LEDS AND LIGHTING CLASS

6 Lessons Beginner Level

There are many ways to produce light and dispel the darkness of night.

In this class, we will go over some of the most popular means of doing so. Covering methods as diverse as light bulbs, LEDs, LED strips, and EL wire, this class provides a crash course on the subject of electric lighting.

No prior experience of electronics is necessary to get started. However, if you do have some previous experience, this class also has optional sections for advanced students which briefly covers Arduino-control.

I hope you will join me and make things that shine above the rest.

Class Author:
randofo (/member/randofo/)

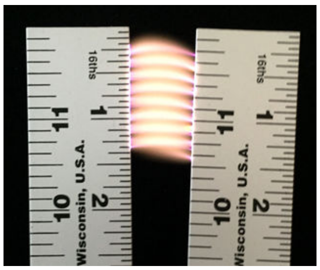
Randy Sarafan is an artist, designer, inventor, and founder of the Instructables Design Studio. Over the last 10 years he has created hundreds of step-by-step tutorials (https://www.instructables.com/member/randofo/?show=INSTRUCTABLES) on diverse subjects ranging from pancakes to self-driving robotic queen-sized beds. He has authored two books, 62 Projects to Make with a Dead Computer (http://www.workman.com/products/9780761152439/) and Simple Bots (https://itunes.apple.com/us/book/id1107111656).

His work has been showcased by the NY Times, Popular Mechanics, The Today Show, The Tonight Show, NPR, the BBC, Core77, Boing Boing, and the National Examiner (to name a few). He currently splits his time between Brooklyn, NY and the internet.

Lessons

Lesson 1: Getting Started

A brief introduction to the class and tools needed.

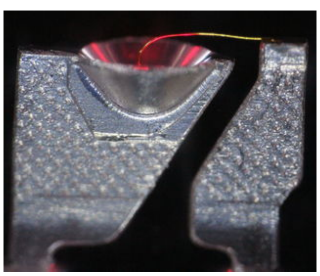


Lesson 2: Electronics Crash Course

Learn the bare minimum of electronics necessary to begin working with lights.

Lesson 3: Light Bulbs

All you ever wanted to know about light bulbs.

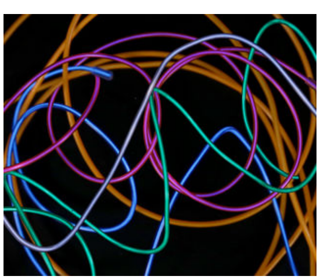


Lesson 4: LEDs

An in-depth look at the fundamentals of LEDs

Lesson 5: LED Strips

The basics of LED strips.

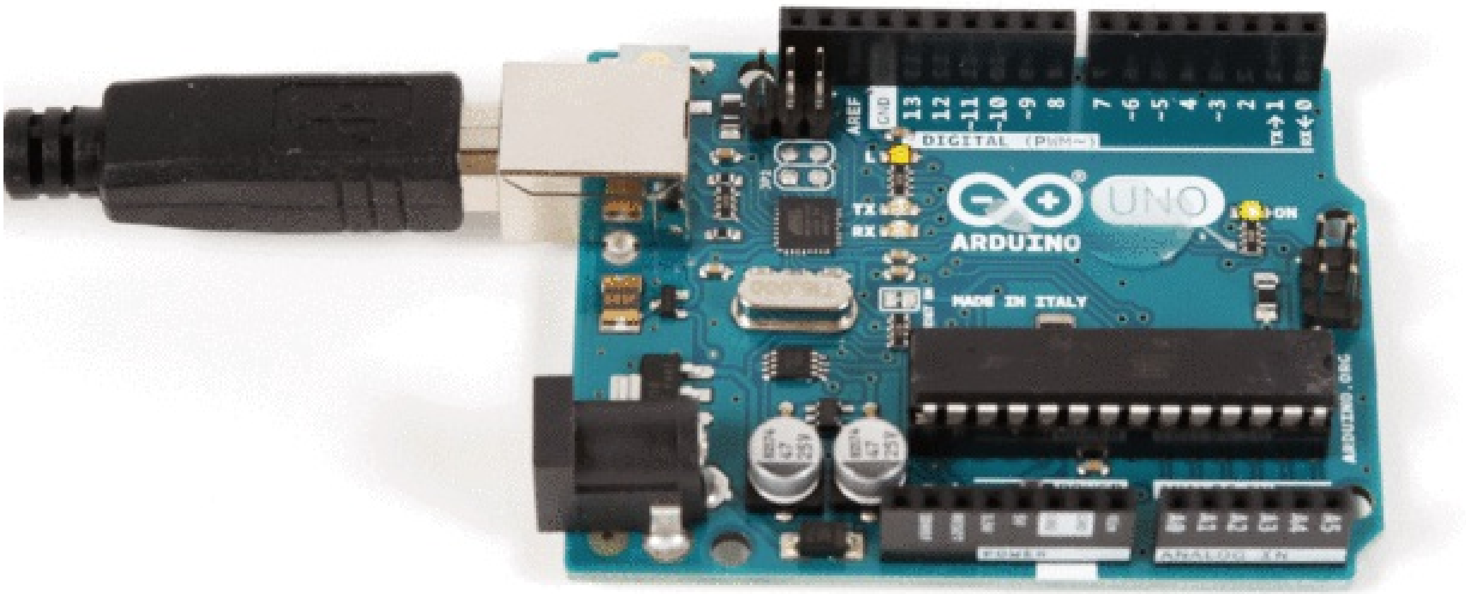


Lesson 6: EL Wire

An introduction to EL wire and panels.

LESSON 1: GETTING STARTED

Working with lights and making things glow is easy enough that you don't need any knowledge of electricity to get started, but complex enough that you can get an advanced degree in it. Our approach is going to be very hands-on and practical, but we will cover some technical theory from time-to-time (particularly working with LEDs).



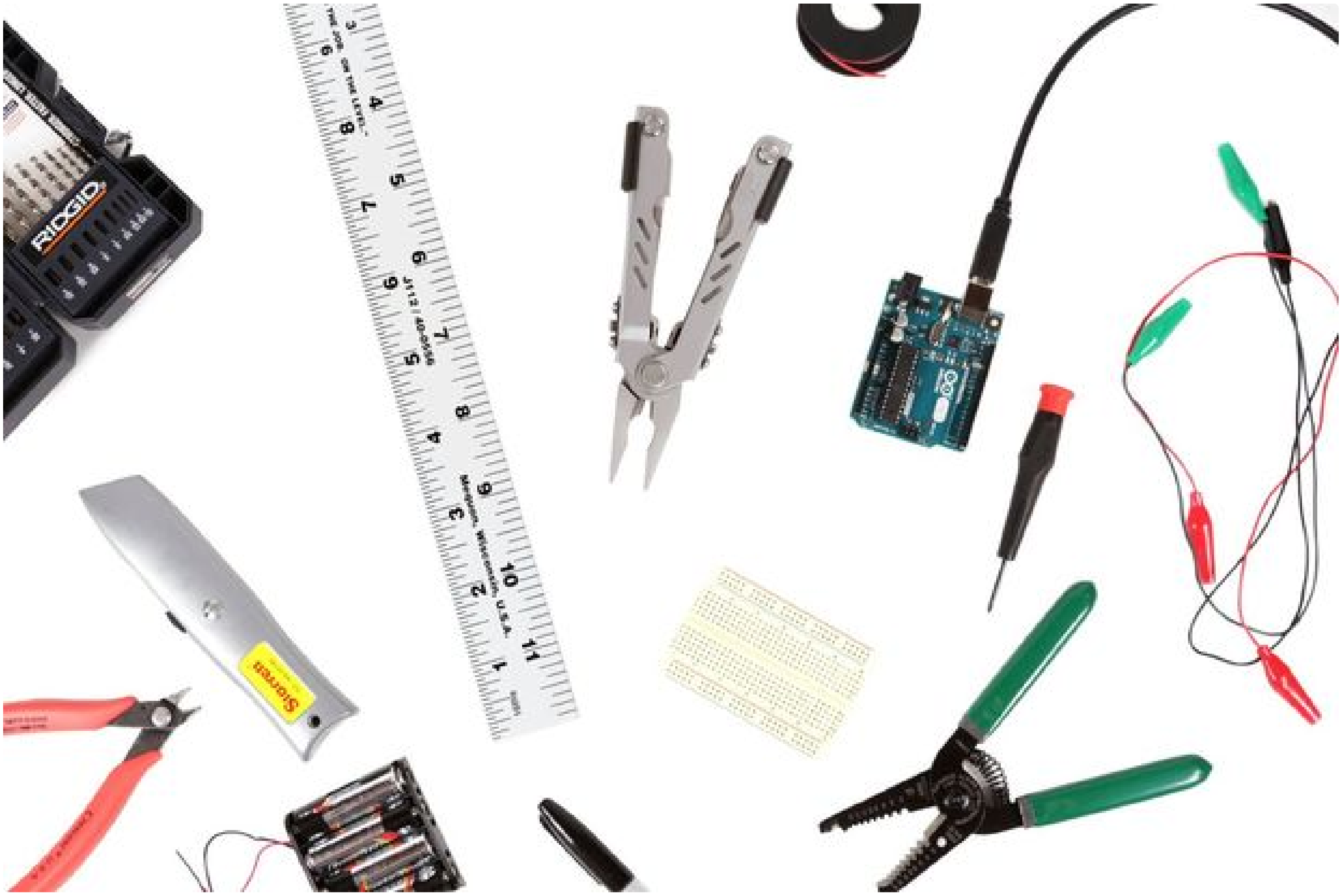
Arduino Control

While you don't need to know Arduino at all to take this class, throughout this class I will briefly provide optional steps for advanced students. These will cover controlling various types of lights using an Arduino microcontroller.

These directions assume a basic understanding of Arduino and are meant for people who already have experience using one. This information is just there for people who would like to try to go further.

These steps are labeled "advanced", and you should feel free to skim or skip over them if you have no idea what I am talking about.

If you would like to learn how to use Arduino, you can check out Becky Stern's Arduino Class (https://www.instructables.com/class/Arduino-Class/).

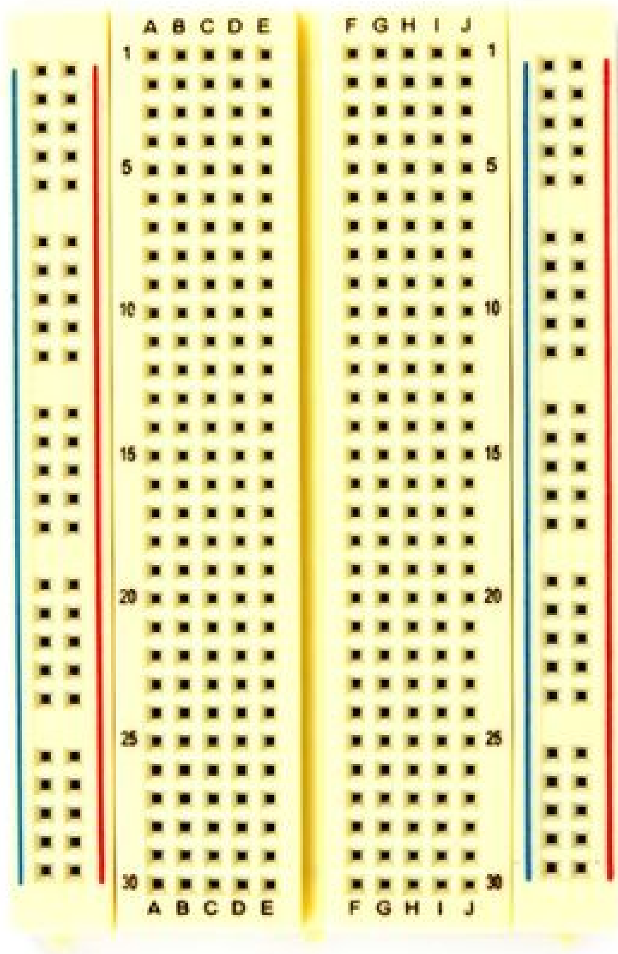


Tools and Materials

This class does not require too many supplies, and we will cover the required materials in each lesson. However, there are some basics you should have on hand before starting this class. Bear with me as we go over them. Some of them will be new to you, but most you will likely have.

Here is a list of the general tools and materials you will need for this class. We will go over this in more depth below.

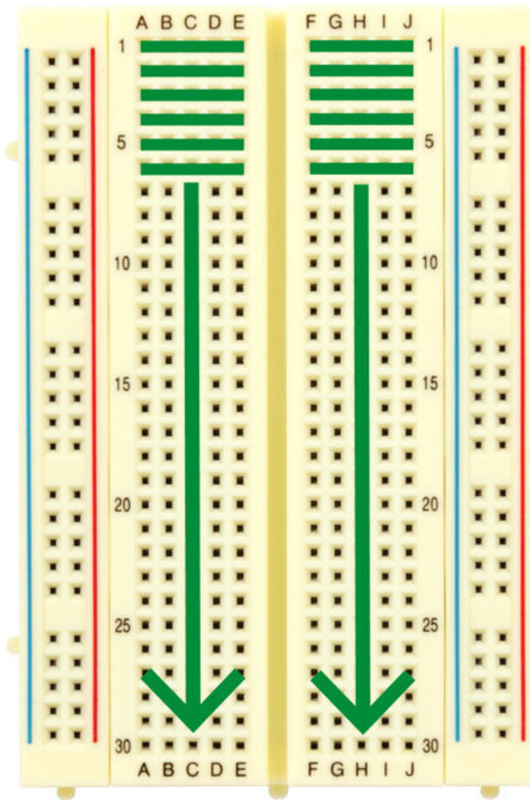
(x1) Breadboard (http://www.amazon.com/Yueton-Tie-point-Solderless-Breadboard-Pack/dp/B013DLU6I8/?tag=instructabl09-20)
(x1) Wire cutters (http://www.amazon.com/Tools-VISE-GRIP-Stripper-Crimper-2078309/dp/B000JNNWQ2/?tag=instructabl09-20)
(x1) Diagonal cutters (http://www.amazon.com/Channellock-338-8-Inch-Diagonal-Cutting/dp/B00004SBDD/?tag=instructabl09-20)
(x1) Heat gun (http://www.amazon.com/Kawasaki-840015-Black-10-Piece-Heat/dp/B000H4I67I/?tag=instructabl09-20)
(x1) Shrink tube (http://www.amazon.com/SummitLink-Assorted-Shrink-Colors-Tubing/dp/B00LVFDLUO/?tag=instructabl09-20)
(x1) Jumper cables (http://www.amazon.com/SE-TL10-10-Piece-Alligator-Clips/dp/B0002KRABU/?tag=instructabl09-20)
(x1) Battery holders (https://www.amazon.com/3Pcs-Battery-Holder-Standard-Connector/dp/B014YSFMXI/)
(x1) 22AWG stranded wire (https://www.amazon.com/Electronix-Express-Hook-Stranded-Gauge/dp/B00B4ZQ3L0/)
(x1) Power drill (http://www.amazon.com/DEWALT-DC970K-2-18-Volt-Compact-Driver/dp/B002RLR0EY/?tag=instructabl09-20)
(x1) Drill bits (http://www.amazon.com/DEWALT-DW1354-14-Piece-Titanium-Drill/dp/B0045PQ762/?tag=instructabl09-20)
(x1) Screwdrivers (http://www.amazon.com/Craftsman-Screwdriver-Phillips-Slotted-Made/dp/B006YVTAFU/?tag=instructabl09-20)
(x1) Mini screwdriver set (http://www.amazon.com/Herco%C2%AE-HE826-Precision-Screwdriver-Set/dp/B000CCUFT2/?tag=instructabl09-20)
(x1) Scissors (http://www.amazon.com/Westcott-13901-Sewing-Scissors-8-Inches/dp/B000P0LNRE/?tag=instructabl09-20)
(x1) Razor blade (http://www.amazon.com/Stanley-10-099-Classic-Retractable-Utility/dp/B00002X204/?tag=instructabl09-20)
(x1) Multipurpose tool (http://www.amazon.com/Leatherman-830039-Multitool-Leather-Combination/dp/B0002H49BC/?tag=instructabl09-20)
(x1) Ruler (http://www.amazon.com/Starrett-ASE-48-Anodized-Aluminum-Straight/dp/B002BXPUKO/?tag=instructabl09-20)
(x1) Permanent marker (http://www.amazon.com/Sharpie-Permanent-Markers-36-Pack-35010/dp/B001ELJOOM/?tag=instructabl09-20)
(x1) Soldering iron kit (https://www.amazon.com/gp/product/B01M0DLDCG/)
(x1) Helping Hands (https://www.amazon.com/SE-MZ101B-Helping-Magnifying-Glass/dp/B000RB38X8/)
(x1) Desk light (optional) (https://www.amazon.com/Newhouse-Lighting-Energy-Efficient-Architect-Black/dp/B00EVKU45Q/)
(x1) Exhaust fan (https://www.amazon.com/Weller-WSA350-Bench-Smoke-Absorber/dp/B000EM74SK/)



When you need to quickly and temporarily prototype a circuit, you will be using a breadboard. While you might not need one to complete the class, throughout the class I will be showing examples of circuits built on breadboards. Thus, I am explaining how they work.

Breadboards (https://www.amazon.com/Aketek-Solderless-BreadBoard-tie-points-power/dp/B01258UZMC/) are meant to make quick non-permanent connections between electronic components. They are covered in tiny socket holes which are connected in rows. The board itself is broken into four sections. There are two inner sections full of short horizontal rows, and two outer sections with longer vertical rows.

The inner sections are typically used for connecting components, and the outer sections are typically used as power bus lines. In other words, you can connect a battery to one of the outer lines and then power components on the inner section by connecting a wire to this section.



In the above graphic you can visually get a sense of how the rows on breadboards are electrically connected. The two inner sections have short horizontal rows repeated down the board. The two outer sections each have two long vertical rows. These are marked in red and blue and are meant to signify a row for power (red) and a row for ground (blue). Not all breadboards are marked with lines like this, but they are all laid out the same way.

To use a breadboard to prototype circuits, you simply insert components or wire into the appropriate sockets to connect them together.

On account of their ease of use for circuit building, it is good to have one on hand.

As mentioned, working with electronics requires its own unique set of tools. Here are a few more you will want to add to your tool box if you do not already have them.

You will want both a wire cutter (http://www.amazon.com/Tools-VISE-GRIP-Stripper-Crimper-2078309/dp/B000JNNWQ2/?tag=instructabl09-20) and a pair of mini diagonal cutting pliers or "snippers (http://www.amazon.com/Hakko-CHP-170-Stand-off-Construction-21-Degree/dp/B017ODDPNO/?

tag=instructabl09-20)." The wire cutter is used for cutting and stripping insulation off of wires. The snippers are used for trimming away excess wire leads after you solder. When you are doing this for a while and start to get the hang of it, you can use snippers for everything (in place of the wire strippers).

Another indispensable set of tools include a heat gun (http://www.amazon.com/Kawasaki-840015-Black-10-Piece-Heat/dp/B000H4I67I/?tag=instructabl09-20) and shrink tube (http://www.amazon.com/SummitLink-Assorted-Shrink-Colors-Tubing/dp/B00LVFDLUO/?tag=instructabl09-20). These are used for insulating soldered wire connections and small components. You might be thinking that electrical tape can do the same thing and is much cheaper. Just - NO! Get that horrible thought out of your head. Electrical tape is dumb and unreliable. If you want your circuits to break in mysterious ways, use electrical tape. If you want to make working circuits, then you should purchase shrink tube in a variety of colors and sizes. Shrink tube is exponentially more reliable and aesthetically pleasing. In terms of a heat gun, they all basically work the same. Just get something that makes you look cool. For instance, this black and green Kawasaki one is fairly rad.

Jumper cables (http://www.amazon.com/SE-TL10-10-Piece-Alligator-Clips/dp/B0002KRABU/?tag=instructabl09-20) (or test leads) are used for connecting wires together without soldering and are important for prototyping. They have insulated alligator clips on both ends which allow you to easily grab onto most electrical contacts. It is important to have these lying about to easily test things before making more permanent connections. Get a set of about a dozen-or-so to start.

Battery holders are used to power your projects. Typically, when one is required it is specified in the list of materials. However, in some of the lessons we use them for testing and experimenting. That said, it is recommended that you pick up a few extra 3 X AA and 4 X AA battery holders.

You also want to pick up a red, green, and black spool of 22AWG stranded wire. Even though all wire essentially works the same regardless of color, these three colors comprise a generally agreed upon color-coding system for DC electronics.

Red indicates a power wire.

Black indicates a ground wire.

Green (or any color not red or black) indicates a signal wire.

It's best to use the proper color wire to be able to easily debug your work, and thus you should have all three on hand.

Go get a drill (http://www.amazon.com/DEWALT-DC970K-2-18-Volt-Compact-Driver/dp/B002RLR0EY/?tag=instructabl09-20). This can be a cordless or corded drill. It does not matter. Cordless drills are more convenient in some ways, but corded drills are cheaper and just as (or sometimes more) effective. Either will do the job. We are only going to be drilling through wood, plastic parts and some soft metal like aluminum.

It is not important to get anything too fancy. Just about any drill will do for the purposes of this class. Albeit, it couldn't hurt to spend a little extra dough if you plan on continuing building things after this class. Nevertheless, the most important part is to find something aesthetically pleasing. It is always important to look good while making things.

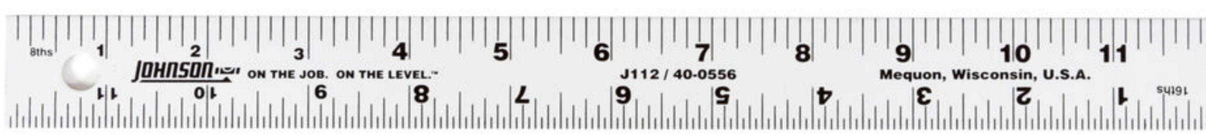
Get a set of standard sized multipurpose drill bits (http://www.amazon.com/DEWALT-DW1354-14-Piece-Titanium-Drill/dp/B0045PQ762/?tag=instructabl09-20). If this is your first time doing something like this, any old set will do. Don't spend a lot of money. You will likely destroy them and need to buy another set at some point anyhow. As you start to figure out what you are doing, then you can invest in the fancy expensive drill bits.

Even though you can technically screw things very tight with your power drill, sometimes you just want to screw things the old fashioned way. It's good to have a range of screwdrivers (http://www.amazon.com/Craftsman-Screwdriver-Phillips-Slotted-Made/dp/B006YVTAFU/?tag=instructabl09-20) in your arsenal. While I am not going to dive too deep into this, I will say that you should get a set of mini screwdrivers (http://www.amazon.com/Herco%C2%AE-HE826-Precision-Screwdriver-Set/dp/B000CCUFT2/?tag=instructabl09-20). These will come in particularly handy when working with electronics.

You will also need a pair of scissors (http://www.amazon.com/Westcott-13901-Sewing-Scissors-8-Inches/dp/B000P0LNRE/?tag=instructabl09-20). You should already have one of these lying about, and learned how to use them if you ever attended Kindergarten. So... Moving on...

The other razor sharp tool you should have is a razor blade (http://www.amazon.com/Stanley-10-099-Classic-Retractable-Utility/dp/B00002X204/?tag=instructabl09-20) or craft knife. It is recommended you get something with a nice safe handle like a box cutter.

As a general rule, you should get at least one pair of general use snub nose pliers when working with wire and electrical outlets. Pictured here is a multipurpose tool centered around a pair of pliers. If you have the income at your disposal, you may as well invest in a nice multipurpose tool (http://www.amazon.com/Leatherman-830039-Multitool-Leather-Combination/dp/B0002H49BC/?tag=instructabl09-20). The added functionality always comes in handy and it will make you seem more legit to have one of these in your arsenal. Again, I would like to reiterate the importance of looking like you really know what you are doing.



Aside from making great construction material, it is very helpful to have a few rulers (http://www.amazon.com/Starrett-ASE-48-Anodized-Aluminum-Straight/dp/B002BXPUKO/?tag=instructabl09-20) around. As they say, 'measure twice - cut once.'

And, of course, if you are going to be employing rulers in your electronics activities, you have got to have some permanent markers (http://www.amazon.com/Sharpie-Permanent-Markers-36-Pack-35010/dp/B001ELJOOM/?tag=instructabl09-20) to go along with them. We will be making a few cuts and drill marks, and your marker will get some use.

When working with LEDs and EL wire in particular, you will want a soldering iron and setup. As a beginner, you can get a 40W fixed temperature soldering iron. These are cheap and will get the job done while you are just getting started. By the time you decide you want to continue and go deeper into electronics, it will likely be time to upgrade to something more refined.

The two most popular methods for cleaning the tip of the soldering iron involves using a brass wire pad or a slightly damp sponge. Both work. However, deciding which works better is a highly contentious topic. Personally, I feel the the brass wire pad is more effective in quickly cleaning the tip. From what I can tell, advocates of the damp sponge feel it keeps the tip cleaner for longer.

Like wire, solder comes in spools and of different thicknesses. The solder I like working with is in the 0.02 - 0.04" range. It is important not to get solder that is too thick because you will have to heat up your parts for too long in order to melt enough solder onto it. It is also important to not get solder that is too thick or you will get too much solder all over the board, which aside from being messy can result in mistakes.

The other choice you need to make is to use solder with (pictured left) or without lead (pictured right). It is recommended that you use lead free solder. However, keep in mind, that just because it is lead free does not mean it is any better for you. Lead free solder has replaced the lead with other additives and actually produces more caustic fumes when melted. Lead free solder also melts at a higher temperature and is harder to work with. On account of this, you might at some point be tempted to work with lead solder. If you do, remember to always wash your hands after handling it!

Helping hands is basically a stand with two (or more) alligator clips attached. As the name implies, it is extremely helpful. These are sometimes called a "third hand," and as you can guess by that, this is basically used in those instances when a third (or fourth) hand would be handy. This is particularly useful for holding wires in place while soldering. Many come with a magnifying glass, which is great for inspecting solder pads and reading the tiny print on components.

Depending on your ambient lighting, and overall optical dexterity, you may want to consider getting a desk light. Solder connections are typically small. To see things well, it sometimes helps to have more light.

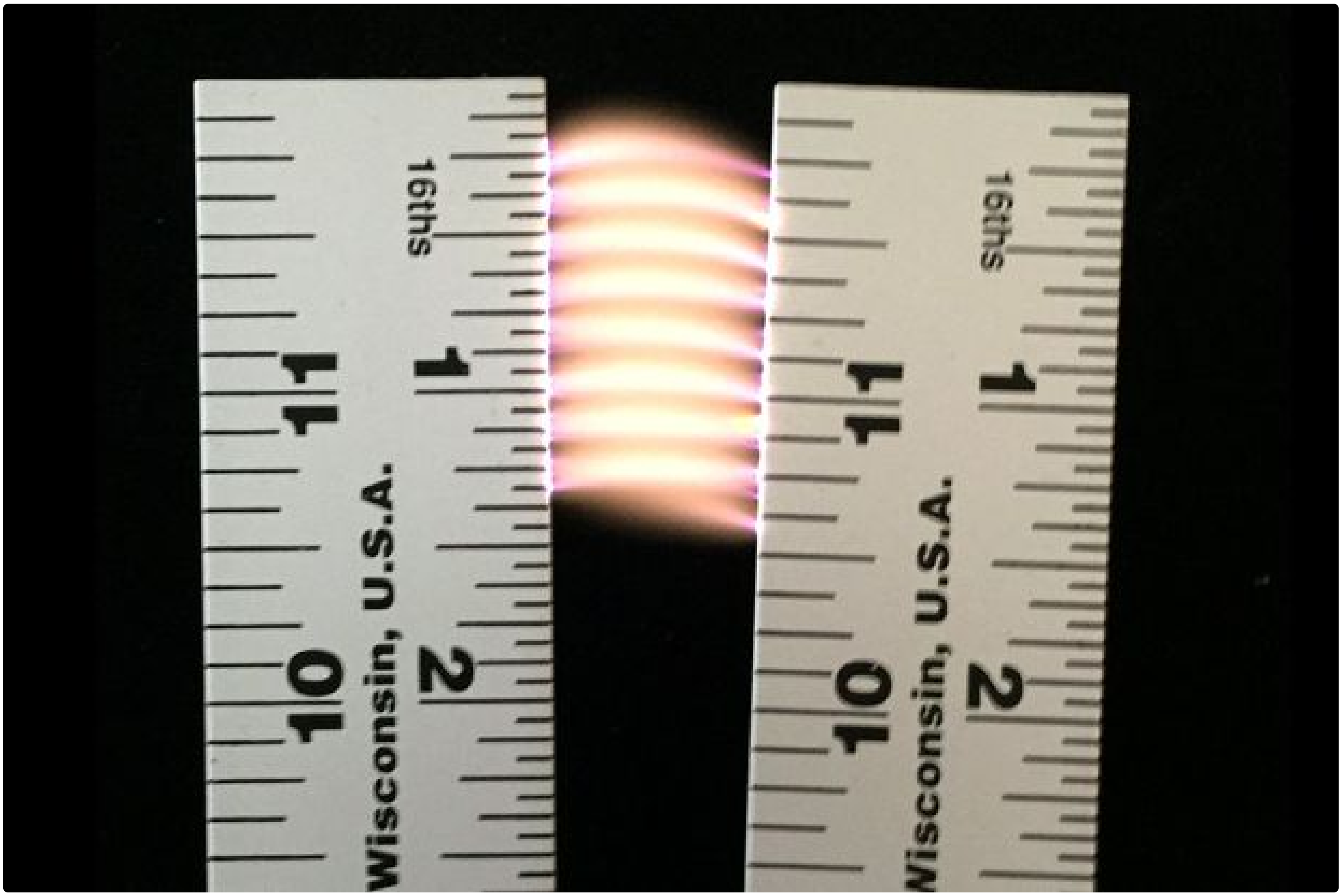
Last, but not least, you will want a fan or some other form of ventilation. I highly recommend one like the one pictured, with an activated charcoal filter. This will not only suck the air away from you, but filter out some of the particulates from continuing to circulate in the room.

That's It!

Now is time to gather your supplies and prepare yourself to have fun!

The second lesson is nearly upon us.

LESSON 2: ELECTRONICS CRASH COURSE



In order to make things light up, we need to have a basic understanding of electricity, and the tools required to work with it. In other words, we need to cover the basic of electronics; the art of regulating the flow of electricity. By controlling the flow of electricity in different ways, we can work with the different light sources to achieve all kinds of lighting effects. However, before we can do that, it is important to review the fundamentals. This is a little bit difficult at times, but please stick with me.

A charge is the build up of positively or negatively charged electrons.

Ground is an area that neutralizes that charge by removing excess charge.

For instance, charged electrons build up in a thundercloud. When it reaches a certain threshold of charge, the electricity is able to ionize the air and arc across the sky as a plasma. Albeit it could travel in any direction, it goes towards the Earth because of its large difference in charge. Just like the north and south poles of a magnet attract, so do negative and positive charges.

However, unlike magnets which, keep their charge when they meet, electrical charge functions differently. When the (typically) negative charge from the cloud strikes the much larger positively charged surface of the Earth, the Earth is able to absorb and dissipate the negatively charged particles from the thunder cloud. This is what is meant by electric ground neutralizing the charge. The same thing that happens during a storm also happens on a much smaller scale with all electronics.

AC / DC

When we are talking about AC/DC, we are not talking about the Australian hard rock band, but the two different types of electrical current.

There is alternating current or AC. It is called alternating current because the electrical signal alternates above and below the electrical ground. So, if you were to look at the picture of the 12V AC waveform above you will notice that it alternates above and below the electrical ground (indicated by the little yellow marker on the left). This type of waveform consists of a current that is constantly fluctuating between a positive and a negative voltage.

AC electricity is the type of current you will find coming out of your home wall socket.

The other type of current is direct current or DC. It is so named because it travels in a direct line above ground. If you will look at the waveform of a 12V DC voltage supply, you will notice that it's basically a solid yellow line running parallel above the ground. This type of electricity consists of a steady positive voltage, set apart from a ground plane.

DC electricity is the type of current that comes from batteries, which are basically special containers that store a predetermined amount of voltage.

AC wall current can also be rectified (more on this later) to become DC voltage. Just because a device plugs into the wall does not necessarily make it an AC device. If you look carefully at a power adapter, it will tell you what the output is. Aside from voltage and current, if you look carefully at the bottom of the label, you will see an illustration that even tells you the inside of the plug is a positive DC voltage and the outer barrel is ground.

Ohm's Law

Imagine a ball being thrown through the air.

Voltage is the speed the ball is traveling. This is measured in Volts. It's symbol is a capital V.

Current is the size of the ball being thrown. This is measured in Amperes (or Amps for short). Its symbol is a capital A.

Before I dive into ohm's law, let's revisit our ball analogy. If you have a small ball traveling at a very high speed, it could potentially have as much or more power as a large ball traveling at a very low speed. In this way, you could say there is a direct relationship between the speed a ball is traveling, the size of the ball, and the potential power of the ball.

Of course though, we are actually not really talking about balls, but electricity. When dealing with electricity, voltage and current are in a direct relationship with power. In a circuit, power is expressed in terms of Watts. The symbol for this is a W.

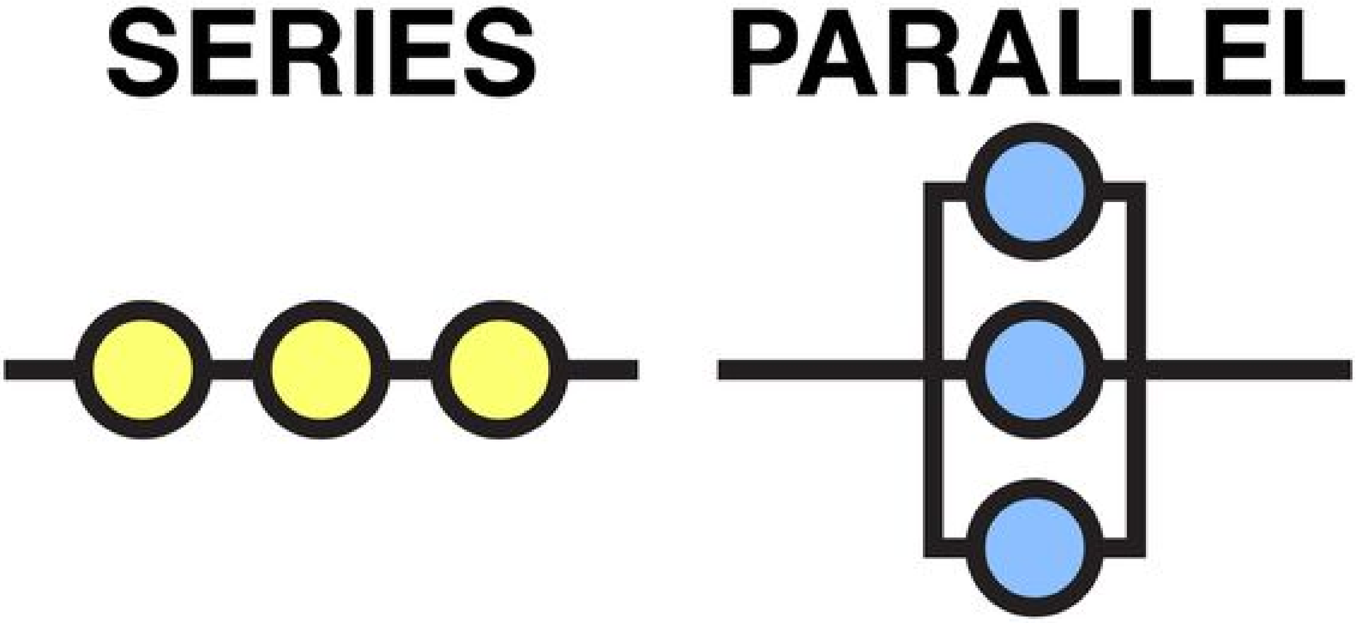
You likely have heard the term Watts before in relation to light bulbs. All light bulbs are measured in the amount of power they consume.

If we know how many watts a light bulb can consume, and that it is receiving 120 volts from a wall outlet, we can then deduce how much current it will require. By dividing 60W by 120V, we are left with the value of 0.5 amps of power. On account of this relationship between the three, given any two values, we can solve for the third.

There is also another factor we have yet to talk about that also plays a role, and that is resistance. In our analogy, resistance is the headwind that the ball must fight against to move forwards. On a calm day, there might be little resistance to it's flight, but on a windy day, it might have to fight against the wind pretty hard. Again, we are actually talking about electrical resistance in a circuit and not throwing a ball.

Resistance pushes against the flow of electricity. As such, it is also in direct relationship with Watts, Voltage and Current. Resistance is expressed in Ohms (after it's discoverer). This mathematical relationship between Watts, Voltage, Current and Resistance is unsurprisingly called Ohm's Law.

Ohm's Law is not something you must memorize, but it will play an important role later when determining how much resistance a circuit ***must*** have. Thanks to this law, a circuit having a minimum amount of resistance is not optional, but necessary. The energy in the circuit must encounter resistance in order to expend itself. The thing in the circuit which uses energy is considered the Load. If an electrical supply is connected to ground without a load to use up the energy, bad things will happen.



When building a circuit, there are basically two ways in which you can connect a load. They can either be in series or parallel.

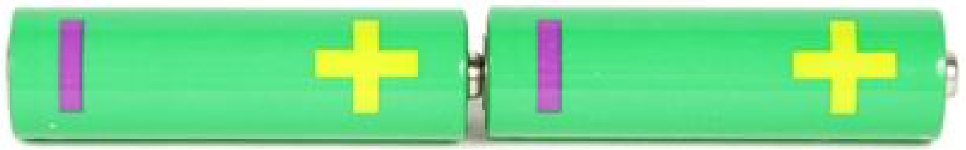
When you wire electrical components in series, they are in a line.

So, if you were to break the circuit in any way -- say by unplugging a light bulb -- electricity has no path to continue flowing and the whole connection is broken.

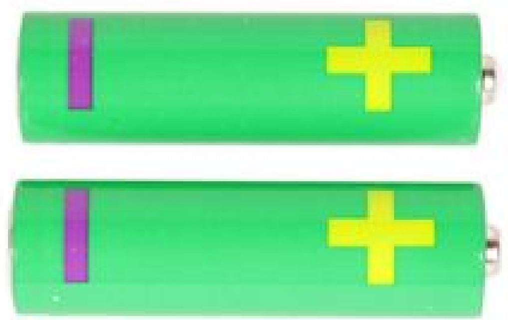
Alternately, you can prevent this problem by wiring the light bulbs in parallel. When wired in this way, they are connected side-by-side and share the same electrical connections on both ends.

Thus, when you unplug one bulb, electricity can continuing flowing through the other one unfettered.

SERIES



PARALLEL



Power supplies such as batteries can also can be connected in series and parallel. However, before we get to that, let us take a moment and talk a bit more about batteries.

The most common types of batteries you will encounter are standard cylindrical dry cell batteries. Most notably these consist of AAA, AA, C, and D batteries. What is important to know about these batteries, is that even though they are different sizes, they are all rated at 1.5V (remember - V is the abbreviation for volts).

What changes as they get bigger in size is the amount of power they are capable of producing. A D battery will be able to provide power for much longer than a AAA battery. In other words, a bigger battery can provide more amperes for a longer amount of time than a smaller battery.

Batteries are measured in Amp Hours or Ah. This is basically the measure of how many amperes can be drawn from the battery in an hour. For instance, a 20Ah battery will let you draw 1 ampere for 20 hours. However, let's say you are building a giant robot and it needs 5 amperes per hour; in this case you can run that robot for about 4 hours using the same battery until it runs out (20Ah / 5A = 4 hours).

It may have by now dawned upon you that 1.5V is not very much. You might be wondering why we don't just use a 9V battery instead? Assuredly a 9V battery is producing more power than a 1.5V battery.

This, in fact, is not true at all. 9V batteries actually are not great in producing power at all. A good way to think of a 9V battery is to imagine 6 really small 1.5V batteries smushed together inside. In fact, if you take a 9V apart, that is essentially what you will find inside. Now, compare that to the size of 6 AA batteries for instance. The 9V batteries are rather tiny by comparison!

The only time 9V batteries come in handy is when you need a relatively high voltage for a project that doesn't require a lot of current and it needs to fit it into a small enclosure.

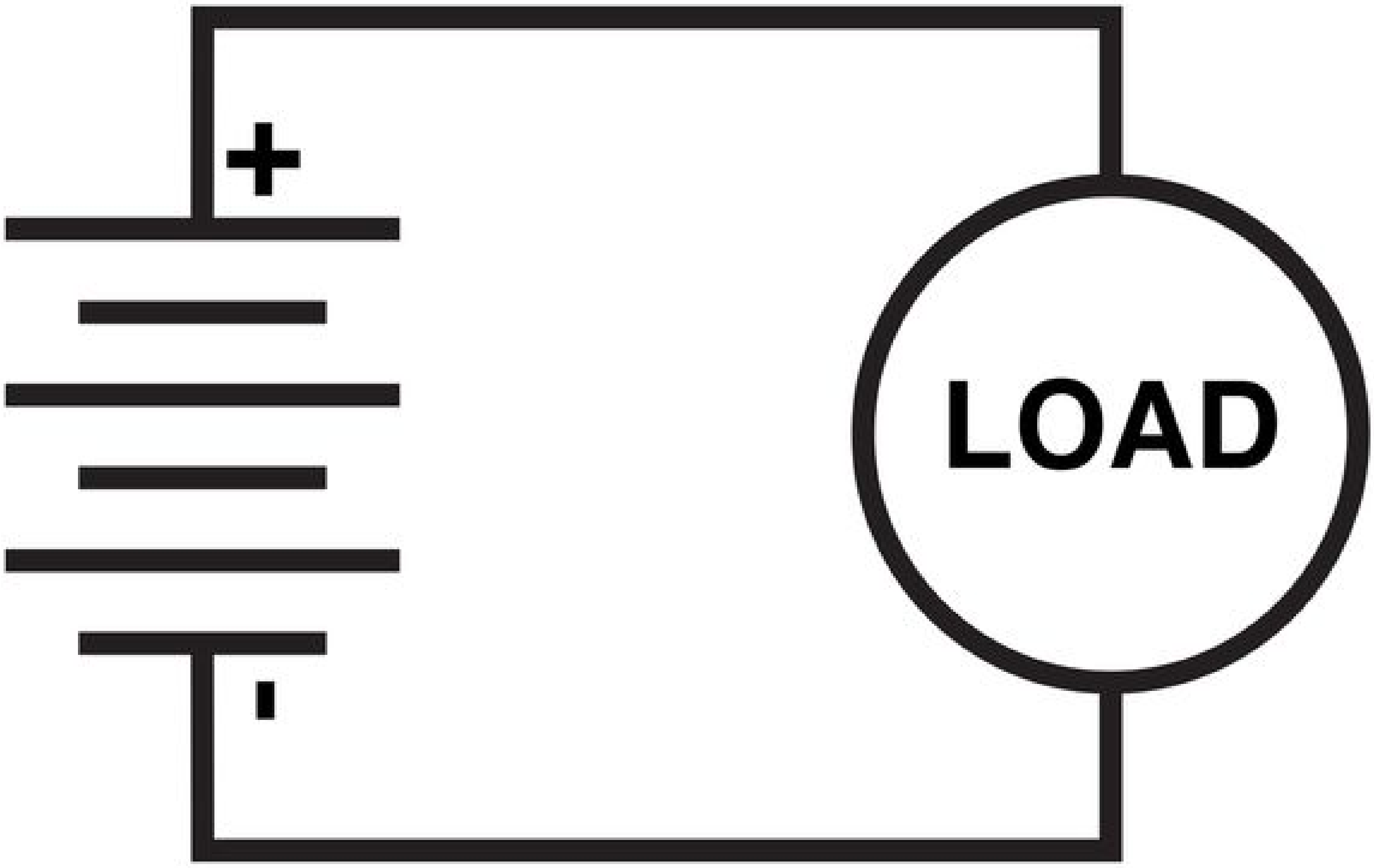
Well then, you may be wondering how you can power anything if batteries are only 1.5V? The answer is rather simple. We connect them in series.What this means is that we connect them front-to back in a row. So the positive (plus) end of one battery gets connected to the ground (minus) end of the next battery, and so on, and so forth. We can then calculate the new voltage simply by adding 1.5V for each battery in the series. So, if you have three 1.5V batteries in series you could multiply 1.5V times three to get a total of 4.5V.

The easiest way to connect batteries in series is to use a battery holder. To calculate the voltage that a battery holder provides, you simply need to count the number of batteries it holds and multiply it by 1.5V, just as you would with any other set of batteries connected in series. So, a 4-cell battery holder would produce 6V of power (1.5V x 4 = 6V).

To access the power provided, simply connect the red wire to the positive terminal on your project, and the black wire to ground. As a reminder from earlier, red wires always indicate a positive voltage, and black always indicate ground.

We can also connect batteries side-by-side in parallel so long as they have identical voltage ratings. When power sources are connected in parallel, the voltage remains the same, but the amount of available current increases. This is useful when a single battery does not provide enough current to power your circuit.

Keep in mind, this will only work if the batteries are the exact same voltage and should be avoided if possible. Without the proper diode protection circuit, fluctuation in voltage between the batteries will force them to try to charge one another, decreasing their lifespan.



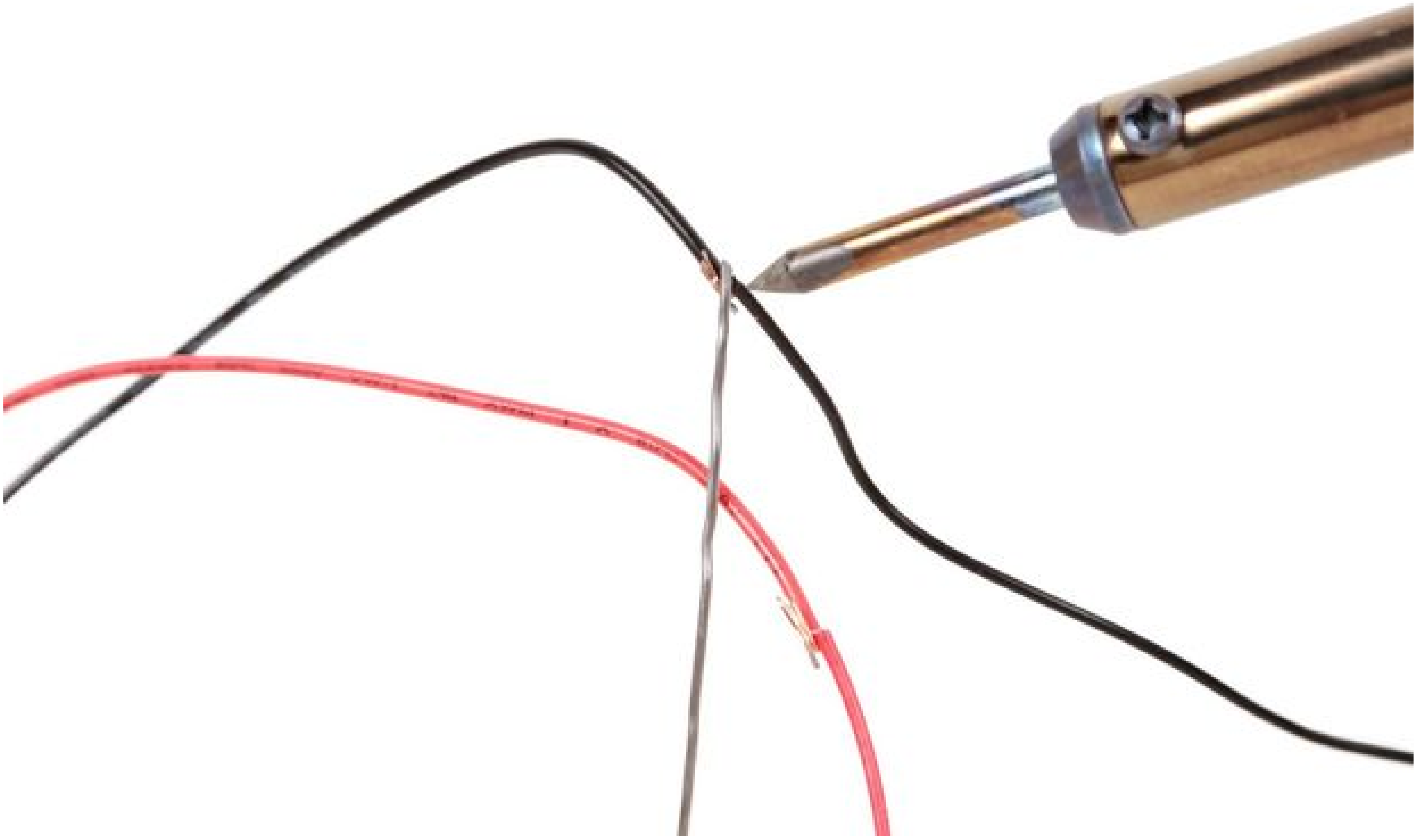
Circuits

A circuit is a complete loop in which electricity can flow. An ideal circuit is any path in which electricity can flow from start to finish and pass through a Load, where the energy is put to use. This Load can be almost anything that uses the power, such as a light bulb, LED, or EL wire.

Circuits for lights are usually fairly simple. A power supply is connected to both terminals on a light source, and then electricity is allowed to flow through it, which completes the circuit and turns the light on.

That is the most fundamental circuit that can be made.

Of course more complex circuits can be made. Multiple lights can be wired together in series and/or parallel, or a switch can be placed in series to turn lights on and off. Additional components can also be added. For instance, when dealing with LEDs, we will also include a component called a resistor in series with the LED. However, more on that in a bit.



Soldering

To make lighting circuits, sooner or later you will need to know how to solder. So, there is no sense dancing around the subject. Let's get down to business.

Holding the Iron

A soldering iron is held like a pencil, but with one significant difference. Instead of holding it by the tip, you hold the soldering iron further back by the insulated handle.

That's all there is to that.

Never touch the metal part of the soldering iron while it is turned on. This can result in nasty burns, and is generally unpleasant.

Never leave soldering iron resting on the table. It will burn your work surface and could potentially start a fire.

Soldering can build up a mighty appetite, but don't eat while soldering. Some solder has lead in it, a known carcinogen. Even lead free solder has things in it you likely do not want to ingest. Before chowing down on a slice of pizza, turn off the soldering iron, take a break, and wash your hands with soap and water.

Breathing in the fumes from soldering is bad for you. Always use some sort of ventilation fan to minimize your exposure. Your lungs will thank you.

While arguably not necessary, it is recommended that you wear safety glasses while soldering. Solder has been known to splash and splatter. Albeit a rare occurrence, getting burning hot solder in your eye can be an unpleasant experience (or bits of cut wire, for that matter).

After soldering, you will always want to remember to wash your hands with soap and water.

Tinning the Iron

Turn on the soldering iron and wait for it to heat up. If you splurged on an adjustable temperature model, you can dial yours in to about 650 degrees.

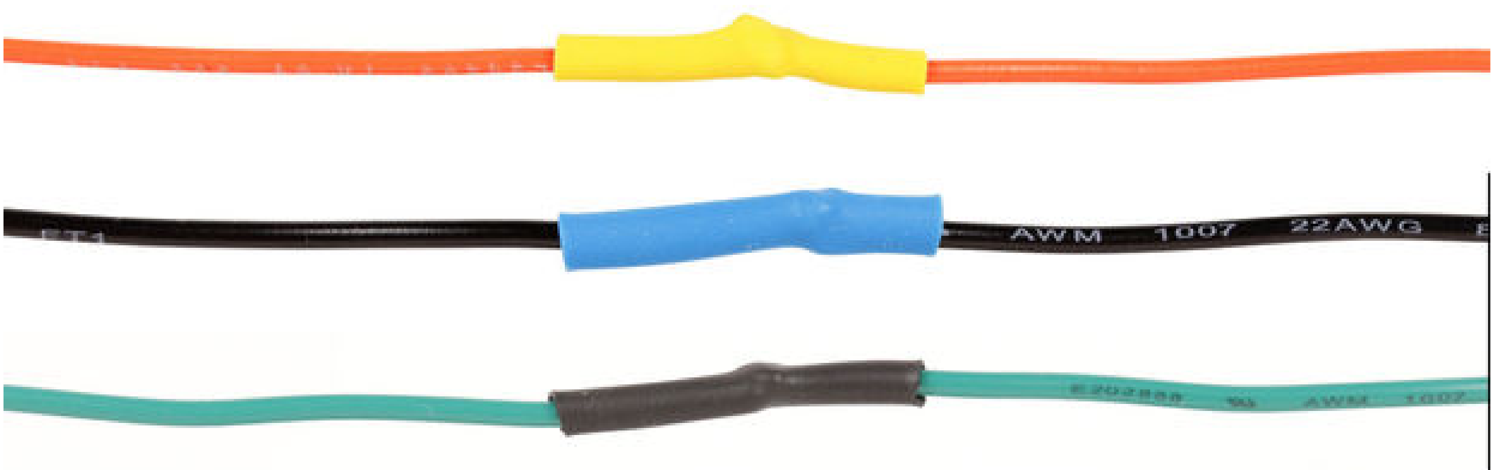
Once it is heated up, you will want to tin the tip before using it for the first time.

All this involves is thoroughly melting solder all over the tip of the iron. This makes sure the tip has a nice solder coating, which will make it easier to melt solder the next time you use it.

Cleaning the Iron

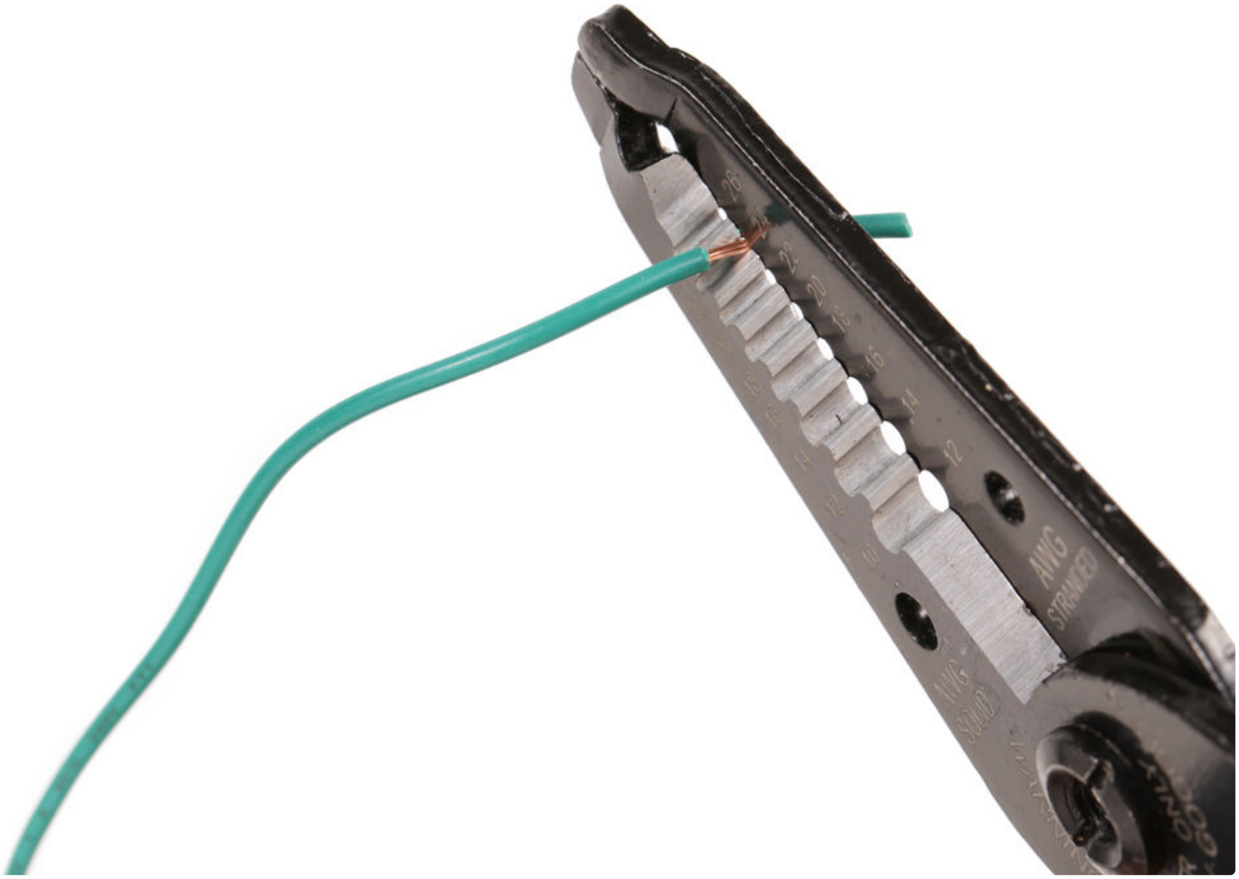
Every time you melt solder using the tip, you will want to clean it off.

To do this, simply drag the tip 2 or 3 times across the cleaning pad.

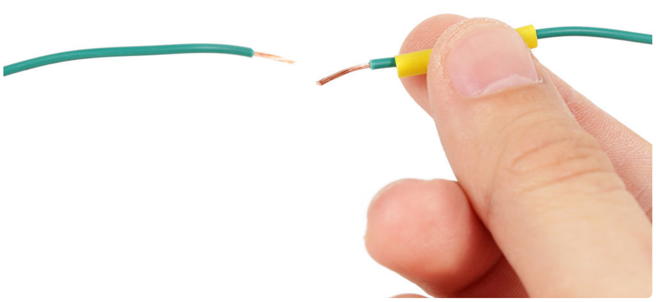


Solder Wires

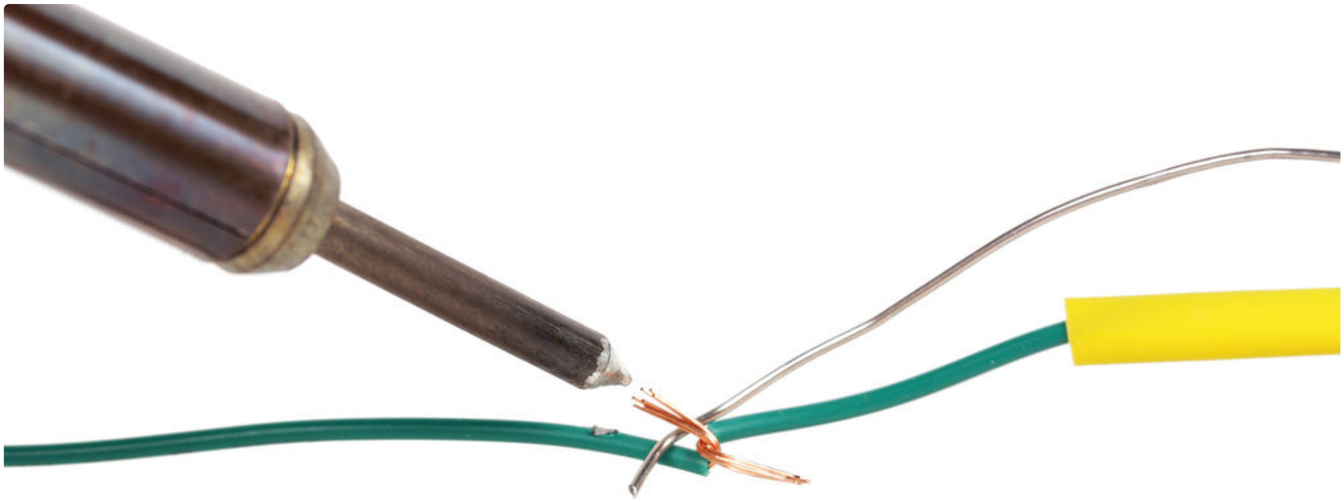
Now is time to solder some wires together.



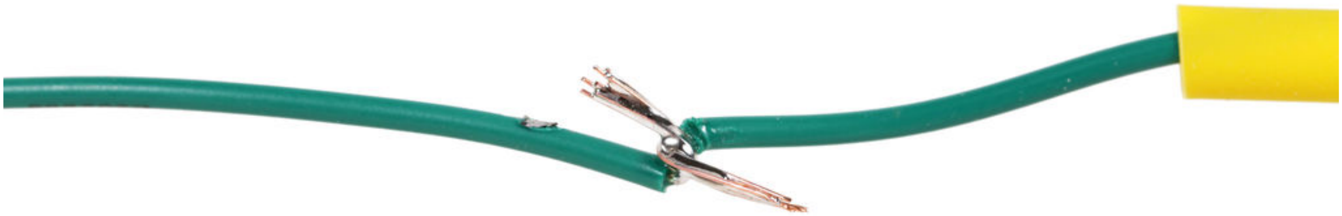
To do this, strip the insulation off of the ends of two pieces of stranded wire using your wire stripper.



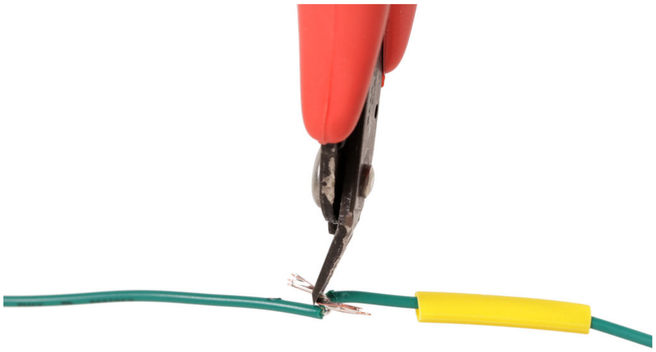
Slide a 1" piece of shrink tube onto one of the wires and then twist the two ends of wire together.



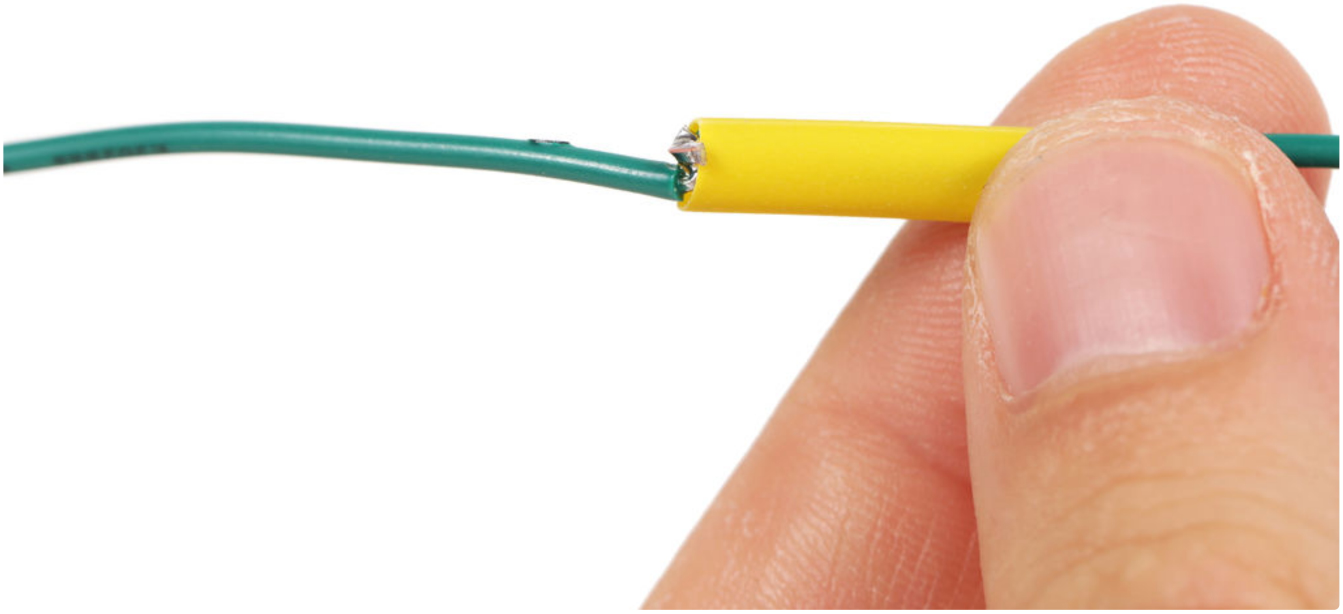
Place the soldering iron against the wire to heat it up, and push the solder into the wire. It should start to melt and get wicked up into the wire, coating it in silver.



Remove the soldering iron to let it cool.



Trim the excess parts of wire so the connection is as compact as possible.



Slide the heat shrink tube over the solder joint.

Shrink it into place with a heat gun.

Congratulations! You have just soldered something together. Continue practicing until the act of soldering feels comfortable.

LESSON 3: LIGHT BULBS

The incandescent light bulb was invented in 1879 and quickly changed the world. No longer were people reliant on natural cycles of light and dark. Being able to create buildings with electric light - many times as bright as a candle - allowed them to safely get bigger and taller without the reliance on natural light. In turn, urban centers were able to grow more dense and turn into the metropolises we know today. Light bulbs may not seem like much, but they made the modern world possible. Stick with me as I talk a little bit about what they are and how to use them.

How a Light Bulb Works

The incandescent light bulb consists of a thin tungsten filament inside of an inert gas-filled glass bulb. When electricity is applied across the filament, electrons begin to flow. These electrons encounter resistance from the tungsten material, and in turn produce energy as they collide. This energy turns into heat.

Since the heat rises above a certain threshold (around 4000 degrees Fahrenheit), it begins to emit photons (light particles) in the visible light spectrum. Thus, the light bulb glows.

Under normal conditions, the heat required to get the metal to glow would cause the filament to catch on fire, melt, and stop the electricity from flowing. However, tungsten has a very high melting point and the inert gas prevents the tungsten from breaking down and igniting (since there is no oxygen). This combination of factors allows the light bulb to glow for an exceptionally long time without the filament burning up.

Powering a Light Bulb

A typical light bulb has two terminals: an outer base consisting of metal threads and a round conductive "foot" contact on the bottom.

By connecting electricity to each terminal, a current is allowed to flow through it, and produce light.

The incandescent light bulb is the only component we will be dealing with in this class that can be powered with either AC or DC electricity. This statement is not true of even other types of light bulbs.



Sockets

A socket is a mechanical connector that makes it easy to make electrical contact with the light bulb's base and foot. The socket typically has either screw terminals or wires for quickly connecting the light bulb to a power source.

When working with light bulbs, you will want to use a socket.

Types of Light Bulbs

There are three types of light bulbs you may encounter. They are incandescent, fluorescent, and LED. They nominally function the same by producing light, but are all different from one another.

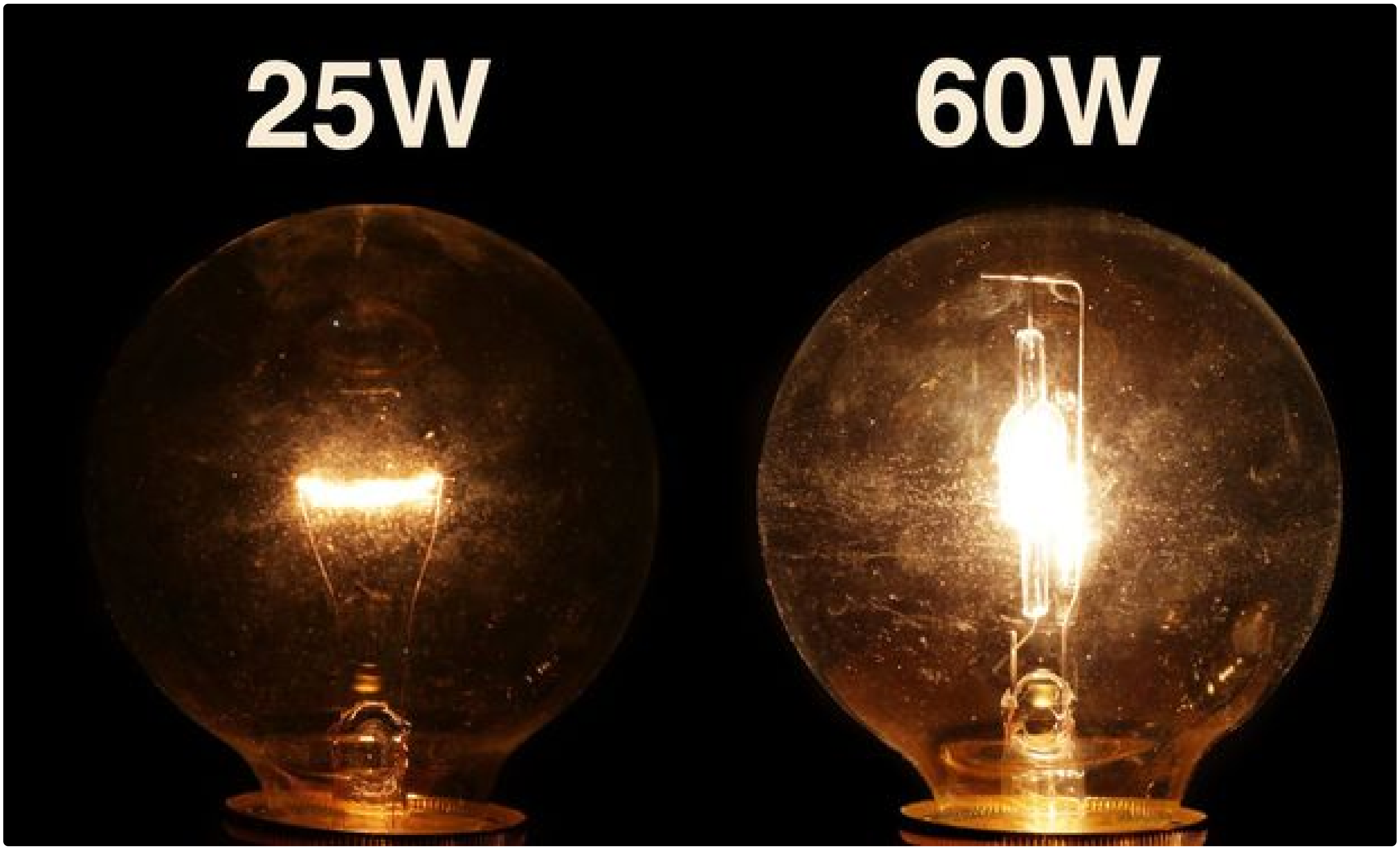
Incandescent bulbs are the standard glass light bulb that we have been discussing thus far. It is the most common type of light bulb and has been in use for over 100 years. These bulbs tend to emit a warm white light.

Incandescent bulbs come in a host of different shapes, and sizes. This opens up a world of aesthetic lighting possibilities and make them fun to experiment with. However, if you are going to - do it quick. They are phasing out the sale of incandescent light bulbs (in the USA at least) in favor of more environmentally friendly versions over the next couple of years.

Fluorescent bulbs are similar to incandescent bulbs in that they are sealed glass containers filled with gas. However, where they differ is in that they require a special driver circuit to convert wall current into high voltage AC electricity. The high voltage causes mercury vapor inside of the bulb to ionize and emit UV (ultraviolet) photons (light particles). The UV photons are then converted to visible light by a special coating inside of the glass. These bulbs tend to be a cool white light.

Both incandescent and fluorescent bulbs all glow in roughly the same color, but can alter this by tinted the glass of the bulb. In doing so, you can often find these light bulbs in a host of fun colors, which provide interesting lighting effects.

Lastly, there are LED bulbs. An LED bulb is typically just a light bulb shaped enclosure with a circuit board inside that is covered in LEDs. For all intents and purposes they look like and (mostly) function like a standard lightbulb. However, like fluorescent lights, they too require a special driver circuit in order to power them. In the case of LED bulbs, they convert AC wall current into low voltage DC current. These bulbs can come in either warm or cool white light. In fact, some are even adjustable between the two. There are even some that have multi-color LEDs installed on them, and can be set to glow any color.



Brightness

The brightness of light bulbs is typically described in terms of the amount of Watts, which is not actually a measure of brightness at all. Watts is the amount of power a light bulb draws from a power supply.

Based on how incandescent bulbs convert energy into light, it goes to follow lights which draw more power, glow brighter. This assumed correlation has carried over to fluorescent and LED light bulbs, which actually draw significantly less power than incandescent bulbs, but still have their brightness described in terms of Watts.

The most accurate measure for the brightness of light bulbs is Lumens, which is a measure of the amount of light emitted over time from a standardized source. In plain English, it is a standardized measurement of brightness.

A standard 60 Watt incandescent bulb is equivalent to 800 Lumens. However, the correlation between wattage and Lumens is not linear. A 40 watt bulb is only 450 Lumens, which is only 1/3 less power, but nearly half as bright. These correlations are important to keep in mind when finding LED and fluorescent equivalents.

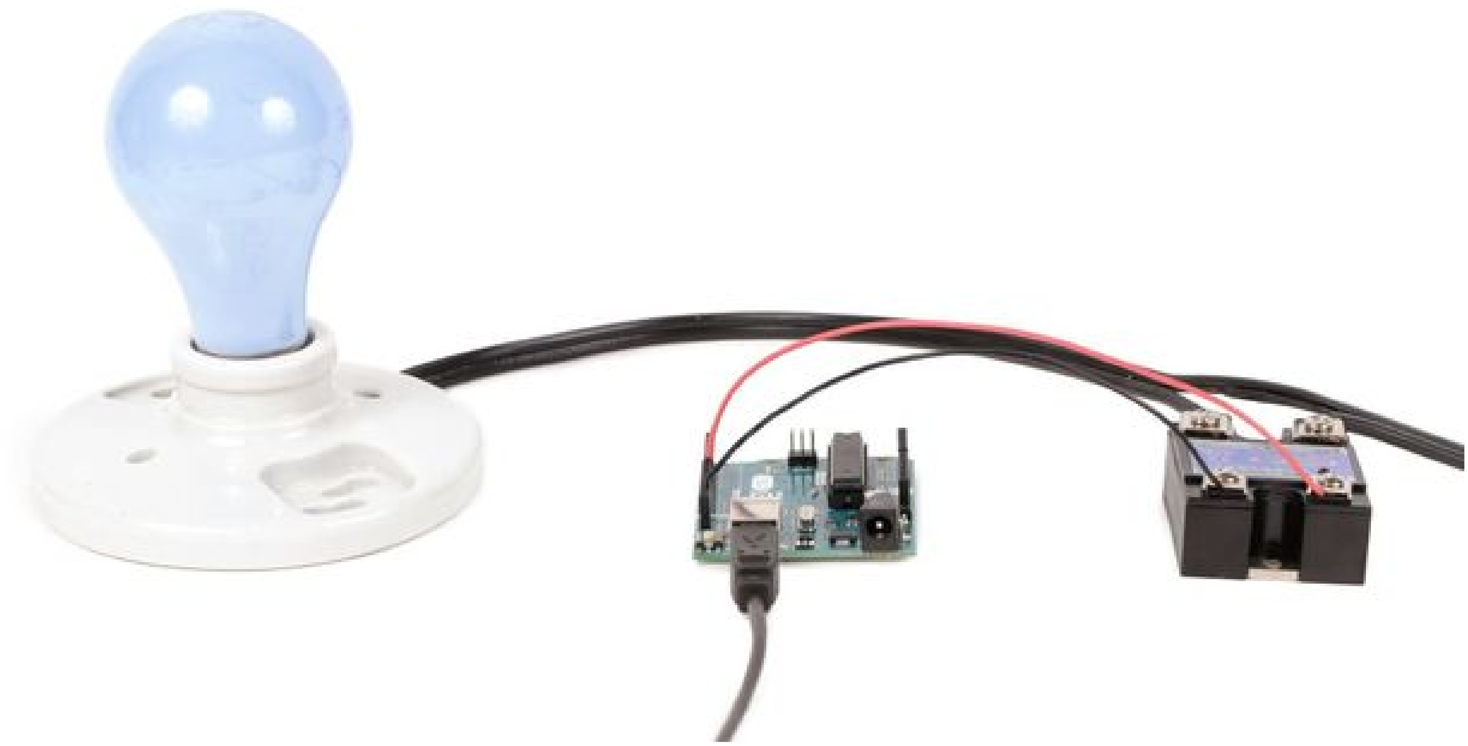
Controlling Light Bulbs

Light bulbs can be toggled on and off with a power switch. A switch is basically just a mechanism for making and breaking an electrical connection. There are many different types of light switches such as the standard light switch (as pictured), and in-line switches which are connected directly to a lamp cord (not pictured). To wire a switch, you connect the terminals in series between one of the power connections, and one of the light bulb's connections.

Light bulb brightness can be adjusted using a dimmer. This is wired in series with the light like the switch. Dimmers work with all incandescent bulbs, but not all fluorescent or LED light bulbs. If you plan to dim an LED or fluorescent bulb, you need to make sure that you buy one that explicitly states that it can be dimmed.

The third green wire pictured above is for a socket's ground terminal. For most lamp applications, this is not needed.

If you would like to learn more about wiring switches and dimmers to light bulbs, you can check out the Lamps Class (https://www.instructables.com/class/Lamps-Class/).



Arduino Control (advanced Topic)

For more advanced control of a light bulb, you can also use an Arduino. If you don't understand what an Arduino is, feel free to skip ahead to the final lamp project (and perhaps return to it at a later time). These instructions are meant for advanced students with an existing understanding of microcontrollers and electronics.

To turn a light bulb on and off using an Arduino, the best way is to use a solid state "puck" relay (https://www.amazon.com/dp/B00E1LC1VK/) (so called, because they look like hockey pucks). These relays use a low voltage DC signal to control a high voltage and/or high current AC or DC signal. To be more technical, inside of the relay, the low voltage DC side controls something akin to an LED inside of the relay, which in turn triggers a sensor on the high voltage AC side to optically switch the higher voltage signal on or off. It is important to find one with a rating higher than the current you are using.

You can determine the current rating easily by using Ohm's Law. If we know the wattage of a light bulb, and we know how much power they are receiving from an outlet, we can use Ohm's law to determine how much current they consume. For instance, a 60 watt light bulb, being powered by 120 volts, is using 1/2 an amp power. This is because 60 Watts / 120 Volts = 0.5 Amps (or Amperes - to be technical about it).

This relay is rated for 40A, which is way more than we will be needing, which makes it okay to use. The relay should always be about double the maximum calculated current to be safe.

To wire up the Arduino to control a light bulb, make the following connections:

- To begin, it should go without saying that the light bulb should always be unplugged from the wall when handling its wires. You should never touch any metal electrical connection when the light bulb is plugged in!

- The supply wire from the wall socket to the bulb should be split in half and connected to the high voltage AC terminals on the relay.

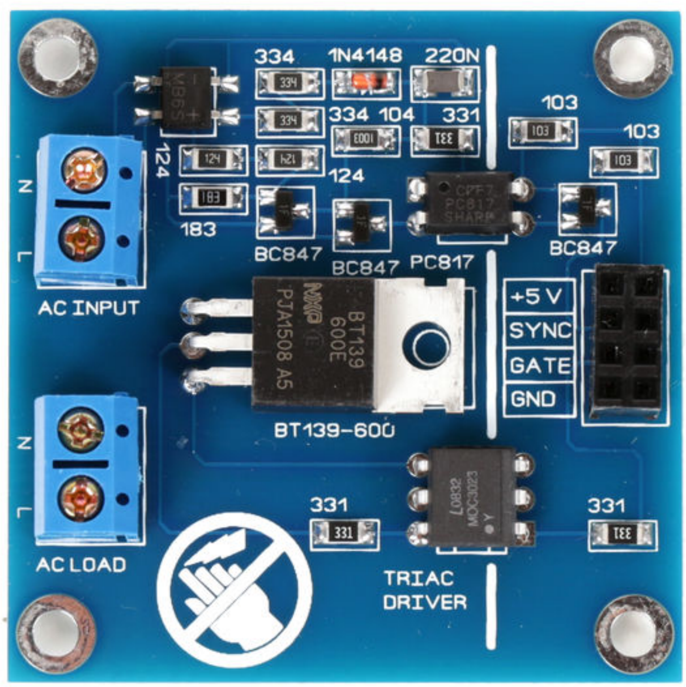
- Pin 7 (or digital pin of choice) on the Arduino should be wired to the low voltage DC positive (+) terminal.

- Ground on the Arduino should be connected to the relay's ground (-) terminal.

Load the following code onto your Arduino:

In the code, the relay is turned on and off in the same manner you would turn and LED (or most anything) on and off using an Arduino. Basically, when a digital pin goes high (5V) it turns on, and then when it is pulled low (ground), it turns off. It is very simple.

This code should cause the light bulb to blink. You can modify the timing to blink the light bulb at different rates.



Dimming a light bulb with a microcontroller is a bit trickier, and requires a special controller board. This type of controller board differs between manufacturers, and is by no means standard. However, they all typically have a connector for an AC input from a wall socket, a connector to output the voltage to a light bulb, and a third connector for connecting a microcontroller (like an Arduino).

The one pictured is a generic programmable light dimmer board (https://www.amazon.com/gp/product/B01B783Q5O/) I found on Amazon. It is a triac based dimmer, which is an electrical component that can control the flow of AC current, and is a tiny bit like a transistor for AC current.

The board has two control pins that are meaningful to us. The first is the Gate pin connected to the "gate" of the triac, which turns the triac on and off. The second pin is the Sync pin, which tells us when the waveform is crossing zero, as it arcs up and down. This is used for timing the AC signal and triggering the triac at the appropriate time.

To wire it up, make the following connections:

- Connect 5V on the Arduino, to the 5V socket on the light controller board.

- Connect Ground on the Arduino to the Ground socket on the light controller board.

- Connect Pin 3 on the Arduino to the Sync socket on the light controller board.

- Connect Pin 7 on the Arduino to the Gate socket on the light controller board.

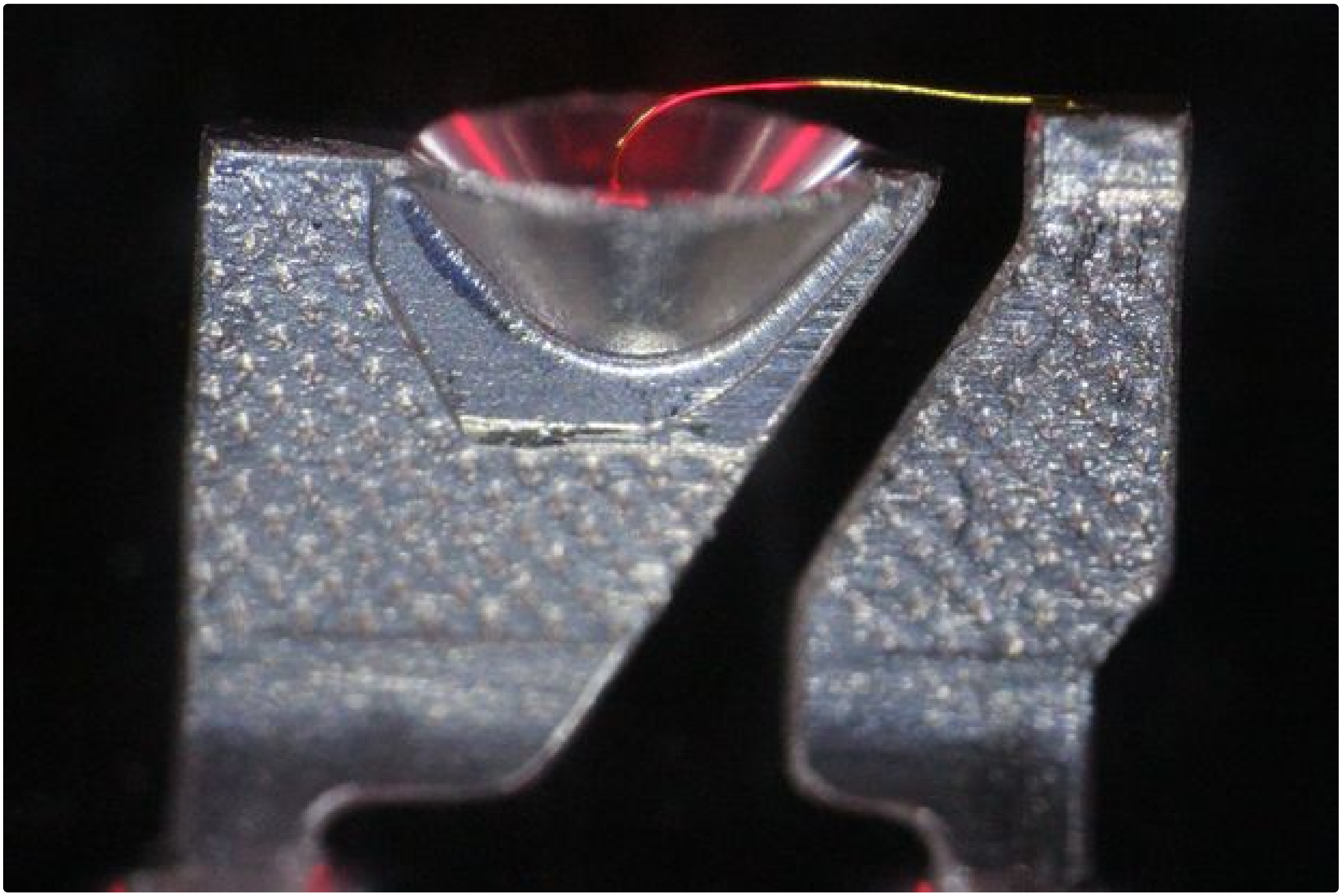
- Connect the AC supply to the AC input sockets, and the light bulb to the Load sockets.

Once it is all wired up, the following code fades the light bulb in and out:

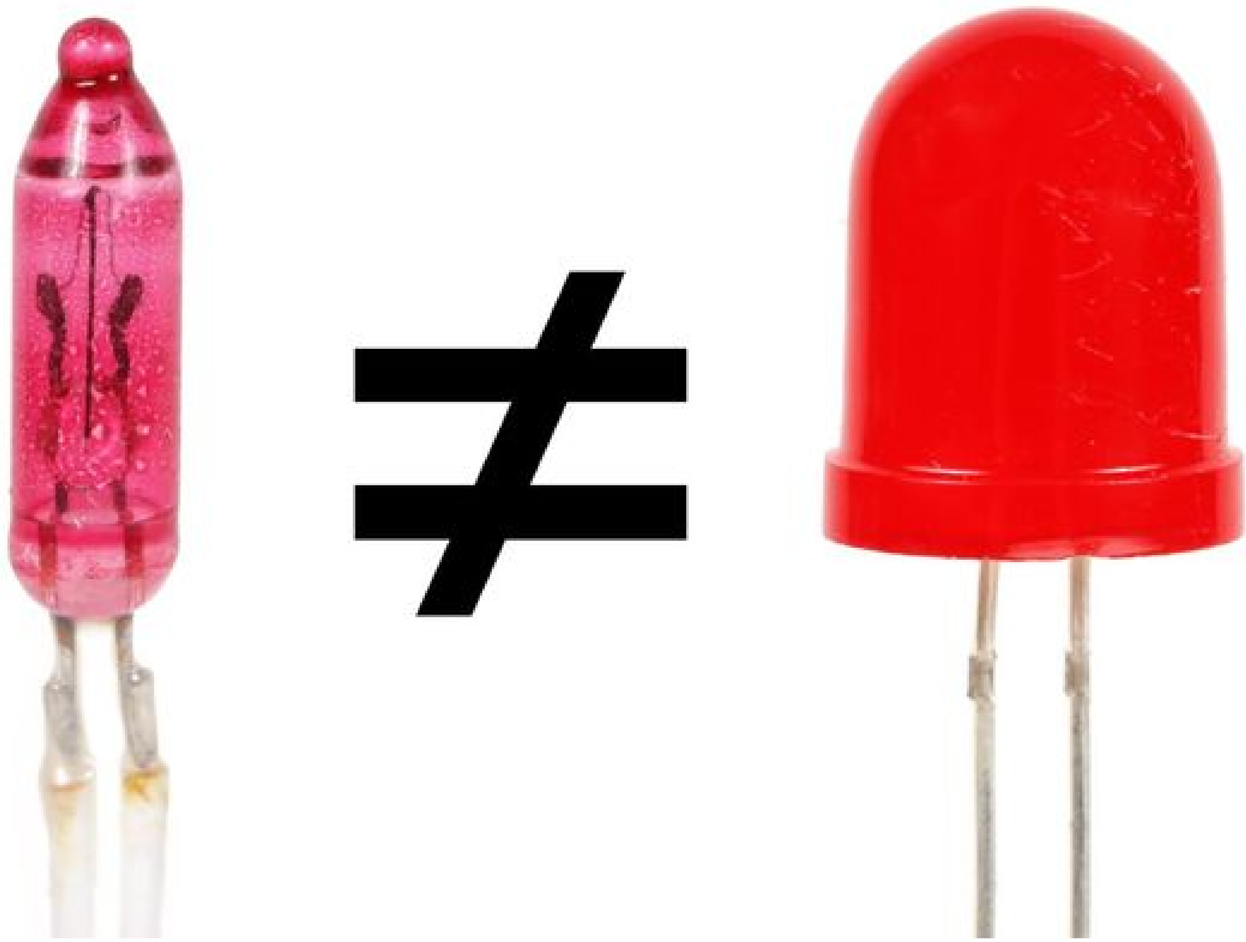
It is important to research the protocol that is needed for properly having the microcontroller talk to the circuit board before you try to use it. Often you will find example code provided by the manufacturer or retailer. If not, you usually can find example code by searching online. Rarely are you the first person who needs to solve a problem.

The light bulb should now be fading in and out. You can change the rate, by altering the length of the delays in the loop() function.

LESSON 4: LEDS



As you can see from this extreme closeup of an LED pictured above, it is actually quite different from a light bulb. LED is an abbreviation for light emitting diode. It is a special type of electronic component that emits photons when electricity flows through it in the right direction. Over the last two decades, LED technology has changed and improved dramatically. LEDs now come in so many countless types and configurations, it would be impossible to survey them all in this class. On account of their versatility and pervasiveness, you could say that LEDs currently shine brighter than all other lights. Let's see why.



Light Bulbs Vs. LEDs

An LED is nothing like a classic incandescent light bulb. For starters, a light bulb heats up a filament to a very high temperature, which creates heat, and forces metal to emit light. This requires a lot of energy and a big power source. On the other hand, LEDs emit photons when electrical current passes through a semiconductor. The semiconductor material generates little to no heat during this process. This draws very little energy, and does not require much power at all.

Additionally, a light bulb is non polarized. This mean that it will light up regardless of which way a DC electrical current is attached to its terminals. An LED on the other hand has a right and wrong way to connect electricity. If a DC current is wired in the wrong way, the LED will do nothing.

Also, light bulbs are omnidirectional in light production, whereas LEDs are designed to emit light in a beam at a certain angle

Understanding Diodes

In order to understand LEDs, you need to first understand what a diode is.

A diode is an electronic component that allows electricity to flow through in one direction, and all but stops it from flowing the opposite way.

A diode's primary role is to route electricity within a circuit. This is extremely useful for preventing an electrical signal from taking unwanted or unexpected routes or flowing in the wrong directions.

All diodes are polarized. This means they have an anode (positive side) and cathode (negative side). You can tell the difference because the cathode has a little line painted around it.

What this means is that electricity can only flow through in one direction. A positive voltage should be connected to the anode and the cathode should be connected to ground.

If you look very carefully inside of an LED, you will be able to see its anode and cathode. The thin wire bond attached to the anode bridges across to the center of a small reflective bowl attached to the cathode. In the center of the reflective bowl sits the semiconductor die. When current flows from the anode to the cathode, the semiconductor material emits photons, reflects off the bowl, and is further amplified by the resin material of the LED.

How Diodes Work

Before we dive too deep into LEDs, it is important to understand a bit more about how the anode and the cathode actually work. While this is going to get a little bit technical, it will be important for understanding LEDs later on.

A diode consists of a PN junction made of P-type silicon and N-type silicon separated by a depletion region. The depletion region acts like an insulator. Put simply, the P-region is connected to the anode, and the N-region is connected to the cathode. The depletion region sits between the two.

When the P-region is connected to ground and the N-region is connected to a positive voltage, the depletion region actually grows in size. This ensures little to no electricity is able to flow through the diode between power and ground. In this configuration the diode is considered reverse biased.

When a positive voltage is applied to the P-region and the N-region is connected to ground, the depletion region all but disappears and allows electricity to flow. In this state the diode is considered forward biased.

In order to overcome the depletion region, a little bit of voltage must be sacrificed. This is called the voltage drop. In a standard silicon diode like the one pictured this is typically 0.7V. However, and LED can have a much higher voltage drop. A typical voltage drop in an LED is 1.8 to 3.3 volts, and this varies by color.

In other words, if you have a 5V signal and it passes through an LED with a 1.8V drop, the voltage that comes out the other end will be 3.2V. It can fluctuate above or below this value depending on the type of LED.

This drop in voltage is what is referred to as an LED's "Forward Voltage."

If you have three diodes in series, you will lose 0.7V through each diode and the voltage at the far end of this chain will be 2.9V. If you consider LEDs offer a voltage loss more than double this amount, connecting three in series would add up to a significant loss, and is the reason LEDs should be connected in series sparingly.

While diodes charge a toll to cross the depletion region in the form of voltage, they offer no real resistance. If you put only diodes in a circuit without a load to use up the electricity, it will virtually look like a short circuit and draw as much current as the power supply is able to provide. Since that is likely higher than the diode's maximum current rating, it will release the diode's magic smoke.

Current Limiting Resistors

Since an LED is basically a diode and offers no resistance in a circuit, it typically requires a component called a resistor (that offers a fixed amount of resistance) in series with it.

This prevents the LED from being shorted and - given enough current - literally exploding.

As a general rule of thumb, a 470 ohm resistor should be more than enough to protect just about any low-power LED.

However, should you want to calculate the proper resistor for maximizing brightness, you can calculate this by using this equation. Even more simply, you can search online for "LED resistor calculator."

For instance, given this LED with a 3V voltage drop (forward voltage), 20mA operating current, and a 9V source, we can calculate that the proper resistance is 300 ohms. However, that is the absolute minimum resistor, and since resistors tend to have a tolerance range, it is best to increase the value a little to be on the safe side. It is safe to say then that a 330 ohm resistor should do the job. However, you don't want to increase it too much because the more resistance there is, the dimmer the LED becomes.

Understanding Resistors

Resistors have their value printed on them in color codes. To begin with, you can probably just get away using an online resistor calculator (http://www.dannyg.com/examples/res2/resistor.htm) to determine their value. If you chose to go this route, you may skip this section.

However, if you are curious on how to decipher them yourself, read on. I'm about to show you.

Telling its current rating can typically be established by the size of the resistor. This is something you will figure out intuitively in time, and not remarkably important for the kind of low-current circuits you will be working with when getting started.

Determining how much resistance a resistor offers is a little trickier and can be established by deciphering the colored stripes from left to right towards the tolerance marking. You will typically see four stripes, but you may also encounter resistors with five.

Resistors with four stripes are the most common. These will likely be the type you are working with most.

When reading a resistor with four stripes, the first two stripes are combined together to form a number between 1 and 99. The third marking is the multiplier. The last marking determines the tolerance, which is basically the accuracy of the resistor and not typically important to know about when working with LEDs. If you would like to learn more, check out the Resistors lesson (https://www.instructables.com/lesson/Resistors/) in the Electronics Class (https://www.instructables.com/class/Electronics-Class/).

For instance, in the following example, the first two lines represent 1 and 0, which is combined together as the number 10. This is then multiplied by 10,000 (which is the multiplier). The result is 100,000■■

However, when a resistor is 1,000 or more ohms, we measure it in kilo-ohms. A kilo-ohm is basically equal to 1,000 ohms. So, 100,000■ is shortened to 100k■■ Basically, it is 1,000 ohms times 100. All we are essentially doing is removing three zeros from the number, and replacing them with with k.

If that was confusing, let us look at another example. This resistor has the same initial number of 10, but a multiplier of 1,000. When multiplied together, these numbers yield a resistance of 10,000■ or 10K■■

Now, let's say the first two numbers were to change, and the multiplier were to decrease. In this example, the first two colors when combined create the number 68. When multiplied by 10, we get the number 680. Since 680■ is less than 1,000, we just call this resistor 680■■

One last thing, if there is a million or more ohms, we then measure in mega-ohms. For example, this resistor is worth 1,000,000[redacted] This is shortened to 1M[redacted]

Resistors with 5 stripes are a little less common, but just as easy to read. Let us briefly consider how to read them. Like the 4 band resistor, you first find the tolerance marking on the far edge, and then read left to right towards the marking.

However, where they differ is in that the first three stripes get read as a single number, and the fourth stripe is the multiplier. So, in this case, we can determine the first number is 100 and it gets multiplied by 1,000, giving us a resistance of 100K.

The fifth stripe is the tolerance marking.

Deciphering LEDs

Like resistors, diodes also need to be interpreted based on their packaging.

There are typically three ways to tell a standard 5mm LED's anode from its cathode.

1) The leg connected to the anode is typically longer than the one connected to the cathode.
2) The body of the LED typically has a flat spot on the cathode side.
3) If you look inside the LED, the little metal bit connected to the anode lead is much smaller than the cathode.

Types of LEDs

There are so many different types and form factors of LEDs at this point, it is hard to keep up.

LEDs come in different shapes and sizes. The 5mm domed is the most common, but you are liable to also find them in 3mm domed, 10mm domed, rectangle, oval, and square (to name a few).

LEDs also come in many different colors. Often the plastic is tinted to indicate what color they are. However, clear LEDs are deceptive in that you might assume they glow white, but can actually glow a host of different colors.

LEDs have different levels of brightness that are typically measured in MCD (millacandella). One thousand millacandella is equivalent to the brightness of one candle. So, an LED like the one pictured above with an intensity of 6,000mcd is equal to the brightness of 6 candles. It is not uncommon to also see extremely bright high-power LEDs to be measured in Lumens - another unit of light measurement - or Watts.

LEDs have different viewing angles, or beam widths. What this means is that the visible brightness of the LED seems to decrease when you are looking at the LED from and a spot outside of its ideal viewing angle. This angle also determines the size of the spotlight created by the LED. The viewing angle on an LED can vary widely.

LEDs also draw different amounts of power. In fact, some high power LEDs draw so much power that they are mounted on metal heatsinks to dissipate heat. While LEDs such as these tend to be very bright, they sometimes require special constant current circuitry to drive them.

LEDs can come grouped together into display modules. With these LED dot, bar, and 7-segment numerical displays, each individual light-up segment is a discrete LED. For instance, the 8X8 matrix on the left actually has 64 separate LEDs inside of it.

Multicolor or "RGB" LEDs are individual red, green, and blue LEDs built into a single LED package. Typically, each color has its own anode, and they all share a common cathode. By varying the voltage on each anode, the amount of red, green and blue light being emitted can be varied. By mixing these lights together, you can create nearly any color in the visible light spectrum. These LEDs are miniaturized and attached to the multicolor LED strips we will encounter in the next lesson.

Applying Power to an LED

To power an LED, you simply connect it to a battery pack in series with an appropriate current limiting resistor. As a general rule of thumb, a 470 ohm resistor is typically more than enough resistance for any 5mm LED that is being powered with 9V or less.

If the LEDs are all the same, they can easily be put in parallel to your heart's content - well, within reason. You need to keep in mind how much current they are drawing in relation to how much current your power supply can provide.

If you want to put different colors in parallel, each one needs it's own current limiting resistor. This is because each color of LED has it's own forward voltage, and forward voltages change depending on the type of LED and who manufactured it. It's important to always look up the forward voltage and calculate the correct resistance.

For example, if you have 3 blue LEDs and 1 red LED wired in parallel, the three blue LEDs can share a single resistor, and the red one requires it's own different resistor. This is to ensure you don't accidentally destroy the red LED by giving it too much current, or under-power it by giving it too little.

You can place LEDs in series, but every time you do so, there is a voltage drop across the LED. This changes the amount of resistance required. For instance, if you calculate that one single LED requires a 220 ohm resistor, and then put 3 LED in series with this resistor, it is going to have too much resistance and be fairly dim.

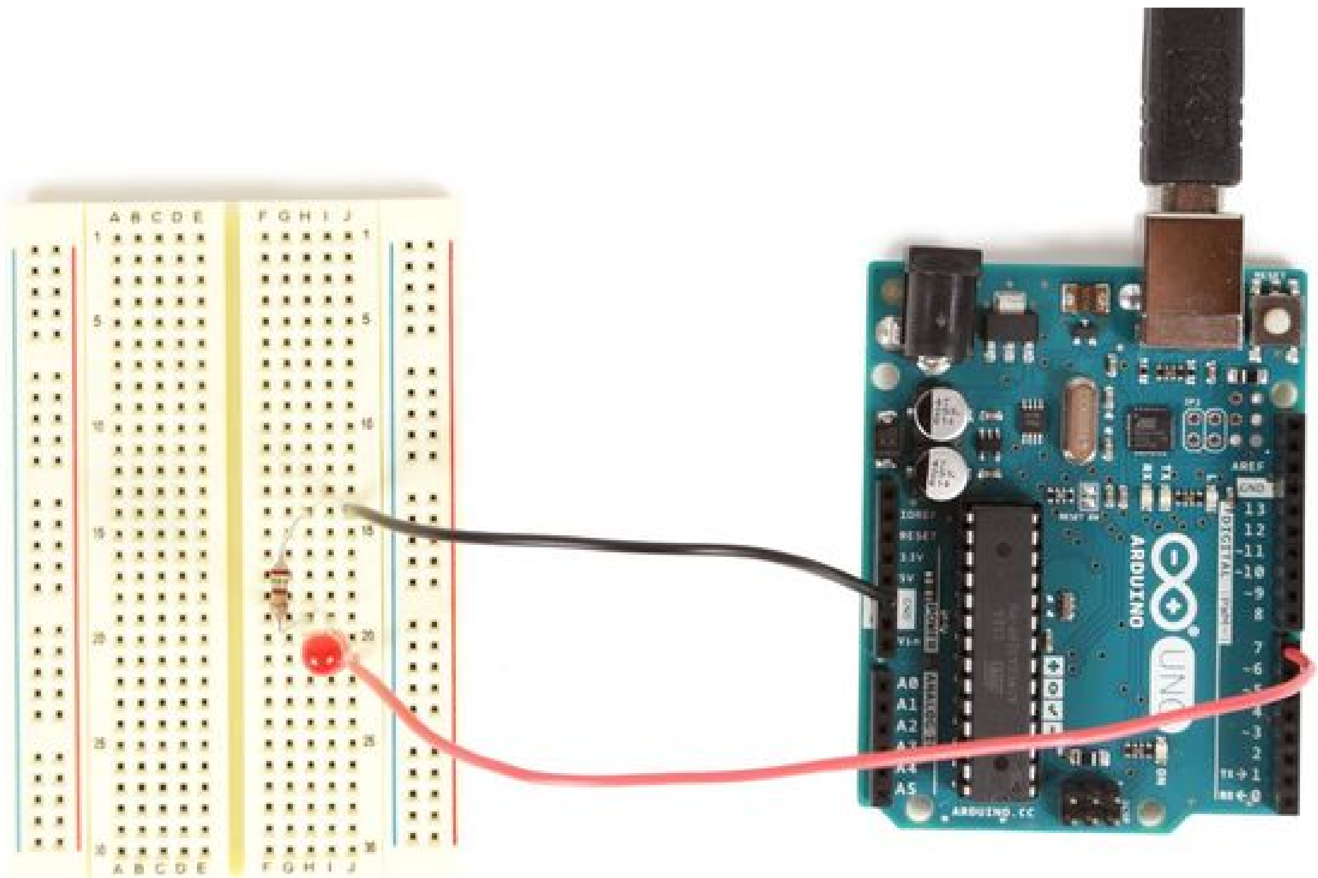
You need to decrease the resistance to maintain brightness because of the voltage loss throughout the circuit. With the formulas you already have learned for calculating voltage drops and the proper resistor, you should be able to figure this out. Or - you can do as I do - and use this online calculator (http://ledcalc.com/).

An LED can be turned off using a switch placed in series between it and the power supply. This does not have to be just a basic toggle switch. You can explore specialty switches such as tilt or, magnet switches. You can learn all about switches in the Switch lesson (https://www.instructables.com/lesson/Switches/) of the Electronics class (https://www.instructables.com/class/Electronics-Class/).

Adjusting the brightness of an LED can be adjusted quite simply using a 1K potentiometer in series with its current limiting resistor. This adjustable knob will sweep the resistance between 0 and 1K ohms. The addition of extra resistance will cause the LED to dim as the resistance increases.

We can also replace the potentiometer with any variable resistor, such as a photocell to make it light controlled.

To learn more about potentiometers and photocells, once again, I recommend checking out the Resistor Lesson (https://www.instructables.com/lesson/Resistors/) of the Electronics Class (https://www.instructables.com/class/Electronics-Class/).



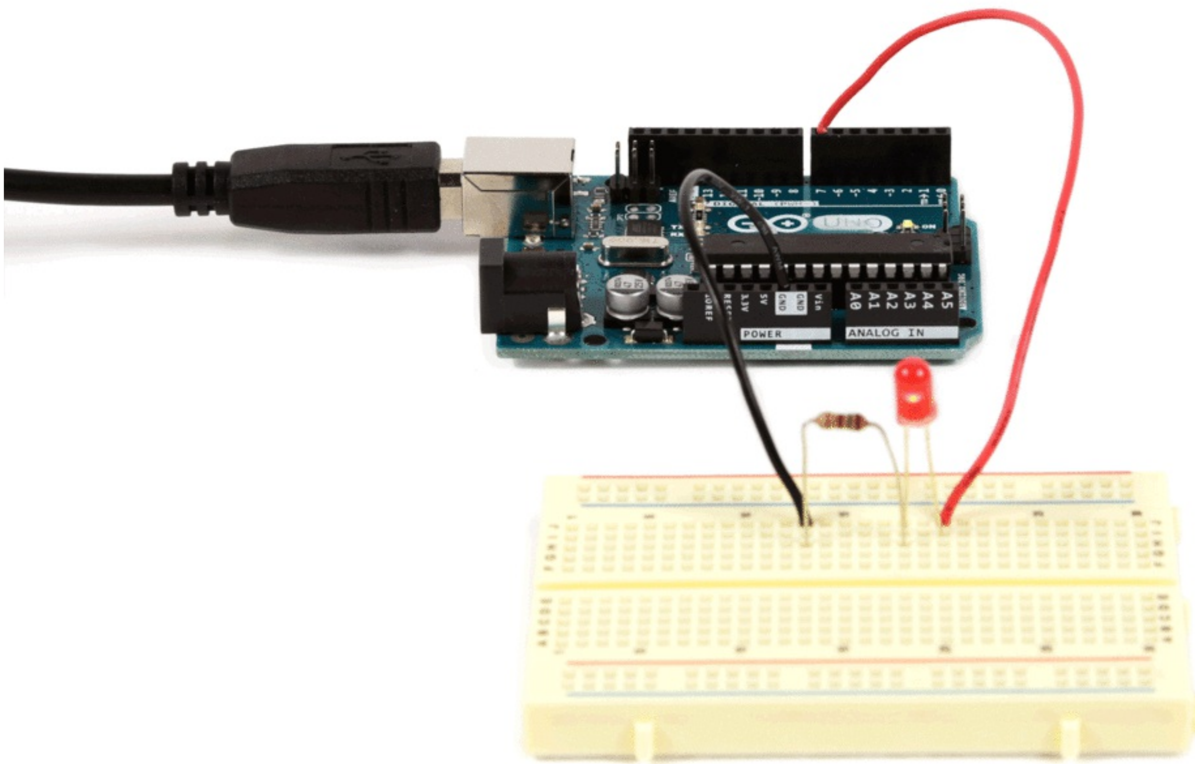
Arduino Control (advanced)

If you already have an understanding of Arduino, controlling LEDs is easy.

To blink the on-board LED connected to pin 13, simply open and upload the following example code:

01.Basics --> Blink

If you know how to use Arduino, chances are you have already done this a long time ago.

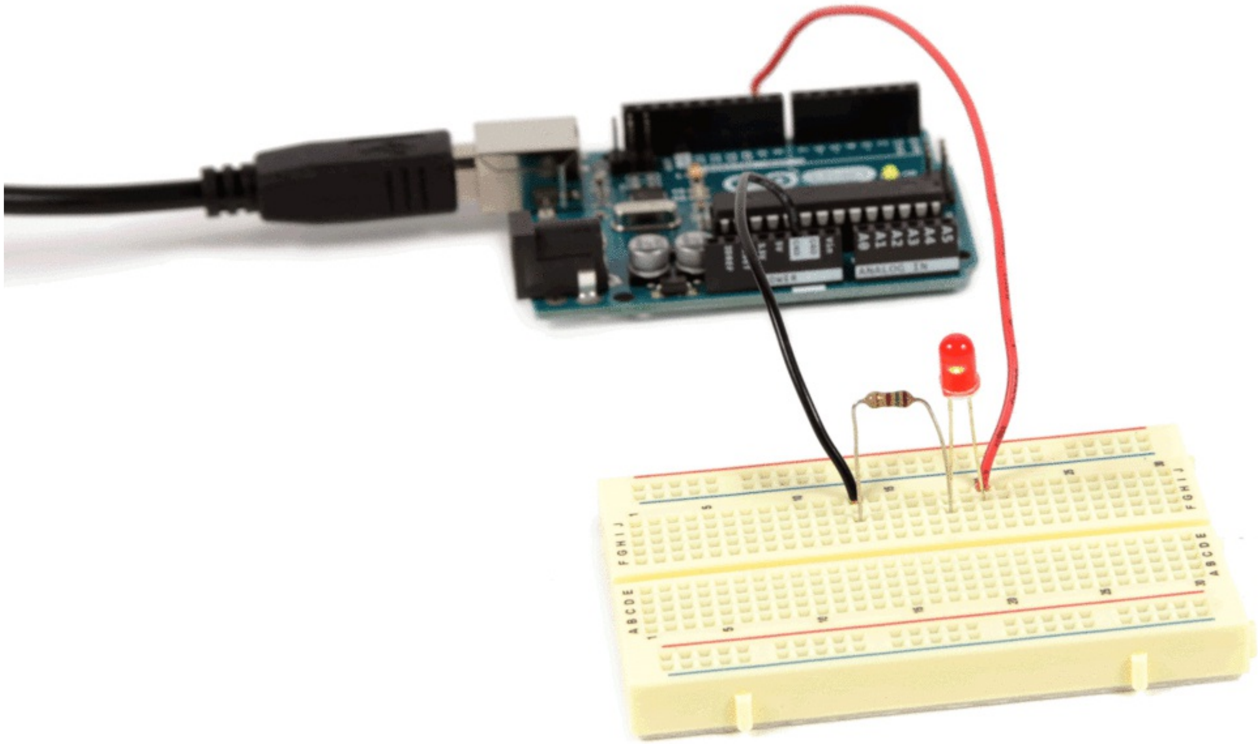


If you would like to blink an external LED, insert an LED into a breadboard. Connect a 150 ohm resistor in series with the LED's cathode.

Using a black solid core wire, connect the opposite end of the resistor (the side not connected to the LED) to ground on the Arduino.

Using a red solid core wire, connect the LED's anode to digital pin 7 on the Arduino.

Finally, go to the "Blink" example code and change all the number 13s to the number 7. By doing this, you are simply changing the digital pin that is being pulsed on and off from 13 to 7 in order to match the circuit you built on your breadboard.



Aside from blinking an LED, we can also make one fade. To do this we need to use a PWM pin. The PWM pins are special digital pins on the Arduino that allow for an analog-like output that simulates an output voltage between 0 and 5V. They are all labeled with a ~ in front of the pin number.

PWM stands for pulse width modulation. Put simply, PWM is toggling a pin on and off so fast that it gives the appearance of dimming the LED.

A dim LED glowing at 1/4 brightness means that the signal being sent to it is toggled off much more than it is toggled on. For instance, it is turned off 75% of the time and turned on 25% of the time. A brighter LED at 3/4 brightness is receiving a PWM signal that is the opposite. So it would be on 75% of the time and off 25%. The thing is, it is happening so fast, you don't see that it is being turned on and off, but only experience the LED as being slightly dim.

Anyhow, if you want to fade the LED, from the examples menu select:

03.Analog --> Fading

Once done, swap the wire connected from digital pin 7 to digital pin 9, and upload the code to your Arduino.

The LED should now fade in and out.

LESSON 5: LED STRIPS

LED strips are thin conductive circuit ribbons which have tiny surface-mount LEDs (and other components) soldered to them. On account of this, LED strips are flexible in more ways than one. They can provide lighting in hard to reach spaces, be attached to things which bend, follow contours of non-linear shapes, and glow in any color you can imagine. On account of their compact size, brightness, and variability, there is a world of possibility illuminated by LED strips.

Analog LED Strip

The most common type of LED strip you will encounter are analog strips. These can be either single or multi-color. These types of LED strips typically use 12V power, but you will want to double check. Sometimes they can also be 5V.

Single color LED strips are quite simple to power up. They have two wire attachments, one for 12V power and one for ground. When they are connected to a power source, they glow a single color.

You can find single color LED strips in a variety of colors.

Multi-color LED strips are a little bit trickier to use. These consist of surface mount multi-color LEDs, which can produce colors across the visible spectrum. This makes them very versatile and fun to play with.

By varying the amount of electricity being applied to the red, green or blue pins, you can mix the three light sources and create a wide range of different colors.


MODE +
SPEED –
DEMO
SPEED +
COLOR +
MODE –
BRIGHT +
COLOR –
BRIGHT –
RF Wireless


LED CONTROLLER

LED Strip Controllers

The easiest way to control analog LED strips is with a out-of-the-box LED strip controller. These plug-and-play controllers are typically suitable for most LED strip projects. Before I try to build custom circuitry, I always check to see if there is a controller that suits my needs.

These controllers are simply connected in series between the LED strip and the power.

They are then controlled wirelessly via remote. Different controllers have different functionalities which you can tell by looking at the remote. At that, they are dead simple to use.

One thing to keep in mind about wireless control, is that there are two types of ways these comes. Some are radio, which works even if the receiver is hidden. Others are IR (infrared) and require the remote to have "line of sight" to the receiver (like your TV). These receivers have a cable connected to a little plastic box.

The only thing to be mindful of is whether you are getting a controller for single color LED strip or multi-color LED strip. The quickest way to tell the two apart is that multi-color controllers have color settings on their remotes and single color controllers don't.

Arduino Control (advanced)

To control an analog LED strip using an Arduino, you need to use a TIP120 power transistor. If you are not familiar, you can learn all about transistors (https://www.instructables.com/lesson/Transistors/) in the Electronics Class (https://www.instructables.com/class/Electronics-Class/).

To put it simply, the transistor allows you to use the small 5V current being output by the Arduino pin to control the large 12V current required for the LED strip to function. Note that the 12V ground gets connected to the 5V power supply ground. When wiring together different DC electricity circuits, ground always gets connected even if the voltage is different.

Wire the circuit as follows:

- Arduino Pin 5 to transistor base (pin 1)
- LED strip power to 12V power
- LED strip ground to transistor collector (pin 2)
- 12V and Arduino ground to transistor emitter (pin 3)

The base of a TIP120 transistor is wired to the I/O pin on the Arduino. By applying voltage to this pin, a proportional voltage is sent through the LED strip.

The LED strip is turned on and off in relation to the amount of current applied to the transistor pin.

Should you want to try it out, here is code which blinks the LED strip. Albeit this code does not fade the LED strip, it can be easily modified to do so. With this setup you simply control the LED strip that same you control a single LED.

To control a multi-color LED strip, you just need to add a new transistor for each new color wire.

The above code cycles through different colors at random. It demonstrates how varying the amount of power applied to each RGB wire, changes the color being displayed.

Aside from analog strip, there is also addressable LED strips. This type of LED strip uses a digital communication protocol to control each LED or "pixel" individually. While all of these strips operate roughly the same, there are a number of different communication protocols for controlling LED strips. It is important to understand which protocol to use. This can be determined by checking the documentation provided by the distributor of the LED strip.

For our example we are going to use Adafruit's 60 LED neopixel LED strip (https://www.adafruit.com/product/1138). This LED strip uses a single-wire protocol, and by varying the length the signal is high (5V) or low (ground), determines the type of data being sent. It is very confusing.

Fortunately, Adafruit has created a library to do all the complicated timing and single-wire communication for you. It just requires downloading, and copying their Neopixel library into your Arduino software's library folder. Once it's copied, just reset the Arduino software and it should be installed.

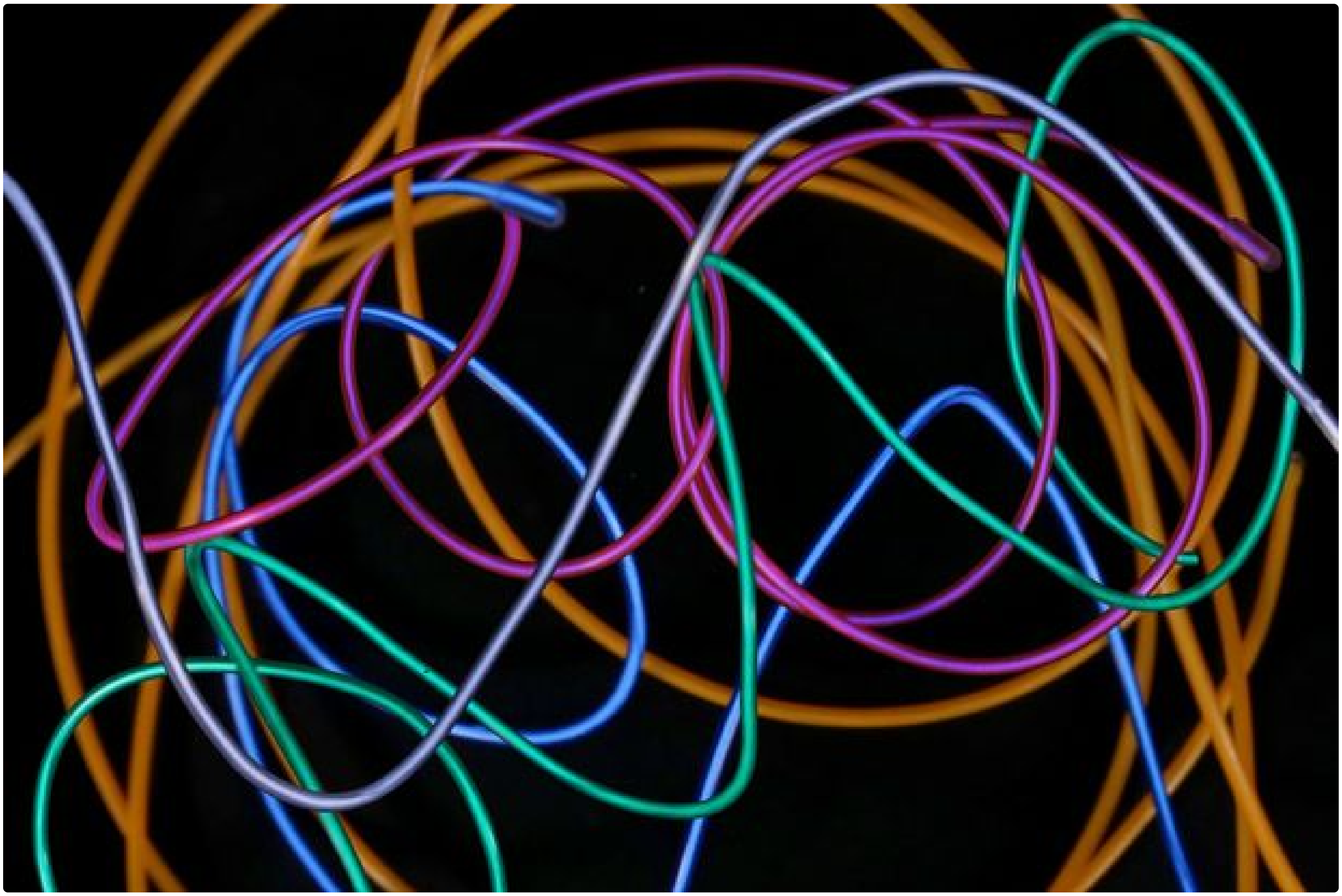
To make use of the Neopixel library (https://github.com/adafruit/Adafruit_NeoPixel), load the following file:

File --> Examples --> Adafruit Neopixel --> RGBWstrandtest

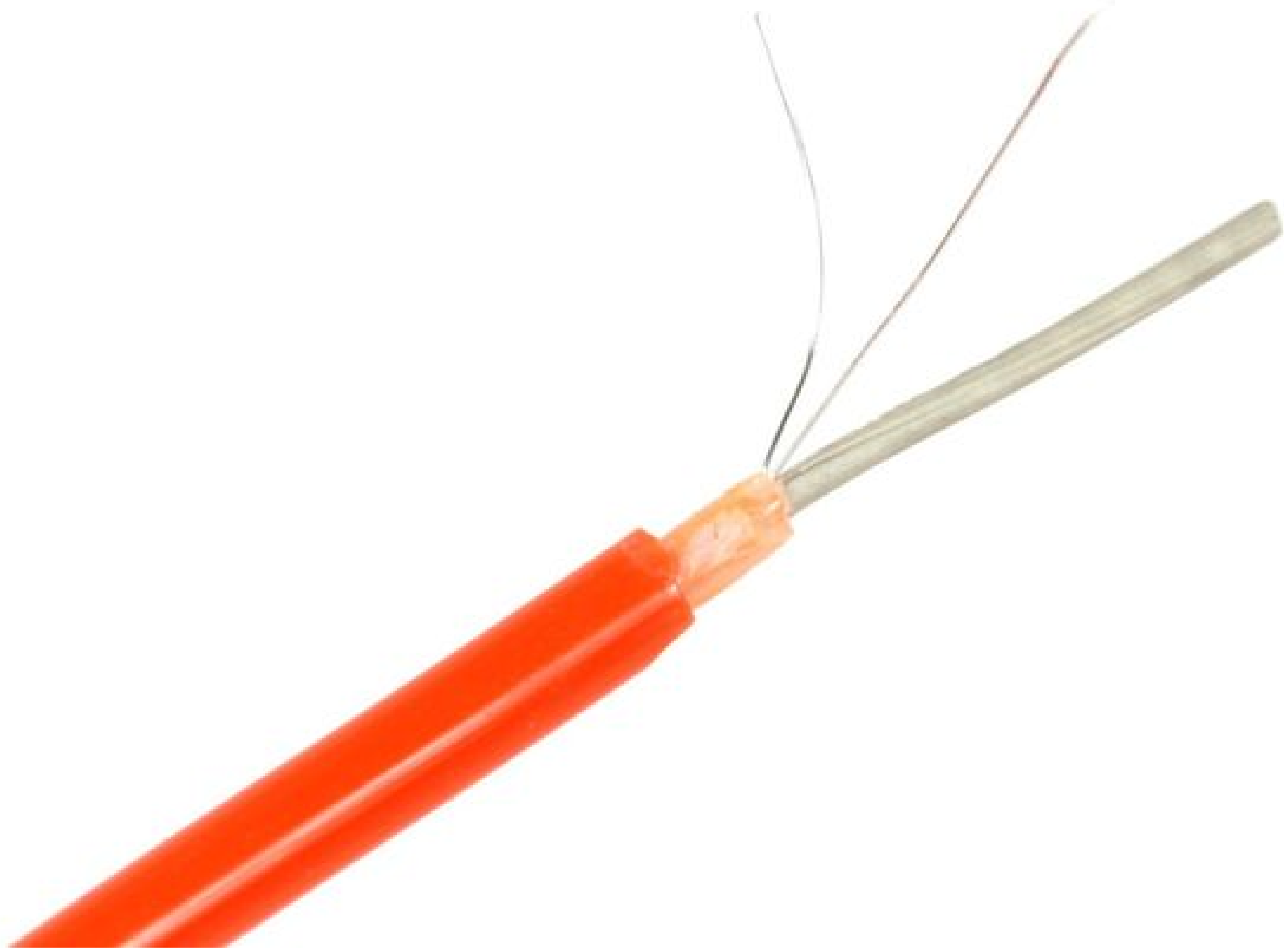
The LED strip should now run through a series of test routines to demonstrate their use. Notice how each LED is capable of being a different color. This is what sets addressable LED strips apart from analog.

To learn much more about addressable LED strips (and Arduino), check out the Arduino class.

LESSON 6: EL WIRE



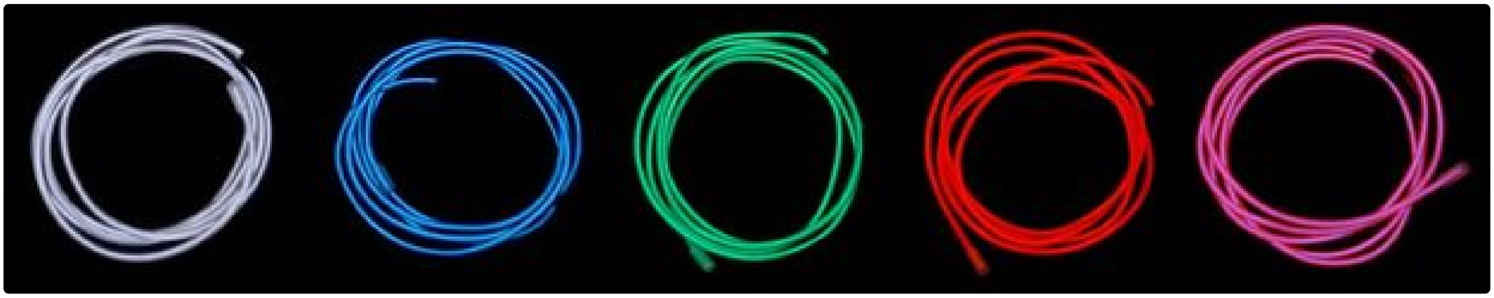
El (electroluminescent) wire is a thin, flexible, self-illuminating wire that glows along its length. It does not emit as much light as a light bulb or LED, and is not typically used as a light source. It is meant to be used as a decorative light source and is popular for costume or lighting effects. Since EL wire operates at very high voltage AC (alternating current). It offers less control and flexibility than the other light sources we have looked at, both on account of the voltage supply and the fact that it is not very bright to begin with.



How Does EL Wire Work?

EL wires consists of a thin central copper wire coated in phosphor, a chemical which glows when exposed to an energy source. This central coated wire has two thin outer copper wires wrapped around it. When alternating current flows through these wires, it moves back and forth through the phosphor coating, constantly exciting it and emitting photons.

The color of EL wire is determined solely by the tint of the flexible outer PVC jacket. Since the plastic can be tinted nearly any color, EL wire comes in a wide range of options. That being said, EL wire is only ever the color it comes manufactured, and there is little that can be done to change this.



EL wire is not the brightest light source, and it is hard to see it illuminated under normal bright daylight lighting conditions. It usually has to be fairly dark to really get the full effect. This makes it ideal for dark places like night clubs, but less ideal for outdoor signage. It is largely meant more for decorative usage under very particular conditions, more so than as a source of cast light.

EL Tape and Panels

Aside from EL wire, electroluminescent lights also comes in tape form and panels. These too operate along the same principle as the wire. The only difference is the form factor. Rather than being a thin wire, these strips and panels glow evenly along their entire surface. This makes them great for special effects like making glowing EL decals.

EL Drivers

An EL driver - or EL inverter - is a device that takes low-voltage DC (typically between 3V and 12V), and converts it to be about 100V AC. While this might sounds dangerous (being around the same voltage as a wall socket), it is actually very low current. If you were to get shocked by an EL driver, it might give you a surprising 'buzz,' but is highly unlikely to harm you. That said, try to avoid getting shocked.

EL drivers are fairly straight forward devices. They have a connector that the EL wire mates directly to. Usually they have a switch to turn them on and off.

Sometimes, they also have a mode to make it blink.

There are even sequencers which respond to music, blink multiple wires in series, and allow you to interface with EL wire using an Arduino.

Cutting EL Material

EL wire can be cut shorter to whatever length you desire. However, if you do, you need to make sure that you seal the end using a hot glue gun to prevent wires shorting or moisture damage to the EL material.

EL Panel can also be cut into any shape you like so long as you don't cut the electrical traces the connector wires are soldered to. Also, like wire, it is very important to seal the edges, and this can easily be done with packing tape.

Depending what you are trying to accomplish, masking the EL Panel with tape, vinyl, or fabric can achieve the same effect with less risk of malfunction or problems. It is also less wasteful. If your project allows for it, It is a much safer alternative.

As you can see, a black masked EL panel, and a cut EL panel more or less have the same effect on a black background.

Soldering EL Wire

EL wire is a pain in the neck to solder, and you should avoid doing this if ever possible. However, sooner or later you may find yourself needing to splice or repair EL wire, and solder lead wires onto it.

Thus, let's quickly review how to solder to EL wire.

First thing's first, to solder to EL wire, you will need some EL wire with one or both ends cut off.

The next step is to carefully strip the color jacket off of one end of the EL wire. The goal is to expose the two outer wires and the phosphor coated center wire. This step may take some practice as the outer wires are very delicate and break easily. It is important to keep both wires intact.

Wrap a piece of long thin piece of copper tape once around the outer jacket of the EL wire. Fold the two outer wires over onto the copper tape and quickly and carefully solder them into place. Once they are soldered, wrap the remainder of the copper tape around this connection to protect it.

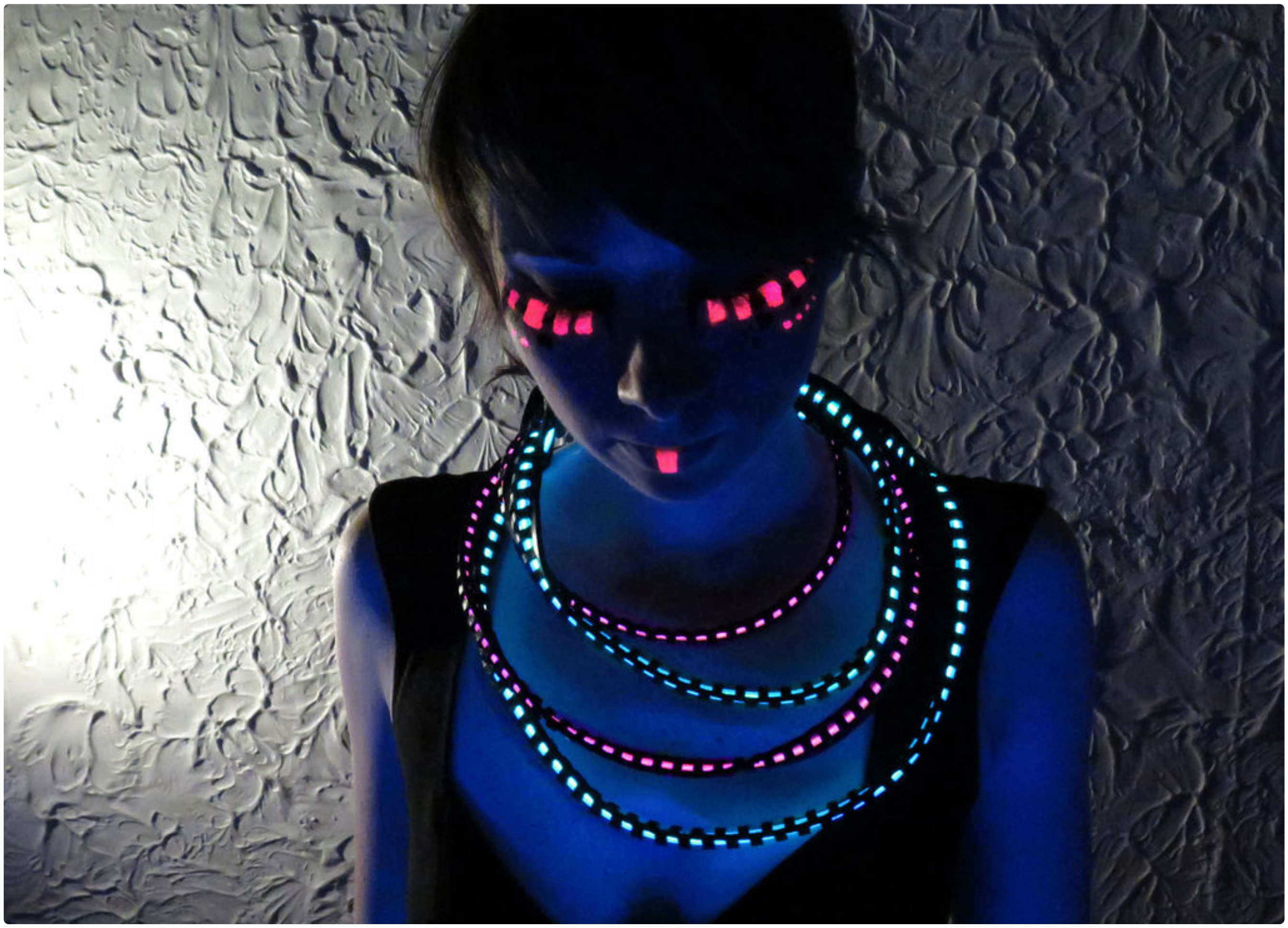
Strip the phosphor coating off of an inch worth of the inner copper core in order to be able to solder to it.

While you could solder any two wires onto the end of the EL wire, it is best to acquire a 2-pin JST female plug (https://www.adafruit.com/products/2880). One of the wires will be soldered to the copper tape, and one wire will be soldered to the inner core. It does not particularly matter which wire is which, since it is AC current.

Slide a piece of shrink tube onto the wire that will get soldered to the center core, and then solder the wire in place. Solder the other wire to the copper tape.

Slide the small piece of shrink tube over the center copper core and shrink it into place. Slide a larger piece of shrink tube over all of the connections and then shrink it into place.

When it's done, connect it to the inverter and turn it on to test that it is working. It should glow.



Attaching EL wire, tape, and panels to costumes is an art unto itself, and beyond the scope of this lesson. There are however many great EL garments on this site such as this EL Wire and Leather Necklace (https://www.instructables.com/id/El-Wire-and-Leather-Necklace/) made by Mikaela Holmes (https://www.instructables.com/member/MikaelaHolmes/).

That said, to work with EL wire in costumes you will want to brush up on your hand sewing (https://www.instructables.com/class/Hand-Sewing-Class/) and machine sewing (https://www.instructables.com/class/Machine-Sewing-Class/) skills (if need be), and experiment.

There is a good guide on the site for adding EL wire to a garment (https://www.instructables.com/id/how-to-add-EL-wire-to-a-coat-or-other-garment/).

You can also get EL wire with welted piping (https://www.adafruit.com/products/676) which has its own set of challenges, but makes it easier to sew it into the seams of garments.