

LED Circuits and Headlights for the SeaPerch ROV – A Primer

Objective: to provide instructions and an explanation for creating an LED circuit, and for headlights to be used on a SeaPerch ROV.

Ohm's Law: the current (Amps, I) through a circuit is directly proportional to the potential difference (voltage, V) across the circuit, and inversely proportional to the resistance (Ohms, Ω) in the circuit.

$$I=V/R$$

The power (Watts) consumed by a circuit is the product of the voltage and the current.

$$P=V \times I$$

Constructing an LED Sample Circuit

Question: How would you construct a circuit containing a switch, a battery, a resistor, and four high-intensity red LEDs? What is the purpose of each component in the circuit?

Materials:

4 LEDs (any color, but all the same color)
Single pole, single throw (SPST) slide or toggle switch
12 VDC battery (such as the type used in cigarette lighters, but any type will do)
Resistor, carbon type, variety of sizes, ½ Watt
20 ga. Hook-up wire
Flux Core Solder
25W Soldering Iron
Wire Cutters
Wire Strippers

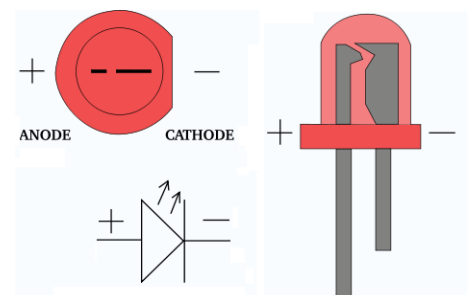
Background:

It is important to remember that this is a direct current (DC) circuit and this will not work with an AC (alternating current) power source. LEDs are not designed for use in AC circuits.

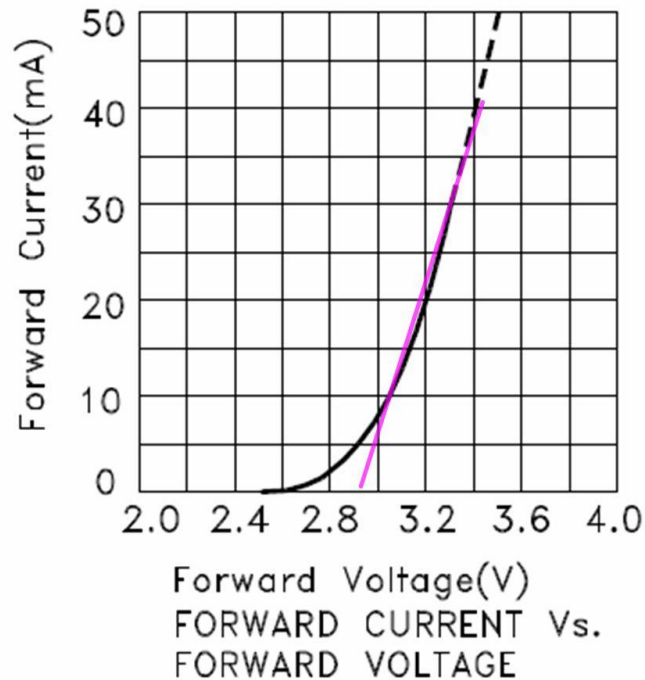
LEDs (Light Emitting Diodes) are a special type of diode that emits light when electrons flow through the diode. Actually, all diodes emit some light when powered by a circuit, but LEDs are specifically designed to emit light while consuming very little power. Hence, they will emit light for a very long time using very small batteries.

Diodes are made of crystalline semiconductor materials, and the choice of the materials used during manufacturing will determine the diodes' function, but common to all diodes is the [P/N junction](#). The P/N junction is most useful in that it allows electrons to flow in one direction only, so it may be used as a type of switch in the simplest case. To learn more about how P/N junctions are made and their operation, see <http://electronics.howstuffworks.com/diode.htm>.

For our purposes in making an LED circuit, it is important to remember that an LED has a directionality or polarity associated with it. It must be inserted into the circuit in the correct orientation or electrons will not flow in the circuit and it will not light. The anode lead of the LED must be connected to the positive side of the circuit. If you look at an LED as it is supplied from the manufacturer, you will see it has two wire leads for connection to the circuit. One lead is longer than the other: this is always the positive lead (anode). Very often, a rim will encircle the base of the LED, and it may be flat on one side. This indicates the negative (cathode) lead of the LED.



LEDs not only require electricity in the proper direction, but they have somewhat stringent voltage requirements. Diodes don't obey Ohm's Law in a strict sense: current is approximately an exponential function of voltage, so a small change in voltage results in a large change in current. This can be illustrated by a current vs. voltage diagram for an LED.



You can see several operational characteristics of LEDs from this graph:

1. Current through the LED does not start to flow until the voltage reaches ~ 2.5 volts. This is called the *threshold voltage* and this must be reached before the LED will start to "fire", i.e. give off light, and
2. Past the threshold voltage, small changes in voltage result in large amounts of current flowing through the LED. Most LEDs can easily tolerate 20 mA, but start to heat up and become less efficient at producing light at 25-30 mA. Past 30 mA, most LEDs will begin to fry.

For these reasons, the amount of current flowing through the LEDs must be limited by using either an appropriately-sized resistor, or a constant-current limiting regulator (also called a driver).

If using a resistor, the value of the required resistor can be calculated as shown on the circuit diagram, Appendix I. Very often, the calculated resistance does not match the value of manufactured resistors: in those cases, round to the next highest value resistor.

The above discussion does not specify any particular color of LED, and LEDs come in a wide variety of colors. It should be noted that the color emitted by an LED is not due to the color of the plastic lens covering it, but to the nature of the particular semiconductor materials used to make it and the voltage at which they are driven. In general, as LEDs emit light of shorter and shorter wavelengths (going from darker colors to brighter colors), the threshold voltage tends to increase. That is, it takes less voltage to drive a red LED (1.9 VDC) than a white LED (3.4 VDC).

Sometimes, you know the forward threshold voltage required by the LED you are using, but many times you are handed an LED of unknown value, and LEDs have no code markings on

them as do resistors (see below). So, you can often use a chart such as the one below to determine the voltage the LED requires.

		LED Chip Code	Peak Wave length (nm)	Dominant Wave length (nm)	Color Name	Nominal Fwd Voltage (V _f @20ma)	Intensity (mcd) 5mm LEDs (For Reference)	Radiant Power mW/sr	LED Die Material
851	IR	IR851	843	N/A	Infrared	1.7	N/A	86mW@50mA	GaAlAs/GaAs
0UR		R3KF/R6	654	641	Ultra Red	1.9	1000mcd@20mA	13mW@20mA	GaAlAs/GaAlAs
00R		R3/R4/R5	640	625	HE Red	2.0	220mcd@20mA	1.8mW@20mA	GaAsP/GaP
0ER		E3K	634	624	Super E.Red	2.2	8000mcd@20mA	45mW@20mA	InGaAlP
0UO		O3KF	616	610	Super Orange	2.0	2000mcd@20mA	7mW@20mA	InGaAlP
00O		O4/O5	609	604	Orange	2.0	220mcd@20mA	0.7mW@20mA	GaAsP/GaP
0UY		Y3KF	598	593	Super Yellow	2.0	5000mcd@20mA	10mW@20mA	InGaAlP
0PY		Y3KH	592	589	Super P.Yellow	2.3	4000mcd@20mA	8mW@20mA	InGaAlP
00Y		Y3/Y4/Y5	582	584	Yellow	2.1	170mcd@20mA	0.3mW@20mA	GaAsP/GaP
0IW			3000K	N/A	Warm White	3.3	5500mcd@20mA	17mW@20mA	InGaN
XPW			6000K	N/A	Pale White	3.3	5500mcd@20mA	17mW@20mA	InGaN
0WW			8000K	N/A	Cool White	3.3	5800mcd@20mA	23mW@20mA	InGaN
0UG		G1K	575	573	Super L.Green	2.0	1800mcd@20mA	3mW@20mA	InGaAlP
00G		G3/G4/G5	563	569	HE Green	2.3	210mcd@20mA	0.03mW@20mA	GaP/GaP
UPG		PG350	563	564	Super P.Green	2.1	400mcd@20mA	0.6mW@20mA	InGaAlP
0PG		PG5	557	560	Pure Green	2.2	140mcd@20mA	0.2mW@20mA	GaP/GaP
0AG		AG10K	522	528	Aqua Green	3.4	15,000mcd@20mA	30mW@20mA	InGaN
0BG		BG7K	501	502	Blue Green	3.4	4300mcd@20mA	16mW@20mA	InGaN
0PB		PB4KB	455	460	Super Blue	3.2	3000mcd@20mA	61mW@20mA	InGaN
00B		UB500	425	447	Ultra Blue	4.0	250mcd@20mA	5mW@20mA	SiC/GaN
405	UV	UV405	402	420	Ultra Violet	3.8	39mcd@20mA	53mW@20mA	SiC/GaN

The related information is provided by LEDtronics www.LEDtronics.com

If all else fails, assume a nominal voltage of 2.2-2.5 VDC and a current of 20 mA – your LED should fire. It just may not be as bright as it could be.

Resistors are two-lead passive components that are common to all electrical circuits. Even the filament of a light bulb is a resistor of sorts. When a voltage is applied across a resistor, current will flow through that resistor in direct proportion to the voltage. Think of a resistor as a valve constricting the flow of water in a hose: the greater the “pinch” (value) of the valve, the more the current is reduced:

$$I=V/R,$$

as R increases, I decreases.

Resistors most commonly used in the circuits described here are axial-lead carbon composite resistors that are manufactured in a range of values that cover several decades of resistance (1 ohm to several million ohms). Determining the value of a resistor can be done in two ways:

1. Use a multimeter to measure the resistance across the axial leads, or
2. Read the color code on the body of the resistor.

Four-band identification is the most commonly used color-coding scheme on resistors. It consists of four colored bands that are painted around the body of the resistor. The first two bands encode the first two significant digits of the resistance value, the third is a power-of-ten multiplier or number-of-zeroes, and the fourth is the tolerance accuracy, or acceptable error, of the value. The first three bands are equally spaced along the resistor; the spacing to the fourth band is wider.



For example, green-blue-yellow-red is $56 \times 10^4 \Omega = 560 \text{ k}\Omega \pm 2\%$. An easier description can be as followed: the first band, green, has a value of 5 and the second band, blue, has a value of 6, and is counted as 56. The third band, yellow, has a value of 10^4 , which adds four 0's to the end, creating $560,000 \Omega$ at $\pm 2\%$ tolerance accuracy. $560,000 \Omega$ changes to $560 \text{ k}\Omega \pm 2\%$ (as a kilo- is 10^3). The following chart can be helpful:

Resistor Color Codes ↑					
Band Color	1st Band #	2nd Band #	*3rd Band #	Multiplier x	Tolerances \pm %
Black	0	0	0	1	
Brown	1	1	1	10	$\pm 1\%$
Red	2	2	2	100	$\pm 2\%$
Orange	3	3	3	1000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	$\pm 0.5\%$
Blue	6	6	6	1,000,000	$\pm 0.25\%$
Violet	7	7	7	10,000,000	$\pm 0.10\%$
Grey	8	8	8	100,000,000	$\pm 0.05\%$
White	9	9	9	1,000,000,000	
Gold				0.1	$\pm 5\%$
Silver				0.01	$\pm 10\%$
None					$\pm 20\%$

If you have a smartphone, several sites offer free apps to decode resistor color bands for you.

Resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit. Power dissipation in a circuit or across any component of the circuit is calculated by the equation:

$$P=I \times V,$$

where I is the circuit (or component) current in amps (A), V is the circuit (or component) voltage drop in volts (V), and P is the power generated in Watts (W). In the sample circuit shown in Appendix I, we will be operating the circuit at 12 VDC with four 2 VDC LEDs, resulting in a voltage drop across the resistor of 4 VDC and a current of 0.020 A, which results in a required power dissipation by the resistor of 0.08 W. Resistors are manufactured in standard power ratings of 1/10th, 1/8, ¼, and ½ W (and so on), so for this circuit, a ¼ W resistor is more than adequate. Resistors have no polarity; hence, they may be added to a circuit with the leads in either orientation.

Procedure:

1. Determine the threshold voltage required for the LEDs you will be using and calculate the value of the resistor required, as demonstrated in Appendix I.
2. Cut two pieces of red hook-up wire ~ 4" long, and one piece of black hook-up wire ~6" long. Strip about 1/8" of insulation from all of the wire ends.
3. Gather the components of your circuit together and lay them out in close approximation to the diagram in Appendix I.
4. Heat up your soldering iron and be sure to keep the tip clean and "tinned" by melting some flux core solder on it.
5. Solder one end of a red wire to one of the terminals on the switch. See Appendix II, *How to Solder Like a Pro*. Solder one end of the second piece of red wire to the other switch terminal.
6. Solder the other end of one red piece of wire to one of the axial leads on the resistor.
7. Solder the other axial lead of the resistor to the anode of the first LED in the series. Solder the cathode lead of this LED to the anode lead of the next LED in the series. Continue until all of the LEDs have been soldered together.
8. Solder one end of the black hook-up wire to the cathode lead of the last LED in the series.
9. Using a rubber band to hold the wires in place, attach the red wire to the positive pole of the battery and the black wire to the negative pole of the battery. Use the switch to turn your circuit on and off.
10. If the LEDs don't light:
 - Check to be sure all of the LEDs are installed in the correct orientation-positive leads connected to the positive terminal of the battery,
 - Check your calculations to make sure you have the correct resistor value,
 - Check your solder connections to make sure one is not loose.

There are lots of fun and decorative things you can do with your simple LED circuit. One would be to make a novel night light for your home. The LEDs can be mounted in any of a number of configurations like the one shown here.



I cut a ¼" slot in a small piece of ½" plywood and drilled 4 holes 13/64" up through the slot, countersunk just a bit with a 15/64" bit. Five mm LEDs fit nicely into the holes and the rim locks into the countersink. I also drilled a hole to accept the slide switch and 12 VDC battery. The artwork are two sheets of 1/8" Plexiglas and the design was made by using a conical stone mounted in a Dremel to distress one face of the Plexiglas using the design as shown. Then, sandwich the two pieces of Plexiglas together, tape to hold, and insert in the slot. Voila! I have done this with middle school and high school kids in about 90 minutes, including the circuit work.

Making an LED Headlight for your SeaPerch

Headlights for your SeaPerch can be constructed in many ways, and there are multiple sites on the Web that have instructions for doing so. Some of the sites are listed in the **Resources** section at the end of this discussion.

Described here is a set of headlamps I constructed using design ideas from Ben McLuckie of the Hoonah, AK school district. Many thanks to Ben.

Materials:

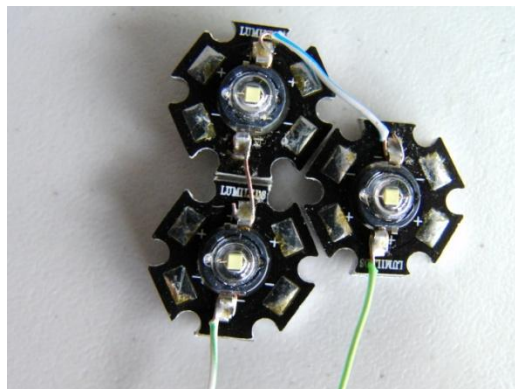
6 Luxeon Lumiled LEDs, Allelectronics.com, Cat#LED-154
Constant current regulator, Ebay, Cat#MB16551
Hook-up wire
2-part marine epoxy or electronics potting epoxy

Note: the LEDs shown in the pictures are no longer manufactured, but the LED-154 is a good substitute. These are 1W LEDs with a maximum forward voltage of 4 VDC at 700mA. They are pricey, though - \$6.50 each.

Any constant current driver of adequate range would work, but the ones on Ebay, if you can find them, are reasonable. Alternatively, you could use a resistor. At the voltage and current ratings of the LED (you will be constructing two parallel legs of 3 LEDs in series each, so you are not exceeding the available voltage of the standard 12 VDC SeaPerch battery, which actually puts out ~12.8 VDC), you would need a 2Ω resistor. But, the power dissipation is nearly 9W, so you would need a 10W ceramic resistor with a heat sink. It will get quite hot!

Procedure:

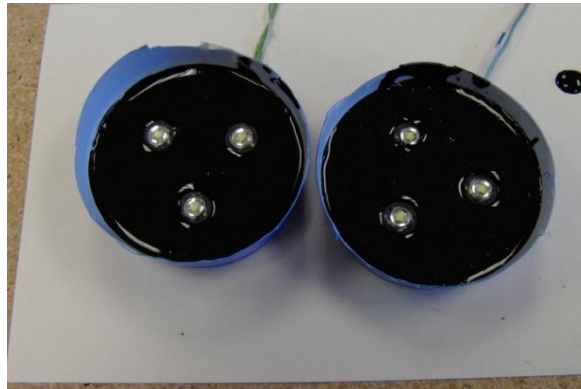
1. The Lumiled LEDs are surface mounted and are different in physical configuration from the T1-3/4 LEDs used in the sample circuit, but they still need to be assembled into the circuit with the correct polarity. The anode and cathode is marked on the body of the LED with a "+" and a "-". These LEDs are six-sided so they may be packed together, and are metal-backed to help in heat dissipation. Group them together as shown and solder jumper wires to connect them together, negative to positive, as above.



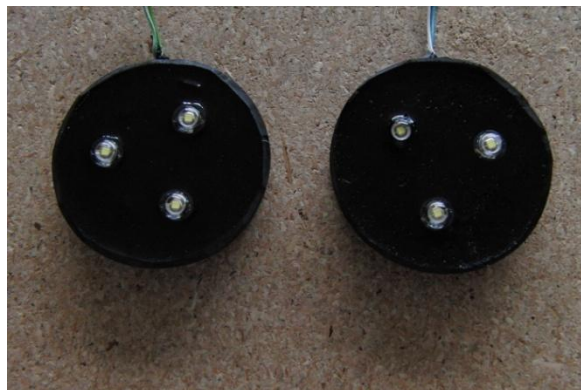
2. Solder wire leads (~ 12") to the remaining positive and negative terminals. These will later be used to connect the lights to your power source.
3. Get two plastic drinking cups (12 oz) and cut off the top, leaving the bottom with sides about 1" high. Cut a small slit in the bottom of the cups and pass the wire leads through the slit so the LED array can sit snugly on the bottom of the cup. Put a small piece of electrical tape over the slit on the outside of the cup to seal the hole.



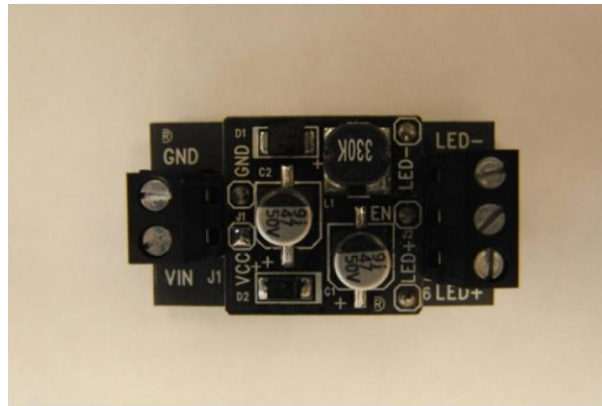
4. Mix up a batch of your epoxy according to manufacturer's directions and carefully! pour the epoxy into the bottom of the cup so it just covers the electrical contacts on the face of the LEDs. Be sure the junction where the LED lens meets the body is covered, but do not cover the lens. Let it cure for the specified time.



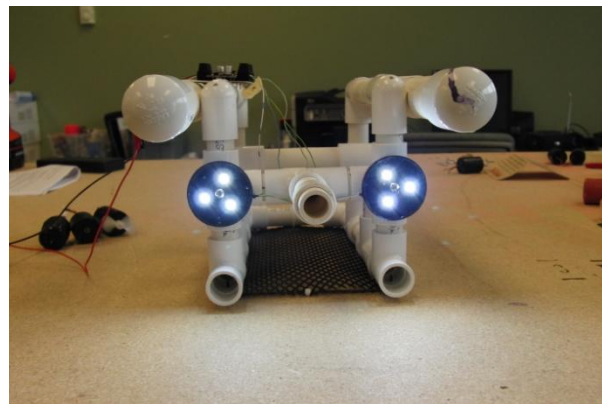
5. Remove the array assembly from the cup. I drilled a mounting hole through the center of the array and attached my headlights to the frame of the ROV using #8 self-tapping metal screws.



- The two series arrays of LEDs will be connected in parallel to the power source. To do this, twist together the two leads coming from the positive pin of the arrays with a piece of red hook-up wire about 6" long. Solder the wires together and wrap with electrical tape or butyl rubber tape. Do likewise with the leads from the negative pins of the arrays using a piece of black hook-up wire. Connect the red and black hook-up wires to the brown twisted pair of the tether that comes from the control box.
- In the control box, connect the other end of the brown twisted pair to the power out terminals on the constant current driver. Be sure to connect solid brown to the positive terminal and brown/white to the negative terminal. Connect the red and black hook-up wires carrying power into the box from the battery to the power in terminals on the driver, again, positive to positive and negative to negative.



- Mount the driver in the control box. I used a small piece of butyl rubber tape and just stuck it on the underside of the driver, and then stuck the driver onto the wall of the control box. Done!



Resource Websites

Electronic components:

<http://www.allelectronics.com/>

www.mouser.com

www.sparkfun.com

www.elexp.com

www.ledsupply.com

Headlight Instructions:

[Advanced SeaPerch Lighting Bank-MIT](#)

[LEDs for your SeaPerch-Instructables](#)

More on LEDs:

[Light Emitting Diode-Wikipedia](#)

[How Stuff Works](#)

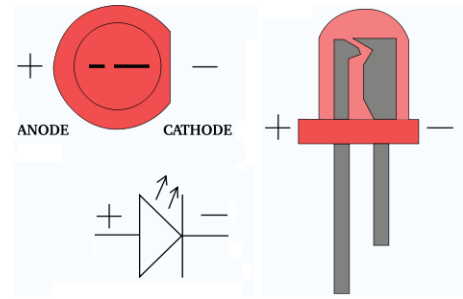
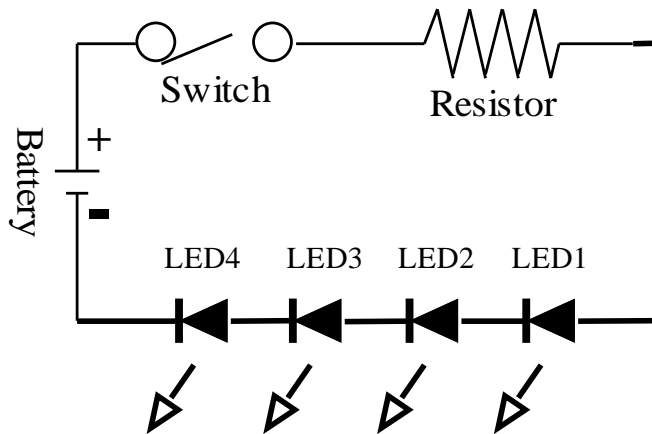
[Notes on LEDs](#)

[Designing Circuits for LEDs](#)

Standards Compliance

Content Standard	Content Level		
	K-4	5-8	9-12
Science as Inquiry - A			
Physical Science – B		✓	
Life Science – C			
Earth & Space Science - D		✓	✓
Science & Technology - E		✓	✓
Science in Personal and Social Perspective - F			
History and Nature of Science - G			

Appendix I: Sample Circuit



Battery: 12 VDC

Switch: Single Pole, Single Throw Slide Switch

Resistor: 160Ω, ½ W (see below for calculation)

LEDs: High intensity red, 2V threshold voltage, 20mA current

From Ohm's Law:

$$V = I \times R$$

Voltage = Current x Resistance

and therefore,

$$R = \frac{V}{I}$$

For LED circuits in series:

$$R = \frac{V_s - V_l}{I}$$

where V_s = supply voltage (battery voltage)

V_l = total LED voltage.

With 4 LEDs in a series circuit (4 LEDs in a row), the total LED voltage is the sum of the individual LED voltages, in this case:

$$V_l = 2.0VDC \times 4 = 8VDC$$

then,

$$\begin{aligned} R &= \frac{12 - 8}{0.02} \\ &= 160\Omega \end{aligned}$$

Finally,

$$P = V \times I$$

Where P = power dissipated by the resistor (Watts)

$$\begin{aligned} P &= 4 \times 0.02 \\ &= 0.08W \end{aligned}$$

A 1/4W resistor is more than adequate for this circuit.

Appendix II: How to Solder Like a Pro

Basic soldering is a skill that's easy to learn and not too hard to master. It just takes practice.

There is a huge range of soldered joints out there, from tiny chip resistors on circuit boards to large UHF connectors. There is also a large variety of irons, tips and solder to choose from, and it certainly does help to have the right tool for the job.

Although we will focus on the middle range of connector and cable size in this tutorial (using audio cable and connectors as examples), the theory can be applied to a solder joint of any size.



Good luck, and remember....good soldering takes practice!

Soldering Tools

The only tools that are essential to solder are a soldering iron and some solder. There are, however, lots of soldering accessories available.

Different soldering jobs will need different tools and different temperatures too. For circuit board work you will need a fine tip, a lower temperature and finer grade solder. You may also want to use a magnifying glass. Audio connectors such as XLR's will require a larger tip, higher temperature and thicker solder. Clamps and holders are also handy when soldering audio cables.

Soldering Irons

There are several things to consider when choosing a soldering iron.

- Wattage
- adjustable or fixed temperature
- power source (electric or gas)
- portable or bench use



I do not recommend soldering guns, as these have no temperature control and can get too hot. This can result in damage to circuit boards, melt cable insulation, and even damage connectors.

Wattage

It is important to realize that higher wattage does not necessarily mean a hotter soldering iron. Higher wattage irons just have more power available to cope with bigger joints. A low wattage iron may not keep its temperature on a big joint, as it can lose heat faster than it can reheat itself. Therefore, smaller joints such as circuit boards require a lesser wattage iron - around 15-30 watts will be fine. Audio connectors need something bigger - I recommend 40 watts at least.

Temperature

There are a lot of cheap, low watt irons with no temperature control available. Most of these are fine for basic soldering, but if you are going to be doing a lot you may want to consider a variable temperature soldering



iron. Some of these simply have a boost button on the handle, which is useful with larger joints; others have a thermostatic control so you can vary the heat of the tip.

If you have a temperature controlled iron you should start at about 315-345°C (600-650°F). You may want to increase this however - I prefer about 700-750°F. Use a temperature that will allow you to complete a joint in 1 to 3 seconds.

Power

Most soldering irons are mains powered - either 110/230v AC, or benchtop soldering stations which transform down to low voltage DC. Also available are battery and gas powered. These are great for the toolbox, but you'll want a plug in one for your bench. Gas soldering irons lose their heat in windy outside conditions more easily than a good high wattage mains powered iron.



Portability

Cheaper soldering irons will need to plug into the mains. This is fine a lot of the time, but if there is no mains socket around, you will need another solution. Gas and battery soldering irons are the answer here. They are totally portable and can be taken and used almost anywhere. They may not be as efficient at heating as a good high wattage iron, but they can get you out of a lot of hassle at times.

If you have a bench setup, you should consider using a soldering station. These usually have a soldering iron and desoldering iron with heatproof stands, variable heat, and a place for a cleaning pad. A good solder station will be reliable, accurate with its temperature, and with a range of tips handy it can perform any soldering task you attempt with it.



Solder

The most commonly used type of solder is rosin core. The rosin is flux, which cleans as you solder. The other type of solder is acid core and unless you are experienced at soldering, you should stick to rosin core solder. Acid core solder can be tricky, and better avoided for the beginner.



Rosin core solder comes in three main types - 50/50, 60/40 and 63/37. These numbers represent the amount of tin and lead present in the solder, as shown below.

Solder Type	% Tin	% Lead	Melting Temp (°F)
50/50	50	50	425
60/40	60	40	371
63/37	63	37	361

Any general purpose rosin core solder will be fine.

Soldering Accessories

Soldering Iron Tips

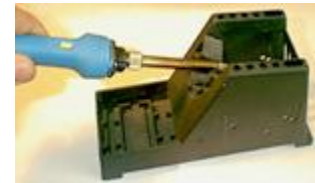
Try to use the right size tip whenever you can. Smaller wires and circuit boards require small fine tips, and mic cable onto an XLR would need a larger tip. You can get pointed tips, or flat tipped ones (sometimes called



'spade tips'). If you have a solder station with a desolderer, you will also want a range of desoldering tips and cleaners.

Soldering Iron Stands

These are handy to use if you are doing several or more joints. It is a heat resistant cradle for your iron to sit in, so you don't have to lie it down on the bench while it is hot. It really is essential if you are planning to do a lot of bench soldering as it is only a matter of time before you burn something (probably your elbow resting on the hot tip) if you don't use one.



Clamps

I strongly recommend clamps of some sort. Trying to hold your soldering iron, the solder, and the wire is tricky enough, but when you have to hold the connector as well it is almost impossible. There are adjustable clamps that can be manipulated to hold both the connector and the wire in place so you still have two free hands to apply the heat and the solder. These are cheap items, and I know mine have paid for themselves many times over.



Magnifying glass

If you are doing work on PCBs (printed circuit boards) you may need to get a magnifying glass. This will help you see the tracks on the PCB, and unless you have exceptional sight, small chip resistors are pretty difficult to solder on without a magnifying glass. Once again, they are not expensive, and some clamps come with one that can mount on the clamp stand.



Solder Wick

Solder wick is a mesh that you lay on a joint and heat. When it heats up it also melts the solder which is drawn out of the joint. It is usually used for cleaning up solder from tracks on a circuit board, but you will need a solder sucker to clean out the holes in the circuit board. Place the wick on the solder you want to remove then put your soldering iron on top of the wick. The wick will heat up, then the solder will melt and flow away from the joint and into wick.



Solder Suckers

If you don't have a solder station with desolderer, and you work on PCB's, you are going to need one of these before too long. They are spring loaded and suck the melted solder out of the joint. They are a bit tricky to use, as you have to melt the solder with your iron, then quickly position the solder sucker over the melted solder and release the spring to suck up the solder. I find solder wick to be easier to use and more effective.



Fume Extractors

Solder fumes are poisonous. A fume extractor will suck the fumes (smoke) into itself and filter it. An absolute must for your health if you are setting up a soldering bench.



Preparation

Step 1: Preparation

If you are preparing the cable for a connector, I strongly suggest you put any connector parts on now (the screw on part of an XLR, or casing of a 1/4" jack for example). Get into the habit of sliding these on before you start on the cable, or else you can bet it won't be long before you finish soldering your connector only to discover you forgot to put the connector casing on, and have to start all over again.



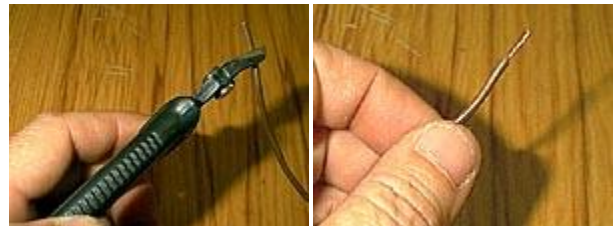
Once you have all the connector parts on that you need, you will need to strip your cable. This means removing the insulation from the end of the wire and exposing the copper core. You can either use a wire stripper, side cutters, or a knife to do this.

The obvious tool to choose to strip a wire would be.....a wire stripper. There are many types of wire stripper, and most of them work the same. You simply put the wire in, and squeeze it and pull the end bit off. It will cut to a preset depth, and if you have chosen the right depth it will cut the insulation off perfectly. It *is* possible to choose the wrong depth and cut too deeply, or too shallow, but they are very easy to use.



On the other hand, some people (myself included) prefer to use a knife or side cutters. I use side cutters for small cable and a Stanley knife for bigger cables...and although I have a couple of wire strippers, I haven't used them for years. This may seem odd, but I've got my side cutters and knife with me anyway, and they do the job fine.

If you are using side cutters (as shown here), position them about 10mm (1/2 inch) from the end, and gently squeeze the cutters into the insulation to pierce it, but not far enough to cut the copper strands of the core. Open the cutters slightly so you can turn the wire and pierce the rest of the insulation. You may have to do this a few times to cut through all of the insulation, but it is better to cut too shallow and have to turn and cut again rather than cut the core and have to start again. Now you should be able to slide the insulation off with your cutters, or pull it off with your fingers. This may sound a tedious method, but in no time at all you will be able to do it in two cuts and a flick of the cutters.



I won't explain how I use a knife to do larger cable, as I'd hate someone to slice a finger or thumb open following my instructions. Using a sharp blade like that certainly does have its risks, so stick with wire cutters or side cutters if you are at all unsure.

If your connector has been used before, make sure you remove any remnants of wire and solder from the contacts. Do this by putting the tip of your soldering iron into the hole and flicking the solder out when it has melted. *Common Sense Alert!* Please be careful when you flick melted solder...flick it away from you.

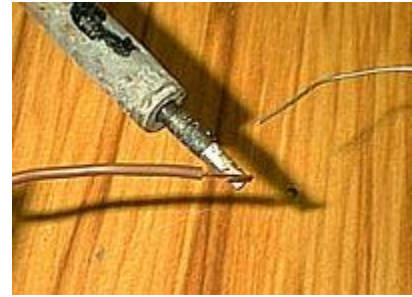


Tinning

Step 2: Tinning

Whatever it is you are soldering, you should 'tin' both contacts before you attempt to solder them. This coats or fills the wires or connector contacts with solder so you can easily melt them together.

To tin a wire, apply the tip of your iron to the wire for a second or two, then apply the solder to the wire. The solder should flow freely onto the wire and coat it (if it's stranded wire the solder should flow into it, and fill the wire). You may need to snip the end off afterwards, particularly if you have put a little too much solder on and it has formed a little ball at the end of the wire.



Be careful not to overheat the wire, as the insulation will start to melt. On cheaper cable the insulation can 'shrink back' if heated too much, and expose more copper core than you intended. You can cut the wire back after you have tinned it, but it's best simply not to overheat it.

The larger the copper core, the longer it will take to heat up enough to draw the solder in, so use a higher temperature soldering iron for larger cables if you can.



To tin a contact on an audio XLR connector, hold the iron on the outside of the contact for a second or two, and then apply the solder into the cavity of the contact. Once again, the solder should flow freely and fill the contact. Connectors such as jacks have contacts that are just holes in a flat part of the connector. To tin these you put your iron on it, and apply the solder to where the iron is touching. The solder should flow and cover the hole.



Once you have tinned both parts, you are ready to solder them together.

Soldering

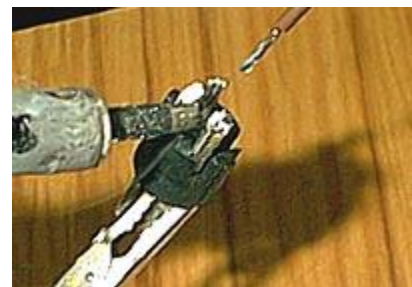
Step 3: Soldering

This step can often be the easiest when soldering audio cables.

You simply need to place your soldering iron onto the contact to melt the solder.

When the solder in the contact melts, slide the wire into the contact.

Remove the iron and hold the wire still while the solder solidifies again.

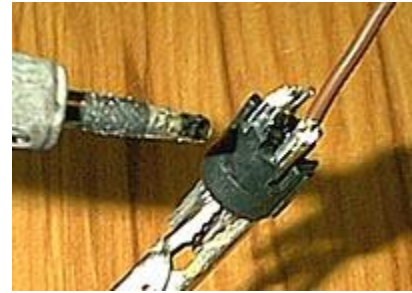


You will see the solder 'set' as it goes hard.

This should all take around 1-3 seconds.

- A good solder joint will be smooth and shiny.
- If the joint is dull and crinkly, the wire probably moved during soldering.
- If you have taken too long it will have solder spikes.

If it does not go so well, you may find the insulation has melted, or there is too much stripped wire showing. If this is the case, you should desolder the joint and start again.



Cleaning Your Soldering Iron

You should clean your tip after each use. There are many cleaning solutions and the cheapest (and some say best) is a damp sponge. Just rub the soldering iron tip on it after each solder.

Another option is to use tip cleaner. This comes in a little pot that you push the tip into. This works well if your tip hasn't been cleaned for a while. It does create a lot of smoke, so it is better not to let the tip get so dirty that you need to use tip cleaner.



Some solder stations come with a little pad at the base of the holder. If you have one of these, you should get into the habit of wiping the tip on the pad each time you apply solder with it.



If you need to clean solder off a circuit board, solder wick is what you need. You place the wick on the joint or track you want to clean up, and apply your soldering iron on top. The solder melts and is drawn into the wick. If there is a lot of solder the wick will fill up, so gently pull the wick through the joint and your iron, and the solder will flow into it as it passes.



Tips and Tricks

1. Melted solder flows *towards* heat.
2. Most beginning solderers tend to use too much solder and heat the joint for too long.
3. Don't move the joint until the solder has cooled.
4. Keep your iron tip clean.
5. Use the proper type of iron and tip size.

Troubleshooting

If either of the parts you are soldering is dirty or greasy, the solder won't take (or 'stick') to it. Desolder the joint and clean the parts before trying again.

Another reason the solder won't take is that it may not be the right sort of metal. For example you cannot solder aluminum with lead/tin solder.

If the joint has been moved during soldering, it may look grainy or dull. It may also look like this if the joint was not heated properly while soldering.

If the joint was overheated the solder will have formed a spike and there will be burnt flux residue.

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