

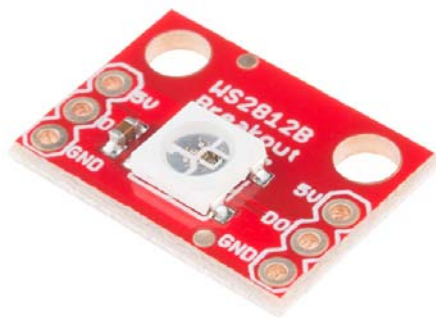


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## WS2812 Breakout Hookup Guide

### Preface

The WS2812 is an unassuming RGB LED with an integrated control circuit hidden underneath. We love the simplicity of this little IC/LED combo. It's at the heart of a number of products including the the simple WS2812 Breakout Board.



The LilyPad Pixel shares the same circuit as the breakout board, but it comes on a circular, purple LilyPad board. These are perfect for sewing onto clothing or other fabric, and embedding into an e-textiles project.



Finally, the WS2812 serves as the heart and soul of a variety of LED strips. These strips come in four flavors: 5 meter sealed, 1m sealed, 5m bare, and 1m bare.



What makes the WS2812 really special is the way its controlled. The IC embedded into the LED communicates via a very **unique one-wire** interface. With the help of some libraries, they're really very easy to control. Plus they're chain-able – the output of one LED can be connected to the input of another to create strips of hundreds of LEDs. The more boards you have linked together, the fancier your animations can be!

In this tutorial we're going to get you familiar with the workings of the WS2812. We'll go over some of the ways you might want to hook up to the breakout board, LilyPad, or strips. And we'll close the tutorial out with some example Arduino code.

## Required Materials

Stating the obvious: you'll need a WS2812-based board or strip. The more the merrier! In the example hookup we'll be linking together five breakout boards, but the example should be adaptable to the other products. Grab however many you think you'll need for your project, regardless of how many you have, it's not enough.

Aside from the star of the show, you'll also need a **microcontroller**. Something that can send the series of 1's and 0's used to control the LEDs. Our go-to is the classic Arduino Uno, but any Arduino board should do. Or you can try to adapt the example code to your favorite microcontroller.

You'll also need some **way to connect** between the board and an Arduino. You could use a combination of male headers and breadboard. Or you could just go with a few pieces of wire.

## Tools

In order to get a good, solid, electrically-sound connection to the breakout boards, you'll need to **solder** to the pins. That means you'll need at least a basic soldering iron as well as solder. Check out our how to solder tutorial for help, if this is your first time soldering.

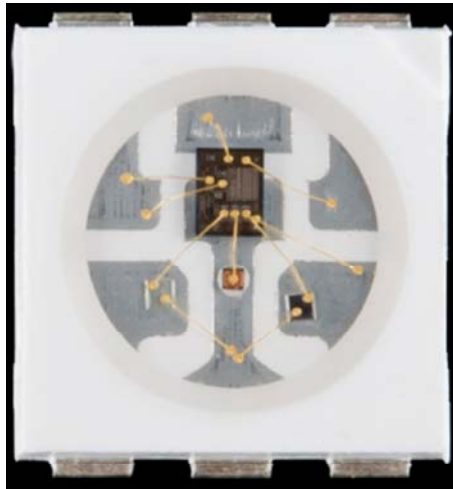
## Suggested Reading

These boards aren't too hard to use. If you've done anything with Arduino before, you'll be prepared to work with the WS2812. If you're not exactly sure what this "Arduino" thing is, or if you're not familiar with the topics below, consider reading their tutorials:

- What is an Arduino
- Binary
- How to Use a Breadboard
- How to Solder
- How to Power a Project

## WS2812 Overview

The WS2812 is much more than meets the eye. It may look like a common 5050-sized (5x5mm) LED, but there's actually an integrated circuit embedded inside there too. If you look really hard, you can see the tiny black chip hidden in there, along with minuscule gold wires connecting the chip to the LED.



*Pretty nifty view at the guts of the WS2812.*

The LED itself is like any RGB (Red/Green/Blue) LED. The brightness of each color can be adjusted using pulse-width modulation to one of 256 different levels. That means there are 16,777,216 ( $256^3$ ) possible combinations of colors. You can produce any color from white to black (off), or salmon to sienna.

## Breakout Board Pinout

The Breakout board mounts that multi-talented LED onto a PCB, and breaks out the few pins required to control the LED.



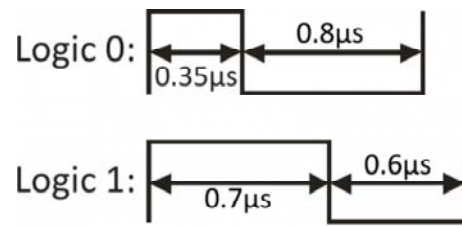
Four unique pins are broken out:

- **5V** – This should be a **regulated** supply voltage between 5V and about 7V. More than that could harm the LED, less than 5V will either reduce brightness, or it just won't turn on.
- **GND** – The common, ground, 0V reference supply voltage.
- **DI** – Data from a microcontroller (or another WS2812 pixel) comes into this pin.
- **DO** – Data is shifted out of this pin, to be connected to the input of another pixel or left floating if it is the last link in the chain.

## Data Transmission Interface

*Note: this stuff is ugly, and not critical to understand if you just want to use the breakout board. (That's what libraries are for, right?!) It's interesting to talk about, because the interface is so unique.*

The communication interface between a microcontroller and the WS2812 is weird. It's one wire, but it's not like a standard, UART serial interface. This interface is very time-specific. Both a logic 0 and a logic 1 require a square pulse, and it's the length of the pulse that defines which it is.



*Timing diagram for a single bit of value 0 or 1.*

The data is sent in a sequence containing 24 of those bits – 8 bits for each color – followed by a low “reset” pulse of at least 50µs.



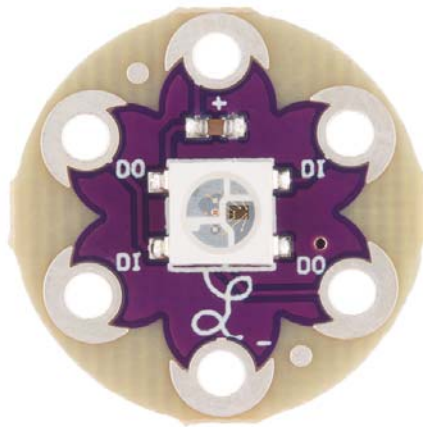
*A sequence of 24 timed-bits sets the color for each channel. 8-bits per channel. Green first, then red, then blue.*

The larger the value of a specific color is, the brighter it will be. If every color is set to 0, the LED will be off. If every color is set to max – 255 – the LED will be as bright and white as can be.

This is all to say that the interface is **very time-specific**. To run the LEDs you'll need a real-time processor, like an Arduino; microprocessors like those on the Raspberry Pi or pcDuino can't give you a reliably-timed pulse. Even if one bit is less than a microsecond off, that could mean the difference between purple and maroon.

## LilyPad Pixel

Want to embed the WS2812 LEDs into your clothing? We have a thing for that! The LilyPad Pixel Board is the e-textile version of the WS2812 Breakout. The functionality and pinouts are exactly the same, though the pins are in slightly different location to make threaded traces easier.



Rather than solder these boards, you can use conductive thread to connect them to other LilyPad boards. You can control individual LEDs, or chain them together to create a multitude of colors on your clothing. The examples in this tutorial use the WS2812 Breakout, but you can substitute the LilyPad Pixel for any of the breakout boards.

## Addressable LED Strips

If you need an abundance of WS2812 LEDs in a slick, pre-assembled form factor these addressable LED strips might be for you.

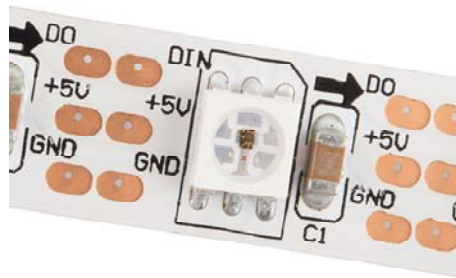


*The LED strips come on a reel as shown above.*

The WS2812 Addressable LED strips come in four product options, which vary by size and sealant. You can get them in either 1m or 5m lengths, and for each length the strip can be either covered by a waterproof sealant or left bare.

- 5 meter Sealed
- 1m Sealed
- 5m Bare
- 1m Bare

The waterproofed strips are rated IP65 – dust tight and protected from water jets.



Each strip has **60 LEDs per meter**, which are spaced about 1.65cm away from each other.

## Connecting to the Strips

Each end of the LED strip is terminated with a set of three colored wires: red, yellow, and green. Two wires are for power, and the third transmits data either into or out of the strip:

Wire Color	Function	Notes
Red	Vcc	WS2812 power supply. Should be a <b>regulated</b> supply <b>between 5V and 7V</b> .
Yellow	GND	Ground. 0V.
Green	Data In/Out	Serial data in or out. Look at arrows and labels on strip to check which it is.



Each of the wire pigtails are terminated by a three-pin JST SM connector, which you can use to connect **string strips together**. For the first strip in a string, you can either connect to a mating connector, or cut and strip the wires, and connect them to your controlling device.

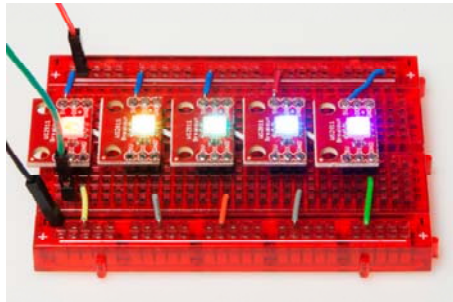
## Hardware Hookup

The great thing about these LEDs is they're super easy to chain together. Plus just one, single pin from your microcontroller is required to control an entire strip of LEDs. In this example we'll link together five LEDs, but you should be safe to increase that ten-fold or even more.

## Solder/Sew/Wire Something

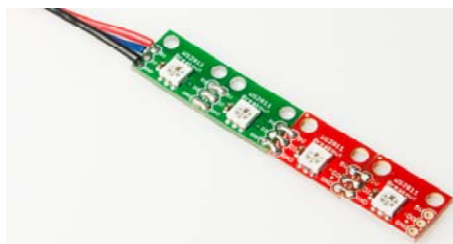
The first assembly step for each of these products is creating a reliable, electrical connection from the LED to your control board. You'll need to solder either headers or wires to your breakout boards. Or sew your LilyPad Pixel with conductive thread. Or strip and splice some wire to connect up the LED strips.

If you're going to stick the boards into a breadboard or other prototyping board, straight male headers might be the best choice.



*WS2812 breakouts linked together on a breadboard. Hidden under each is a white wire that connects DO of one to DI of the next.*

If you're going to make a big strip of boards, you may need to opt for the stranded wire route.



*Link WS2812 boards together in a chain, by connecting DIs to DOs (don't forget power too). Sorry, the fancy green boards aren't available :(.*

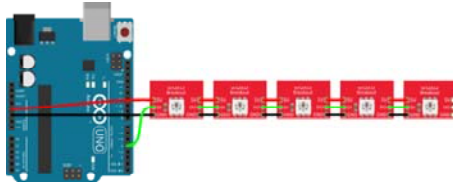
## Select a Power Source

The WS2812 requires about 5V to work. It should operate at anywhere between about 4V to 7V, but 5V is readily-available on most boards. The 5V header on an Arduino board, for example, is a perfect voltage supply for the LEDs.

Also consider how much current your LED strip is going to pull. With every single LED on at full brightness, each breakout board can pull about 60mA (20mA per channel). Even with just ten breakout boards strung together, you're looking at upwards of a possible 600mA. Yikes! If you're stringing together a lot of these things, make sure your power supply can provide the necessary current-umph. If you end up using an external power supply, make sure you connect the power supply ground to your Arduino ground as well.

## Connecting an Arduino

This hookup is fairly straightforward. You can power the breakout board(s) using the Arduino's **5V** and **GND** pins. Then all you need is to pick a free I/O pin to send data to the LED. Let's go with **pin 4**. To link more breakouts together, simply connect the output pin of one to the input of the next. Make sure each breakout also gets some power delivered to it.

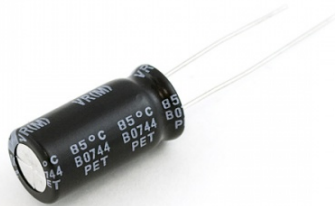


## Protect your WS2812's!

In addition to the hookup above we recommend the following additions to help you get the most out of your WS2812-based devices:

### Add a Big Smoothing Capacitor

Before connecting the WS2812 to a power source, connect a big capacitor from power to ground. A cap between 100 $\mu$ F and 1000 $\mu$ F should be good.



This cap will help to smooth out your power supply. The current draw of a WS2812 can vary wildly, and as current draw grows and shrinks it'll be up to your power source to compensate. The cap will act as a "power reservoir" to store energy in case the supply dips.

Try to place this cap **as close to your WS2812 as possible**.

### Add an In-Line Resistor On the Data Signal

Placing a small-ish resistor between your Arduino's data output and the WS2812's data input will help protect the data pin. A resistor between 220 and 470  $\Omega$  should do nicely.



Try to place the resistor as close to the WS2812 as possible.

### Keep Wires Short!

Wires don't conduct perfectly. They'll inevitably induce some voltage loss, especially when they're really long. Try to keep wires between your power supply, Arduino, and WS2812 as short as possible to minimize this loss.

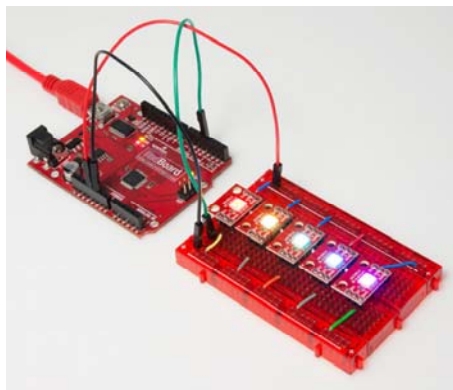
## Adding Firmware

For our example code, we'll be making use of Adafruit's fantastic NeoPixel library.

Click [here](#) to download a copy of both the example code, as well as the NeoPixel library. The library is located in the "Adafruit\_NeoPixel" folder, and the example code is found in the "WS2812\_Breakout\_Example" folder.

You'll need to **install the library**. For help there, check out our [installing Arduino libraries tutorial](#).

With the library installed, open up **WS2812\_Breakout\_Example.ino** within Arduino. Before you upload the code, make sure you adjust the **PIN** and **LED\_COUNT** definitions near the top of the sketch. These define which pin the first pixel is connected to, and how many total LEDs are linked up. Then upload away and enjoy the show!



## Using the NeoPixel Library



## Setup

There are a few lines of code required to set up your sketch to use the library. First, **call the constructor** near the top of your code (before `setup()`), you'll probably want it to be a global variable).

```
#define PIN 4
#define LED_COUNT 8

// Create an instance of the Adafruit_NeoPixel class called "leds".
// That'll be what we refer to from here on...
Adafruit_NeoPixel leds = Adafruit_NeoPixel(LED_COUNT, PIN, NEO_GRB + NEO_KHZ800);
```

The `PIN` and `LED_COUNT` parameters in that function call should be set, respectively, to the **Arduino pin** you've connected to the first breakout's "DIN" pin and the total **number of breakout boards** you have linked up.

The rest of the setup is calling the `leds.begin()` function somewhere near the beginning of the `setup()` function.

## Setting An LED

Setting an LED with the Adafruit NeoPixel library is a two step process.

First, you have to set a pixel color using the

`leds.setPixelColor(position, color)` command. The color parameter in that function can either be a 24-bit RGB color-code, or three separate bytes for each color. For example:

```
leds.setPixelColor(4, 0xFF00FF); // Set fourth LED to full
red, no green, full blue
leds.setPixelColor(4, 0xFF, 0x00, 0xFF) // Also set fourth LE
D to full red, no green, full blue
```

Setting a pixel's color does not equate to that pixel actually turning on though. For that, you need to call `leds.show()`. Note that when this function is called *any* LED that was previously set will turn on.

## The Rest of the Code

After you've gotten the hang of using the NeoPixel library, the remaining parts of the sketch are finding ways to manipulate the pixel colors. There are some fun functions in this example code, which create the classic "cylon" laser scanner, or draw a rainbow. We hope you can adapt them to make even more creative animations.

The included "WS2812\_Definitions.h" file defines a huge list of standard colors. In there you'll find anything from navy to saddle brown to ghost white.

Have fun!

## Going Further and Resources

### Resources

- Breakout Board Schematic
- Breakout Board Eagle Files
- Breakout Board github Repository
- WS2812 Datasheet
- Example Code and NeoPixel Library
- Adafruit NeoPixel Library github

## Going Further

Now that you've got the gist of the WS2812 Breakout board, how are you going to use it in a project? Need some inspiration? Check out these tutorials:

- Using OpenSegment – The OpenSegment is a very large, 4-digit 7-segment display. If you're on a blinky-high after playing with the WS2812 LEDs, this is another fun component to play with.
- Getting Started with the LilyPad MP3 Player – If you're into e-textiles (or even if you're not, this thing is awesome), check out the LilyPad MP3 Player. Combine the LilyPad MP3 player with the WS2812 to make a nifty LED-music show.
- Designing PCBs: Advanced SMD – If you'd like to lay out your own, custom PCB for the WS2812 LED/chip, check out this tutorial. It'll walk you through every step required to design your very own circuit board using free software. You can use the WS2812 footprint from our parts library to get started.