This step is to set your IDE to identify the Plum Geek Programming Adaptor and the attached Ringo robot.



1 **Verify:** Compiles and approves your code. It will catch errors in syntax (like missing semi-colons or parenthesis).

2 **Upload:** Sends your code to the attached Ringo robot. When you click it, you should see the red lights on the Plum Geek Programming Adaptor blink rapid. IT IS VERY IMPORTANT TO MAKE SURE YOUR RINGO IS SWITCH ON PRIOR TO UPLOADING.

3 **New:** This button opens up a new code window tab.

4 **Open:** This button will let you open up an existing sketch.

5 **Save:** This saves the currently active sketch. Note, the sketch is not saved automatically when uploading or verifying.

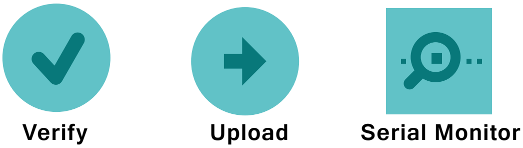
6 **Serial Monitor:** This will open a window that display any serial information your Ringo is transmitting. It is useful for debugging.

7 **Sketch Name Tab:** This shows the name of the sketch you are currently working on. You will often see extra tabs here also. The extra tabs represent extra documents that contain some of the under-lying code used by Ringo. Normally you won't edit these extra tabs. If you become a more advanced user we would encourage you to look around these tabs and feel free to modify. If you come up with better ways to write or organize these background functions please share with us. This is an area we would appreciate help with from the user community. Thanks!

8 **Code Area:** This is the area where you compose the code for your sketch.

9 **Message Area:** This is where the IDE tells you if there were any errors in your code, or if there are errors in the process of uploading your code to your Ringo robot.

These are the most important buttons in the IDE:



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Software Installation

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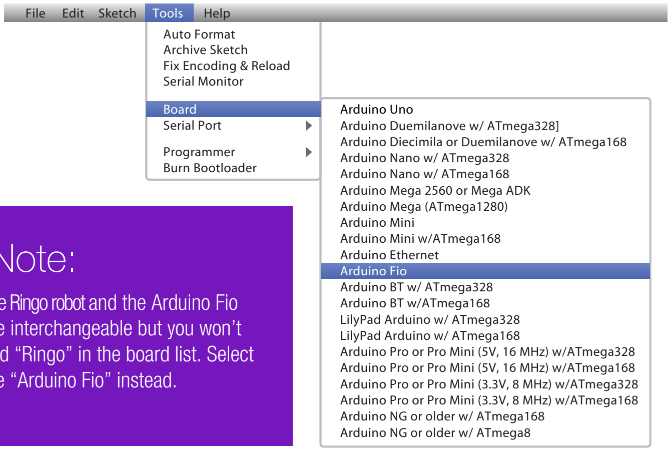
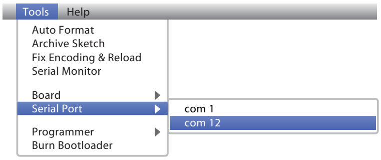

File
Edit
Sketch
Tools
Help
Auto Format
Archive Sketch
Fix Encoding & Reload
Serial Monitor
Board
Serial Port
Programmer
Burn Bootloader
Arduino Uno
Arduino Duemilanove w/ ATmega328]
Arduino Diecimila or Duemilanove w/ ATmega168
Arduino Nano w/ ATmega328
Arduino Nano w/ ATmega168
Arduino Mega 2560 or Mega ADK
Arduino Mega (ATmega1280)
Arduino Mini
Arduino Mini w/ATmega168
Arduino Ethernet
Arduino Fio
Arduino BT w/ ATmega328
Arduino BT w/ATmega168
LilyPad Arduino w/ ATmega328
LilyPad Arduino w/ ATmega168
Arduino Pro or Pro Mini (5V, 16 MHz) w/ATmega328
Arduino Pro or Pro Mini (5V, 16 MHz) w/ATmega168
Arduino Pro or Pro Mini (3.3V, 8 MHz) w/ATmega328
Arduino Pro or Pro Mini (3.3V, 8 MHz) w/ATmega168
Arduino NG or older w/ ATmega168
Arduino NG or older w/ ATmega8

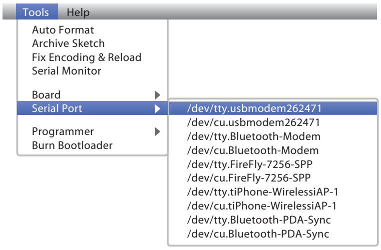
Note:

The Ringo robot and the Arduino Fio are interchangeable but you won't find "Ringo" in the board list. Select the "Arduino Fio" instead.

Select your Serial Device



Select the serial device of the Ringo robot from the Tools | Serial Port menu. This is likely COM3 or higher. It may take a few seconds for a new COM port to show up after connecting the PG Programmer. If a port doesn't show up, try disconnecting and re-connecting the programmer. Make sure you have installed the FTDI drivers in the earlier step.



Select the serial device of the Ringo robot from the Tools | Serial Port menu. On the Mac, this should be something with **/dev/tty.usbmodem** or **/dev/tty.usbserial** in it.

For Linux, visit the web page:
http://www.arduino.cc/playground/Learning/Linux

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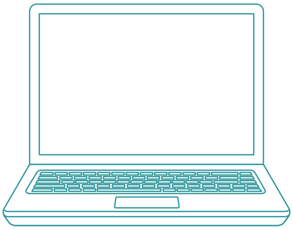
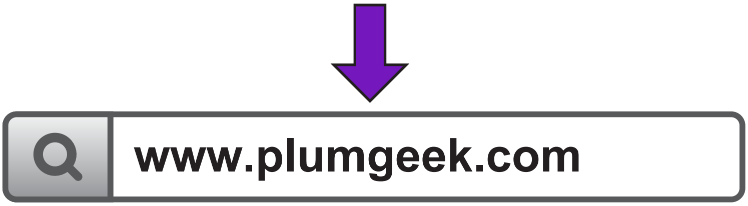


Visit the Plum Geek website



Visit the plumgeek.com website. Download libraries & examples, and install them in your Arduino folder.

In order to easily program and use your Ringo robot, you will require several library folders, as well as a folder full of examples. You will need to place the three library folders (**RingoMsTimer2**, **RingoWire**, and **Adafruit_NeoPixel**) into your **Arduino/libraries** folder. You will also want to place the **Ringo_Examples** folder into your **Arduino/examples** folder. Please see the illustrations on the following page.

Note: The Ringo libraries require Arduino IDE version 1.0.6 or later.

Note: The location of your Arduino Libraries directory may be slightly different than the path provided below. Follow the instructions for library installation on the Plum Geek website for known alternate directory structures you may encounter. The library install only needs to be done once.

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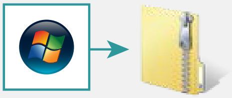
Software Installation

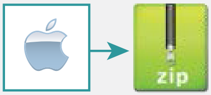


Unzip the file “**Ringo_Libraries**”. It should be located in your browser’s “**Downloads**” folder. Right clic the zipped folder and choose “unzip”.

Start → Programs → arduino → libraries

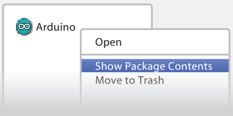
Copy the following folders (contained inside the .zip file) into Arduino’s folder named “libraries”.

RingoMsTimer2
RingoWire
Adafruit_NeoPixel



Unzip the file “**Ringo_Libraries**”. It should be located in your browser’s “**Downloads**” folder. Right clic the zipped folder and choose “unzip”.

Find “Arduino” in your applications folder. Right click(ctrl + click) on “Arduino”. Select “Show Package Contents”.



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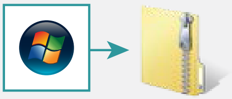
libraries

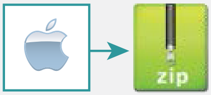
Copy the three folders RingoMsTimer2, RingoWire, and Adafruit_NeoPixel into Arduino’s folder named “examples”.



Unzip the file “**Ringo_Examples**”. It should be located in your browser’s “**Downloads**” folder. Right clic the zipped folder and choose “unzip”.

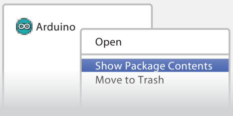
Start → Programs → arduino → examples

Copy the following folder “Ringo_Examples” into Arduino’s folder named “examples”.



Unzip the file “**Ringo_Examples**”. It should be located in your browser’s “**Downloads**” folder. Right clic the zipped folder and choose “unzip”.

Find “Arduino” in your applications folder. Right click(ctrl + click) on “Arduino”. Select “Show Package Contents”.



Contents
↓
Resources
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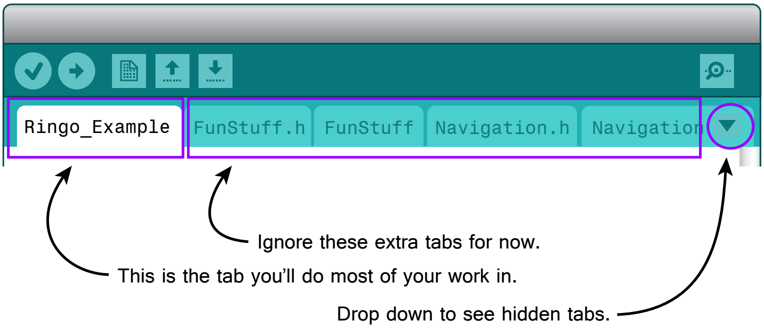
Java
↓
examples

Copy the three folder “Ringo_Examples” into Arduino’s folder named “examples”.

This section has been largely reproduced from the SIK Guide for the SparkFun Inventor’s Kit.



Ignore these extra tabs for now.

This is the tab you'll do most of your work in.

Drop down to see hidden tabs.

A quick note about tabs in the Arduino IDE...

Arduino likes to store all the files associated with a sketch in a single folder. It then opens the main sketch (the first tab) as well as any additional files it finds in the folder. The additional files are opened in additional tabs across the top of the IDE window.

Don't let these extra tabs intimidate you. For now you can largely ignore them. These extra tabs hide the background functions used by Ringo. Rather than install them as a library (in which case they wouldn't appear as tabs), we've included them with each sketch so more advanced users can easily study and edit them. As you are getting started, keep all your code in the first tab, which has the same name as the file name of the sketch you are working on.

Those more experienced with coding are encouraged to have a look at these extra tabs. Feel free to modify or improve them as the Ringo software is a work in progress and we welcome the user community to add features and make improvements. There are more tabs than are visible in the window (unless you really stretch out the window). To access the hidden tabs, use the drop down arrow circled above.

Code Basics

Let’s cover a few basics...

I know you’re itching to make Ringo do cool stuff, so play with some of the pre-loaded behaviors for a while. Eventually, you’ll want to customize how Ringo behaves. For this, you’ll need to learn a few basics about the code. This guide is not intended to be a complete course in programming. There are lots of great resources for this (see the end of this section for some links!) However, we’ll try our best to start you off in the right direction. Let’s dive right in.

Below you’ll see a box containing code. We’ll use boxes like this throughout the guide to represent code you’ll write or edit in the Arduino IDE. The important parts of the code in a given example are highlighted in purple.

```
/*
    Opening Heading. This area includes basic information about the program.
    It is not actually loaded onto Ringo. These are just notes for the reader.
*/

#include “RingoHardware.h”  //this makes the IDE include some outside
                            //files when loading code into Ringo

void setup(){         //the setup() function configures Ringo on startup
  HardwareBegin();    //Sets all of Ringo’s I/O pins correctly
  otherstuff();       //there may be other lines of code inside setup()
}                     //this closing curley bracket is the end
                      //of the setup() function

void loop(){            //this is where the real action happens!
  commandsToDoStuff();  //functions inside the loop() function make Ringo
  doMoreCoolStuff();    //do all his cool stuff. You will write most of
  evenMoreFun();        //your code inside the loop() function
}                       //this closing curley bracket is the end
                        //of the loop() function
```

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Code Basics

Code! Yay! Let's talk about the above example...

Each sketch includes code and comments. Comments are super important because they give human readers important notes about what's going on in the sketch. Comments are ignored by the Arduino IDE when it compiles the code before sending it to Ringo's brain. Comments can be written two ways.

A pair of forward slashes denotes everything else following them on the same line as a comment, and thus is ignored by the compiler.

```
thisIsCode(); //this part is a comment. This part is ignored by the compiler.
```

But what if your comment is going to require more than one line to write? There's a solution for that. You can begin a comment block with a forward slash followed by a asterisk. Then you can write as many lines of comment as you like. You then end the comment block with an asterisk followed by a forward slash. Here is an example of a comment block including the starting and ending characters.

```
/*
 This is a comment block. You can write as much as you want inside a
 code block and the comment can take up many lines. You do have to end
 a code block eventually with closing characters.
*/
```

Great. Now let's talk about the `#include “somefile”` line. This tells the compiler to copy and paste the referenced file at this point in the code. It is then compiled in as if you had actually pasted it in this place. This is a good way to include some external files (which may be really long) at the top of your code without making your main code window look cluttered.

You'll learn more about include files eventually. For now, just leave the existing `#include` lines in the examples and be careful not to edit or delete them. If they are altered, the Arduino IDE may refuse to compile your code sketch.

Code Basics

Now lets talk about the void setup() function. Everything between the opening curley brace { and the closing curley brace } of this function is run one time when Ringo first powers up (and also after you press and release the Reset user button on Ringo’s body). This function is useful for “setting up” Ringo’s brain for operation. You should include a function inside setup() called HardwareBegin(); which sets up Ringo’s brain to use the electronic parts included on Ringo’s body.

The setup() function for many of the Ringo examples is shown below.

```
void setup(){
  HardwareBegin();         //initialize Ringo’s brain to work with his circuitry
  PlayStartChirp();        //play startup chirp and blink eyes
  delay(1000);             //wait 1 second
  NavigationBegin();       //startup the gyro and accelerometer
  RestartTimer();          //capture start time
}
```

After setup() finishes, the loop() function runs over and over again, forever (or until you turn off or reset Ringo, or until his battery runs too low and he shuts off automatically). The loop() function is where the bulk of you program usually lives.

Further learning...

You’ll learn a lot as you work your way though this guide which will show you how to use all of Ringo’s parts on a basic level. However, this guide will not teach you all the nuances of programming. If you’d like to learn more on your own, please check out the following links.

Learn the basics about sketches and programming technique here:
http://www.arduino.cc/en/Tutorial/Foundations

Learn the core Arduino functions. This is the “go to” reference for functions:
http://www.arduino.cc/en/Tutorial/HomePage

(continued on next page)

Code Basics

If you look around on YouTube you'll find lots of great explanations as well as awesome projects people around the world have created with Arduino. Here are a few video courses we think you'll enjoy. Remember that Ringo is basically an Arduino board without connecting headers - we've just connected the electronics directly to the microcontroller, so many of the examples you'll find online are still applicable to Ringo.

Arduino Course for Absolute Beginners
https://youtu.be/QNTaQ5qjniE?list=PLYutciIGBqC2rqlBw3wVX4LjFlcjtWjGP

Tutorial Series for Arduino by Jeremy Blum
https://youtu.be/fCxzA9_kg6s?list=PLA567CE235D39FA84

If you come across any other great resources you feel would be helpful to others, please send us a link and we'll add them to this guide.

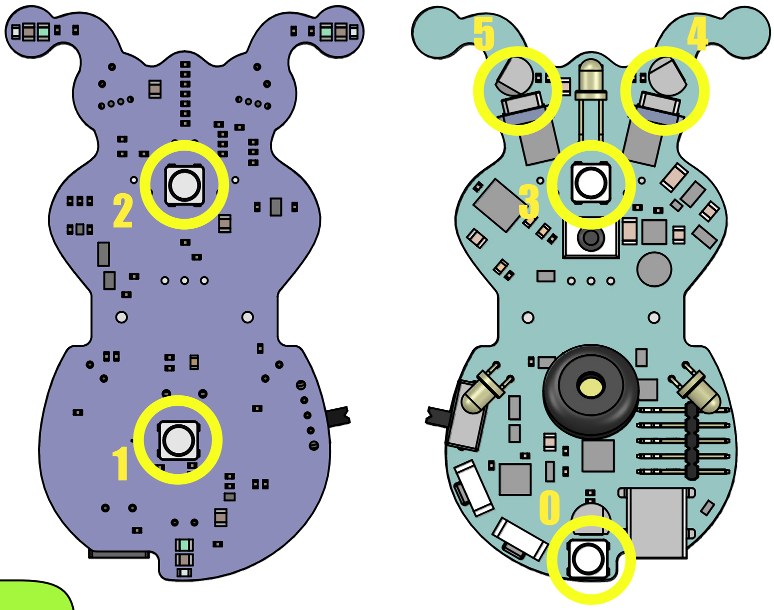
Using Ringo’s Color Lights

Ringo is fitted with six color lights. They are called "RGB" lights, which stands for "Red, Green, and Blue". Each light actually contains three small colored lights inside. You guess it - they are red, green, and blue. It turns out you can create any color you can think of by mixing different amounts of these three primary colors. Your TV screen creates colors in the same way.

The RGB Lights in Ringo were made popular by Adafruit Industries, coining the name “NeoPixels”. We owe them a huge high-five for writing the code required to communicate with these awesome little lights.

Each light can have each of its red, green, and blue LEDs set to any level between 0 and 255. When set to 0, the given color is off, and when set to 255, the given color is on at max brightness. The NeoPixel lights are extremely bright, so a value from 100 to 150 is still plenty bright.

As stated, Ringo has six of these color lights. Computers like to number things beginning with 0. So the lights are actually numbered 0 through 5 (not 1 through 6 as you may expect). This address number of each light is printed next to it on the circuit board for easy reference. Check out the graphics below showing each light with its address.



1
SKILL
LEVEL

Using Ringo’s Color Lights

A few setup steps...

You need a few lines of code in your project to tell the Arduino IDE to compile in the super special Adafruit NeoPixel driver software. This code is already present in the example projects, so don’t let this part scare you. The code belongs in your main project page above the line: `void setup(){`

Like this:

```
#include “RingoHardware.h”
```

This include line will insert the `RingoHardware.h` file, which itself includes a special line: `#include <Adafruit_NeoPixel.h>` By including `RingoHardware.h`, the IDE will automatically include the `Adafruit_NeoPixel.h` file which allows Ringo to talk to his lights.

```
void setup(){
  HardwareBegin();          //Sets all of Ringo’s I/O pins correctly
  SwitchButtonToPixels();   //set shared line to control NeoPixel lights
  // (it’s okay if there is more stuff below here)
}
```

Time for fun! Let’s Do This!

Now we’re ready to make the lights go! You will control the lights with the function `SetPixelRGB();` Here is an example of how the function is formatted.

```
SetPixelRGB(address,red,green,blue);  //example formatting of function
```

You’ll replace the word “address” with the address of the pixel you want to adjust. Remember this is a number between 0 and 5. Then you’ll place a number between 0 and 255 in place of the words “red”, “green”, and “blue”. The number you use will correspond to how bright or dim each of the three colors are.

Using Ringo’s Color Lights

If you have trouble remembering the address of each pixel, note that the address is printed on Ringo’s circuit board right next to the light. You may also refer to each pixel by using key words as follows:

```
EYE_LEFT          //Pixel 5
EYE_RIGHT         //Pixel 4
BODY_TOP          //Pixel 3
BODY_BOTTOM       //Pixel 2
TAIL_TOP          //Pixel 0
TAIL_BOTTOM       //Pixel 1
```

You can use the key word interchanably with the pixel address when calling the SetPixelRGB() function. Like this:

```
SetPixelRGB( 3, 0, 0, 200);         //this code is the same
SetPixelRGB( BODY_TOP, 0, 0, 200);  //as this code
```

Lets see if we can make the light on the top of Ringo’s body turn blue. You’ll be writing most of your code inside the `void loop(){` function (at least until you start writing your own functions!). Make your `void loop()` function look like this:

```
void loop(){
  SetPixelRGB( 3, 0, 0, 200);   //set pixel 3 to 0 red, 0 green, and 200 blue
}
```

Now try to compile and load this code onto your Ringo. About a second after you turn on the power switch, the light on the front top of Ringo’s body should be bright blue. Now let’s talk about what happened, and why.

The `SetPixelRGB()` is taking four numbers, called “arguments” which control what the function does. The first number, in this case “3” tells Ringo’s brain to target the pixel at address “3”. The next three numbers tell the pixel at address 3 how bright to turn on the red, green, and blue lights inside the pixel. In this case, the red is set to 0 so it won’t be on at all, as well as the green will be set to 0 so it won’t be on either. The last number is 200, which corresponds to the blue led which will be turned on at a brightness of 200, which as you can see, is pretty bright!

Using the basic example above, we can start to play with the numbers in the function to change the behavior of the pixels. Let’s say your favorite color is something different than red, or green, or blue. Like, PLUM! You can easily create different colors by mixing different amounts of the three primary colors Red, Green, and Blue. Try this example code. Compile it, load it, and observe what happens.

```
void loop(){
  SetPixelRGB( 3, 220, 30, 160);  //set pixel 3 to 220 R, 30 G, and 160 B
}
```

Sweet! Purple, right? I think you’re getting the idea now. So what if you want to control more than one pixel at a time? What if we want to make both of Ringo’s eyes turn purple? We just do the same thing, except we call the SetPixelRGB function more than once. We call it once for the right eye, and again for the left eye, then finally after both eyes have been commanded to a new value, we will latch the new colors by executing the RefreshPixels(); function. Like this:

```
void loop(){
  SetPixelRGB( 4, 220, 30, 160);  //set pixel 4 (Right eye)
  SetPixelRGB( 5, 220, 30, 160);  //set pixel 5 (Left eye)
}
```

Purple eyes? Easy right? I think you’ve got the hang of it now. Now lets have some real fun. One more example then you can go off and play on your own.

```
void loop(){
  SetPixelRGB( 4, 220, 30, 160);  //set pixel 4 (Right eye)
  SetPixelRGB( 5, 220, 30, 160);  //set pixel 5 (Left eye)
  delay(100);
  SetPixelRGB( 4, 30, 220, 210);  //set pixel 4 (Right eye)
  SetPixelRGB( 5, 30, 220, 210);  //set pixel 5 (Left eye)
  delay(100);
}
```

Example Sketch: Ringo_Guide_Pixels_01

After you take that example for a spin, see if you can figure out what's going on. And what's up with `delay(100);` I added to the code? Any idea why the main function we're editing is called `loop()` ? Does anything in this example appear to be looping? Think it over and discuss it. Then see the "Discussion Answers" at the end of this section and see if you've got the right idea.

Gotcha! A couple warnings to keep in mind...

In this section of each lesson, you'll find some helpful tips and warnings to keep in mind. Ringo is designed with robust components and he has some built-in protection systems to keep him safe. Here are some situations you may run into.

Over Current Limit:

Each NeoPixel LED draws a current of 60 milliamps when all three of its colors (red, green, and blue) are turned on full brightness. If you did this to all six NeoPixels at once, then Ringo would need to draw about 360 milliamps from his battery. Battery current draw is beyond the scope of this lesson, but suffice to say, Ringo's battery can only safely supply about 200 milliamps. For this reason, all the parts on Ringo that are capable of drawing a lot of current (the NeoPixels, motors, sound chirp, underside edge sensors, and the three infrared emitters) are all powered through a limit switch that limits current to the safe 200 milliamps. Ringo's brain is however not powered through this switch - so his brain will usually remain active even during current limit. When the current limit is engaged, you will see the pixels and other current limited parts stop working or behave in strange ways. This is okay and does not cause them any harm. Just edit your code and reduce the brightness of your NeoPixels, speed of your motors, etc. In most cases you'll never hit this current limit as you're not usually running motors full speed while turning on lots of NeoPixels at high brightness. As you saw in this lesson, even at only 100 brightness, the light is still pretty bright, so going full blast to 255 is usually just wasting current.

NeoPixel/Button Shared Line:

We based Ringo on the Arduino UNO as it is the most popular Arduino board. However, the processor on that board (and thus the processor in Ringo) is somewhat limited on how many signal lines it has. For this reason, we have doubled up on some signal lines.

The signal line controlling the NeoPixel LEDs is also used to sense if someone is pushing the User Button. When controlling the NeoPixels, this line is an output. When looking at the button, it is an input. By default it is set to control the NeoPixel lights.

Pressing the User Button will block communication to the NeoPixel lights while it is pressed. This does not harm the button, the NeoPixels, or Ringo’s brain, but it is something you should be aware of. We’ve provided two simple functions that can be used to change the mode of this line as follows:

```
SwitchPixelsToButton(); //use this function before reading button
SwitchButtonToPixels(); //use this function to resume pixel operation
```

Note that SwitchButtonToPixels() is called automatically with all of the light functions, so it is not necessary to call it explicitly.

It no workey. (Sad Ringo).

If you spend more than five minutes learning how to code, you will find your patience tested. Writing code is really pretty simple, but there is a small catch. Computers expect to see instructions formatted a very specific way. There are different rules in each computer language that must be followed. A piece of software that runs in the background on your computer (called a “compiler”) reads your code and turns it into a bunch of 1’s and 0’s that make sense to Ringo’s brain. The it is very easy to make the compiler grumpy, in which case it will throw a fit and refuse to do what it’s told. The solution to keeping it happy is to pay close attention to how you format your code. Here are some common mistakes you may be making, and how to correct them.

```
SetPixelRGB( 1, 120, 50, 90);   //correct upper-lowercase function. This works.
setpixelRGB( 1, 120, 50, 90);   //no workey
setpixelrgb( 1, 120, 50, 90);   //no workey
SETPIXELRGB( 1, 120, 50, 90);   //no workey

delay(100);                     //correct delay. This works.
Delay(100);                     //no workey
```

Be sure you're using commas between the arguments.

```
SetPixelRGB( 1, 120, 50, 90);  //using commas correctly. This works.
SetPixelRGB( 1; 120; 50; 90);  //wrong. semi-colons between arguments. no workey
SetPixelRGB( 1 120 50 90);    //forgot commas between arguments. no workey
```

Be sure you're using normal parentheses around arguments.

```
SetPixelRGB( 1, 120, 50, 90);  //normal parenthesis. This works.
SetPixelRGB{ 1, 120, 50, 90};  //curley braces are wrong. no workey
SetPixelRGB[ 1, 120, 50, 90];  //brackets are wrong. no workey
```

Don't forget the semi-colon at the end of every line! (Yes, I realize there are some lines in the example code that don't have semi-colons at the end. The mean people who created the C language did this to confuse you. We'll discuss this later). For now, suffice to say that missing a semi-colon is the most sure way to upset the compiler.

```
SetPixelRGB( 1, 120, 50, 90);  //correct semi-colon. This works.
SetPixelRGB( 1, 120, 50, 90)   //oops. no semi-colon. upset compiler. no workey
SetPixelRGB( 1, 120, 50, 90),  //this is a comma, not a semi-colon. no workey
```

As pickey as the compiler can be, it is usually okay with extra blank spaces. Sometimes adding some extra space between arguments of a function can make the function easier to read.

```
SetPixelRGB(1,120,50,90);        //the compiler sees this the same as...
SetPixelRGB( 1, 120, 50, 90);   //this
```

Discussion Answers:

1) What's up with the `delay(100);` inserted into the code? Well, "delay" does just what you'd expect it to. It causes Ringo's brain go spin in a circle and do nothing for a certain amount of time. The argument passed is the number of milliseconds Ringo's brain should wait before proceeding. Keep in mind there are 1000 milliseconds in one second. So this line causes Ringo to pause for a tenth of a second before going ahead in the code.

2) Why is the main function we're editing called `loop()` ? As you probably noticed, Ringo keeps doing the same thing over and over. He sets his eyes to one color, then latches the color, then delays a short time, then sets his eyes to a different color, then latches the new color, then delays a short time... then he does it all again. The `void loop()` function runs all

the code contained within its curley braces. Once it reaches the end, it “loops” and does it all again. This loop function is where you’ll be writing most of your code for a while (you’ll eventually start writing your own stand-alone functions). Forget about the word “void” at the start of the line for now. Just know that it needs to be there and you don’t need to know why at this point.

Experiments & Challenges:

Now that you’ve mastered controlling Ringo’s color lights, go ahead and experiment. Here are some suggestions and challenges.

1) What happens if you play with the argument inside the delay(); function? What happens if you make the delays different values?

2) What happens if you use the SetPixelRGB() function to control pixels at different addresses? Can you make Ringo’s bottom lights work without any further hints from me?

3) Good job! You made the bottom lights work! What happens if you now take Ringo into a dark room and place him on different surfaces while the bottom lights are lit up? (Hint, look for something semi-opaque, a clear table top, and a white surface and see what happens).

4) What color do you get if you make all three Red, Green, and Blue values the same?

5) What happens if you run this code:

```
void loop(){
  SetPixelRGB( 4, 255, 255, 255);  //set pixel 4 (Right eye)
  SetPixelRGB( 5, 255, 255, 255);  //set pixel 5 (Left eye)
  RefreshPixels();
}
```

Woah! That’s BRIGHT!!! Now take Ringo into a dark room. What do you see projected on the walls of the room? Why is this happening?

6) Remember the example where we made Ringo’s eyes flash between two colors? Can you make his eyes flash between three different colors now? What about ten colors? Twenty? Try lots of different mixes of color and different delays.

7) Write the code on your own to turn on any NeoPixel then wait a short delay. How do you now make it turn back off? Can you make a certain NeoPixel blink on and off repeatedly?

8) Can you give Ringo oogley eyes? Try making a color alternate between the two eyes. (The right eye turns on one color while the left is not turned on, then you turn on the left eye to the same color while turning off the right eye - then loop).

9) Can you make Ringo look like his eyes are hypnotized?

10) Can you do something cool with Ringo's lights that we haven't even though of yet?

Bonus Function:

Now that you've familiar with the SetPixelRGB() function, we'll tell you about another function you can use to control the lights.

```
SetAllPixelsRGB(red,green,blue);  //example formatting of function
```

The `SetAllPixelsRGB()` function is useful for doing exactly what you would expect. This single function sets every light to the same value. It also automatically refreshes the pixels, so you don't need to call the `RefreshPixels()` after running it. This function is most useful for turning off all the NeoPixel lights at the same time. Occasionally, if Ringo is reset (or the User button is pressed) during a command to the lights, some of them may "stick" on with strange colors. Using `SetAllPixelsRGB()` with zeros is an easy way to make sure all lights are turned off, which clears any "stuck" pixels.

Like this:

```
SetAllPixelsRGB(0,0,0);  //turns off all NeoPixel lights
```

A few more examples...

```
SetAllPixelsRGB(0,0,50);  //all pixels to Blue
SetAllPixelsRGB(50,0,0);  //all pixels to Red
```

Use caution when using the SetAllPixelsRGB() function. As stated above, the pixels draw a bit of current, so trying to set them all to a high value at once will likely cause the over-current switch to trip. This isn't dangerous to Ringo, but it will make the lights go all wonkey on you until Ringo is reset and loaded with new code that doesn't draw so much current.

There are a handful of other similar functions as follows. Experiment with these on your own and you'll get the hang of using them.

```
OffPixels();                        //turns off all pixels
OffPixel(Address);                  //turns off a specific pixel
OnEyes(Red, Green, Blue);           //makes eyes the given color
LeftEye(Red, Green, Blue);          //sets left eye to given color
RightEye(Red, Green, Blue);         //sets right eye to given color
OffEyes();                          //turns off eye lights
```

Using Ringo's Motors

Ringo is fitted with a pair of small motors. These allow him to move around. The ends of the motors reach down and touch the surface he is sitting on. We can make him move forward, backward, or turn depending on how we control these motors.

Controlling the motors from your code is really easy. Let's jump right into an example then we'll talk about it.

```
void loop(){
  Motors(LEFT, RIGHT);       //this function makes the motors go!
}
```

The Motors(); function accepts two numbers as arguments: one for left motor speed, and one for right motor speed. The values can range from -255 to positive 255 for each. When this line of code is executed, Ringo's motors will immediately start running at the commanded speed.

Let's see how this works with an example on the next page, but first, let's consider a few important notes.

Ringo is not an all-terrain robot, so he does require a smooth surface to move properly. Desktops, counter tops, and smooth flooring are ideal surfaces.

Be careful Ringo doesn't jump off your table. He does have sensors to see the edges of tables, but he won't respond to them unless your code specifically tells him to do so. We'll get to that eventually, but these simple examples do not automatically look for edges.

If Ringo's motors are forced to stop, they will not be damaged due to over-current, but it's still good practice to allow the motors to spin freely without forcing them to stop.

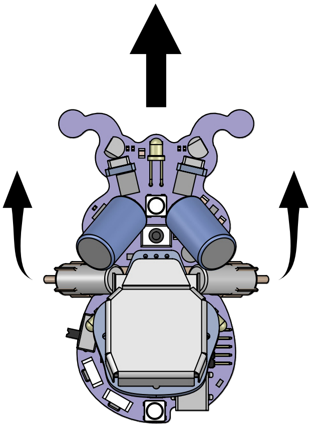
Using Ringo’s Motors

Forward Movement

If we can make both motors turn in the forward direction, then Ringo should move forward. Let’s try this example and see what happens:

```
void loop(){
  Motors(200, 200);          // set left and right motors to 200 speed
  delay(1000);              // wait 1 second
  Motors(0, 0);             // make both motors stop
  delay(3000);              // wait 3 seconds
}
```

In this example, we use the command Motors(200,200); to set the left and right motors to a speed of 200. This makes Ringo start driving forward. Then we tell his brain to wait one second with delay(1000); so he will drive forward for one second. Then we set both of Ringo’s motors to speed 0 with the command Motors(0, 0); which makes both motors stop moving. Finally, the command delay(3000); makes Ringo wait for three more seconds. After this final line of code, the loop will repeat again from the start.

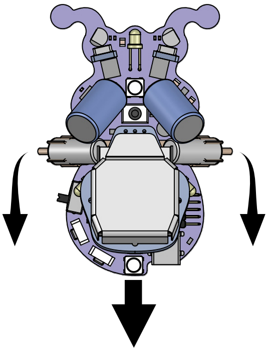


Backward Movement

Now lets make Ringo move backward. Backward movement works the same way as forward movement, you just give Ringo negative movement numbers. Try this example:

```
void loop(){
  Motors(-200, -200);       // set left and right motors to NEGATIVE 200 speed
  delay(1000);              // wait 1 second
  Motors(0, 0);             // make both motors stop
  delay(3000);              // wait 3 seconds
}
```

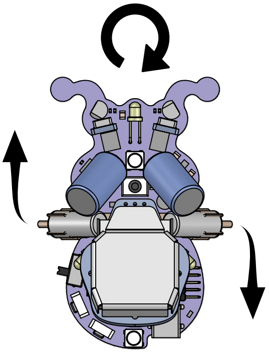
This example is exactly the same as the previous example, except that we’ve told Ringo to move the motors in the negative direction by placing minus signs in front of the speed numbers. The command `Motors(-200,-200);` does this for us.



Turning Movement

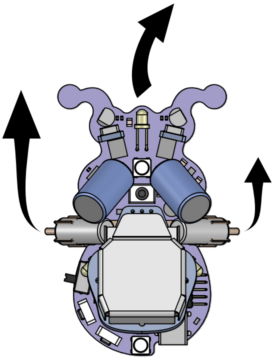
Have a guess at how we could make Ringo turn? We can set one motor to move forward and the other motor to move backward. Try using this command to set motor speed: `Motors(200, -200);` What happens? This is causing the left motor to move at speed 200 in the forward direction, and the right motor to move at speed 200 in the backward direction (the minus sign makes the motor move backward).

What if we reverse these numbers? Try using this command to set motor speed: `Motors(-200, 200);` We now set the left motor to negative speed and the right to positive speed. This should cause Ringo to spin in the opposite direction.



Arc Movement

If you simply run both motors in opposite directions, we see Ringo turns around on his own footprint, which makes for a very agile little bug for sure. But what happens if you run both motors in the same direction, but at slightly different speeds?



Let's try running the motors like this: `Motors(200, 100);` The left motor is now running about twice the speed of the right motor. Ringo still moves forward, but he is turning to the right.

Spend a few minutes playing with the numbers in the `Motors();` function. You'll notice you can change the arc depending on how you set the numbers.

"Straight" movement?

Lets go back to where we started in this discussion and look at forward movement a bit more closely. Let's try the example code below. Ringo is going to drive much further this time, so you may want to test this example on a floor. If you're doing this on a table, be ready to catch him before he jumps off the edge.

```
void loop(){
  Motors(150, 150);        // make both motors run
  delay(3000);             // wait 3 seconds
  Motors(0, 0);            // make both motors stop
  delay(5000);             // wait 5 seconds
}
```

Did Ringo drive in a perfectly straight line? We set both motors to forward speed 150, so both motors should be turning at the same speed, right? You would think Ringo would have been driving in a perfectly straight line but I'm guessing he didn't (though you may have gotten lucky this time and perhaps he does travel perfectly straight, but not likely).

Let Ringo drive this "straight" line a few times. You'll probably notice he tends to veer off one direction or another. Study the Arc Movement example above and see if you can adjust the numbers you use in the `Motors();` function to make him go a bit more straight. Hint, if Ringo veers to the right, increase the right motor number a bit, and if he veers off the left, increase the left motor number a bit.

Mechanical Systems Aren't Perfect

Let's talk more about the previous experiment. Do you have any idea why Ringo didn't go straight even when the same motor speed numbers were used? The reason is that mechanical systems are never made perfectly. Each motor will run at a slightly different speed even when driven with the same power source as one will be slightly more efficient than the other. There are lots of other variables at play also - the surface may be more bumpy on one side, one motor tip may be getting better grip on the surface, etc. All mechanical systems have some variation. It's possible to minimize the variation (by using very expensive and super accurate motors for example), but some variation will always exist.

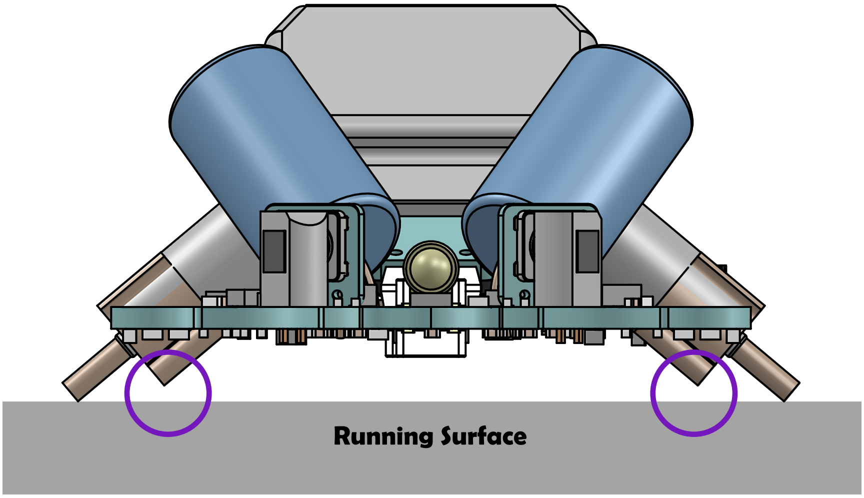
It isn't very practical to constantly guess and adjust a robot's speed settings to make it go in a straight line as you experienced in the last example. For this reason, most robots require some way of sensing how they are moving. Wouldn't it be smart if Ringo could somehow know that he was starting to veer to the right and automatically adjust the speed of his motors to compensate and resume a straight path? Well lucky for Ringo (and you!), he has two sensors that can be used for this purpose. One is called a Gyroscope, which basically allows Ringo to know when he is turning. The second one is called an Accelerometer, which basically allows Ringo to know how fast he is moving and how far he has traveled. Using these awesome sensors is beyond the scope of this lesson on basic motor operation, but check out the Navigation lesson later in this guide for the full run down.

Using Ringo's Motors

It no workey. (Sad Ringo).

The motors are the only real "mechanical" part of Ringo. It is important that they are oriented correctly to the running surface to operate properly. They may occasionally become misaligned in the motor clip, become bent, or get gummed up with hair or other yuk that Ringo may have driven through. Here is a quick guide to inspecting Ringo's motors and fixing any issues you may encounter.

1) Mis-Aligned Motor Clip: Make sure Ringo's motor clip is not dragging on the running surface. Look straight on to Ringo while he is on a surface. Look at the areas with the purple circles. There should be a gap of about 1mm between the running surface and the lowest portion of Ringo's motor clip.



If you find the motor clip is dragging, it can be corrected by making two adjustments.

a) Make sure Ringo's motors are flush with the end of the motor clip. If the motors have been pushed further inward into the clip, the shaft is effectively shortened. Re-set motors to flush with the clip.

b) The clip is spring steel and should be very difficult to deform, but you can carefully bend the ends of the motor clip downward. This causes a greater angle with the surface and thus creates more space between the clip and the surface.

2) Bent Motor Shaft: This should not be a common problem, but it is possible. If Ringo takes a fall onto a hard surface and happens to land right on one of his motor shafts, it is possible the shaft could become bent. In all our testing, our Ringos have taken many hard falls onto a concrete shop floor from 3 to 4 feet heights. In all these drops, we managed to slightly bend one motor shaft which was easily fixed as follows. You'll notice it is bent because as Ringo moves, one side will "thump" along rather than running more smoothly. Correcting a bent motor shaft is possible with some care. Closely examine the shaft to determine the direction it is bent, then, using a tool of some sort, carefully reverse the bend. This will likely return Ringo to service. If the bend is so extreme that it cannot be reversed, motor replacement may be required. Contact us to order replacement motors.

3) Gunk on Motor Shaft: Ringo is very good at picking up debris in his motor shafts - especially hair from your pets when he is run on the floor. Usually this is easy to remove. Using tweezers, carefully pluck the hair off the shaft by rolling the shaft with your fingers. A bit of hair build up isn't a major problem, but if enough is allowed to accumulate, it can effect the performance of the bearing inside the motor where the shaft exits.

WARNING! If you do feel the need to remove a motor from the clip (this shouldn't be required, but we know some of you will try to do it anyway) - the best way to remove the motor is to slide it completely through the clip outward. It is tempting to rock the top end of the motor (where the wires come out) upward until it prys open the clip then rotate it outward. THIS IS A BAD IDEA THOUGH. As the motor is rotated out of the clip, all the force is placed on the motor shaft as the motor shaft hits the bottom of the clip. This force (if pryed all the way out of the clip) is enough to bend the motor shaft. Instead, slide it through the clip until it pops out the end. Be careful you don't break the wires when doing this. To re-install the motor, align it over the clip so the end is flush, then use finger pressure to snap it into the clip from the top through the open "jaws" of the clip.

Chirps, Zips, and Pings! Sound!

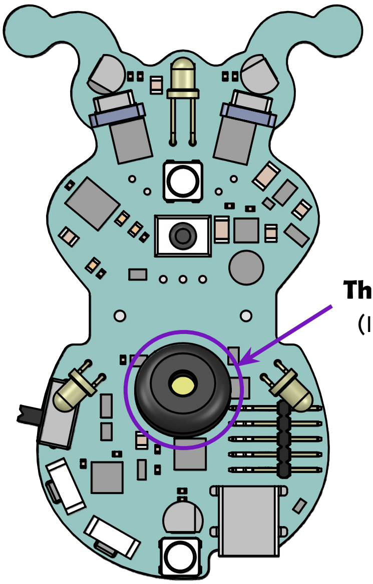
Ringo can make simple sounds with a piece of hardware called a piezo. The piezo is similar to speaker, and can be used to create tones.

Causing Ringo to emit a tone from his piezo is super easy. Just use the PlayChirp() function. The PlayChirp function takes two arguments. Arguments are bits of information you pass into a function when it is run. You did this with the pixel and motor functions in the previous example and didn't even realize it. :-)

Let's look at an example:

```
PlayChirp(Frequency, Amplitude);
```

You pass a frequency, which is the pitch of the tone to be played in hertz. Amplitude is a variable that controls the overall tonal quality and loudness. An amplitude of about 50 results in the loudest tone for most pitches. Normally you'll pass the amplitude as 50, but you can experiment with this number a bit to see what happens. Usually, amplitudes greater than 50 will result in more current being used (shorter battery life) without really making the piezo much louder.



This is Ringo's Piezo Element

(It is tucked under the battery)

1

SKILL LEVEL

Let’s look at a working example. Try entering the following code into your main loop() function and see what happens.

```
void loop(){
  PlayChirp(2000, 50);     //start playing a tone at 2000 hertz
  delay(1000);             //wait 1 second
  PlayChirp(4000, 50);     //start playing a tone at 4000 hertz
  delay(1000);             //wait 1 second
  OffChirp();              //stop playing tone
  delay(2000);             //wait 2 seconds
}
```

Run the code on Ringo and see (hear?) what happens. You should hear a mid pitch tone for one second that then transitions to a higher pitch tone for one second, then you should hear silence for two seconds, then the process should repeat.

The line PlayChirp(2000, 50); causes the tone to begin. It should be noted that Ringo can do other things while a tone is playing. As you already know, the delay(1000); causes Ringo to wait for 1000 milliseconds (which is one second) before executing the next line PlayChrip(4000, 50); which causes Ringo to now begin playing the tone at 4000 hertz.

The OffChirp(); is important because this is what is required to make Ringo stop playing a tone. You can also make him stop playing a tone by either setting the frequency, or the amplitude, or both, to zero.

```
OffChirp();                //turn off chirp the easy way
PlayChirp(0, 50);          //set Frequency to zero. Ringo stops playing tone
PlayChirp(1000, 0);        //set Amplitude to zero. Ringo stops playing tone
PlayChirp(0, 0);   //set Frequency & Amplitude to zero. Ringo stops playing tone
```

Playing Note Pitches:

If you want Ringo to play a song, you can tell him to play specific notes. Look at the tabs across the top of the Arduino IDE (or click the little down arrow at the end of the tabs if you can't see them all) and select the tab called "Pitches.h". This file "defines" each piano key note to the corresponding pitch in hertz. The "middle C" key of the keyboard is defined as "NOTE_C4". Let's make Ringo play middle C. Go back to the main tab in the Arduino IDE (the one on the far left) and try this code.

Like this:

```
void loop(){
  PlayChirp(NOTE_C6, 50);         //start playing the pitch for middle C
  delay(333);                     //wait about 1/3 of a second
  PlayChirp(NOTE_E6, 50);         //start playing the pitch for E
  delay(333);                     //wait about 1/3 of a second
  PlayChirp(NOTE_G6, 50);         //start playing the pitch of G
  delay(333);                     //wait about 1/3 of a second
  OffChirp();                     //stop making sound
  delay(1000);                    //wait 1 second before looping
}
```

Example Sketch: Ringo_Guide_Chirp_01

Ringo should be playing the C-Major chord every second. If you work with the notes and timings it is possible to make Ringo play simple songs.

Playing Sweeps:

You can "sweep" between tones to create interesting effects. Like this:

```
//PlaySweep(Start_Note, End_Note, Dwell_Time);   //dwell time is in microseconds

void loop(){
  PlaySweep(1000, 4000, 330);
  delay(500);                 //wait 1/2 second
  PlaySweep(4000, 1000, 330);
  delay(500);                 //wait 1/2 second before looping
}
```

Example Sketch: Ringo_Guide_Chirp_02

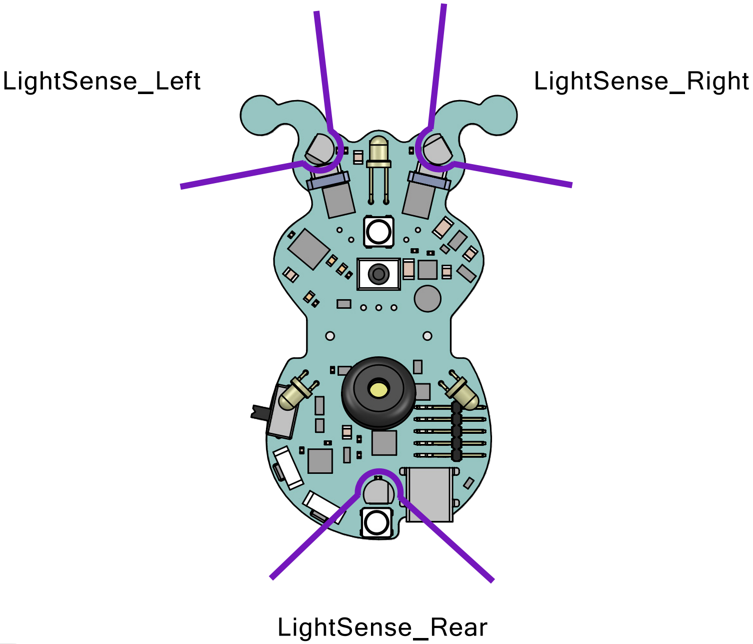
Using Ringo's Light Sensors

Ringo has some light sensors that he can use to observe his environment. These sensors can be used to control all kinds of behaviors and they are easy to use. Each sensor returns a value between 0 and 1024. The value goes up as more light reaches the sensor. Easy.

Setup...

Ringo's brain has three inputs that can read the analog light sensors. However, there are actually six light sensors on Ringo's body - there are the three ambient light sensors on the top side, and there are also three light sensors on the bottom side of Ringo to sense lines and edges. We can select which set of sensors are active by changing the Source_Select pin to either HIGH or LOW. Like this:

```
digitalWrite(Source_Select, HIGH);  //This selects the top light sensors
digitalWrite(Source_Select, LOW);   //This selects the bottom light sensors
```



1
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Using Ringo’s Light Sensors

The best way to see how the sensors work is to use the Arduino Serial.print functions to send the light sensor readings to your computer screen so you can see how they change as you point lights at Ringo, or cast shadows on his sensors. Plug Ringo into his programming adaptor, then plug the programming adaptor into your computer. Go ahead and leave the adaptor connected to Ringo during this lesson. Let’s load up the following code example and see what happens.

```
#include “RingoHardware.h”  //include Ringo background functions

int sensorValue;   //declares variable “sensorValue”

void setup(){
  HardwareBegin();   //initialize Ringo’s circuitry
  PlayStartChirp();  //play startup chirp and blink eyes
}

void loop(){
 digitalWrite(Source_Select, HIGH);  //select top side light sensors
 sensorValue = analogRead(LightSense_Right);  //read right light sensor
 Serial.println(sensorValue);        //print sensorValue through serial port
 Serial.println();                  //print a blank line feed
 delay(250);                        //delay 250 milliseconds
}
```

In previous examples we simply told Ringo to do something. In this example, we’re going to read a value from a sensor. Ringo needs to mark a location in his memory space to remember the value when it is read from the sensor. The line int sensorValue; “declares” the variable “sensorValue”. Once the variable is declared, the variable can be used to store a value, to perform an operation on a value (like adding a number to it), or to recall the value from it.

We then use digitalWrite to set the Source_Select pin to HIGH, which enables the top side light sensors. Next we tell Ringo to perform an analog read of the LightSense_Right pin, and place the result of that analog read into our variable called sensorValue. An analog read simply creates a numerical value based on a voltage created by the light sensor. As the light is increased, this voltage is increased and thus, the result of the analogRead will increase.

Ringo now knows the present light level of his sensor (stored in the sensorValue variable), but you can’t see it yet because it’s only stored in Ringo’s brain. The line Serial.println(sensorValue);

tells Ringo to send this value out his serial port to the programming adaptor, and the programming adaptor sends it to your computer. Open the serial monitor window and you will see the sensor value pop up in the window. The next line `Serial.println();` tells Ringo to print a line with nothing on it. This is basically a carriage return in your serial monitor window to create a space between readings. The last line `delay(250);` causes a quarter second delay between readings.

When you run this code, you should see a value between 0 and 1024 pop up in your serial monitor window four times per second. Let this run for a few seconds, then place your hand over Ringo's right eye. You should see the value go down a bit. It should go really low if you cover Ringo in a towel or blanket that will almost completely block out the light. If you turn him toward a bright light or window, you should see this value go up.

You may notice a few interesting things. First, it is impossible to bring this value all the way down to zero. This is beyond the scope of the lesson, but the light sensor always leaks a tiny bit of current which prevents it going all the way to zero. This is normal. In a similar way, the light sensors are designed to never totally max out the input of Ringo's brain, so even in direct sunlight you won't reach all the way to 1024.

You will also notice that the value goes up and down a bit even when the light in your room isn't changing. This is normal and can be caused by several things. Most room lighting actually flashes brighter and dimmer 60 times per second, which Ringo's sensors can pick up. This can also be caused by tiny bits of electronic "noise" coming from Ringo's power supply. If Ringo is charging his battery you'll see even more noise caused by the charging system.

A final item to note, is that Ringo's top side light sensors are "logarithmic". This basically means that they respond to differences in light levels the same way your eyes do, and they can see differences in a wide range of light ranging from very dim to very bright.

Using Ringo’s Light Sensors

Three sensors at once...

Reading one sensor is great, but if we read more than one sensor, Ringo can make better decisions based on what he sees. Let’s try an example where we read and serial print all three sensors at once. Can you guess how we would do this?

```
#include “RingoHardware.h”  //include Ringo background functions

void setup(){
  HardwareBegin();  //initialize Ringo’s circuitry
}

int sensorRight;   //declares variable “sensorRight”
int sensorLeft;    //declares variable “sensorLeft”
int sensorRear;    //declares variable “sensorRear”

void loop(){
 digitalWrite(Source_Select, HIGH);  //select top side light sensors
 sensorLeft = analogRead(LightSense_Left);  //read left light sensor
 sensorRight = analogRead(LightSense_Right);  //read right light sensor
 sensorRear = analogRead(LightSense_Rear);  //read rear light sensor

 Serial.print(sensorLeft);        //print sensorValue through serial port
 Serial.print(“  “);              //print a couple blank spaces
 Serial.print(sensorRight);       //print sensorValue through serial port
 Serial.print(“  “);              //print a couple blank spaces
 Serial.print(sensorRear);        //print sensorValue through serial port
 Serial.println();                //print a blank line feed
 Serial.println();                //print a blank line feed
 delay(250);                      //delay 250 milliseconds
}
```

Example Sketch: Ringo_Guide_LightSense_01

I think you can see what is happening here. We’re using three variables now instead of just one. We read each sensor value into each variable, then use `Serial.print` to send it to your computer screen. Note in this example we’re using `Serial.print()` rather than `Serial.println()`. The function `Serial.print()` basically prints information without a carriage return at the end, so all the values end up on the same line. The two `Serial.println();` functions at the end create a carriage return at the end of the output data, as well as a blank line between data sets.

Using Ringo’s Light Sensors

Using top side light sensors when Ringo’s eyes are lit up...

Have a close look at Ringo’s eyes. You’ll notice that a NeoPixel LED shines through the clear ambient light sensor. Whenever the NeoPixel is turned on (Ringo’s eyes are lit up), this light from the NeoPixel is picked up by the top side light sensor directly in front of it. If you have Ringo’s eyes lit up and want to read the light sensors, you will need to briefly turn off Ringo’s eyes before reading the light sensors. The sensor read is very quick (about 100 microseconds per sensor) which is much too fast for your eye to see. If Ringo’s NeoPixel eye lights are turned off, then the light sensors are read, then the eye lights are turned back on immediately following, it will appear that Ringo’s eyes were lit up the entire time.

Try this code and see what happens:

```
#include “RingoHardware.h”  //include Ringo background functions

int sensorRight;   //declares variable “sensorRight”
int sensorLeft;    //declares variable “sensorLeft”
int sensorRear;    //declares variable “sensorRear”

void setup(){
  HardwareBegin();    //initialize Ringo’s circuitry
  PlayStartChirp();   //play startup chirp and blink eyes
  digitalWrite(Source_Select, HIGH);  //select top side light sensors
}

void loop(){
 SetAllPixelsRGB(0,0,0);            //turn off all NeoPixel lights
 delay(2);                          //delay 2 milliseconds. Important!

 sensorLeft = analogRead(LightSense_Left);  //read left light sensor
 sensorRight = analogRead(LightSense_Right);  //read right light sensor
 sensorRear = analogRead(LightSense_Rear);  //read rear light sensor

 // ... continued on next page ....
 // ... continued from previous page ....

 SetPixelRGB( 4, 220, 30, 160);  //set pixel 4 (Right eye)
 SetPixelRGB( 5, 220, 30, 160);  //set pixel 5 (Left eye)
 RefreshPixels();                //turn on the pixels

 Serial.print(sensorLeft);        //print sensorValue through serial port
 Serial.print(“  “);              //print a couple blank spaces
 Serial.print(sensorRight);       //print sensorValue through serial port
 Serial.print(“  “);              //print a couple blank spaces
 Serial.print(sensorRear);        //print sensorValue through serial port
 Serial.println();                //print a blank line feed
 Serial.println();                //print a blank line feed
 delay(500);                     //wait a half second before looping
}
```

Now we’ll talk about what is happening. You’ll notice a few differences in this example.

Firstly, we placed the digitalWrite(Source_Select, HIGH); in the setup() function because in this case, it only really needs to run once (as we’re not switching to read the lower sensors in this case). This is fine to do, but you probably want to include this in your main loop() function if you’re reading both top and bottom sensors.

We first start by turning off all the pixels. The next step delay(2); is super important. The light sensors are amplified through a part called an “op-amp”, and this particular op-amp takes about a millisecond to adjust to the lower light level after Ringo’s eyes are turned off. By delaying 2 milliseconds, we can be certain that Ringo is no longer seeing any “after glow” from having his eyes turned on. As soon as this delay is complete, we can go grab the three readings we want with analogRead() functions. As soon as the readings are complete, we flip Ringo’s eyes back on. Once the eyes are back on, we send the serial data of the readings back to your computer, and finally, we wait a half second before doing it all again.

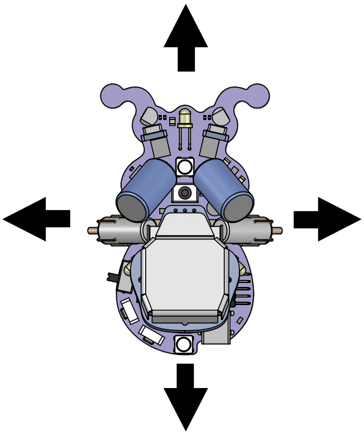
In the next section, we’ll talk about reading Ringo’s bottom sensors which can be used to sense lines and edges.

Using Ringo’s Navigation

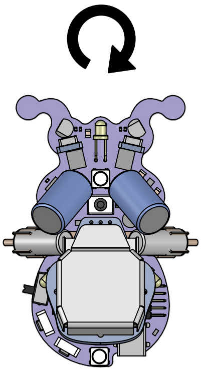
Ringo has two incredible sensors that can be used to sense his motion. The first sensor is called an Accelerometer. An Accelerometer senses movement in front-back, left-right, and up-down motion. It can be used to determine how far Ringo moves. The second sensor is called a Gyroscope. A Gyroscope senses rotational movement. For example, if you keep Ringo in the same location but you rotate him in a turn, the Gyroscope can be used to determine how many degrees he has rotated.

Taken together, these sensors embody an “inertial navigation” system, where Ringo can determine how far he has moved and how his orientation is changing. You could for example, make a 45 degree turn and move forward 1 meter. Awesome!

This is the first “Skill Level 2” lesson. We’ll get a bit more advanced in the discussion here but have no fear - the actual functions used to move Ringo are fairly straightforward.



Accelerometer



Gyroscope

Background Information...

Let's start with some background information about how these sensors work. Don't let this part of the discussion scare you - this is good information to help you understand how and why the movement functions work the way they do.

The accelerometer doesn't actually tell you where Ringo is or how far he has moved. The sensor simply measures acceleration - which is how quickly Ringo's speed is changing at any given instant. It measures this 800 times per second, and stores the measurements in a memory inside the sensor. Every so often (about every 80 milliseconds in Ringo's case), Ringo's brain needs to establish a data connection with the sensor and unload these values. Becasue we know how much time elapsed between each measurement, Ringo can do some math and determine that a certain acceleration force will result in a certain speed, and that taken over time can determine distance. If the sensor data isn't read out every 80 milliseconds, the memory inside the sensor (called a "buffer") will "overflow". The overflow doesn't hurt anything, but it will forget the values it has already taken which means when Ringo eventually runs the math on those samples, the end result may not be accurate.

The gyroscope works in a similar way. It doesn't actually tell you what direction Ringo is facing. Instead, it takes snapshots of "angular velocity" at regular intervals timed very close together and stores those values in its own buffer. Ringo establishes a data connection to the gyroscope and unloads these values. Again, some math can be done on these values and determine that a given angular velocity over a given period of time will result in a predictable number of degrees of rotation and thus, Ringo can keep up on what direction he is facing.

Lucky for you, this process of reading values out of the sensors and performing the math on them (which is rather complex) has already been worked out and is performed automatically by calling a few simple functions.

Using Ringo's Navigation

Here is a quick list of the navigation functions along with a short description of each. These functions take care of the data communication between Ringo's brain and the sensors as well as performing the required math on the resulting data so they are easy to use.

Base setup functions:

`NavigationBegin();` This function turns on and initializes the gyroscope and accelerometer. It is important to call this function before running the other navigation functions. It can be called over and over with no harmful effects.

`CalibrateNavigationSensors();` This function calibrates the sensors. Even when the sensors are perfectly still, they do have a slight offset because no sensor is perfect. To calibrate the sensors, we measure some samples when they are still to see what this offset is. Ringo then remembers this offset and subtracts it out of future measurements. The NavigationBegin() function calls this CalibrateNavigationSensors(), so you don't need to call it a second time. It is important that Ringo is perfectly still when calling this CalibrateNavigationSensors(). Vibrations or wiggles on your table will adversly effect the calibration. The sensors should be recalibrated every so often. Keep in mind that it is useful to place a delay() before each calibration to make sure Ringo isn't still moving from a previous motor operation, etc. Wait a second or so to calibrate after the Reset or User buttons are pressed as the presense of your finger on the robot will adversly effect the calibration accuracy.

`ZeroNavigation();` Ringo keeps a memory of his X and Y location as well as his rotation. The X location is left/right of his starting location, with a positive number to the right, and a negative number to the left. The Y location is front/rear of his starting location with positive numbers in the forward direction and negative numbers in the rear direction. Units are in millimeters of travel. Rotation is in units of degrees. Positive degress are in the right (clockwise) direction and negative degrees are in left (counter-clockwise) direction. Note that the degrees do not loop. For example, if you rotate one and a half turns in the clockwise direction, the resulting rotation value will be 540. The ZeroNavigation() function zeros these running X, Y, and rotation numbers to zero.

`GetHeading();` The GetHeading() function returns Ringo's present heading in degrees.

Movement Functions:

Ringo's inertial navigation can be used in lots of interesting ways, and we encourage you to explore the possibilities. The most obviously useful function is in controlling Ringo's motors to move him in predictable ways. We have written a selection of functions that move Ringo's motors while reading the navigation sensors to go certain distances, turn in certain ways, etc. These functions handle running the motors including speed and direction, reading the sensors, performing the math on the sensor data, and adjusting motor speed to achieve the desired movement.

All movement functions use a "PID" software loop, which is a software technique commonly used to move robot arms. Basically, a PID loop causes the motors to move more quickly if they are further from their target, and more slowly as they reach the target. For example, when rotating, if Ringo needs to turn 180 degrees, the motors will run quickly at first and will slow progressivly as Ringo nears the 180 degree point. So the speed is naturally self correcting and minimizes over-shoot.

Rotation:

`DriveArc()` This function causes Ringo to drive forward (or backward) while performing a turning movement. It causes Ringo to drive in an "arc" type movement. The function takes five arguments and is prototyped as follows.

NOTE: `DriveArc()` requires use of Base_Sketch_04 or later.

```
void DriveArc(int TurnDegrees, int left, int right, \
                             int MaxExpectedTurnTime, int MaxExpectedSkidTime);
```

The terms work as follows. `TurnDegrees` is the number of degrees to be rotated during the turn. Positive or negative numbers can be used. Ringo will stop when either the `MaxExpectedTurnTime` expires, or the desired rotation is achieved during the arc movement. `left` and `right` are the speed for each motor. This controls how fast Ringo will move. Normally you'll use different numbers for left and right so Ringo will actually curve during movement. `MaxExpectedTurnTime` is the time (in milliseconds) Ringo will allow to reach his target rotation before giving up and moving on in the code. Without this feature Ringo would drive his motors as long as required until his sensors tell him that he has arrived at the target rotation. Because there is some rotational inertia to Ringo and his motors, he won't stop immediately. He will skid on the surface for some period of time. Once the motors are turned off, Ringo will continue to evaluate his gyroscope and accelerometer and wait for the readings to indicate that he has in fact come to a complete stop. Similar to the MaxExpectedTurnTime, the MaxExpectedSkidTime is the maximum time Ringo will remain looking for a complete stop. This time can be fairly short as he will normally stop very quickly and move ahead to the next instruction on his own.

Lets consider a working example. This should cause Ringo to move in a star step movement arcing to the right then left then repeating.

```
#include “RingoHardware.h”  //include Ringo background functions

void setup(){
  HardwareBegin();     //initialize Ringo’s circuitry
  PlayStartChirp();    //play startup chirp and blink eyes
  delay(1000);         //wait 1 second after restart before starting navigation
  NavigationBegin();   //initialize navigation system
}

void loop(){
              //rotation, left, right, turntime, skidtime
 DriveArc(90, 200, 75, 3000, 100);   // stop driving at 90 degrees
 delay(1000);                             // wait 1 second
               //rotation, left, right, turntime, skidtime
 DriveArc(-90, 75, 200, 3000, 100);  // this time go to the left
 delay(1000);                             // wait 1 second
}
```

In this example, we call NavigationBegin() one time in the setup function. In the main loop, we first tell Ringo to set motors to (200, 75) and stop them once he naturally achieves a 90 degree turn to the right. He will attempt to reach 90 degress for 3 seconds. If he cannot reach 90 in this time, he will skip out of the DriveArc() function and proceed to the next line of code. Once he stops, he will wait 1 second to reach a complete stop. These turn and skid times should be plenty to reach the target. The loop then makes the same movement in reverse and continues in a loop.

Hint: When you experement on your own, if you see Ringo consistantly fails to turn far enough, have a look at the MaxExpectedTurnTime argument and make sure you're allowing him enough time to complete the maneuver.

RotateAccurate() This function makes Ringo rotate in his own footprint. If Ringo over-shoots the target rotation, he will reverse direction and attempt to reach the target rotation more accurately. It is prototyped as follows.

```
char RotateAccurate(int Heading, int MaxExpectedTurnTime);
```

The RotateAccurate() function accepts two arguments: Heading and MaxExpectedTurnTime. Heading is the target rotation, and like the last example, the MaxExpectedTurnTime is the max time Ringo will attempt to complete the maneuver.

Note: The gyroscope on each Ringo unit is slightly more or less sensitive and thus, "RotateAccurate()" may over or under-shoot regularly. Open and load the sketch "Ringo_CalibrateGyroscope_Rev01". This sketch can be used to calibrate the gyroscope on your individual Ringo unit so the navigation functions are much more accurate.

Movement:

MoveWithOptions() This is the most basic function for movement. It accepts seven arguments and is prototyped as follows.

```
void MoveWithOptions(int Direction, int Speed, int Distance, \
         int MaxExpectedRunTime, int MaxExpectedSkidTime,    \
         void (*EdgeFunction)(char), char Wiggle);
```

The MoveWithOptions() function looks a bit intimidating, but it's actually pretty straighforward. Let's discuss it. The first argument is Direction. Ringo will attempt to turn to this direction as he begins driving. Speed is the average motor speed he should try to maintain. This will be adjusted up or down slightly between the two motors to produce the desired direction. Distance is the overall forward or backward travel distance in millimeters. As with the previous functions, MaxExpectedRunTime is the maximum time Ringo will allow to carry out the attempted maneuver, and MaxExpectedSkidTime is the maximum time Ringo will wait to arrive at a complete stop once he arrives at the commanded destination. The (*EdgeFunction)(char) term allows Ringo to call a certain function if he reaches an edge during his travel. That's a bit more advanced and we'll cover it later, but for now, just pass a 0 in this argument. The Wiggle argument controls how much "buggy swagger" Ringo will show. A 0 in this argument will cause him to move fairly straight with only a minimal wiggle. A 50 in this argument looks pretty buggy - he sways around a lot more. It is suggested that a maximum value of 100 be passed for this argument. Anything more than 100 will cause him to have a real problem maintaining course, but it can be interesting to watch so go ahead and experement with it.

Lets have a look at a working example of this function.

```
#include “RingoHardware.h”  //include Ringo background functions

void setup(){
  HardwareBegin();     //initialize Ringo’s circuitry
  PlayStartChirp();    //play startup chirp and blink eyes
  delay(1000);         //wait 1 second after restart before starting navigation
  NavigationBegin();   //initialize navigation system
}

void loop(){
             //direction, speed, distance, runtime, skidtime, edge, wiggle
 MoveWithOptions(0, 220, 300, 2000, 100, 0, 10);   // go forward 300 mm
 delay(1000);                                      // wait 1 second
 MoveWithOptions(0, -220, -300, 2000, 100, 0, 10);  // go backward 300 mm
 delay(1000);                                      // wait 1 second
}
```

In this example, we call MoveWithOptions() and tell it to drive Ringo in the 0 degree heading (straight ahead) at a motor speed of 220 (motor speeds can be positive or negative 0 to 255) for a distance of about 300 mm. He will allow 2 seconds to complete the maneuver, allow 100 milliseconds to come to a complete stop after the maneuver, and he’ll do it all with level 10 buggy swagger. He then does the same in reverse. To drive in reverse you’ll specify a negaive motor speed (-200 in this case) as well as a negative distance (-300 in this case).

Now lets combine movement and rotation. Like this:

```
void loop(){
               //direction, speed, distance, runtime, skidtime, edge, wiggle
 MoveWithOptions(GetHeading(), 220, 300, 2000, 100, 0, 10);
                                       // go forward 300 mm at present heading
 delay(500);                           // wait 1/2 second
 RotateAccurate(90, 2000);             // rotate 90 degrees clockwise
 delay(500);                          // wait 1/2 second
}
```

In this example, we’ve made a change to the MoveWithOptions() function. You may notice that instead of going direction 0, we instead have plugged another function into this spot - GetHeading(). Lets talk about this for second.

Lets say we put a 0 instead of GetHeading(). You may want to try this and see what happens on your own. When we put a 0 in this function, Ringo is going to try and drive to the heading of 0 referenced from the last time you called either HardwareBegin() or ZeroNavigation(). Putting a 0 in here the first time through the loop causes him to drive straight as expected. But after we rotate him 90 degrees, he is no longer headed in the 0 degree direction. If we call MoveWithOptions() a second time after the rotation, and we put a 0 for direction, Ringo will make a left turn as he starts to drive because he is trying to return to the 0 degree direction.

An easy way to avoid this, is to always place GetHeading() in place of the zero. The GetHeading() function reads Ringo’s current heading and automatically passes this current heading to the MoveWithOptions() function each time it is called. By passing GetHeading() for the direction, Ringo will always travel in a straight line each time the function is called, no matter how much you rotate him.

You could do other cool things like passing “GetHeading()+15” which would cause Ringo to make a 15 degree clockwise turn during each movement.

These are the basics to get you started. We will continue to fill out this guide with additional examples and greater explanation as we move forward. Cheers!!

Using Ringo's Edge Sensors

Ringo has three light sensors on his under side. These sensors can be used to sense differences in the surface he is running on, such as edges of tables, lines, boxes, etc. These light sensors are intended to work together with three infrared light sources placed near the three light sensors.

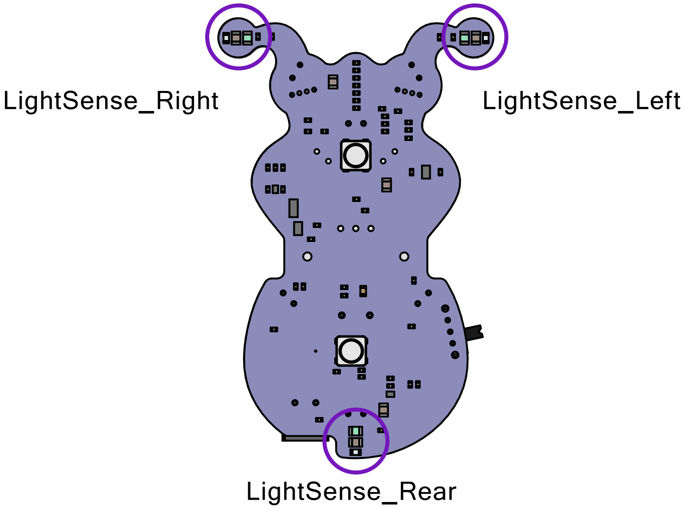
Setup...

As stated in the previous chapter, the LightSense lines to Ringo's brain are shared between the top "ambient" light sensors and the bottom light sensors. To select the lower light sensors, you need to set the `Source_Select` pin to `LOW`.

Like this:

```
digitalWrite(Source_Select, LOW);    //This selects the bottom light sensors
```

RINGO BOTTOM SIDE

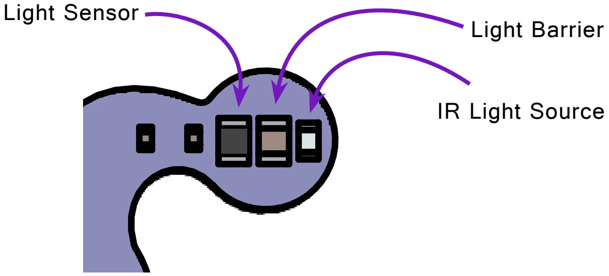


Using Ringo's Edge Sensors

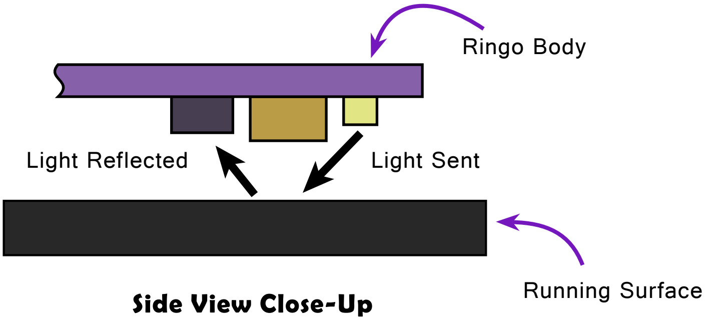
Next to each light sensor is a light source that produces infrared light. This light is invisible to your eye, but Ringo's edge sensor can see this light. All three lights are turned on and off together by setting the `Edge_Lights` pin. This infrared light is important. Lets discuss for a minute then it will be more clear what the code is actually doing. Don't let the details overwhelm you - later on in this section we present a couple super easy functions that automate the edge detection process.

How edges are measured...

The edge sensors are just light sensors mounted to Ringo's bottom side. If Ringo is placed on a white surface, these light sensors will see a bit more light, and if he is placed on a black surface, he will see less light. However, because Ringo's body casts a shadow on the surface, this measurement is only possible in well lit rooms. By adding extra light from the light sources on the `Edge_Lights` pin, we can do a neat trick to determine what sort of surface he is on.



Light Sensor Close-Up



Side View Close-Up

We first turn on the infrared Edge_Lights sources. While these are turned on, we take a reading of one or more of the bottom light sensors and store the result in a variable. At this time, the light sensors are mostly seeing light reflected from the surface by the infrared light emitters. Each surface, material, or color will reflect a different amount of this infrared light.

We then turn off the edge light sources and take the same measurement again. This second measurement will show us the amount of ambient light being picked up by the edge light sensors (this is light from the room that may be getting into the sensor).

Once we have these two values, we can subtract them to determine the difference. This is essentially the amount of light reflected from the surface with the light from the room removed. Because each surface will reflect a different amount of light, this "difference" value can be evaluated and we can draw some assumptions about the surface from the "difference" value.

Darker surfaces will reflect less light, and brighter surfaces will reflect more light as you would expect.

We can now take this a step further and store a few historic "difference" readings. Each time we take a new reading, we can compare it to the last few readings. If the reading decreases suddenly, we can assume that the sensor has either moved over a darker feature in the surface (like a black stripe on the surface), or, that the sensor is hanging off the edge of the running surface - because there is no longer a surface present to reflect the light.

We have placed a capacitor between the light source and the light sensor. This capacitor is not electrically connected to anything. Instead we are using this capacitor as a "light barrier" which prevents the light from the light source from shining directly into the light sensor, so most of what the light sensor is seeing is in fact the light reflected from the surface.

Using Ringo’s Edge Sensors

Using the bottom light sensors…

The bottom sensors can be read directly easily enough and used directly in your program. Consider this example:

```
#include “RingoHardware.h”  //include Ringo background functions

void setup(){
  HardwareBegin();    //initialize Ringo’s circuitry
  PlayStartChirp();   //play startup chirp and blink eyes
}

int leftOn, leftOff, rightOn, rightOff, rearOn, rearOff; //declare variables
int leftDiff, rightDiff, rearDiff;                      //more variables

void loop(){

 digitalWrite(Source_Select, LOW);         // select bottom light sensors

 digitalWrite(Edge_Lights, HIGH);          // turn on the IR light sources
 delayMicroseconds(200);                   // let sensors stabilize

 leftOn = analogRead(LightSense_Left);     // read sensors w/ IR lights on
 rightOn = analogRead(LightSense_Right);   // read sensors w/ IR lights on
 rearOn = analogRead(LightSense_Rear);     // read sensors w/ IR lights on

 digitalWrite(Edge_Lights, LOW);           // turn off the IR light sources
 delayMicroseconds(200);                   // let sensors stabilize

 leftOff = analogRead(LightSense_Left);    // read sensors w/ IR lights off
 rightOff = analogRead(LightSense_Right);  // read sensors w/ IR lights off
 rearOff = analogRead(LightSense_Rear);    // read sensors w/ IR lights off

 leftDiff = leftOn-leftOff;                // subtract out ambient light
 rightDiff = rightOn-rightOff;             // subtract out ambient light
 rearDiff = rearOn-rearOff;                // subtract out ambient light

// ... continued next page ...             // turn the page  :-p
// ... continued from previous page ...

 Serial.print(leftDiff);   // print the results to the serial window
 Serial.print(“  “);
 Serial.print(rightDiff);  // print the results to the serial window
 Serial.print(“  “);
 Serial.print(rearDiff);   // print the results to the serial window
 Serial.println(“”);       // blank line with carriage return
 delay(250);               // wait 1/4 second before doing it again
}
```

In this example we turn on the invisible infrared lights (sometimes called “IR” lights) to light up the surface. Then we wait 200 microseconds (2/10ths of a millisecond) to give the light sensors time to react and stabilize to the new lighting level. The `delayMicroseconds()` function is used for this. `delayMicroseconds()` is useful for delaying very short amounts of time. A microsecond is a millionth of a second. It is good practice to add a slight delay between changing the input to a sensor (like the light level) and reading the sensor as it may take a short time for the sensor to stabilize to the new input level. After we let the sensors stabilize to the new light level, we read each of them.

We then do the same process after turning off the IR lights. Finally we subtract out the ambient light level and send the results to your serial monitor window so you can see the readings.

Experiment with Ringo over different surfaces and see how the number changes. The first number in the serial window is the front left, then front right, then rear sensor value. As you place a sensor over a different material you will see this value change. Hold him a ways off the surface and these numbers will likely go under 100. On a black surface or dark desk, you’ll probably see 100 to 150, and if you place him on a white piece of paper, the values should shoot up to 800 or more.

It is easy to make Ringo react in different ways to these values. For example, if you run him on a white surface and surround it with black tape, you could turn on his motors and repeatedly evaluate if the reading remains over 500, and if it ever drops below 500, you stop the motors. This would cause Ringo to drive until he reached the tape line.

Edge Sensing Functions (the easy way)...

There is an easier way to sense edges. We have written functions that can be called in the background to see if an edge or line is present. Have a look at Pre-Loaded Behavior #5 “Follow The Line” for a working example.

We use one main function to look for edges.

```
LookForEdge();    //The magic function to look for edges on all 3 sensors.
```

Lets talk about LookForEdge(). It does a few interesting things. LookForEdge() calls a second function called LookAtEdge(). LookAtEdge() goes around and automatically does the process described above - it looks at each edge sensor with the light off and then on. It also updates a running average for each sensor of the last 8 times it was called. After LookAtEdge() is called, several global variables are updated which you can then use anywhere in your code. These are as follows:

```
LeftEdgeSensorValue  //diff between the On & Off of most recent read for Left
RightEdgeSensorValue //diff between the On & Off of most recent read for Right
RearEdgeSensorValue //diff between the On & Off of most recent read for Rear

LeftEdgeSensorAverage  //Running average of past 8 reads of Left Edge Sensor
RightEdgeSensorAverage  //Running average of past 8 reads of Right Edge Sensor
RearEdgeSensorAverage  //Running average of past 8 reads of Rear Edge Sensor
```

You can then compare, for example, the LeftEdgeSensorValue to the LeftEdgeSensorAverage to determine if the left edge sensor has recently moved to a surface that is brighter or darker compared to the running average. You can call LookAtEdge() by itself on your own if you like.

Now lets get back to talking about LookForEdge(). As we said, LookForEdge() calls LookAtEdge(). After calling LookAtEdge(), the rest of the LookForEdge() function determines if an edge was seen for each of the 3 sensors, and furthermore, determines if a bright edge was seen or a dark edge is seen. LookForEdge() returns a byte which includes 8 “bits”. Each “bit” is flipped to a 1 depending on which edge was seen and whether it was bright or dark.

Don't let this "bit" business scare you though. More advanced programmers will understand this and can further understand the bit order by studying the LookForEdge() function notes in the "RingoHardware.h" tab.

For everyone else, we've provided a few more functions to evaluate the coded bits in the value returned by LookForEdge(). Let's look at an example below and things will be more clear.

```
void setup(){
 HardwareBegin();     //initialize Ringo's brain to work with his circuitry
 PlayStartChirp();     //Play startup chirp and blink eyes
 ResetLookAtEdge();    //Zeros the LookAtEdge() running average
}

char edge;       //define a holder for the value returned by LookForEdge()

void loop(){
  edge=LookForEdge();  //Read all sensors, update average, determine if
                       //if any edges were seen, place the coded binary
                      //result in the variable "edge". This "edge" variable
                     //will be zero if no edge was seen.
  if(FrontEdgeDetected(edge)){
     // do something if either front edge was detected
  }
  delay(100);        //wait a while before looping
}
```

Okay, lets talk about this example. For starters, you should call ResetLookAtEdge() once before using the edge functions. This zeros out the running average and makes sure the memory is clear and ready to take new readings. The variable "edge" is declared before starting the loop() function. This will hold the response returned from LookForEdge().

Once inside the loop, we call LookForEdge(), but we don't call it by itself. We actually tell Ringo to put the result of LookForEdge() in the variable "edge". We can then pass "edge" to "FrontEdgeDetected()" which is a function that evaluates if the bits in "edge" indicate that either of the front edge sensors saw something.

Using Ringo's Edge Sensors

In addition to FrontEdgeDetected() you can use several other functions that work in a similar way. Here's a quick list:

```
FrontEdgeDetected()  //True if either front edge sensor saw an edge
BackEdgeDetected()  //True if the rear edge sensor saw an edge
RightDetected()      //True if front Right edge sensor saw an edge
LeftDetected()      //True if front Left edge sensor saw an edge
BrightDetected()     //True if a bright edge was seen
DarkDetected()       //True if a dark edge was seen
```

IR Communication

Ringo is able to receive commands from the IR remote control or from other Ringos, and similarly, can send commands or information to other Ringos or other IR devices like your TV.

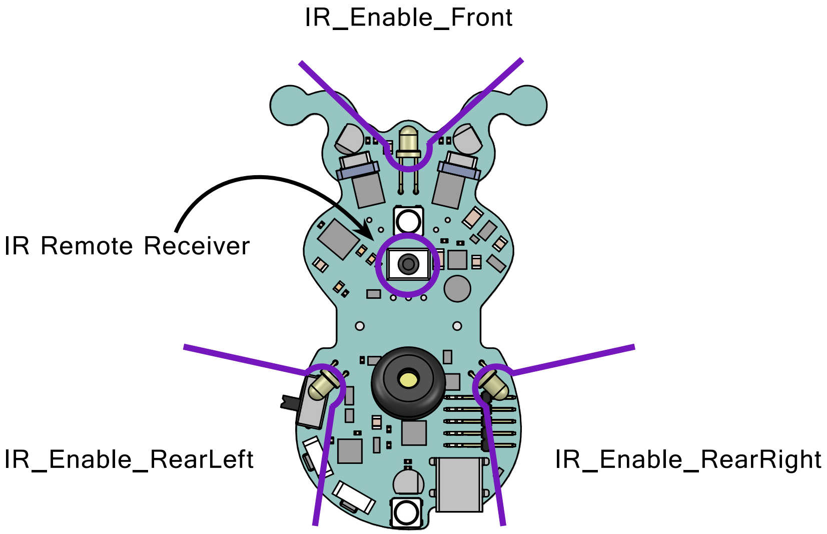
Setup...

Ringo can send IR signals through 3 different emitters which allow him to transmit 360 degrees. Each emitter may be independently enabled allowing for flexibility in how you want Ringo to communicate with other Ringos or devices around him.

```
digitalWrite(IR_Enable_Front, HIGH);      //Enable Front IR source
digitalWrite(IR_Enable_RearLeft, HIGH);   //Enable RearLeft IR source
digitalWrite(IR_Enable_RearRight, HIGH);  //Enable RearRight IR source
                 //Set any of these to LOW to disable the given source
```

Once you have the sources configured as desired, the enabled IR sources are controlled together at the same time with the IR_Send pin.

```
digitalWrite(IR_Send, HIGH);   //Turns ON all enabled IR Light Sources
digitalWrite(IR_Send, LOW);    //Turns OFF all enabled IR Light Sources
```



IR Communication

You can send IR data communication using the 3 IR sources. The supplied remote control sends packets of 4 bytes each time a key is pressed, so it is suggested that any IR communication use packets containing 4 bytes of data.

You can send a packet several ways.

```
byte MyData[]={0x00,0xFF,0x1C,0xE3};  //declare this before the loop() function
                                      //this creates a packet of the 4 bytes to
                                      //be sent. This packet is the same as
                                      //pressing the “5” key on the IR remote.
void loop(){
  TxIR(MyData,4);   //send the array MyData. The 4 means this is a 4 byte packet
  delay(500);       //wait a half second
  MyData[2]=0x52; MyData[3]=0xAD; //change last 2 bytes in array to match
                                   //the “8” key on the remote
  TxIR(MyData,4);
  delay(500);       //wait a half second
}
```

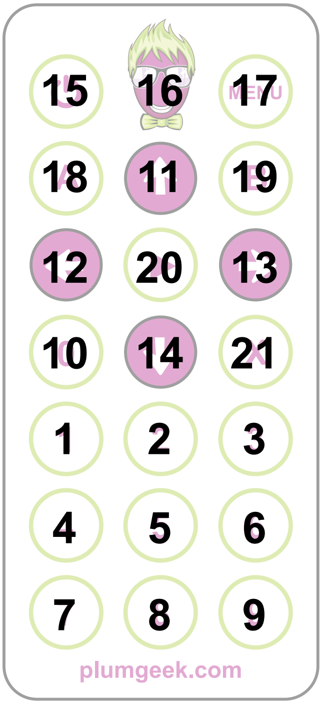
This code loads 4 values into an array called MyData before starting the loop(). The strange numbers are called hexadecimal numbers. (For more info on Arrays, do a quick google search for “Arduino array” - it’s basically a variable that holds several values). The TxIR() function takes an array as an argument, as well as an argument saying how long the array is. TxIR() actually modulates the IR led light sources as required to send this packet as if it were a TV remote control. Next, the last 2 bytes of MyData are changed to new values, in this case, to match the “8” key on the remote.

But there’s an easier way to send commands from Ringo as if Ringo was the IR remote control. Here’s how.

```
void loop(){
  TxIRKey(1);   //Send the same packet as pressing the “1” button on the remote
  delay(500);   //wait a half second
  TxIRKey(12);  //Send same packet as pressing the “left arrow” remote button
  delay(500);   //wait a half second
}
```

IR Communication

The function TxIRKey() is the easiest way to send commands from Ringo just like he was a remote control. You can use this to communicate with other Ringos. Have a look at the graphic below. This shows the "key number" for each of the keys on the remote control, as well as the actual data packet sent by each key. So by passing a given key number to TxIRKey(), Ringo will send the packet corresponding to that key.



Packet Sent by Keys

⏻	00 FF 45 BA	1	00 FF 0C F3
MENU	00 FF 47 B8	2	00 FF 18 E7
A	00 FF 44 BB	3	00 FF 5E A1
↑	00 FF 40 BF	4	00 FF 08 F7
B	00 FF 43 BC	5	00 FF 1C E3
←	00 FF 07 F8	6	00 FF 5A A5
▶	00 FF 15 EA	7	00 FF 42 BD
→	00 FF 09 F6	8	00 FF 52 AD
0	00 FF 16 E9	9	00 FF 4A B5
↓	00 FF 19 E6		00 FF 46 B9
X	00 FF 0D F2		

Advanced User Note: We are presently having problems with the TxIR functions which makes the reception of the packet somewhat spotty. It seems the Arduino delayMicroseconds() isn't accurate enough to reliably time the packets. We would welcome any help from the user base to have a look at the TxIR function in the RingoHardware tab. We'd like to replace the several calls to delayMicroseconds() with something more accurate, like polling a timer or something.

Receiving IR Data

Ringo can be set to receive and react to data from the included IR remote control. Have a look at the code for the Pre-Loaded behavior #1, which drives Ringo around based on data received from the remote control.

Here’s an explanation.

```
#include “RingoHardware.h”  //include Ringo background functions

void setup(){
  HardwareBegin();  //initialize Ringo’s circuitry
  RxIRRestart(4);    //re-initialize IR data receive buffer
                     //Tell IR receive function to expect a 4 byte packet
}

byte button;       //holder for any received button or other packet

void loop(){
 if(IsIRDone()){
   button = GetIRButton(); //returns IR remote key number received
}
```

The function RxIRRestart() initializes IR data receive buffer. Once you call this function, the IR receive functions run in the background. You don’t need to do anything else to actually receive data. When a 4 byte packet has been received, IsIRDone() will return a non-zero, which will tell you that a packet has been received. The received packet is placed in the global array IRBytes[] which is 20 bytes long. After you’ve determined that a packet has been received, you can access it directly by looking at IRBytes.

To make life easier, if you’re expecting an IR remote control key, you can simply populate a holder variable with GetIRButton() which looks at the received packet and maps it to a known key on the IR remote (which matches the graphic on the previous page). If the packet is not known to match a key, a zero will be returned by GetIRButton().

After reading the packet, call RxIRRestart() again to clear the buffer and ready the system to receive a subsequent IR packet or IR remote key command.