Electronic Basics

Welcome to Electronics Basics:
Part of the TRCY and Wires and Circuits clubs of Yahoo!

Additions and amendments made by fellow TRCY members Dennis Clark, Gary Croll and Wilf Rigter and thanks goes to all the members of TRCY

We at TRCY and Wires and Circuits hope this tutorial will give all who need it an introduction to electronics. We'll try to teach you about circuit schematics, basic component functions and uses, Multimeter use, and all other info that a beginner needs to know. Over the years, many people have learned the fundamentals of electronics by reading "**Getting Started in Electronics**", by Forrest Mims III and by experimenting with the **All-in-One electronics kit** both available from your local **Radio Shack** store. This tutorial uses the same successful method of presenting information as used in that invaluable Radio Shack book.

While this tutorial is no substitute for taking formal courses in electronics, here you can get an overview of the subject and familiarize yourself with the basic concepts. You'll also find links to the best electronics tutorial websites, many with advanced subject material to help you learn the more complex electronics concepts. To help you locate all those parts for a project, please check out our Reference area for a list of reliable electronics suppliers.

With that said, let's get started learning. Most all electronics components either generate, store, control or switch electricity in someway. A circuit is made of various components that act together to produce a desired effect. There is a lot to learn about electronics and you may never truly understand everything about the subject. But when you break down even the most complex circuits you'll find the same basic building blocks. You'll also find the same basic principles and methods repeated in most electronic devices.

The first REALLY big thing we need to learn is that there are two types of current: DC, which stands for Direct Current and AC, which stands for Alternating Current. DC is what you get from a battery and flows in only one direction. AC on the other hand is alternating current, alternating because it changes direction a number of times per second, which is specified as frequency. The AC we get from the power company has a frequency of 60 cycles per second. We will not go into details of the intricacies of AC and DC, just know that most electronics that we will work will use DC voltage. Some may use AC as power that will in turn be made in to DC current, such as a power supply. DC you can play around with more and you only need worry about ruining a component or two. For circuits that use AC power you better know what you are doing.

The next REALLY big thing we need to learn is Ohm's Law. Ohm's Law is designed to allow us to specify and measure the quantity and power of a direct current. Below you will find a drawing of Ohm's Law.

V or sometimes E stands for Voltage which is a potential difference.
I is Current, which is the flow of electrons. Current is the quantity of voltage passing a given point. The unit of current is the AMP or ampere.
R stands for Resistance. Conductors like resistors and capacitors resist to some degree the flow of current. The unit of resistance is the OHM.
P stands for Power. The work performed by an electrical current is called power. The unit of power is the WATT. The power of a direct current is its voltage multiplied by it's current.

OHM's Law:

$V = IR$

$R = V/I$

$I = V/R$

$P = VI = I^2R$

V - is equal to Current multiplied by Resistance
I - is equal to Voltage divided by Resistance
R - is equal to Voltage divided by Current
P - is equal to Voltage multiplied by Current or Current square multiplied by Resistance

RESISTORS

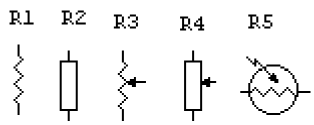
And now after a taste of Ohm's law let us move onto resistors and capacitors. Resistors come in all types of packages but they all do the something, which is to limit current. Resistors are pretty easy to keep track of because they are color-coded. They have three strips on each one that give the resistance value. Most also have a forth band to indicate the tolerance of the resistor. You can connect resistors in any which way, they have no positive or negative ends.

Black	0	0	x1
Brown	1	1	x10
Red	2	2	x100
Orange	3	3	x1,000
Yellow	4	4	x10,000
Green	5	5	x100,000
Blue	6	6	x1,000,000
Violet	7	7	x10,000,000
Gray	8	8	x100,000,000
White	9	9	

Forth Band indicates tolerance or accuracy of the resistance: Gold = 5% Silver = 10% None = 20%

The way this system works is easy, say you have a resistor with the colors Orange, Blue and Red. You find your first number, which is 3. You find your next number for blue, which is 6, and then you multiply by your last number. So we take 36 X 100 and we get 3600 ohms. Now something else that is very important to know is that 1,000 ohm is equal to 1K. Like wise 1,000,000 ohm is equal to 1M. M and K are what you are more often to look up when buying a resistor rather than the pure ohm value. So our resistor with the colors of Orange, Blue and Red is a 3.6K resistor. Pretty simple right?

Below are some common ways resistors are depicted in schematics. The most common way is with the use of R1. In schematics you will usually find the value of the resistor next to it. R3 and R4 are variable resistors. These are resistors, which you can change the resistance of. Variable resistors are called potentiometer. They are used to adjust the volume of radios, brightness of a lamp or adjust the sensitivity of a sensor. These resistors are not color coded, but you'll most often find a stamped labeled on the bottom or inner ring giving the value of pots as they are called. Another version of the variable resistor is the trimmer. These are potentiometers with a plastic thumbwheel or slot for a screwdriver and are designed for occasional adjustments. R5 is a photo resistor, which is sensitive to light and gives a higher or lower resistance value depending on the level of light.



You can use resistors in series to make a higher value resistor. You simple add the value of each resistor in series. So if you need a 42K resistor and you have a 20K and a 22K then you connect them in series and you have your 42K resistor.

CAPACITORS

Capacitors have 3 primary functions:

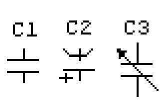
1. To store a charge, much like a battery. These capacitors are normally electrolytic and are used in situations like power supplies where a fluctuating DC voltage needs to be smoothed, or, have the ripple taken out.

2. A capacitor is used to block DC while allowing AC to pass through such as in an audio amplifier where we are passing the audio signal through from one stage to the next.

3. To counteract inductive reactance in order to create a "tuned circuit".

4. A cap can also be used as a spike filtering, which is slightly different than smoothing an AC signal. The term for this purpose is "bypass cap" in case anyone out there was wondering about that one.

When power gets to them they hold a charge right away, but will eventually discharge if left alone or you can discharge a capacitor by hitting both of it's leads together or connect a resistor between both leads. Capacitors have different levels, which are specified in farads. Below are common schematics symbols for capacitors and common farad ratings.



1-Farad = 1F
1-Microfarad = 1mF or uF = .000001F
1-Picofarad = 1pF - .000000000001F

C1 shows a normal fixed capacitor, these you can connect in like resistors. C2 shows one that is polarized, this means you must connect it's positive lead the most positive connection point in it's placement. With polarized capacitors you'll mind that they are marked with either a plus to show the positive side or with a negative to show the negative side. C3 shows a variable capacitor, I have yet to see one of these in a circuit.

For the number:	Multiply by:
0	1
1	10
2	100
3	1000
4	10,000
5	100,000
8	0.01
9	0.1

Capacitors are not color-coded but they do have a numbering system that tells you what their value is. This can be tricky to find the value of an odd capacitor but most of the time you'll see number like this: 151K The first and second digits are the capacitors value. For the third number find it's multiplier value on the chart to the left and simple multiply. So 151K is a 150pF capacitor. You might also see a notation like this, EG 104 or 104K both of which are .1uf caps. Caps, of course here is short for capacitor.

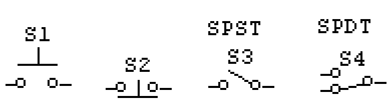
Letter	10pF OR Less	OVER 10 pF
B	0.1pF	
C	0.25pF	
D	0.5pF	
F	1.0pF	1%
G	2.0pF	2%
H		3%
J		5%
K		10%
M		20%

The letter tells you the tolerance of the cap; you can look up the tolerance on this chart. A note I want to add to this capacitor section is that sometimes you may see the letter R on a cap, which would signify a decimal point. So if you see 2R2 that would equal 2.2 (pF or uF). My best advice is to keep your capacitors well organized and with their packaging if you are not confident you can distinguish one capacitor from another.

An important thing to take notice of is that capacitors DO NOT add in series like resistors, just the opposite, two 1mfd capacitors in series equal 0.5 mfd.

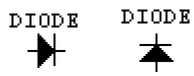
SWITCHES

I know, you are saying I know what a switch is. Well we are going to learn about them anyway. First let's look at S1, this is a Normally Open push button switch. NO is short for Normally Open. This would be a good simple way to add a sensor for a robot when it hits a wall. If this switch hit a wall it would close and complete the circuit and current would travel though it. S2 is a NC or Normally Closed switch. When a NC switch is hit is opens the circuit and so no current runs though it while it is depressed.



S3 is a Single Pole, Single Throw switch. You flip it and power is on...this is like a normal wall switch. S4 is a Single Pole, Double Throw. With this type of switch it is possible to switch between two different devices.

DIODES



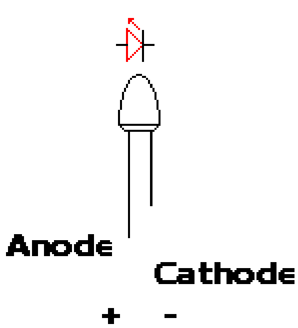
The simplified explanation of how a diode works is to tell you that it allows electricity to flow in one direct (forward) and blocks it in the opposite direction (reverse). To the left is a picture of how diodes appear in schematics. Diodes will have a band on them, this band indicated the cathode end. The other end is the anode.

There are different types of diodes. The most common in small electronics is the signal diode and can be used to transform low current from AC to DC, multiply voltage, perform logic and absorb voltage spikes created by other devices. You also have your zener diodes that can function like a voltage sensitive switch. You also have your LED's, which stand for Light Emitting Diodes, which we will discuss later. And you have your photodiode, which detects light, this also to be addressed later. Circuit schematics will always give you the name of the diode used, it will be something like 1N4003 or 1N914...this is how you will look them up to order or buy them at a local electronics store.

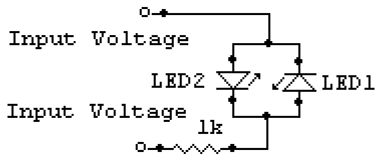
An important note on all forms of diodes is that they are not like resistors; they have positive and negative ends. Current will flow when a diode's Anode end is more positive than it's Cathode end.

LED's and OPTICS

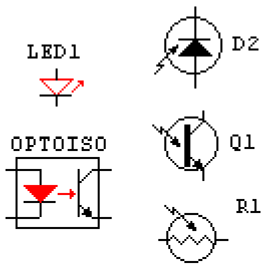
LED stands for Light Emitting Diode. LED's convert an electrical current directly into light. The light emitted by an LED is directly proportional to current through the LED. This means LED's are ideal for transmission of information. However, LED's need direct line of sight and they usually have a short range of light emission. Because LED's are current dependent they need to be protected from excessive current with a resistor. For most robotic applications with power sources of around 9 volts I find that a 1K resistor will always to the trick. A normal schematics symbol for a LED is pictured below along with a drawing of what an actual LED looks like. You'll notice one lead is longer than the other, in most cases a longer lead indicates that it is the positive lead.



It might be easy to dismiss the LED and assume all it does is light up, but LED's are very interesting electronics components and have some surprising functions. For instance if you take a Jumbo LED (of any color) and connect your Multimeter up to it for voltage reading and point the LED towards a very bright light source you'll get a voltage reading. In direct sunlight you can get a reading of 1.5 volts from a normal LED! Some people even think it is possible to make a color sensor using a LED like this, however after much experimenting with this I have found LED's to not be suitable for use as a sensor. But it is interesting and you should not dismiss the LED as something that just lights up.



An LED can stop current flow like any normal diode. The schematic to the left shows a voltage indicator. You can apply a positive and negative voltage to the points labeled "input voltage." If you switch the order of positive and negative the opposite LED will light.



D2 looks a little bit like a LED, but is it? Nope it's a Photo-Diode. It is designed to detect light, which is why there is a little arrow going into the schematic symbol.

Q1 is a Photo-Transistor, it's a bit like a Photo-Diode in the fact that it detects light waves, however photo-transistors, like transistor are designed to be like a fast switch, so for light wave communications or use as light or infrared sensors a photo-transistor is what you want! The most common form of phototransistor is the NPN collector and emitter transistor with no base lead. Light or photons entering the base (which is the inside of the photo-transistor) replace the base - emitter current of normal transistors. See Transistors below for more details on this.

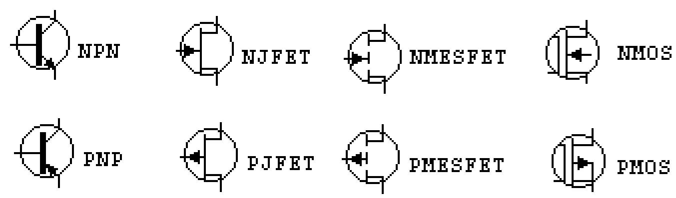
R1 is a resistor, a Photo-Resistor! It acts like a variable resistor because it changes resistance as the light level changes. They have no positive or negative end and there resistance is very high (up to millions of ohms) when no light is present. These are great for simple robotics eye to find the darkest or brightest point in a room or detect the difference between day and night. You'll find photo resistor in many common security sensor and toys, including the Furby.

Now what is the schematics symbol that looks like a box with a LED and phototransistor inside? It is an "Opt isolator" which means simply optical isolator. It really is not much more than a box with a Light Emitting Diode and a phototransistor inside. This would not be used as a sensor. It as used as a switch. Say you have a high-powered motor you want to control with your computer. You would use an opt isolator in-between your computer and motor (along with other proper control circuitry) so that you computer can control your motor with out being directly linked to the motor incase something should go wrong the motor end, nothing will happen to your computer because it is "isolated" via the opt isolator!

TRANSISTORS

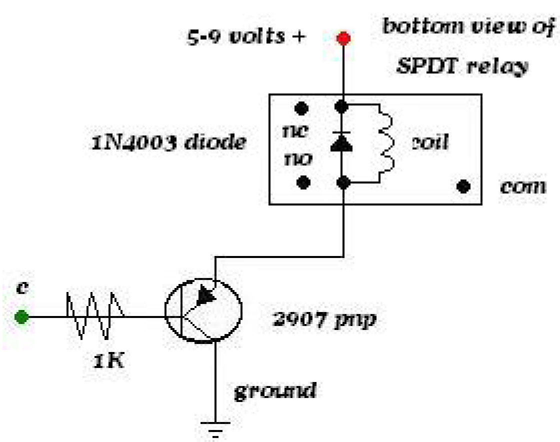
Transistors are semiconductor devices with three leads. For those that don't know "leads" simply refer to the pins or wires coming from a device or component. A very small current or voltage at one lead can control a much larger current flowing through the other two leads. This type of action turns a transistor into a mechanical switch. That's pretty much the basic function, it's a switch. Most integrated chips or IC's as they are commonly called chips with several or many thousands of transistors inside. Computer processors are built up from millions of transistors. However, switching is not all a transistor can do, they can also be used as amplifiers.

The most basic transistor is probably a bipolar transistor and these transistors are made of three layers, which are the Emitter, Base and Collector.



The two schematics symbols for basic bipolar transistors are shown to the far left with the labels NPN and PNP. A small current going to the emitter and base of these transistors will cause a much larger emitter and collector current to flow.

For example if you wanted to control a relay with your computer you would need a transistor of this sort. The transistor would allow the very small current produced by your computer would go to the transistor's base and emitter, which would allow the larger current on the emitter collector to flow to the relay. See the schematics below:



The emitter is the transistor pin that is connected to the ground. The Base is the pin going to the 1K resistor and the other pin is the collector. A data pin from your computer's printer port could connect to other end of the 1K resistor (marked C). You would also need a ground from the computer printer port to complete this circuit. I want to point out the relay in the picture was drawn by hand fully illustrate the pin out from the bottom of the relay.

Do you see the diode that connects across the relay coil? Do you know why it's there? The diode protects the transistor and computer from voltage spike that might come back from the activation of the relay.

Transistors of this sort have a few key features in common for instance the base - emitter junction and a diode will not conduct until the forward voltage exceeds 0.6 volts.

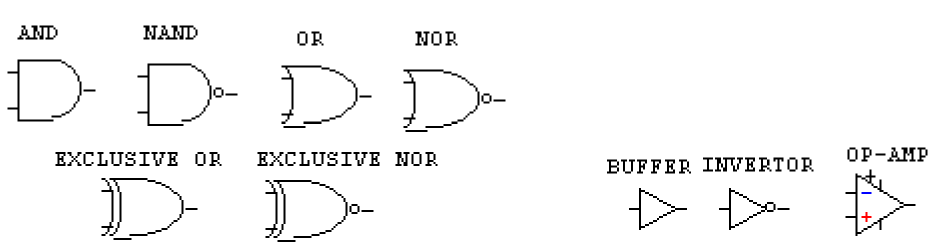
Too much current will cause a transistor to become hot and stop functioning. If a transistor is hot to the touch, disconnect the power it! Some project will force transistors to become hot and so proper heat sinks are connected to these transistors. Transistor meant for heavier loads will come with a metal tab on the back for mounting to a heat sink. A heat sink is black metal that is designed to dissipate the heat coming from these "power" transistors. As they relate to robotics heavy-duty motor controls (for motors 12 volt and up) you might see power transistors like this with heat sinks attached to them. Also power supplies often have these sort of transistors. Transistors of this sort are often MOSFET's, which stands for Metal Oxide Semiconductor Field-Effect Transistor, or MOSFET for short. These transistor schematics symbols are picture to the right in the pervious schematics listing picture. MOSFET allow a few volts to switch or amplify many amperes at very fast speeds, this makes them perfect for control of larger motors.

The middle transistor schematics symbols are JFET's or Junction Field-Effect Transistors. JFET's can be used as amplifiers or switches just like all other transistors but they have a built in high resistance on their Gates (JFET's don't have an emitter, base and collector they have a source, gate and drain pins) so the have little effect on external components connect to their gates. If a JFET were used in the above relay circuit this would mean the computer would be even safer from voltage spikes. JFET's are not often used for high power jobs.

INTERGRATED CIRCUITS

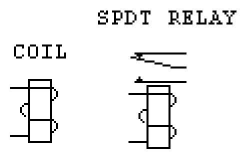
Integrated Circuits or IC's for short reference are small electronics circuits contained inside a silicon chip. For instance an IC's might have for build in transistor with 2 diodes and 2 resistors....this may never be displaced in the schematics symbols but that are build inside by tiny layers of silicon. IC's are what make smaller electronics possible and what drive you computer; there are millions of different types of IC's. At their most common core an IC is built up from basic transistors.

Integrated Circuits some in many different packages, the most common by far is the "dip" which stands for Dual In-line Package, in other words you have two rows of pins of a chip like this. Most IC's will come with a little index marker, which will indicate which is pin 1, the marker looks like a little indented hole. DIP can range in pin count from 4 to 64. Most IC's of this nature are clearly marked with the part number on them, such as 7404 or 555. Some schematic symbols for IC's will look like the actual dip package with a box and the pins labeled and going to the other components of the circuit. This is the case with many schematics with 555 chips in them. However, most of the time the chip is cut up and parts of it are placed though out the circuit schematics. The cut up parts are the gates of the chips. The gates are like individual circuits inside the IC. The functions of these gates are too numerous and complex to go into right now but below the most common schematics symbols for them are shown.



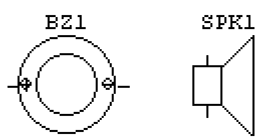
THERE IS MORE TO COME ON IC's!

RELAYS and SPEAKERS



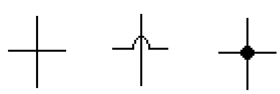
Relays are electromagnetic switch. Small current flows through a coil in the relay, which creates a magnetic field that pulls the one switch contact towards or away from another. Relays are pretty common; in fact when you signed online you probably heard the click of a relay right before your modem dialed up you internet connections!

There are many different types of relays, but they all do the same things, which is to act like a switch. Inside a relay you'll find a coil (as pictured) and an arrangement of contacts which provide different types of switching, such as SPST, SPDT and DPDT or Double Pole Double Through.

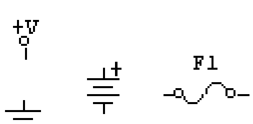


BZ1 is the common schematic symbol for a buzzer. SPK1 stands for speaker1 and is the common symbol for a speaker. The "1" is added so signify the first speaker. You'll often see a number even if there is only one component of the type used.

WIRES and POWER



Here we have a picture of what some wire connections in a schematic look like. The one with the black dot in the middle is the only one that shows connections. The first symbol shows two wire connections over top one another, but they are not connected. The middle symbol is not connected and shows the horizontal wire curving to better illustrate to schematic reads like you that no connections is intended.



These are common schematic symbols associated with power. The one with a +V is showing you where the positive voltage goes. You'll most often see the voltage value next to the V, such as 12V for 12 volts.

The symbol below the positive is the negative or ground line schematic symbol. If you are working on a project such as a robot where you might have many different circuits working together, you'll want to make sure your grounds are connected together.

The middle symbol shows the common schematic symbol for batteries, with a + indicating where the positive end needs to go. If you notice it show a big line, with a small line, and a big line and another small line. This is indicating the proper polarity of battery placement. Say you need 6 volts for a circuit. You can take 4 AA-batteries (1.5 volts each) and connect them in a line with the negative of the first connecting to the positive of the next and so forth...the batteries then add up to create 6 volts. If you try to connect all the positive ends and all the negative ends of the batteries together you are going to have fire hazard on your hands!

The schematics symbols labeled as F1, is a fuse. This would be connected in between the positive side of your power source and the positive side of your circuit. The idea is that a fuse will blow before your batteries or circuit does. You do not always need this protection but it might be a good idea with an AC projects or projects with high voltage motors.

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Electricity and Electronics: Teaching and Learning Resources
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Think something is not right in Denmark? Or at the very least maybe you think something is wrong with the content, well don't blow a gasket, let me know about it! E-mail the author.