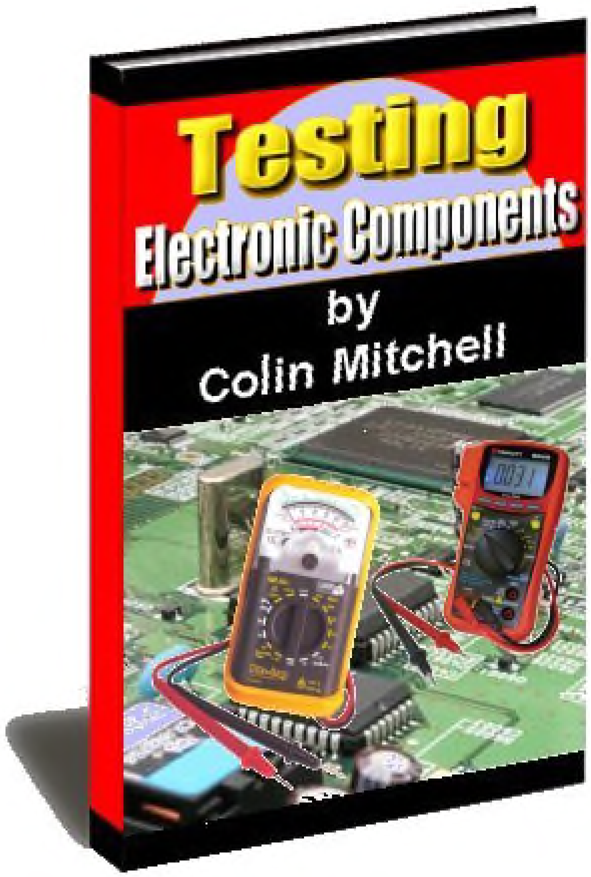

This eBook shows you how to TEST COMPONENTS.
To do this you need "TEST GEAR." The best item of Test Gear is a MULTIMETER. It can test almost 90% of all components. And that's what we will do in this eBook.

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CONTENTS

Use your "brain, knowledge and your fingers."

Before we start, fixing anything is a combination of skill, luck and good diagnosis.
Sometimes you can fix something by letting it run until it finally fails.
Some things start to work as soon as you touch them.
Some things can never be fixed.
But some things can be fixed by feeling the temperature rise and deciding if it is getting too hot.
Sometimes you can smell something getting too hot.
Sometimes you can see SMOKE.
All these things make you a very clever technician and about 50% of faults will be fixed by looking for dry joints, burnt parts, overheating and carefully inspecting an item before you disturb it.
By simply touching different items you can quite often feel a hot item and home-in on the fault - at a saving of hours of work.
Servicing is not "A bull at a gate" approach.
You may be able to service something by turning it on and leaving it for hours - and start thinking.
It may take you a day to come up with the answer.
Believe me. That's how it worked for me - while fixing over 35,000 TV's. But that was in the days of valve TV's and individual parts, soldered from one tag strip to another.
Things have changed now. Parts have become smaller and everything is soldered to a printed circuit board. And we have simple chips and complex chips and microcontrollers and

power chips.
So, you need to be a lot smarter. You need to be very careful when "poking around," and you need a couple of very simple pieces of test equipment. Starting with an Audible Continuity Tester and a Logic Probe.
But firstly this article covers and explains lots of interesting features about testing components so you know what to look for when fixing a piece of equipment.

TEST EQUIPMENT

Everyone thinks TEST EQUIPMENT will "solve the problem."
This is a big big MISTAKE.
Test equipment can help solve a problem and it can "lead to frustration," "give an incorrect answer," "mess you up," and make things worse.
You have to be very careful with test equipment and especially EXPENSIVE equipment because it is very sensitive and can detect pulses and glitches and voltages that are not affecting the operation of the circuit.
You will learn a lot of tricks when reading through this article, but let me say two things.
There are lots of faults and components that you cannot test with "test equipment" (either In or OUT of the circuit) because the fault is either intermittent or the equipment does not load the device to the same extent as the circuit.
And secondly you need both an ANALOGUE multimeter and a DIGITAL meter to cover all the situations.
And if you are working on a car, you only need a $5.00 analogue meter because it will be dropped or fall into a crack, **get oily and dirty** and you will only lose $5.00
You will learn that a digital meter will pick up spikes and signals on a line and show an incorrect reading.
That's why you need to back-up your readings with an analogue meter.
When you charge a battery it gets a "floating voltage" and this will be higher than the actual voltage, when the battery is fitted to a project. An analogue meter will draw a slight current and remove the "floating voltage" after a period of time.
Component testers can also give you a false reading, either because the component is out of range of the tester or intermittent and you need to be aware of this.
Oscilloscopes can also display waveforms that are parts of glitches or noise from other chips and these do not affect the operation of the part of the circuit you are investigating.
Sometimes you cannot pickup a pulse because it is not regular and the trigger on the oscilloscope does not show it on the screen. You may think it is missing.
It all depends on the "speed of the oscilloscope" - it's maximum frequency of operation.
Lastly- Power Supplies. You cannot test globes and motors on a power supply because the starting current can be 5 times more than the operating current. The power supply may not be able to deliver this high current and thus you will think the motor or globe is faulty. Or the power supply is faulty.

You don't have to buy expensive test equipment but you do need it to do the simplest testing and fixing.

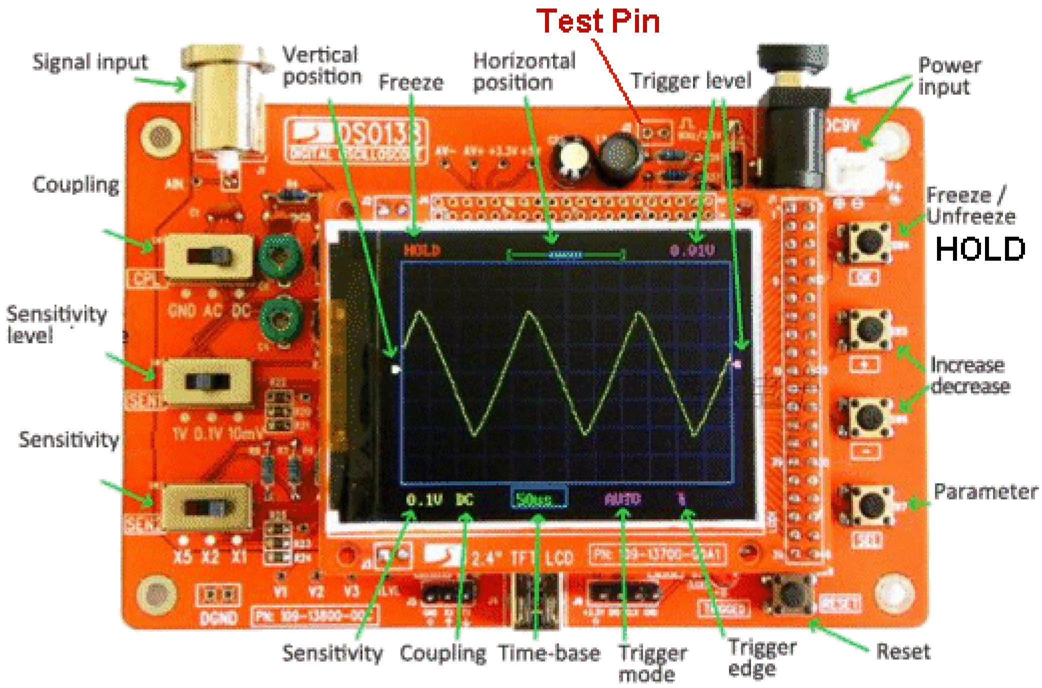
Here are the first four things you will need:

LED TESTER - tests LEDs
See the project: HERE

See the project: HERE

The CRO - OSCILLOSCOPE - DIGITAL CRO

If you want to look at the signals in a project, you can get a low cost DIGITAL OSCILLOSCOPE for less than $40.00, such as this:



It has very good resolution and it needs a little bit of understanding to work out the amplitude and frequency of the signal your are displaying.
You can buy the oscilloscope on Aliexpress for about $40.00 and at the same time buy a LED that flashes RGB (either fast or slow) so you can use the CRO to watch the waveforms produced by the LED. Unfortunately the flashing LEDs are only available for $7.00 for 100.
The CRO comes fully built and tested but it needs a stand so you can use it on the work-bench. Wooden blocs 9 x 17 x 50mm are available from $2.00 shops and if you cut the end at 20° and screw them to the board via the two lower holes you will have an ideal stand as sown in the following image:

Adding a stand so you see the screen

A 9v or 12v battery is needed with a switch to power the CRO and you are ready to see some waveforms.
Firstly you need to see a waveform on the screen and a RGB slow flashing LED has a microcontroller inside the chip that creates the random pattern. Connect the LED to 9v or 12v via a 1k resistor and connect the probe across the LED. The 1k resistor will allow you to see the signal produced by the microcontroller.

This is a much better DSO
It has internal battery and a clip-out stand

It has all the features of the other model and a similar price

SETTING UP THE CRO

The CRO has lots of features and the challenge at the beginning is to get a TRACE on the screen.
Firstly we will explain the terms.
The PROBE in this case is like two test leads (red and black). The RED lead is called the TIP and the BLACK lead is called the EARTH.
The black lead is normally clipped onto the chassis of a project and the red lead touches all the components.
Stick to this convention so the waveform is not inverted.
The top left-hand slide switch is called the COUPLING. It has 3 positions. The left position is connected to the tip of the probe and it "shorts the tip to earth" so that the trace will be a smooth line across the screen.
This is used in the set-up procedure so the trace can be adjusted to travel across the middle of the screen so the amplitude of the waveform can extend equally above and below.
The middle position of the switch connects a capacitor to the tip so only the amplitude of the waveform will appear on the screen.
The right position of the switch connects the tip directly to the input of the CRO and if there is any DC voltage on the waveform, it will shift the waveform up or down the screen.
This might take the waveform above or below the screen and you will not be able to see it, so use the AC coupling when you are setting-up.
The other two slide switches are what we call SENSITIVITY.
The input of the CRO is very sensitive and every line across the screen is equal to a 10mV signal. There are 4 lines above the centre line and 4 lines below the centre-line. These lines are called GRATICULES but we will just call then amplitude lines or X-lines or X-axis lines. They are voltage lines.
But this means the CRO will only show a waveform that is 80mV high.
To show larger waveforms the CRO has attenuation networks - resistor networks - that reduce the incoming waveform so it will appear on the screen.
Flick both switches to the right.
You have now selected 10mV and x1.
This means each line across the screen will be equal to a signal of 10mV

This means each line across the screen will be equal to a signal of 10mV.
When the bottom slide switch is in the middle position, each graticule will represent a waveform that has an amplitude of 20mV. In other words the screen will show a waveform 160mV high.
With the bottom slide switch to the right the screen will show a waveform 50 x 4 x 2 = 400mv high. This still a very small waveform.
Now slide the middle slide-switch to the middle position and the full amplitude on the screen becomes: 100mV, 200mV and 500mV per screen division.
Finally, with the middle slide-switch to the left position, the graticules become 1v, 2v and 5v. This means the screen will display 80v amplitude signals.
On the right-hand side of the module are 4 press-buttons.
We start with the lower button. called **SELECT**
This is the button that is going to put the trace across the middle of the screen. We say: across the Y-axis - through the "origin." The origin is the meeting of the X and Y axis and in this case the X-axis is the left-hand side of the screen and the Y-axis is the middle of the screen.
Turn the module ON and press the lower button. The cursor will highlight parameters at the bottom of the screen at each press and then will seem to disappear. But it is highlighting the arrow at the left of the screen and changing the arrow from yellow to blue. When it is blue, you can move the arrow up and down the screen by pressing the second button to make it go up and the third button to make it go down.
This arrow will take the trace up and down the screen so you can fit all sorts of waveforms on the screen.
When setting-up, place this arrow along the Y-axis so you can see the trace.
The trace is not a line across the screen but a dot or pixel flying across the screen so fast that is leaves a trail that you see as a line.
The fourth button sets the speed at which this dot flies across the screen.
The fastest time is 10 microseconds (10uS) And this is the time for the pixel to travel from one vertical line to the next. In other words it will take 80us to travel across the screen.
But we normally do all our calculations within one division (as you will see in a minute). If a waveform starts on the Y-axis (the line running across the centre of the screen) and rises to a peak when the scan is in the middle of the graticule and then falls to a minimum and then rises again and meets the axis at the vertical line we say the waveform has completed one cycle in 10us.
This is the basis of all our calculations when we determine the frequency of the signal - the signal is the incoming wave.
Here is a table for all the frequencies:

10uS	100kHz
20uS	50kHz
50uS	20kHz
0.1mS	10kHz
0.2mS	5kHz
0.5mS	2kHz
1mS	1kHz
2mS	500Hz
5mS	200Hz
10mS	10Hz
20mS	5Hz
50mS	2Hz
0.1S	1Hz

0.1S	1Hz
0.2S	These
0.5S	are
1S	waiting
2S	times
5S	for a
10S	wave to
.... 500Sec	appear

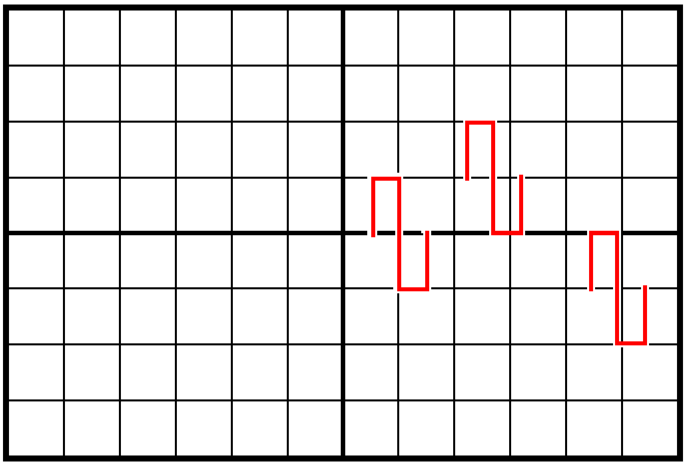
SWEEP

Originally all CRO's were analogue devices and used a CATHODE RAY TUBE, in which an electron beam was projected from the back of the tube (the neck) onto the screen. The screen had a phosphor coating and when the electron beam hit the screen it fluoresced and you could see the spot. The spot was then made to travel from the left of the screen to the right and the screen remained illuminated for a short period of time after the beam hit the area. A bit like the tail of a comet. This gave the effect of a brightly illuminated line across the screen.
The screen on this CRO is DIGITAL and all the effects are created by software in the microcontroller.
So that the screen appears like the original CRO's, the software produces a trace across the screen so you know what is happening.
We can pretend the trace is a "flying spot" and this is called the SWEEP.
The sweep is measured by how long the "spot" takes to travel ONE GRATICULE. That is from one vertical line to the next.
In our case this is as fast as 10 microseconds. If a wave is being processed by the microcontroller, the "flying spot" moves across the screen from the left-side, rises to the amplitude of the signal, moves across the screen at the same amplitude and then falls to the lowest point of the signal and then across the screen, to the rising edge of the wave and continues in the same way to the right of the screen.

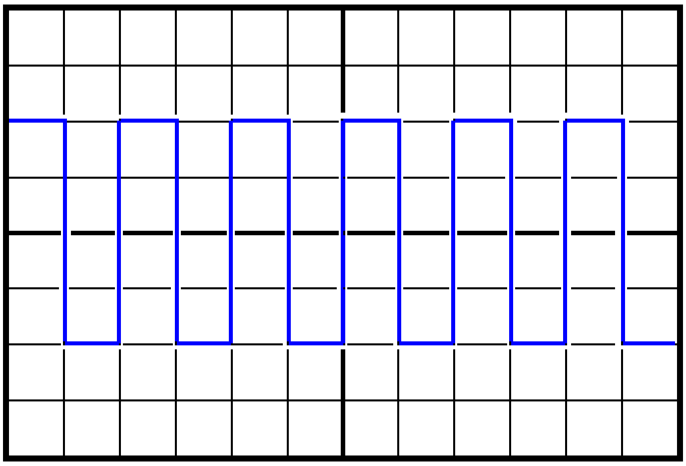
TEST POINT

All CRO's have a TEST POINT (or TEST PIN) that produces a 1kHz square wave with a known amplitude. The tip of the probe touches this point and the screen displays the waveform. This allows the operator to confirm the settings on the screen are correct and the trace is in the middle of the screen.
You don't need to connect the earth lead to view this signal as the earth is connected internally on the board.

The following diagram shows 3 waveforms:



The frequency of the signals is the same (such as 10kHz) and we are only showing one cycle to explain this feature.
The aim is to get the rise or fall of the wave so that it sits ON a graticule so that you can count the number of cycles across the screen and count the number of graticules.

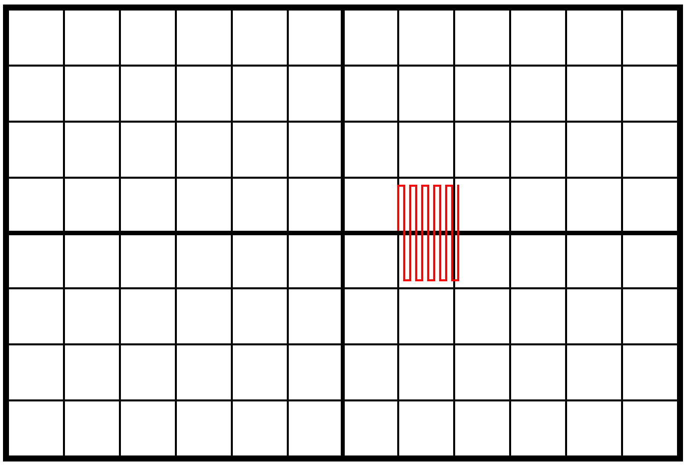


In the image above we have six full cycles across 12 graticules. You cannot see the rise of the first cycle but we can assume (correctly) that it will be exactly the same as the rise of all the other cycles. And the same applies to the last rise.
We now select 10 graticules and this means we select ten "spacings" and in this distance we can count 5 complete cycles. This makes our calculations easy.
So, we have one cycle in 2 graticule-markings.
Suppose the sweep is set to 10uS. If we have one cycle per graticule, the frequency would be 100kHz. But the frequency takes 2 markings for each cycle and it is has a lower frequency than 100kHz. In fact it is 50kHz. To prove this, you can change the sweep to 20uS and each cycle will occupy one graticule.

SAFETY
To prevent damage to the input of the CRO, it is best to fit a 1k resistor to the tip and use the lead of the resistor to probe the equipment you are testing. The input of the CRO is fairly high and 1k will not affect the amplitude of the signal.

MAXIMUM FREQUENCY
This CRO is not MHz or GHz CRO. It is a $40.00 Digital CRO for Audio work and will detect a lot of signals on microcontroller projects that use 1MHz to 4MHz clocking. These projects will

have signals up to 250kHz and 1MHz.
The screen consists of pixels and the waveform must be one pixel wide and one pixel spacing, so you need 4 pixels to show cycle. When the frequency is too high, the lines are simply joined together and nothing can be determined.
However you can detect 4 or 5 complete cycles within a graticule and 5 cycles represents a frequency of 500kHz.



Displaying the Maximum frequency

SHIFTING THE TRACE

We have covered the feature of connecting the tip of the probe to the module by a direct link (called DC) or via a capacitor (called AC). This is called COUPLING and is determined by the top left-hand slide-switch.
We can also shift the trace up and down the screen to get more of the waveform onto the screen, especially when we have selected DC coupling and the wave is shifted up or down due to the DC offset.
DC OFFSET is the the DC voltage on some signals, where say the 12v rail voltage is present and we want to see the ripple. You can either select AC Coupling and see the trace across the centre of the screen or select DC Coupling and move the trace so it can be viewed.
Moving the trace up and down is done by the **SELECT** button.
The **SELECT** button highlights the functions at the bottom of the screen and when it highlights the arrow at the left of the screen and changes from yellow to blue, you can move the arrow up and down the screen by pressing the second button to make it go up and the third button to make it go down.
This arrow will take the trace up and down the screen so you can fit waveforms on the screen.

DETECTING SIGNALS

There are many devices you can use to produce signals on the screen. A simple CRO like this is not magic. It does not produce a waveform immediately as it needs time to process the information and if the signal is from speech, the wave will be very complex. It will consist of large and small waves with varying duration. Clean signals are much easier to understand.
Don't use the CRO near you laptop as the leads pick up scanning signals from the keyboard.
Start with the signal from the TEST POINT and view it on the screen.
You can whistle into a piezo diaphragm or talk loudly into a speaker and see the result.
You can also get a flashing or fading RGB LED and connect it a 12v supply via a 1k resistor.
Put the probes across the 1k resistor and you will see the signal from the microcontroller.

TRIGGERING

We need the trace on the screen to be as stable as possible so we can view the signal and

We need the trace on the screen to be as stable as possible so we can view the signal and work out its characteristics.
To do this there is a detecting circuit that starts to look at the wave when it has increased by a small amount. From this the circuit will start detecting the next cycle at the same point and at least the beginning of each cycle will align with each other.
Waveforms that are constant and accurate are not a problem as they will display cleanly, but the trigger feature is mainly used to stabilize a fluctuating wave.
The CRO has an automatic trigger feature and it "triggers" or "detects" the waveform automatically at a point that is determined by the software.
We can change this point if we think we can do better and the bottom button can be pressed to access the trigger feature. It is set to AUTO and by pressing the second button we can select NORM or SING.
If you want to use the NORM or SING modes, you have to select the next parameter below the screen that shows either a rising edge or falling edge for the trigger and then you have push the SELect button again to get to the right-hand arrow and change it from pink to blue and then press the up/down buttons to select the trigger point.
This feature is mainly used for signals that you are waiting a long time to receive or a waveform that occurs been a long pause.

FREEZE

Digital CRO's are called STORAGE CRO's because they store the information on the screen so it can be processed.
When you are watching the screen it is called the RUN Mode or RUNNING and the waveform may be changing so fast that you cannot see what is happening.
If you press the top button while in the AUTO mode, you will be able to freeze the screen and do some calculations. This is called the HOLD Mode.

With all these features you will able to view audio signals up to 200kHz and digital signals up to maybe 300kHz to 500kHz.

DON'T EXPECT TOO MUCH

Don't think a CRO will solve all your problems. It won't. Most of the time it will just confuse you and show all sorts of glitches and spikes in the signal that are not creating the problem.
You need to combine a CRO with a LOGIC PROBE and also look for power supply problems and smoothing as well as faulty components and dry joints.
This CRO may not be fast enough to pick up the glitch.
However you will learn the basics of operating a CRO and be able to advance to some of the more complex models.

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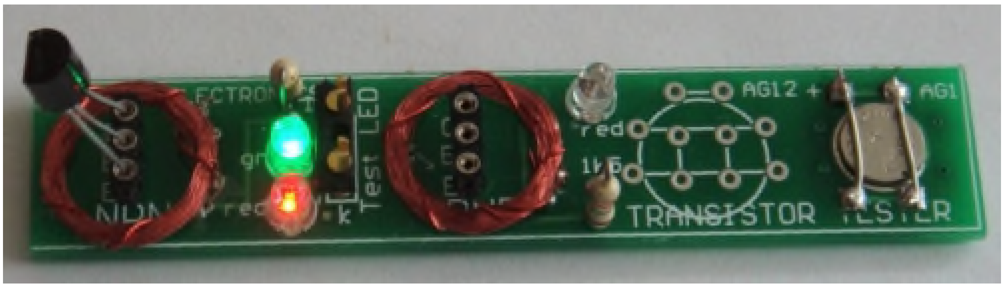
A very simple transistor tester:



See the project HERE

TEST EQUIPMENT - the POWER SUPPLY (Make your own)

Everyone and every text book tells you to buy a BENCH POWER SUPPLY.
But I am going to talk from 50 years experience.
If you are designing or repairing a project, you should connect it to a set of weak AA cells to see how it performs. This "Power Supply" will only deliver a small current and if the project has a fault, the voltage will drop considerably and the current will hopefully be small and the current will not damage anything.
This is the way you do your first "Test-Analysis." By monitoring the voltage of the supply you can work out the current requirement. You can also find out if the project works on a reduced voltage.
Once you know the project does not have any short-circuits, you can use a new set of cells and then advance to a rechargeable set of cells or a BENCH POWER SUPPLY.
This method will also let you find a short circuit or a faulty transistor by feeling each component without blowing it up completely.
The only time I have had to use a Bench Power Supply has been for projects that need a variable power supply to show a cascade of LEDs that indicate the supply voltage.
For everything else I use a weak set of cells, a good set of cells and 12v made from Alkaline cells as it will deliver more than 10 amps.
This covers the whole range of requirements at very little cost.
If you want to power a project for a long period of time, you can buy a Wall Wort or Plug Pack for a few dollars on eBay or use a 5v phone charger or put 2 or 3 discarded chargers in series to get 10v or 15v. Put 1,000u electrolytic across each 5v output to help balance the contribution from each charger.

MULTIMETERS

There are two types:

DIGITAL and ANALOGUE

A **Digital Multimeter** has a set of digits on the display and an Analogue Multimeter has a scale with a pointer (or needle).
You really need both types to cover the number of tests needed for designing and repair-work. We will discuss how they work, how to use them and some of the differences between them.

DIGITAL AND ANALOGUE MULTIMETERS

BUYING A MULTIMETER

There are many different types on the market.
The cost is determined by the number of ranges and also the extra features such as diode tester, buzzer (continuity), transistor tester, high DC current and others.
Since most multimeters are reliable and accurate, buy one with the greatest number of ranges at the lowest cost.
This article explains the difference between a cheap analogue meter, an expensive analogue meter and a digital meter. You will then be able to work out which two meters you should buy.

Multimeters are sometimes called a "meter", a "VOM" (Volts-Ohms-Milliamps or Volt Ohm Meter) or "multi-tester" or even "a tester" - they are all the same.

USING A MULTIMETER

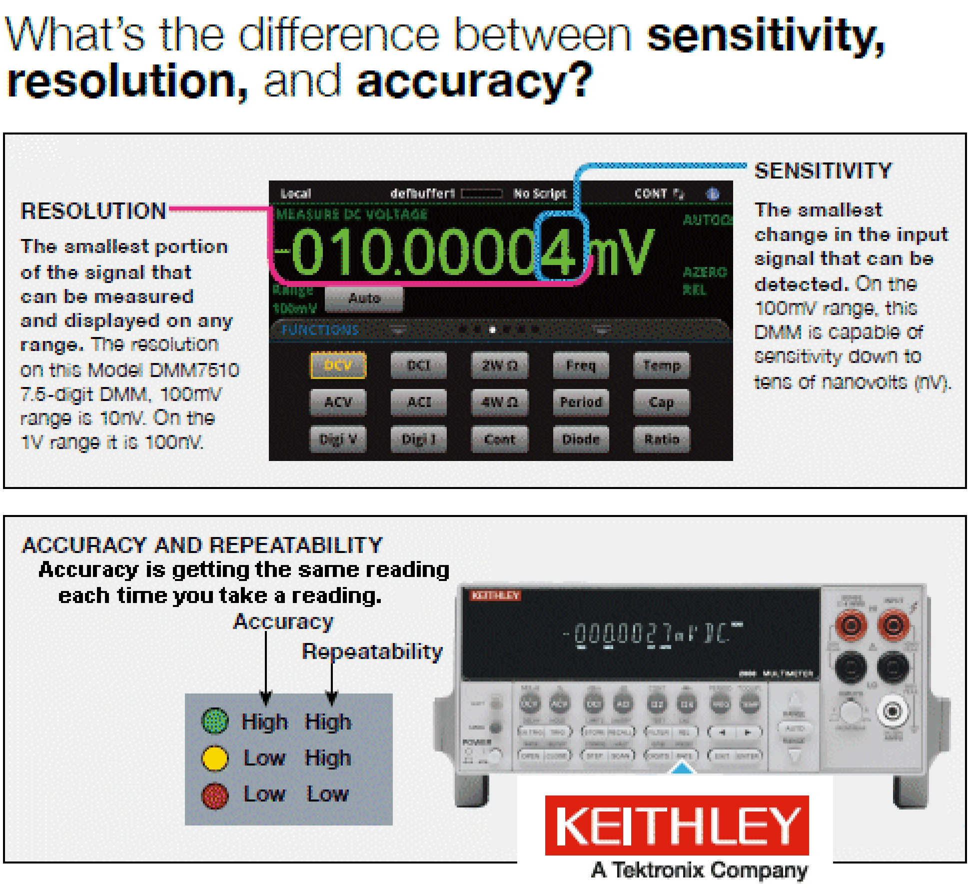
Analogue and digital multimeters have either a rotary selector switch or push buttons to select the appropriate function and range. Some Digital Multimeters (DMMs) are auto ranging; they automatically select the correct range of voltage, resistance, or current when doing a test. However you need to select the function.

Before making any measurement you need to know what you are checking. If you are measuring voltage, select the AC range (10v, 50v, 250v, or 1000v) or DC range (0.5v, 2.5v, 10v, 50v, 250v, or 1000v). If you are measuring resistance, select the Ohms range (x1, x10, x100, x1k, x10k). If you are measuring current, select the appropriate current range DCmA 0.5mA, 50mA, 500mA. Every multimeter is different however the photo below shows a low cost meter with the basic ranges.

The most important point to remember is this:
You must select a voltage or current range that is bigger or HIGHER than the maximum expected value, so the needle does not swing across the scale and hit the "end stop."
If you are using a DMM (Digital Multi Meter), the meter will indicate if the voltage or current is higher than the selected scale, by showing "OL" - this means "Overload." If you are measuring resistance such as 1M on the x10 range the "OL" means "Open Loop" and you will need to change the range. Some meters show "1' on the display when the measurement is higher than the display will indicate and some flash a set of digits to show over-voltage or over-current. A "-1" indicates the leads should be reversed for a "positive reading."
If it is an AUTO RANGING meter, it will automatically produce a reading, otherwise the selector switch must be changed to another range.

The Common (negative) lead ALWAYS fits into the "COM" socket. The red lead fits into the red socket for Voltage and Resistance. Place the red lead (red banana plug) into "A" (for HIGH CURRENT "Amps") or mA,uA for LOW CURRENT.

The black "test lead" plugs into the socket marked "-" "Common", or "Com," and the red "test lead" plugs into meter socket marked "+" or "V-W-mA."   The third banana socket measures HIGH CURRENT and the positive (red lead) plugs into this. You DO NOT move the negative "-" lead at any time.
The following two photos show the test leads fitted to a digital meter. The probes and plugs have "guards" surrounding the probe tips and also the plugs so you can measure high voltages without getting near the voltage-source.



The question above applies to both (every) type of multimeter and the type of meter you use depends on the accuracy you need. Sometimes you are looking for 1mV change on a 20v rail. Only a DMM will (or a CRO) will produce a result.

Analogue meters have an "Ohms Adjustment" to allow for the change in voltage of the battery inside the meter (as it gets old).

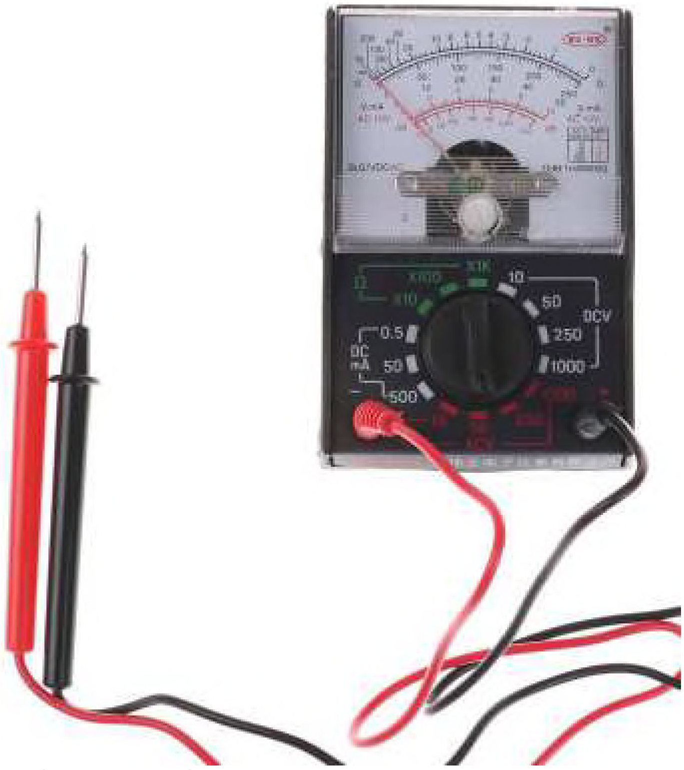
"Ohms Adjust" is also called "ZERO SET"

The sensitivity of this meter is 20,000ohms/volt on the DC ranges and 5k/v on the AC ranges

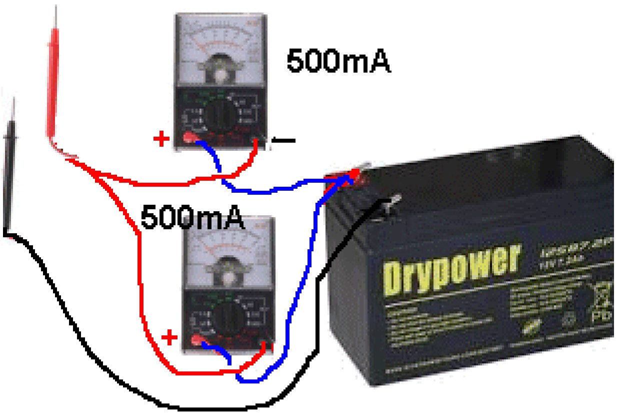
Before taking a resistance reading (each time, on any of the Ohms scales) you need to "ZERO SET" the scale, by touching the two probes together and adjust the pot until the needle reads "0" (swings FULL SCALE). If the pointer does not reach full scale, the batteries need replacing. Digital multimeters do not need "zero adjustment."

THE MULTIMETER

I test all my projects with a $5.00 multimeter !!
WHY???
Because an analogue multimeter puts a load on a circuit and the reading MUST be genuine.
Secondly, an analogue multimeter will show fluctuations in a circuit and show when a certain part of a circuit is not maintaining stability.
And thirdly, an analogue multimeter will respond to changes and pulses much faster than a digital meter.
Lastly, if I can design and test a circuit with a cheap meter, everyone else should be able to do the same when using a more-expensive meter.
Finally, an analogue meter lasts a lifetime. But if you damage it, the cost is only $5.00
And you get 500mA range, a digital meter gives 200mA.
Analogue Meters are on eBay
I have digital meter when I want to read voltages accurately.



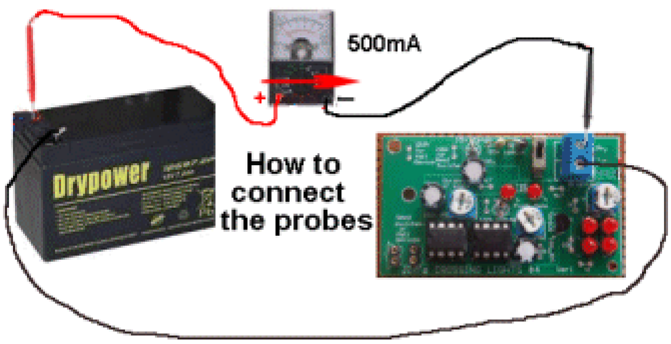
If you buy two multimeters, you can test currents up to 1 amp by placing the multimeters in PARALLEL as shown in the following diagram:



The red and black probes go to the positive and negative terminals of the project you are testing and you simply **ADD** the current readings (shown by the pointer on each meter) to get a final value (up to one amp).

Current flows through the multimeter from the positive probe to the negative probe and the arrow on the meter above shows this direction.
This is how we arrive at that statement:
When taking a measurement of CURRENT, the voltage on the positive probe will be **very slightly higher** than the voltage on the negative probe, because a very small voltage will be dropped across the CURRENT RESISTOR inside the meter. The meter is actually measuring the voltage across this resistor and you are reading the pointer where the scale says **0-500mA**.
We know that current flows from positive to negative and when you trace the circuit above, you can see the meter is part of this circuit.
When measuring CURRENT, you use exactly the same reasoning as when you are measuring voltage.
Look at the circuit or project and work out which point will have the (slightly) higher voltage. The red probe goes to this point.
When measuring CURRENT, even the wires will have a slightly higher voltage at one end. This is the end for the red probe.
When measuring CURRENT, the circuit has to be CUT and the probes inserted into the CUT. You cannot measure the current taken by a component by placing the probes "across it." You have to cut a wire or a track or desolder one of the wires.

If you cannot remember how to connect a multimeter when testing CURRENT, tilt it slightly so the positive terminal is **higher** than the negative terminal and lay the red probe on the bench**, HIGHER** than the black probe.
Now connect the red probe to the positive terminal of the battery and the black probe to the positive "input" of the project. Use another jumper to connect the negative of the battery to the negative (0v) of the project.



See how the current has to flow across the meter (from left to right) to make the point read "up-scale". The probes are connected to the battery as shown in the diagram above.

FIXING A MULTIMETER

A multimeter can get "broken" "damaged" and go "faulty."
I don't know why, but eventually they stop working.
It can be something simple like a flat battery, corroded battery contacts, broken switch or something complex, like the circuitry failing.
Multimeters are so cheap, you can buy a new one for less than $10.00
These meters can have a 10 amp range, transistor tester and measure up to 2 meg ohms.
That's why I suggest buying a $10.00 meter. They are just as good as a $60.00 meter and the cheapest meters last the longest.
Dropping an analogue meter can cause the hair spring to loop over one of the supports and the needle will not zero correctly. You will need to open the cover on the movement and lift the spring off the support with a needle.
A faulty meter can be used in a battery-charger circuit to measure the current or voltage if that scale is still reading-correctly.
Otherwise keep the leads and throw the meter out. It is too dangerous keeping a meter that shows an incorrect reading.
NOTE: When the battery in a digital meter gets low, the digits on the display start to fade and you need to change the 12v battery. But before this happens, the low battery voltage will make a voltage reading higher than the actual value and this can fool you.
This happened to me. The 5v regulator voltage increased to 6v, 7v, 8v and I thought the regulator had failed. Then the display failed and changing the battery solved the problem.

MEASURING FREQUENCY

Before we cover the normal uses for a multimeter, it is interesting to note that some **Digital Multimeters (DMM)** have features such as Capacitance, Frequency and measuring the gain of a transistor as well as a number of other features using probes such as a temperature probe. The VICHY VC99 meter above is an example and costs about $40.00.

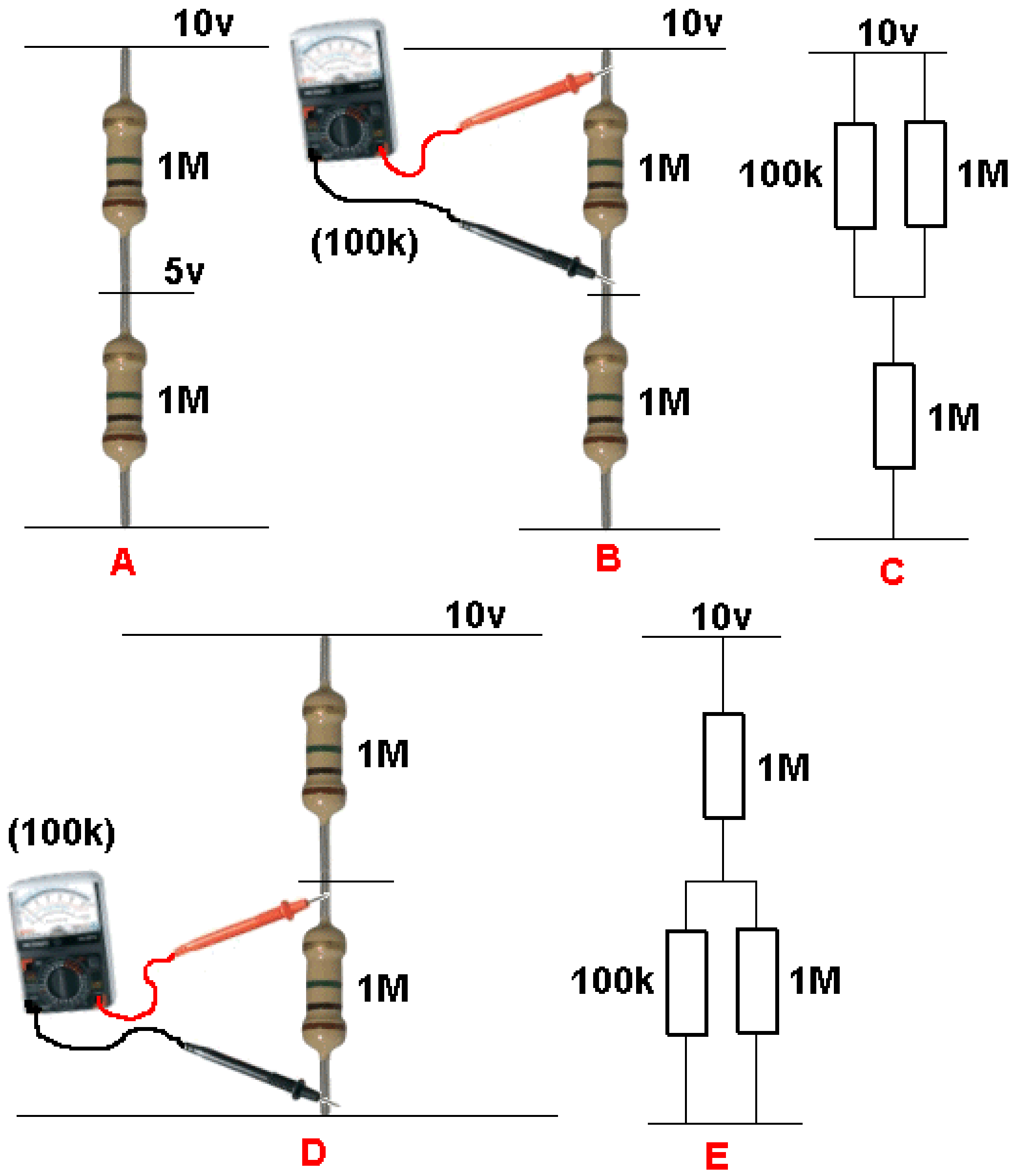
Basic function	Range
DCV	600mV/6V/60V/600V/1000V
ACV	6V/60/600/1000V
DCA	600uA/6000uA/60mA/600mA/6A/20A
ACA	600uA/6000uA/60mA/600mA/6A/20A
Resistance	600Ω/6kΩ/60kΩ/600kΩ/6MΩ/60MΩ
Capacitance	40nF/ 400nF/4uF/40uF/400uF/2000uF
Frequency	100Hz/1kHz/10kHz/100kHz/1MHz/60MHz
Temperature	-40°C~1000°C
	0°F~1832°F

MEASURING VOLTAGE

Most of the readings you will take with a multimeter will be VOLTAGE readings.
Before taking a reading, you should select the highest range and if the needle does not move up scale (to the right), you can select another range.
Always switch to the highest range before probing a circuit and keep your fingers away from the component being tested.
If the meter is Digital, select the highest range or use the auto-ranging feature, by selecting "V." The meter will automatically produce a result, even if the voltage is AC or DC.
If the meter is not auto-ranging, you will have to select V⎓ if the voltage is from a DC

source or V~ if the voltage is from an AC source. DC means Direct Current and the voltage is coming from a battery or supply where the voltage is steady and not changing and AC means Alternating Current where the voltage is coming from a voltage that is rising and falling.
You can measure the voltage at different points in a circuit by connecting the black probe to chassis. This is the 0v reference and is commonly called "Chassis" or "Earth" or "Ground" or "0v."
The red lead is called the "measuring lead" or "measuring probe" and it can measure voltages at any point in a circuit. Sometimes there are "test points" on a circuit and these are wires or loops designed to hold the tip of the red probe (or a red probe fitted with a mini clip or mini alligator clip).
You can also measure voltages ACROSS A COMPONENT. In other words, the reading is taken in PARALLEL with the component. It may be the voltage across a transistor, resistor, capacitor, diode or coil. In most cases this voltage will be less than the supply voltage.
If you are measuring the voltage in a circuit that has a HIGH IMPEDANCE, the reading will be **inaccurate**, up to 90% !!!, if you use a cheap analogue meter.

Here's a simple case.
The circuit below consists of two 1M resistors in series. The voltage at the mid point will be 5v when nothing is connected to the mid point. But if we use a cheap analogue multimeter set to 10v, the resistance of the meter will be about 100k, if the meter has a sensitivity of 10k/v and the reading will be incorrect.
Here how it works:
Every meter has a sensitivity. The sensitivity of the meter is the sensitivity of the movement and is the amount of current required to deflect the needle FULL SCALE.
This current is very small, normally 1/10th of a milliamp and corresponds to a sensitivity of 10k/volt (or 1/30th mA, for a sensitivity of 30k/v).
If an analogue meter is set to 10v, the internal resistance of the meter will be 100k for a 10k/v movement.
If this multimeter is used to test the following circuit, the reading will be inaccurate.
The reading should be 5v as show in diagram **A**.
But the analogue multimeter has an internal resistance of 100k and it creates a circuit shown in **C**.
The top 1M and 100k from the meter create a combined PARALLEL resistance of 90k. This forms a series circuit with the lower 1M and the meter will read less than 1v
If we measure the voltage across the lower 1M, the 100k meter will form a value of resistance with the lower 1M and it will read less than 1v
If the multimeter is 30k/v, the readings will be 2v. See how easy it is to get a totally inaccurate reading.



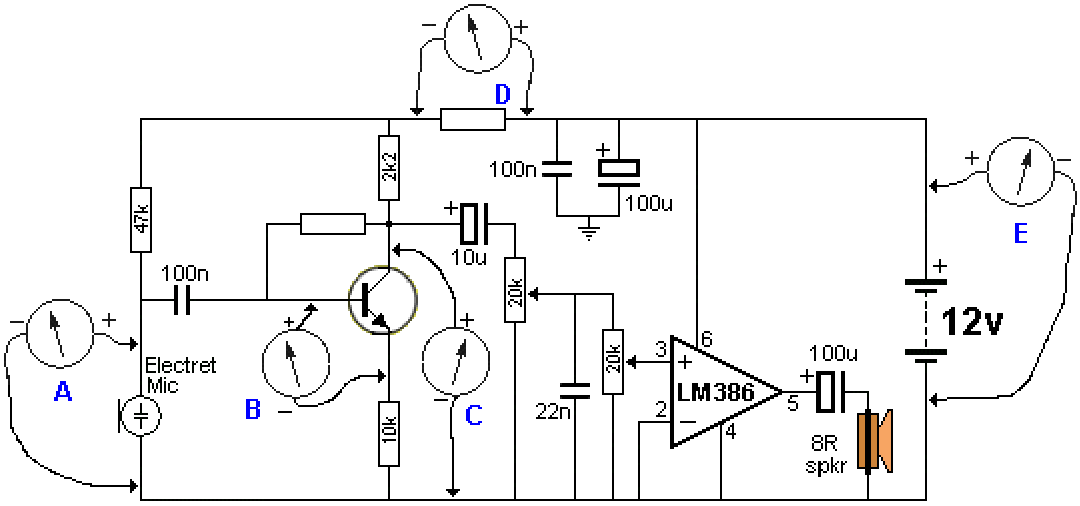
This introduces two new terms:
HIGH IMPEDANCE CIRCUIT and "RESISTORS in SERIES and PARALLEL."

If the reading is taken with a Digital Meter, it will be more accurate as a DMM does not take any current from the circuit (to activate the meter). In other words it has a very HIGH input impedance. Most Digital Multimeters have a fixed input resistance (impedance) of 10M - no matter what scale is selected. That's the reason for choosing a DMM for high impedance circuits. It also gives a reading that is accurate to about 1%.

MEASURING VOLTAGES IN A CIRCUIT

You can take many voltage-measurements in a circuit. You can measure "across" a component, or between any point in a circuit and either the positive rail or earth rail (0v rail). In the following circuit, the 5 most important voltage-measurements are shown. Voltage "A" is across the electret microphone. It should be between 20mV and 500mV.

Voltage "B" should be about 0.6v. Voltage "C" should be about half-rail voltage. This allows the transistor to amplify both the positive and negative parts of the waveform. Voltage "D" should be about 1-3v. Voltage "E" should be the battery voltage of 12v.

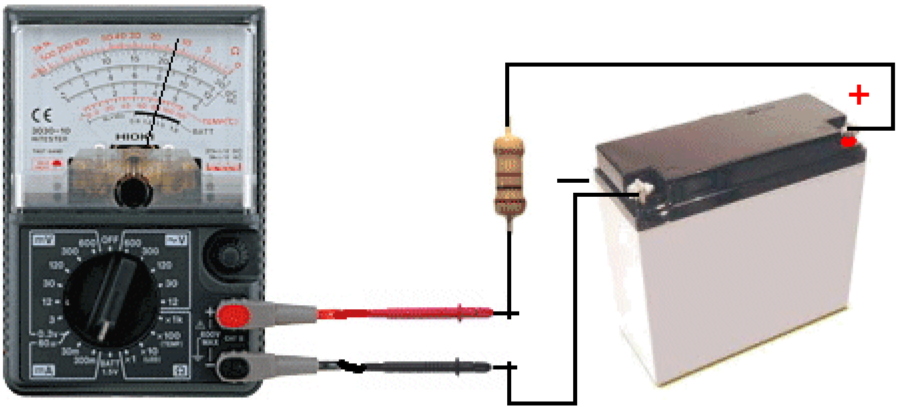


MEASURING VOLTAGES IN A CIRCUIT

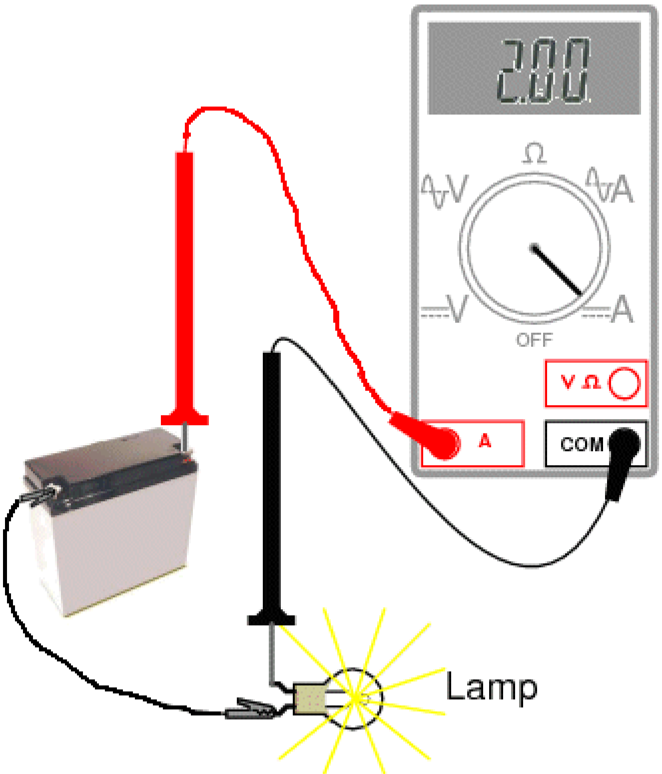
MEASURING CURRENT

You will rarely need to take current measurements, however most multimeters have DC current ranges such as 0.5mA, 50mA, 500mA and 10Amp (via the extra banana socket) and some meters have AC current ranges. Measuring the current of a circuit will tell you a lot of things. If you know the normal current, a high or low current can let you know if the circuit is overloaded or not fully operational.

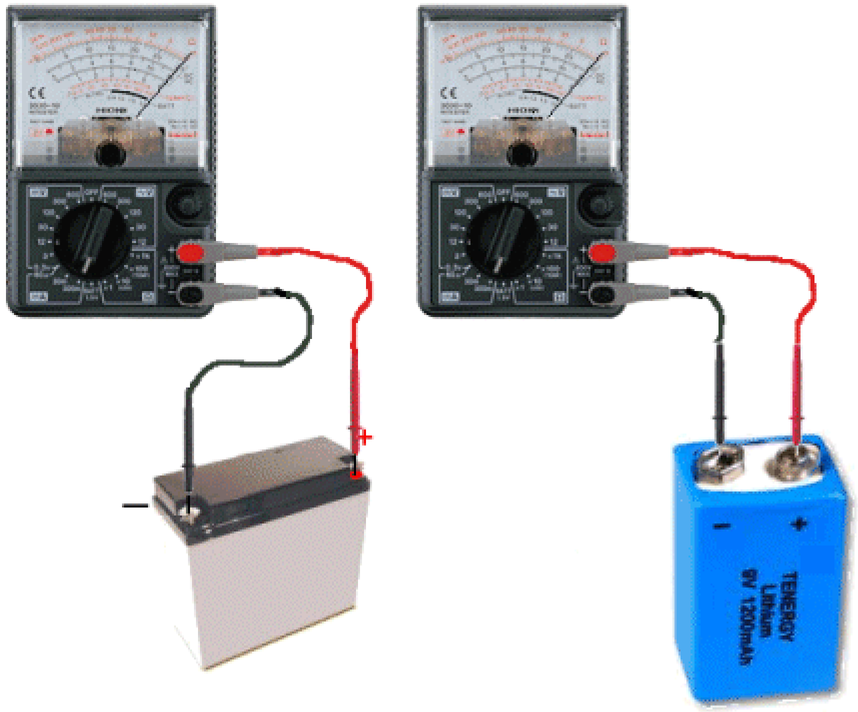
Current is always measured when the circuit is working (i.e: with power applied).
It is measured IN SERIES with the circuit or component under test.
The easiest way to measure current is to remove the fuse and take a reading across the fuse-holder. Or remove one lead of the battery or turn the project off, and measure across the switch.
If this is not possible, you will need to remove one end of a component and measure with the two probes in the "opening."
Resistors are the easiest things to desolder, but you may have to cut a track in some circuits. You have to get an "opening" so that a current reading can be taken.
The following diagrams show how to connect the probes to take a CURRENT reading.
Do not measure the current ACROSS a component as this will create a "short-circuit."
The component is designed to drop a certain voltage and when you place the probes across this component, you are effectively adding a "link" or "jumper" and the voltage at the left-side of the component will appear on the right-side. This voltage may be too high for the circuit being supplied and the result will be damage.



Measuring current through a resistor



Measuring the current of a globe



Do NOT measure the CURRENT of a battery
(by placing the meter directly across the terminals)
A battery will deliver a very HIGH current and damage the meter

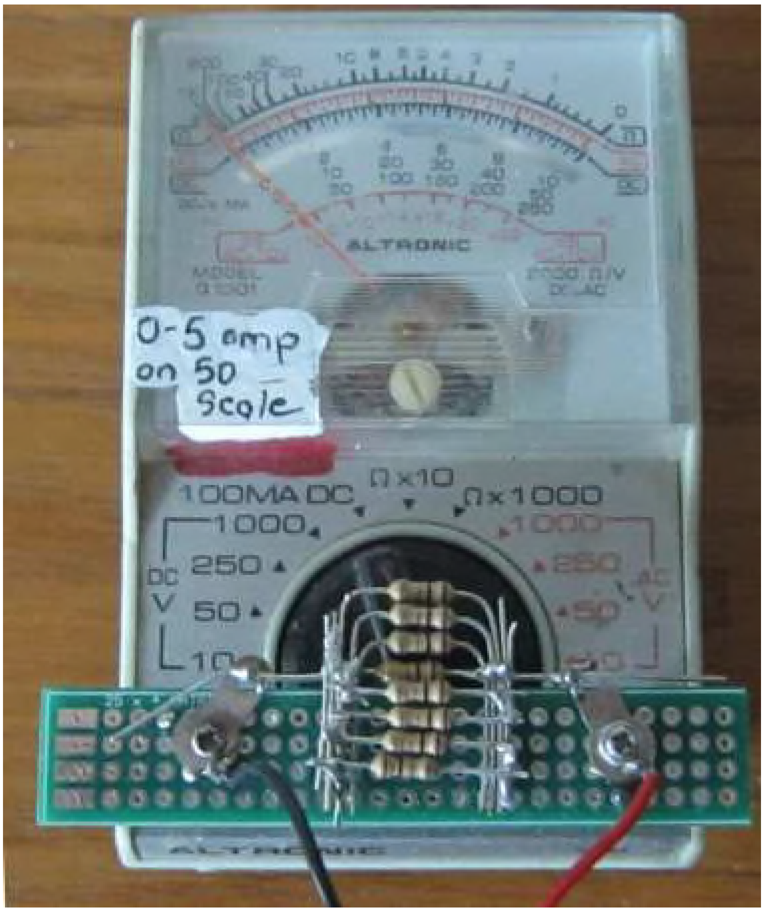
Do not measure the "current a battery will deliver" by placing the probes across the terminals. It will deliver a very high current and damage the meter instantly. There are special battery testing instruments for this purpose.
When measuring across an "opening" or "cut," place the red probe on the wire that supplies the voltage (and current) and the black probe on the other wire. This will produce a "POSITIVE" reading.
A positive reading is an UPSCALE READING and the pointer will move across the scale - to the right. A "NEGATIVE READING" will make the pointer hit the "STOP" at the left of the scale and you will not get a reading. If you are using a Digital Meter, a negative sign "-" will appear on the screen to indicate the probes are around the wrong way. No damage will be caused. It just indicates the probes are connected incorrectly.
If you want an accurate CURRENT MEASUREMENT, use a digital meter.

MEASURING 1 AMP

Most digital multimeters only go to 200mA and most cheap analogue meters only go to 500mA.
But a clever way to measure up to 1 amp is to put 2 cheap analogue meters in parallel and read the two screens. Just add the combined values and you will be able to read up to 1 amp.
Just another time when a cheap $5.00 analogue meter comes in handy.

Here is anther way to increase the current range:

I have converted one of the meters above to 0-5AMP
using 8 x 1 ohm 0.25watt resistors in parallel on the 100mA range and the reading is 0 - 5 amp on the 50v scale.



Turning an old meter into a valuable 0-5Amp meter

This is how you do it.
Get an old meter for conversion.
Get a good meter with a 0-200mA or 0-500mA scale.
Get a 12v supply and 3 or 5 watt wire wound resistors 8R2 and 3R3 etc. As many as you can.

Make a resistive circuit that draws say 100mA and check the current with the good meter (separately) and then with the meter you are going to modify to make sure both meters are detecting the correct amount of current.
Now you have a starting-point.

Make the SHUNT - the resistors soldered in parallel on the matrix board above - using 8 x one ohm resistors.

Connect the two meters in series with (wire wound resistors) to the 12v supply until the good meter (called the calibrating meter) reads FULL DEFLECTION.
If you add another resistor, the needle reading will go DOWN SCALE. If you remove a resistor the needle will move UP-SCALE.
Now adjust the number of resistors until the meter you are calibrating reads the same current.
This is as far as you can go.
You don't need any complex mathematics. Just a simple addition or removal of resistors.
You can use 2R2 or 3R3 to make smaller increments or decrements in the position of the pointer.
This is not the best way to calibrate a meter but it is is the best we can do. Any inaccuracy in our calibration will be multiplied 5 times in the final reading - but this is a simple way to

turn an old meter into something valuable.
Now remove the calibrating meter and reduce the number of wire wound resistors and the needle will move UP-SCALE. Reduce the number of wire wound resistors and the remaining resistors will get HOT and the needle will move up scale to the 5 amp reading.
You now have a valuable 0-5 amp CURRENT METER.
Called an AMMETER (0-5AMP)
Called a 5-Amp Meter or
5-Amp AMMETER (this is the best name).

Here is another way to convert a digital meter:
Most digital meters only read to to 200mA. You can increase this to 1 amp with the following simple set of resistors called SHUNT RESISTORS.
Place the multimeter in series with a load that is taking 200mA.
Now get some one ohm, 2.2ohm and 3.3 ohm resistors. Place them, one at a time, across the two probes and you will find the reading will reduce every time you add a resistor.
You can put them directly across the probes or two in series to get a larger résistance.
Keep experimenting until the reading on the meter is "40." You know this reading is really 200mA, so, when the probes are put on a circuit that reads "200" the real current will be 200 x 5 = 1,000mA or 1AMP!

MEASURING AC CURRENT

Measuring AC current is very difficult to do because the waveform is rising and falling and when the waveform is "on and off" such as the DCC waveform in a DCC Model Railway set-up, the actual current taken by a module will be impossible to measure with a cheap multimeter.
However a simple way to find out the current flowing is to place a 500 ohm pot in the positive line and connect a LED from the middle pin to one of the outer pins and then connect another LED across the LED but in the opposite direction. This will only be suitable for a current up to about 50mA.
As you turn the pot from zero ohms, the LEDs will start to come on.
We are NOT measuring the brightness but the point at which the LED detects a voltage of about 3.2v across the pot. (actually across about half the pot)
Now put the "tester" on a variable power supply and connect a 220R as the load. As you increase the voltage, one of the LEDs will come on with the same very weak brightness.
Now place a DC milliamp meter in line with the tester and measure the current. The value will be very close to the AC current flowing in the original circuit.
The same principle can be used to measure higher currents by using a low-resistance resistor and 2 LEDs.
Suppose you have a 10 ohm resistor and LEDs that illuminate at 3.2v
When the current peaks at 320mA, the LEDs will be illuminated with very low brightness, but because the peak will only be for a very small portion of the cycle, the actual current-flow will not be equal or the same as 320mA DC current. We are just measuring a PEAK.
You have to be careful when making this type of "tester" to prevent damaging the LEDs.
Start with a set of say 5 resistors in parallel with each value 47 ohms or slightly higher or lower. As you remove each resistor, the LEDs will start to come ON.
This will let you know that some point in the cycle the current is 320mA.
If it is a square-wave, such as the DCC waveform for Model Railways, the DC current-flow will be very nearly the same as the AC current measured by this tester.

CURRENT SHARING

This is a term we use when two or more devices are placed in parallel and we hope each device will dissipate half the heat.
Suppose you have a component that gets too hot. You can add a heatsink or place another component "across it."
The first thing you have to remember is this: a lot of the heat from the component goes

The first thing you have to remember is this: a lot of the heat from the component goes down the leads and into the tracks on the printed circuit board.
If you add another component you are sending the heat from two devices to the same tracks. You may need to keep the two devices apart.
However if the device is a transistor or diode the original device will drop a higher voltage when the full current flows and that's why it is getting so hot.
If you add another device on top of it, each device will pass less current and the voltage-drop across the combination will be less and the overall heat loss will be less.
So you will be solving 3 problems at the same time.
1. The voltage-drop across the combination will be less,
2. The heat will be distributed via more devices, and
3. The set-up will fail less often because it is not being driven so hard.

A 1-amp diode can be connected across a 2-amp diode to reduce the heating of each component and the effectiveness needs to be tested with your fingers.
There is no law or rule for this but a silicon diode drops about 0.7v when half the specified current is flowing and rise to 1.1v when full current flows. Buy adding another diode across the first, the overall characteristic voltage drop across the combination can reduced considerably.

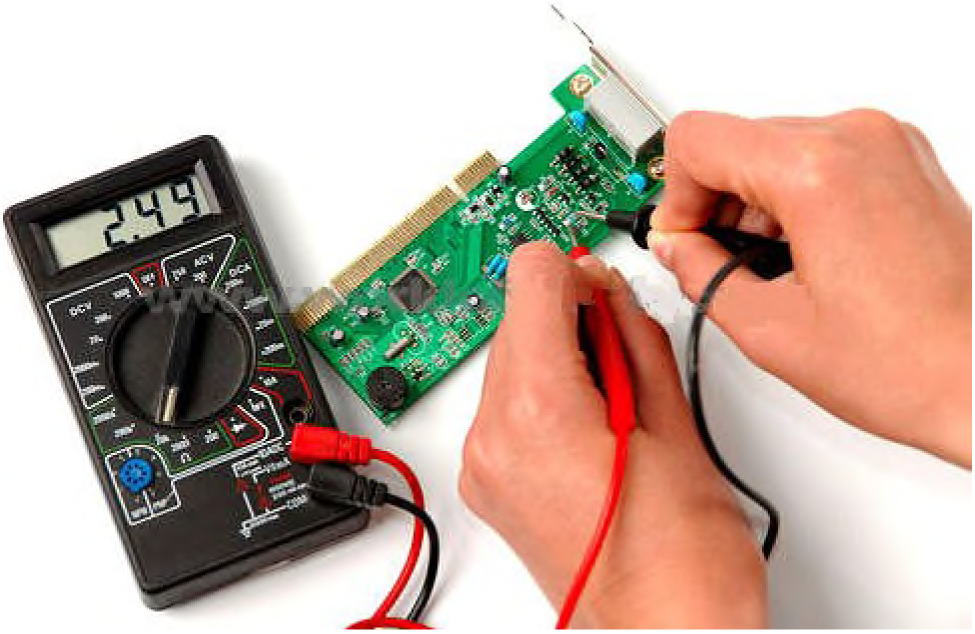
The same concept of current sharing applies to resistors and they can be placed in parallel or series to distribute the heat, but make sure the tracks on the board can dissipate the heat.
The rating of a resistor ONLY applies when it is connected close to the PC board and when the tracks are thick enough to dissipates the heat. Resistors "up in the air" can dissipate very little.

The same concept of current sharing can also be used for 3-terminal regulators and to find if they are equal-sharing, place your fingers on both at the same time and see if you let-go at the same time.

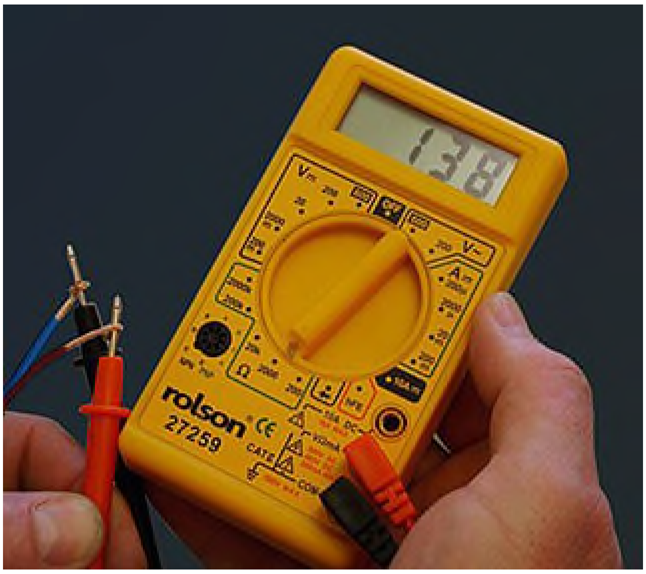
The same concept of current sharing can be used for zener diodes, as the current-capability of a high-voltage zener is less than a low voltage zener. So, two zeners, 6v2 and 6v2 can be used for a 12v supply and the current capability of the set-up will be 64mA whereas a 12v zener of the same 400mW rating will be 33mA. Sometimes you need the zener to dissipate all the wattage when a LOAD is not connected to the circuit. This is the concept of a zener diode as a SHUNT REGULATOR. See: **Zener Diode** - about halfway down the article we describe a SHUNT REGULATOR.

MEASURING RESISTANCE

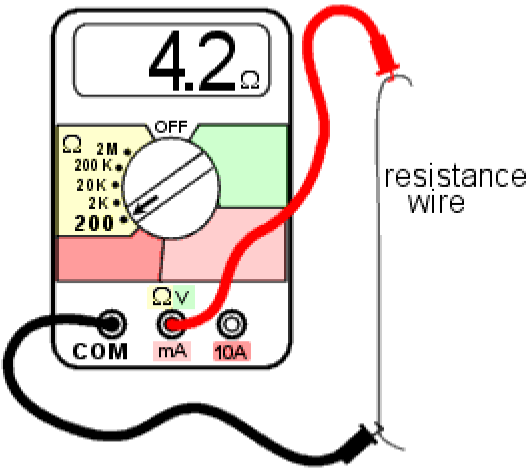
Turn a circuit off before measuring resistance.
If any voltage is present, the value of resistance will be incorrect.
In most cases you cannot measure a component while it is in-circuit. This is because the meter is actually measuring a voltage across a component and calling it a "resistance." The voltage comes from the battery inside the meter. If any other voltage is present, the meter will produce a false reading.
If you are measuring the resistance of a component while still "in circuit," (with the power off) the reading will be lower than the true reading.



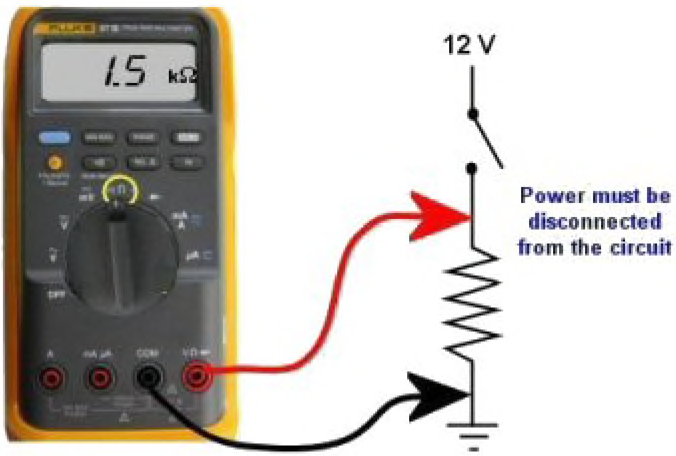
Measuring resistance



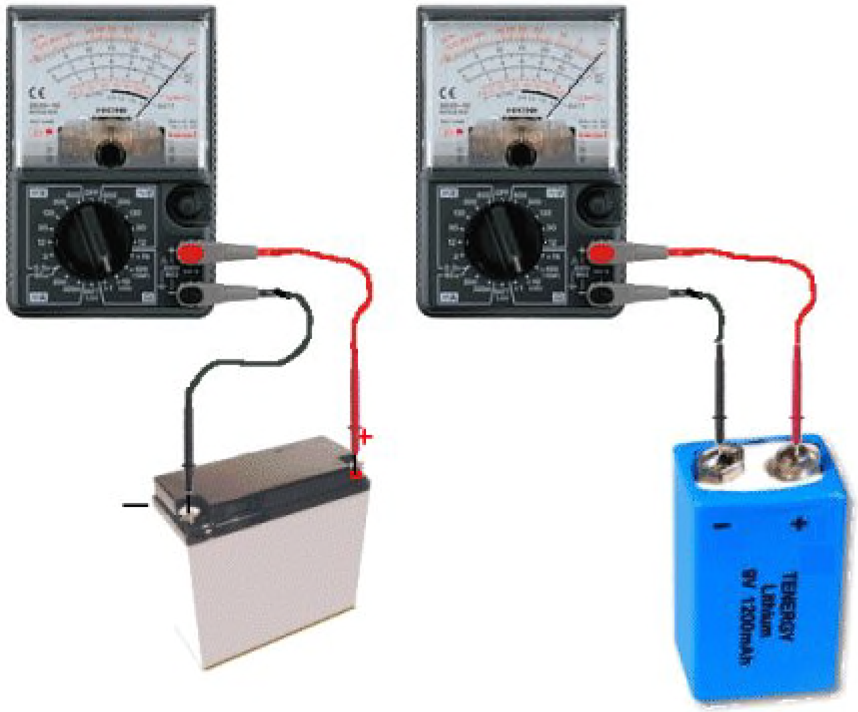
Measuring resistance of a heater
(via the leads)



Measuring the resistance of a piece of resistance-wire



Measuring the resistance of a resistor



Do not measure the "Resistance of a Battery"

1. Do not measure the "resistance of a battery." The resistance of a battery (called the Internal impedance) is not measured as shown in the diagrams above. It is measured by creating a current-flow and measuring the voltage across the battery. Placing a multimeter set to **resistance** (across a battery) will destroy the meter.
2. Do not try to measure the resistance of any voltage or any "supply."

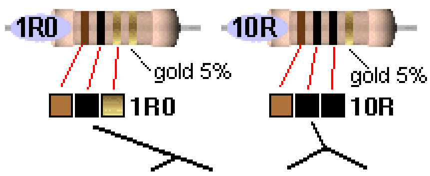
Resistance is measured in OHMs.
The resistance of a 1cm x 1cm bar, one metre long is 1 ohm.
If the bar is thinner, the resistance is higher. If the bar is longer, the resistance is higher.
If the material of the bar is changed, the resistance is higher.
When carbon is mixed with other elements, its resistance increases and this knowledge is used to make RESISTORS. (However, when carbon is mixed with non-conducting powders, the resistance decreases. Such as mixing carbon with depolariser chemicals in a "dry cell.")
Resistors have RESISTANCE and the main purpose of a resistor is to reduce the CURRENT FLOW.
It's a bit like standing on a hose. The flow reduces.
When current flow is reduced, the output voltage is also reduced and that why the water does not spray up so high. Resistors are simple devices but they produce many different effects in a circuit.
A resistor of nearly pure carbon may be 1 ohm, but when non-conducting "impurities" are added, the same-size resistor may be 100 ohms, 1,000 ohms or 1 million ohms.
Circuits use values of less than 1 ohm to more than 22 million ohms.

Resistors are identified on a circuit with numbers and letters to show the exact value of resistance - such as 1k 2k2 4M7

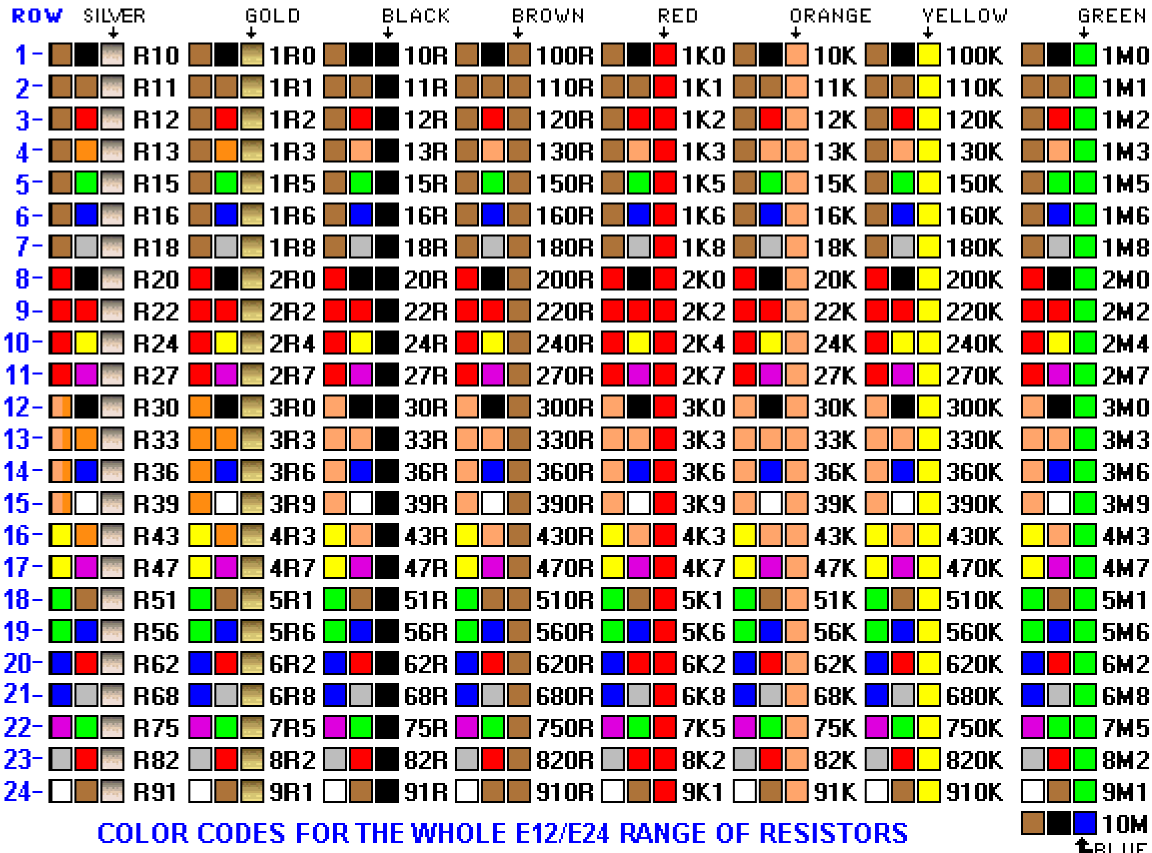
The letter Ω (omega - a Greek symbol) is used to identify the word "Ohm."
but this symbol is not available on some word-processors, so the letter "R" is used. The letter "E" is also sometimes used and both mean "Ohms."
A one-ohm resistor is written "1R" or "1E." It can also be written "1R0" or "1E0."
A resistor of one-tenth of an ohm is written "0R1" or "0E1." The letter takes the place of the decimal point.

10 ohms = 10R
100 ohms = 100R
1,000 ohms = 1k (k= kilo = one thousand)
10,000 ohms = 10k
100,000 ohms = 100k
1,000,000 ohms = 1M (M = MEG = one million)

The size of a resistor has nothing to do with its resistance. The size determines the wattage of the resistor - how much heat it can dissipate without getting too hot.
Every resistor is identified by colour bands on the body, but when the resistor is a surface-mount device, numbers are used and sometimes letters.
You MUST learn the colour code for resistors and the following table shows all the colours for the most common resistors from 1/10th of an ohm to 22 Meg ohms for resistors with 5% and 10% tolerance.



If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

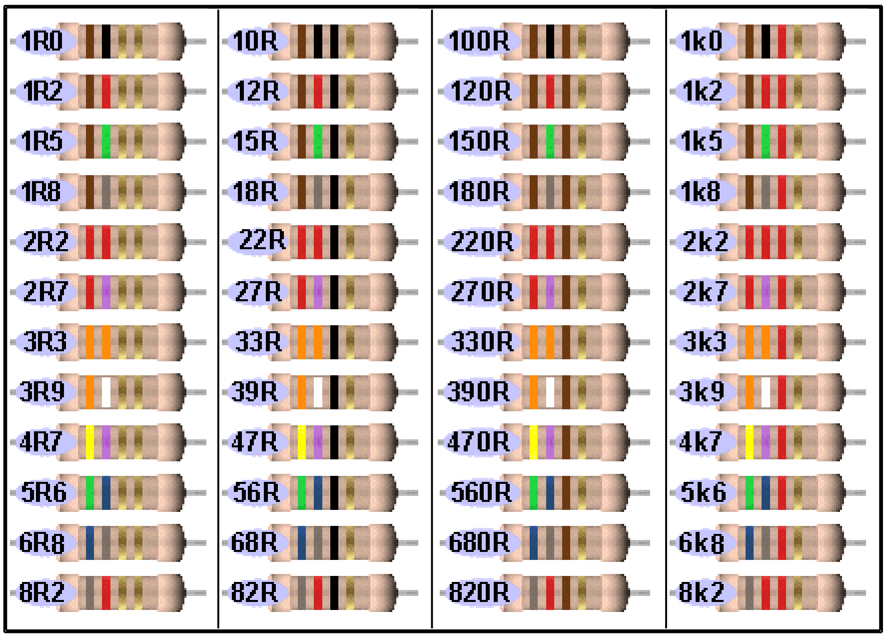


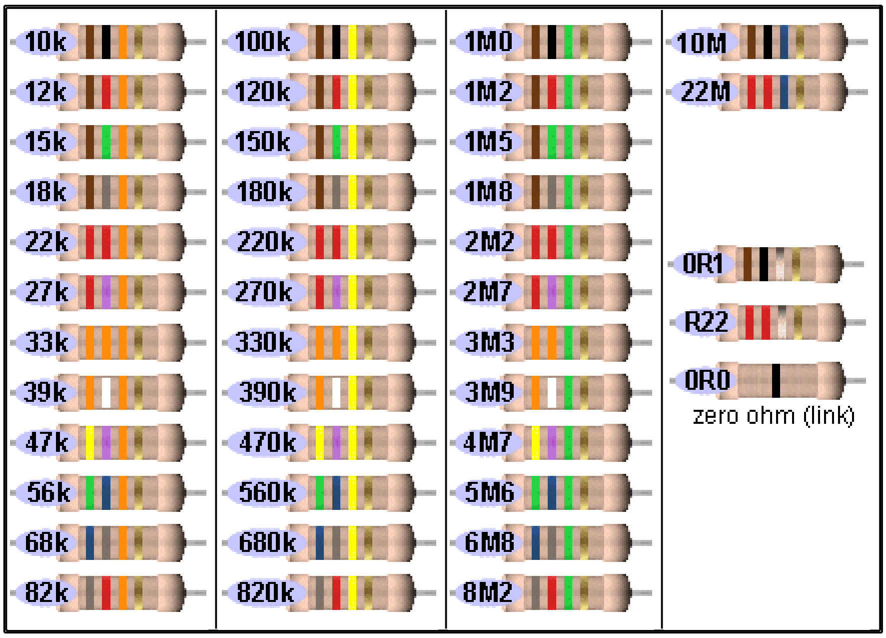
COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS
The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M

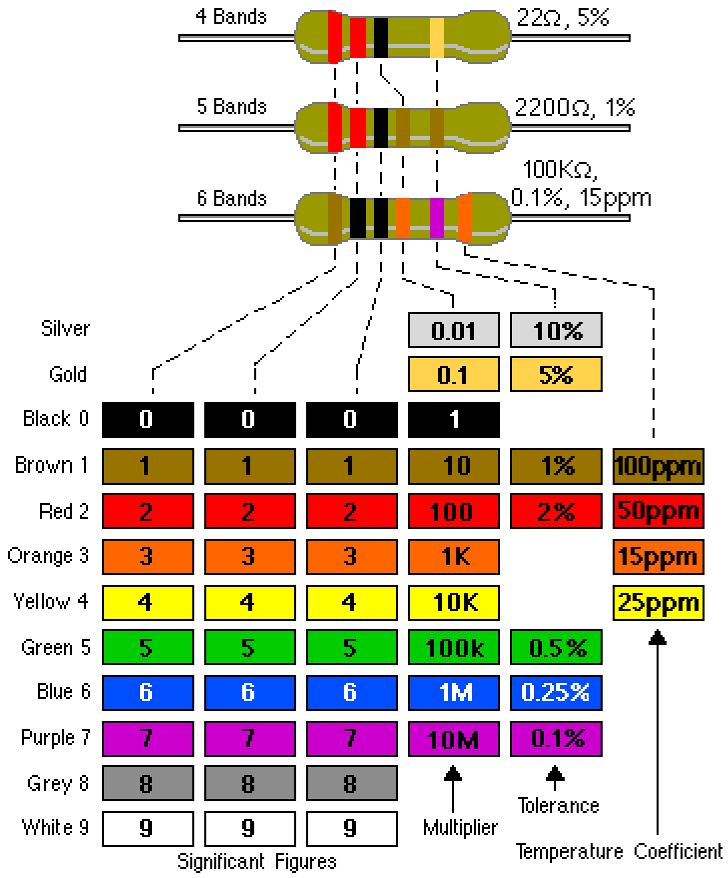
Reading 4-band resistors

The most "common" type of resistor has 4 bands and is called the 10% resistor. It now has a tolerance of 5% but is still called the "10% type" as the colours increase by 20% so that a resistor can be 10% higher or 10% lower than a particular value and all the resistors produced in a batch can be used.
The first 3 bands produce the resistance and the fourth band is the "tolerance" band. Gold = 5%

(Silver =10% but no modern resistors are 10%!! - they are 5% 2% or 1%)

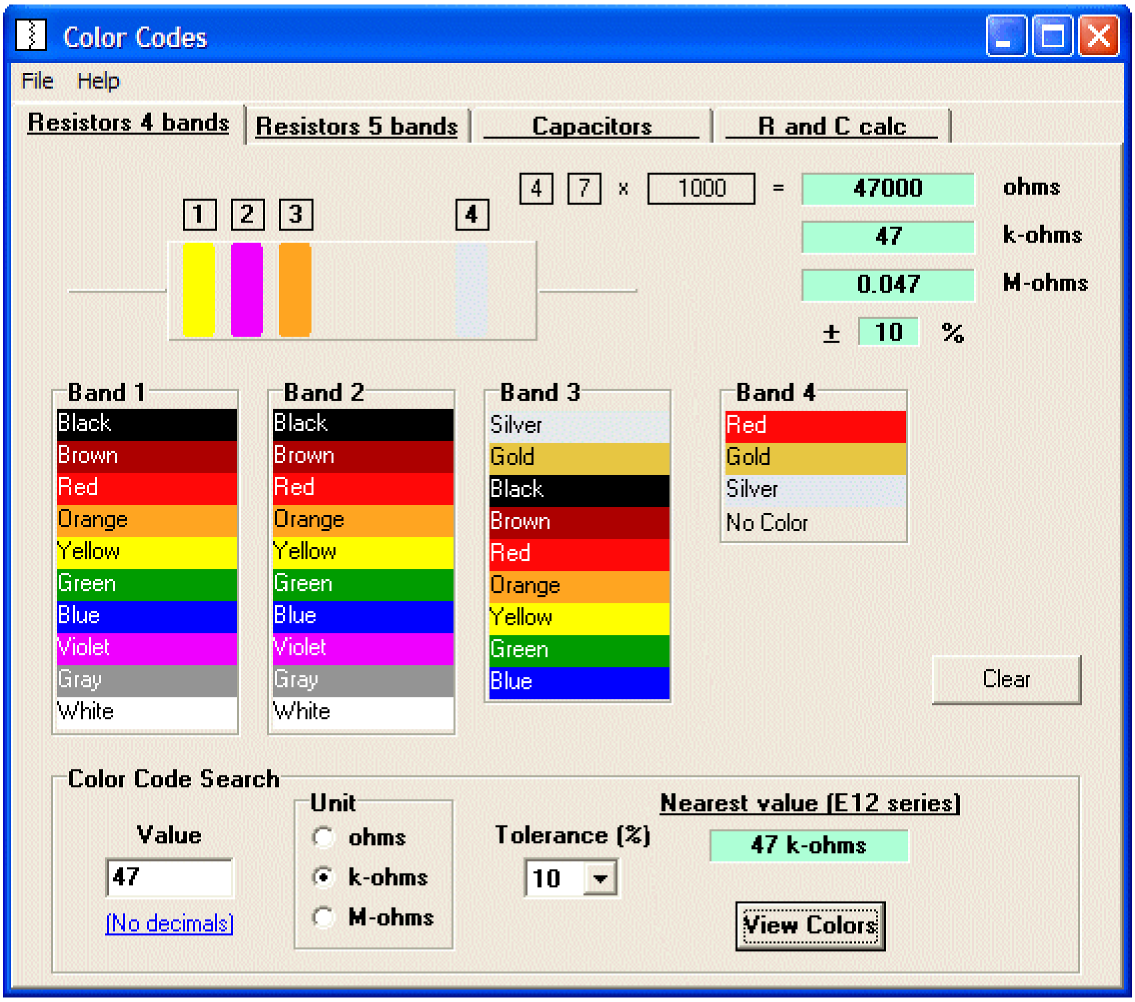






Resistor Color Code System

Here is another well-designed resistor colour code chart:



Download the program and save it on your desk-top for future reference:
ColourCode.exe (520KB)
ColourCode.zip (230KB)
ColourCode.rar (180KB)

RESISTORS LESS THAN 10 OHMS

When the **third** band is gold, it indicates the value of the "colors" must be divided by 10.
Gold = "divide by 10" to get values 1R0 to 8R2
When the **third** band is silver, it indicates the value of the "colors" must be divided by 100.
(Remember: more letters in the word "silver" thus the divisor is "a larger division.")
Silver = "divide by 100" to get values R1 to R82
e.g: 0R1 = 0.1 ohm   0R22 = point 22 ohms
See 4th Column above for examples.

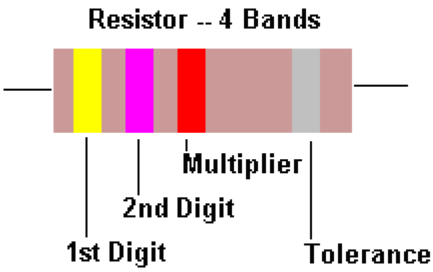
The letters "R, k and M" take the place of a decimal point.
e.g: 1**R**0 = 1 ohm   2**R**2 = 2 point 2 ohms   22**R** = 22 ohms
2**k**2 = 2,200 ohms   100**k** = 100,000 ohms
2**M**2 = 2,200,000 ohms

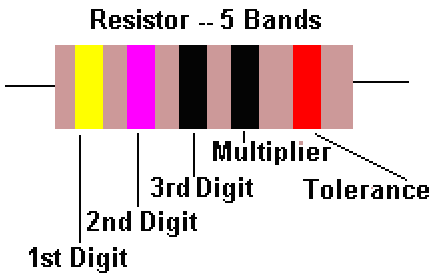
HOW TO REMEMBER THE COLOUR CODE:

Each colour has a "number" (or divisor) corresponding to it.
Most of the colours are in the same order as in the spectrum. You can see the spectrum in a rainbow. It is: ROY G BIV and the colours for resistors are in the same sequence.

black
brown - colour of increasing temperature
red
orange
yellow
green
blue
(indigo - that part of the spectrum between blue and violet)
violet
gray
white

colour	**value**	No of zero's
silver	-2	divide by 100
gold	-1	divide by 10
black	0	No zeros
brown	1	0
red	2	00
orange	3	,000 or k
yellow	4	0,000
green	5	00,000
blue	6	M
violet	7	
gray	8	
white	9	





Band Color	Digit	Multiplier	Tolerance
Black	0	1	---
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	---
Blue	6	1,000,000	---
Violet	7	10,000,000	---
Gray	8	100,000,000	---
White	9	---	---
Gold	---	0.1	±5%
Silver	---	0.01	±10%
None	---	---	±20%

Here are some common ways to remember the colour code:
Bad Beer Rots Our Young Guts, But Vodka Goes Well
Bright Boys Rave Over Young Girls But Violet Gets Wed
Bad Boys Rave Over Young Girls But Violet Gets Wed with Gold and Silver.

Reading 5-band resistors:

5-band resistors are easy to read if you remember two simple points. The first three bands provide the digits in the answer and the 4th band supplies the number of zero's.

Reading "STANDARD VALUES" (on 5-band resistors)

5-band resistors are also made in "Standard Values" but will have different colours to 4-band "common" resistors - and will be confusing if you are just starting out. For instance, a 47k 5% resistor with 4-bands will be: yellow-purple-orange-gold. For a 47k 1% resistor the colours will be yellow-purple-black-red-brown. The brown colour-band represents 1%.
The first two colour-bands for a STANDARD VALUE or "common value" in 1% or 5% will be the SAME. These two bands provide the digits in the answer.
It's the 3rd band for a 5% resistor that is expanded into two bands in a 1% resistor. But it's easy to follow.
For a standard value, the 3rd band in a 1% resistor is BLACK. This represents a ZERO in the answer. (For 5-band resistors BLACK represents a ZERO when in the third band. This is different to 4-band resistors where black represents the word OHMS! If the third band is BROWN, the answer will be 1).
So the 4th band has to represent one-less ZERO and is one colour UP THE COLOUR CHART! In other words the 3rd and 4th bands (combined) on a 1% resistor produces the same number of zero's as the 3rd band on a 5% resistor!

Resistors come in a range of values and the two most common are the E12 and E24 series. The E12 series comes in twelve values for each decade. The E24 series comes in twenty-four values per decade.

E12 series - 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

E24 series - 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

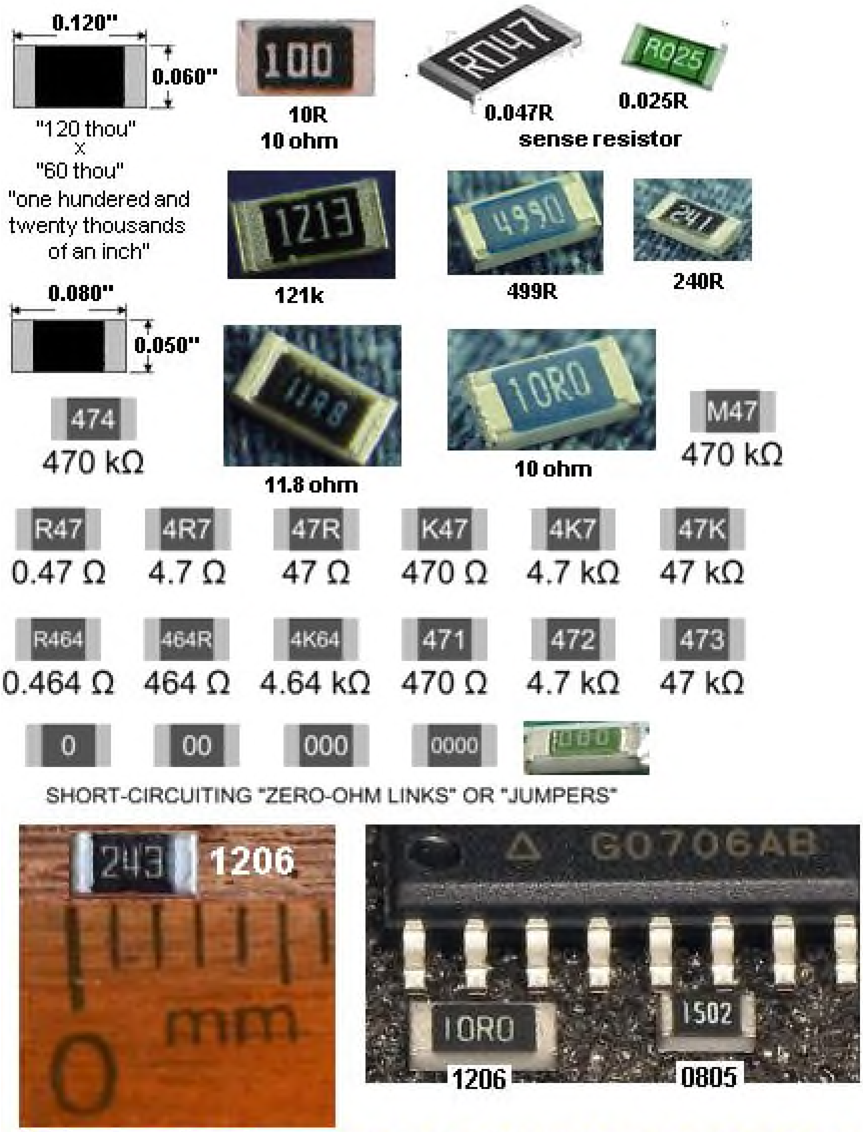
Here is the complete list of 1% 1/4watt resistors from:
CIRCUIT SPECIALISTS. The following list covers 10 ohms (10R) to 1M.
To buy 1% resistors from Circuit Specialists, click: HERE.

10R	121R	806R	3k83	7k15	14k7	39k2	121k
12R1	150R	825R	3k92	7k5	15k	40k2	147k
15R	182R	909R	4k02	7k87	15k8	44k2	150k
18R2	200R	1k0	4k22	71k5	16k9	46k4	182k
22R1	221R	1k21	4k64	8k06	17k4	47k	200k
27R4	240R	1k5	4k75	8k25	17k8	47k5	212k
30R1	249R	1k82	4k7	8k45	18k2	49k9	221k
33R2	274R	2k	4k87	8k66	20k	51k1	226k
36R5	301R	2k21	4k99	8k87	22k1	53k6	249k
39R2	332R	2k2	5k11	9k09	22k6	56k2	274k
47R5	348R	2k43	5k23	9k31	23k7	61k9	301k
49R9	392R	2k49	5k36	9k53	24k9	68k1	332k
51R1	402R	2k67	5k49	9k76	27k4	69k8	357k
56R2	475R	2k74	5k62	10k	29k4	75k0	392k
68R1	499R	3k01	5k76	11k	30k1	82k5	475k
75R	565R	3k32	5k9	12k	33k2	90k	487k
82R5	604R	3k48	6k04	12k1	34k8	90k9	499k
90R9	681R	3k57	6k19	12k4	36k5	95k3	562k
100R	750R	3k74	6k81	13k	38k3	100k	604k
							1M

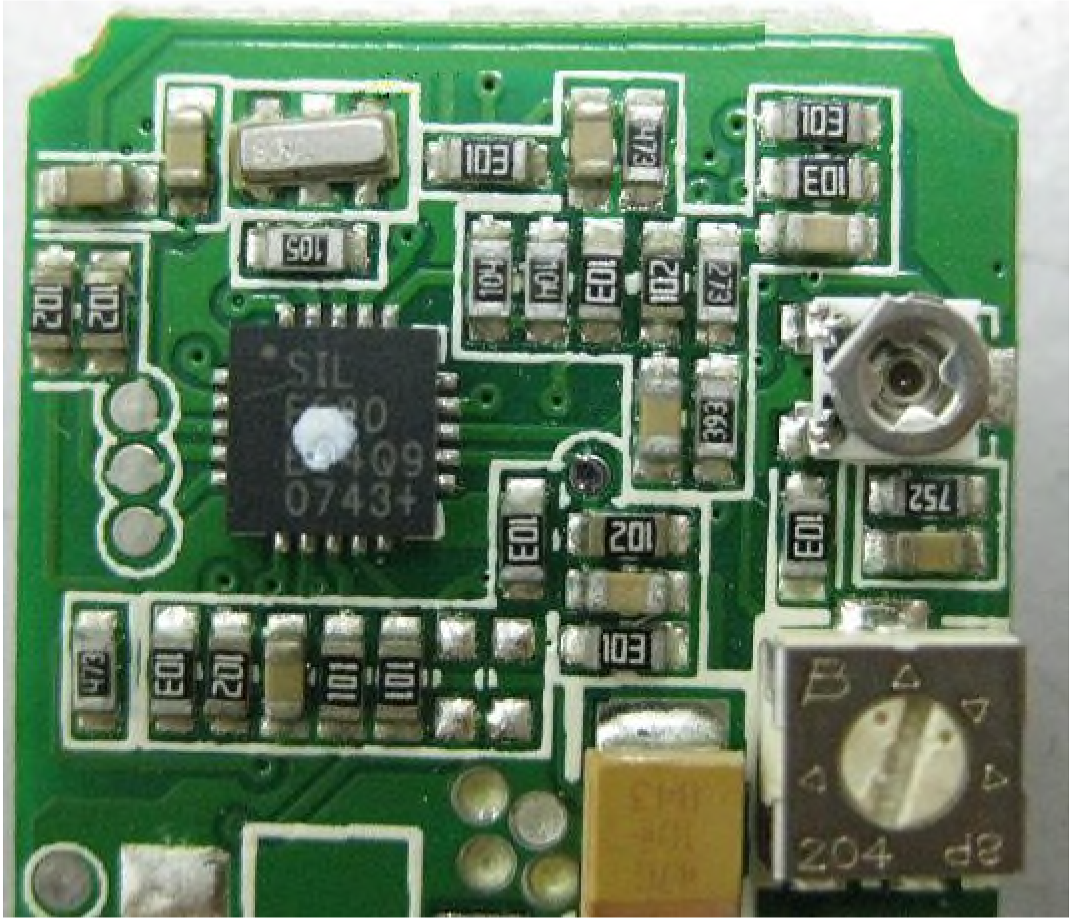
Here is the list of 1% resistors from suppliers (such as Farnell):

1R0	13R	68R	360R	1k8	9k1	47k	240k
1R2	15R	75R	390R	2k0	10k	51k	270k
1R5	16R	82R	430R	2k2	11k	56k	300k
2R2	18R	91R	470R	2k4	12k	62k	330k
2R7	20R	100R	510R	2k7	13k	68k	360k
3R3	22R	110R	560R	3k	15k	75k	390k
3R9	24R	120R	620R	3k3	16k	82k	430k
4R7	27R	130R	680R	3k6	18k	91k	470k
5R6	30R	150R	750R	3k9	20k	100k	510k
6R2	33R	160R	820R	4k3	22k	110k	560k
6R8	36R	180R	910R	4k7	24k	120k	620k
7R5	39R	200R	1k	5k1	27k	130k	680k
8R2	43R	220R	1k1	5k6	30k	150k	750k
9R1	47R	240R	1k2	6k2	33k	160k	820k
10R	51R	270R	1k3	6k8	36k	180k	910k
11R	56R	300R	1k5	7k5	39k	200k	1M
12R	62R	330R	1k6	8k2	43k	220k	

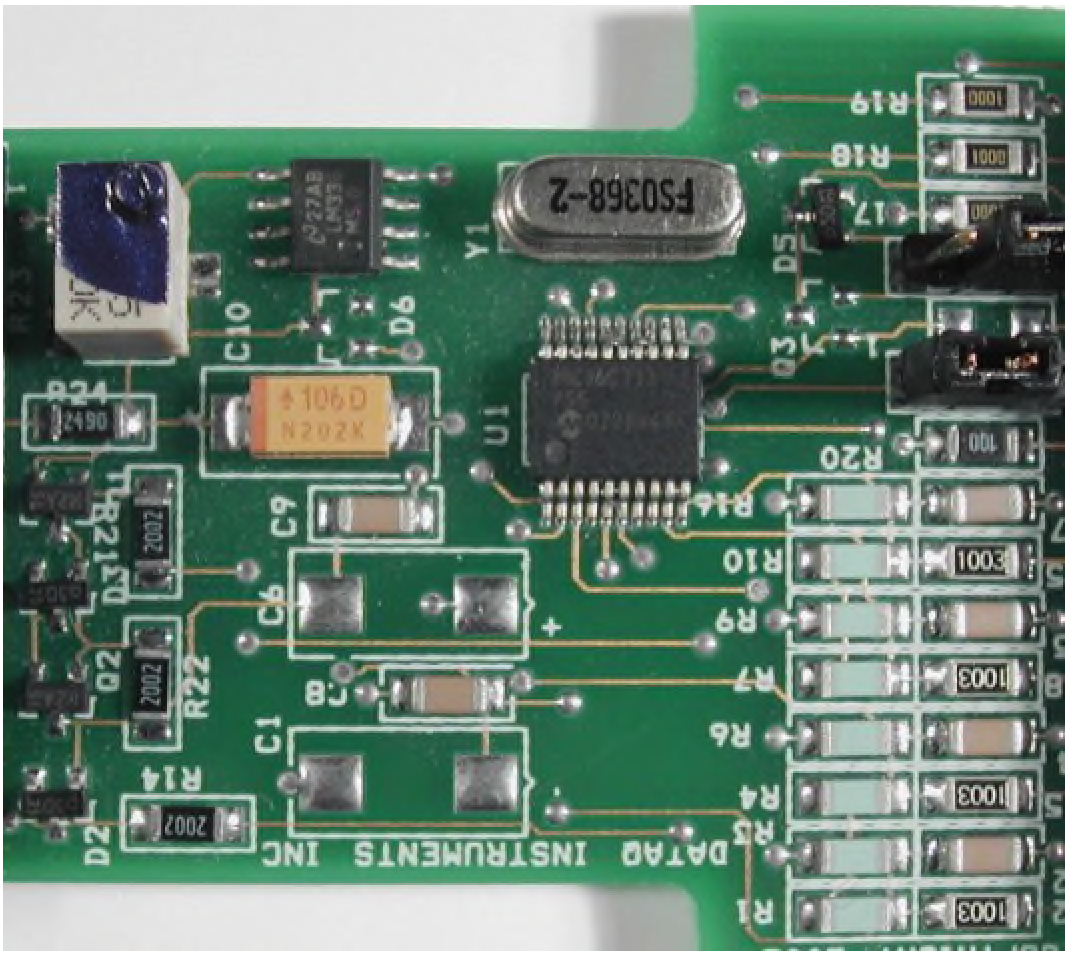
Surface Mount Resistors



1206 and 0805 SURFACE MOUNT RESISTORS

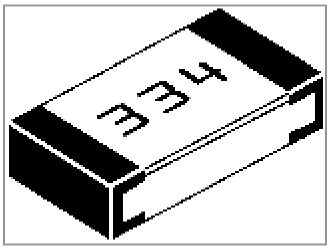


3-digit Surface Mount resistors on a PC board



4-digit Surface Mount resistors on a PC board

The photo above shows surface mount resistors on a circuit board. The components that are not marked are capacitors (capacitors are NEVER marked).
All the SM resistors in the above photos conform to a 3-digit or 4-digit code. But there are a number of codes, and the 4-digit code caters for high tolerance resistors, so it's getting very complicated.
Here is a basic 3-digit SM resistor:



A 330k SM resistor

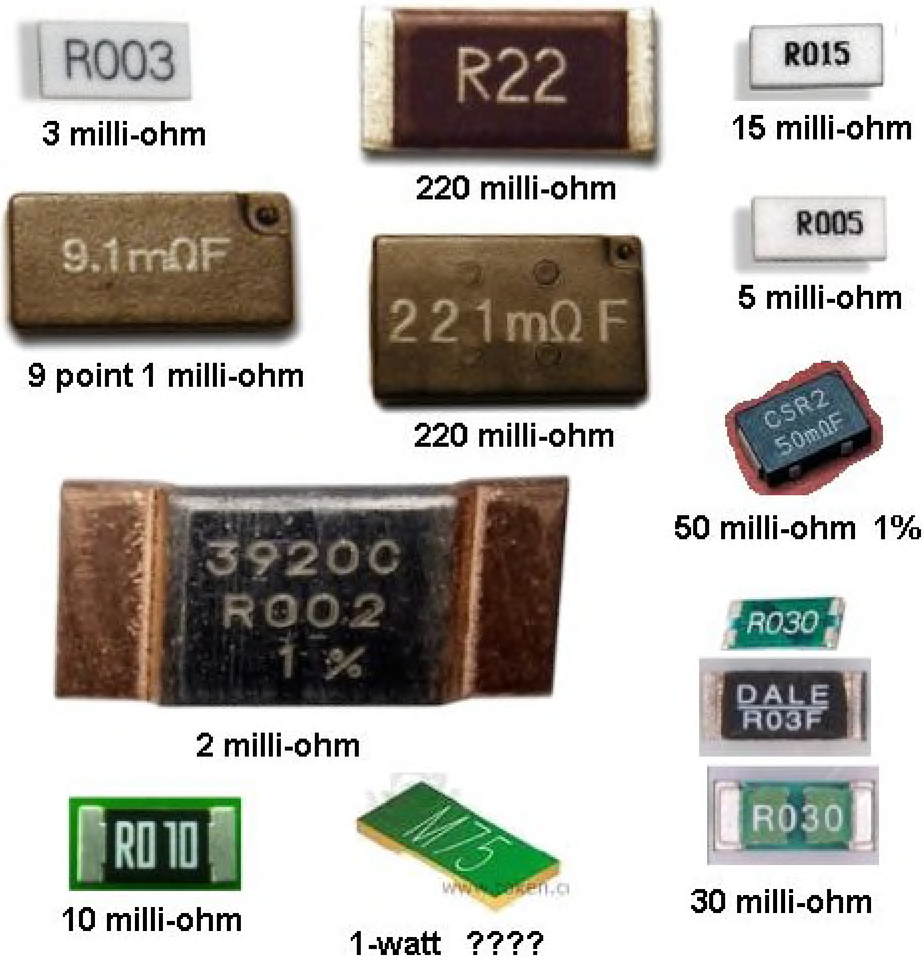
The first two digits represent the two digits in the answer. The third digit represents the number of zero's you must place after the two digits. The answer will be OHMS. For example: 334 is written 33 0 000. This is written 330,000 ohms. The comma can be replaced by the letter "k". The final answer is: 330k.
222 = 22 00 = 2,200 = 2k2
473 = 47 000 = 47,000 = 47k
474 = 47 0000 = 470,000 = 470k
105 = 10 00000 = 1,000,000 = 1M = one million ohms

There is one trick you have to remember. Resistances less than 100 ohms are written: 100, 220, 470. These are 10 and NO zero's = 10 ohms = 10R or 22 and no zero's = 22R or 47 and no zero's = 47R. Sometimes the resistor is marked: 10, 22 and 47 to prevent a mistake.

Remember:
R = ohms
k = kilo ohms = 1,000 ohms
M = Meg = 1,000,000 ohms
The 3 letters (R, k and M) are put in place of the decimal point. This way you cannot make a mistake when reading a value of resistance.

Surface Mount **CURRENT SENSING** Resistors

Many new types of CURRENT SENSING surface-mount resistors are appearing on the market and these are creating lots of new problems.
Fortunately all resistors are marked with the value of resistance and these resistors are identified in MILLIOHMS. A miili ohm is one thousandth or an ohm and is written 0.001 when writing a normal mathematical number.
When written on a surface mount resistor, the letter R indicates the decimal point and it also signifies the word "OHM" or "OHMS" and one milli-ohm is written R001
Five miiliohms is R005 and one hundred milliohms is R100
Some surface mount resistors have the letter "M" after the value to indicate the resistor has a rating of 1 watt. e.g: R100M These surface-mount resistors are specially-made to withstand a high temperature and a surface-mount resistor of the same size is normally 250mW or less.
These current-sensing resistors can get extremely hot and the PC board can become burnt or damaged.
When designing a PC board, make the lands very large to dissipate the heat.
Normally a current sensing resistor is below one ohm (1R0) and it is easy to identify them as R100 etc.
You cannot measure the value of a current sensing resistor as the leads of a multimeter have a higher resistance than the resistor and few multimeters can read values below one ohm.
If the value is not visible, you will have to refer to the circuit.
Before replacing it, work out why it failed.
Generally it gets too hot. Use a larger size and add tiny heatsinks on each end.
Here are some surface=mount current-sense resistors:



THE COMPLETE RANGE OF SM RESISTOR MARKINGS

Click to see the complete range of SM resistor markings for 3-digit code:

0R1 = 0.1ohm

Click to see the complete range of SM resistor markings for 4-digit code:

0000 =00R

0000 is a value on a surface-mount resistor. It is a zero-ohm **LINK**!
Resistances less than 10 ohms have 'R' to indicate the position of the decimal point.
Here are some examples:

Three Digit Examples	Four Digit Examples
330 is 33 ohms - ***not 330 ohms***	**1000 is 100 ohms** - ***not 1000 ohms***
221 is 220 ohms	**4992 is 49 900 ohms, or 49k9**
	1623 is 162 000 ohms, or

683 is 68 000 ohms, or 68k	**1623 is 162 000 ohms, or 162k**
105 is 1 000 000 ohms, or 1M	**0R56 or R56 is 0.56 ohms**
8R2 is 8.2 ohms	

A new coding system has appeared on **1% types**. This is known as the EIA-96 marking method. It consists of a three-character code. The first two digits signify the 3 significant digits of the resistor value, using the lookup table below. The third character - a letter - signifies the multiplier.

code	value	code	value	code	value	code	value	code	value	code	value
01	100	**17**	147	**33**	215	**49**	316	**65**	464	**81**	681
02	102	**18**	150	**34**	221	**50**	324	**66**	475	**82**	698
03	105	**19**	154	**35**	226	**51**	332	**67**	487	**83**	715
04	107	**20**	158	**36**	232	**52**	340	**68**	499	**84**	732
05	110	**21**	162	**37**	237	**53**	348	**69**	511	**85**	750
06	113	**22**	165	**38**	243	**54**	357	**70**	523	**86**	768
07	115	**23**	169	**39**	249	**55**	365	**71**	536	**87**	787
08	118	**24**	174	**40**	255	**56**	374	**72**	549	**88**	806
09	121	**25**	178	**41**	261	**57**	383	**73**	562	**89**	825
10	124	**26**	182	**42**	267	**58**	392	**74**	576	**90**	845
11	127	**27**	187	**43**	274	**59**	402	**75**	590	**91**	866
12	130	**28**	191	**44**	280	**60**	412	**76**	604	**92**	887
13	133	**29**	196	**45**	287	**61**	422	**77**	619	**93**	909
14	137	**30**	200	**46**	294	**62**	432	**78**	634	**94**	931
15	140	**31**	205	**47**	301	**63**	442	**79**	649	**95**	953
16	143	**32**	210	**48**	309	**64**	453	**80**	665	**96**	976

The **multiplier** letters are as follows:

letter	mult	letter	mult
F	**100000**	**B**	**10**
E	**10000**	**A**	**1**
D	**1000**	**X or S**	**0.1**
C	**100**	**Y or R**	**0.01**

22A is a 165 ohm resistor, **68C** is a 49900 ohm (49k9) and **43E** a 2740000 (2M74). This marking scheme applies to 1% resistors only.

A similar arrangement can be used for **2% and 5%** tolerance types. The multiplier letters are identical to 1% ones, but occur **before** the number code and the following **code** is used:

2%	5%

2%				5%			
code	**value**	**code**	**value**	**code**	**value**	**code**	**value**
01	100	**13**	330	**25**	100	**37**	330
02	110	**14**	360	**26**	110	**38**	360
03	120	**15**	390	**27**	120	**39**	390
04	130	**16**	430	**28**	130	**40**	430
05	150	**17**	470	**29**	150	**41**	470
06	160	**18**	510	**30**	160	**42**	510
07	180	**19**	560	**31**	180	**43**	560
08	200	**20**	620	**32**	200	**44**	620
09	220	**21**	680	**33**	220	**45**	680
10	240	**22**	750	**34**	240	**46**	750
11	270	**23**	820	**35**	270	**47**	820
12	300	**24**	910	**36**	300	**48**	910

With this arrangement, **C31** is 5%, 18000 ohm (18k), and **D18** is 510000 ohms (510k) 2% tolerance. Always check with an ohm-meter (a multimeter) to make sure.

Chip resistors come in the following styles and ratings:
Style: 0402, 0603, 0805, 1206, 1210, 2010, 2512, 3616, 4022
Power Rating: 0402(1/16W), 0603(1/10W), 0805(1/8W), 1206(1/4W), 1210(1/3W), 2010(3/4W), 2512 (1W), 3616(2W), 4022(3W)
Tolerance: 0.1%, 0.5%, 1%, 5%
Temperature Coefficient: 25ppm 50ppm 100ppm

EIA marking code for surface mount (SMD) resistors

01S = 1R	01R = 10R	01A = 100R	01B = 1k	01C = 10k	01D = 100k	01E = 1M	01F = 10M
02S = 1R02	02R = 10R2	02A = 102R	02B = 1k02	02C = 10k2	02D = 102k	02E = 1M02	
03S = 1R05	03R = 10R5	03A = 105R	03B = 1k05	03C = 10k5	03D = 105k	03E = 1M05	18F = 15M
04S = 1R07	04R = 10R7	04A = 107R	04B = 1k07	04C = 10k7	04D = 107k	04E = 1M07	
05S = 1R1	05R = 11R	05A = 110R	05B = 1k1	05C = 11k	05D = 110k	05E = 1M1	30F = 20M
06S = 1R13	06R = 11R3	06A = 113R	06B = 1k13	06C = 11k3	06D = 113k	06E = 1M13	
07S = 1R15	07R = 11R5	07A = 115R	07B = 1k15	07C = 11k5	07D = 115k	07E = 1M15	
08S = 1R18	08R = 11R8	08A = 118R	08B = 1k18	08C = 11k8	08D = 118k	08E = 1M18	
09S = 1R21	09R = 12R1	09A = 121R	09B = 1k21	09C = 12k1	09D = 121k	09E = 1M21	
10S = 1R24	10R = 12R4	10A = 124R	10B = 1k24	10C = 12k4	10D = 124k	10E = 1M24	
11S = 1R27	11R = 12R7	11A = 127R	11B = 1k27	11C = 12k7	11D = 127k	11E = 1M27	
12S = 1R3	12R = 13R	12A = 130R	12B = 1k3	12C = 13k	12D = 130k	12E = 1M3	
13S = 1R33	13R = 13R3	13A = 133R	13B = 1k33	13C = 13k3	13D = 133k	13E = 1M33	
14S = 1R37	14R = 13R7	14A = 137R	14B = 1k37	14C = 13k7	14D = 137k	14E = 1M37	
15S = 1R4	15R = 14R	15A = 140R	15B = 1k4	15C = 14k	15D = 140k	15E = 1M4	
16S = 1R43	16R = 14R3	16A = 143R	16B = 1k43	16C = 14k3	16D = 143k	16E = 1M43	
17S = 1R47	17R = 14R7	17A = 147R	17B = 1k47	17C = 14k7	17D = 147k	17E = 1M47	
18S = 1R5	18R = 15R	18A = 150R	18B = 1k5	18C = 15k	18D = 15k	18E = 1M5	
19S = 1R54	19R = 15R4	19A = 154R	19B = 1k54	19C = 15k4	19D = 154k	19E = 1M54	
20S = 1R58	20R = 15R8	20A = 158R	20B = 1k58	20C = 15k8	20D = 158k	20E = 1M58	
21S = 1R62	21R = 16R2	21A = 162R	21B = 1k62	21C = 16k2	21D = 162k	21E = 1M62	
22S = 1R65	22R = 16R5	22A = 165R	22B = 1k65	22C = 16k5	22D = 165k	22E = 1M65	
23S = 1R69	23R = 16R9	23A = 169R	23B = 1k69	23C = 16k9	23D = 169k	23E = 1M69	
24S = 1R74	24R = 17R4	24A = 174R	24B = 1k74	24C = 17k4	24D = 174k	24E = 1M74	
25S = 1R78	25R = 17R8	25A = 178R	25B = 1k78	25C = 17k8	25D = 178k	25E = 1M78	
26S = 1R82	26R = 18R2	26A = 182R	26B = 1k82	26C = 18k2	26D = 182k	26E = 1M82	
27S = 1R87	27R = 18R7	27A = 187R	27B = 1k87	27C = 18k7	27D = 187k	27E = 1M87	
28S = 1R91	28R = 19R1	28A = 191R	28B = 1k91	28C = 19k1	28D = 191k	28E = 1M91	
29S = 1R96	29R = 19R6	29A = 196R	29B = 1k96	29C = 19k6	29D = 196k	29E = 1M96	
30S = 2R0	30R = 20R0	30A = 200R	30B = 2k0	30C = 20k0	30D = 200k	30E = 2M0	
31S = 2R05	31R = 20R5	31A = 205R	31B = 2k05	31C = 20k5	31D = 205k	31E = 2M05	
32S = 2R10	32R = 21R0	32A = 210R	32B = 2k10	32C = 21k0	32D = 210k	32E = 2M10	
33S = 2R15	33R = 21R5	33A = 215R	33B = 2k15	33C = 21k5	33D = 215k	33E = 2M15	
34S = 2R21	34R = 22R1	34A = 221R	34B = 2k21	34C = 22k1	34D = 221k	34E = 2M21	
35S = 2R26	35R = 22R6	35A = 226R	35B = 2k26	35C = 22k6	35D = 226k	35E = 2M26	

36S = 2R32	36R = 23R2	36A = 232R	36B = 2k32	36C = 23k2	36D = 232k	36E = 2M32
37S = 2R37	37R = 23R7	37A = 237R	37B = 2k37	37C = 23k7	37D = 237k	37E = 2M37
38S = 2R43	38R = 24R3	38A = 243R	38B = 2k43	38C = 24k3	38D = 243k	38E = 2M43
39S = 2R49	39R = 24R9	39A = 249R	39B = 2k49	39C = 24k9	39D = 249k	39E = 2M49
40S = 2R55	40R = 25R5	40A = 255R	40B = 2k55	40C = 25k5	40D = 255k	40E = 2M55
41S = 2R61	41R = 26R1	41A = 261R	41B = 2k61	41C = 26k1	41D = 261k	41E = 2M61
42S = 2R67	42R = 26R7	42A = 267R	42B = 2k67	42C = 26k7	42D = 267k	42E = 2M67
43S = 2R74	43R = 27R4	43A = 274R	43B = 2k74	43C = 27k4	43D = 274k	43E = 2M74
44S = 2R80	44R = 28R0	44A = 280R	44B = 2k80	44C = 28k0	44D = 280k	44E = 2M80
45S = 2R87	45R = 28R7	45A = 287R	45B = 2k87	45C = 28k7	45D = 287k	45E = 2M87
46S = 2R94	46R = 29R4	46A = 294R	46B = 2k94	46C = 29k4	46D = 294k	46E = 2M94
47S = 3R01	47R = 30R1	47A = 301R	47B = 3k01	47C = 30k1	47D = 301k	47E = 3M01
48S = 3R09	48R = 30R9	48A = 309R	48B = 3k09	48C = 30k9	48D = 309k	48E = 3M09
49S = 3R16	49R = 31R6	49A = 316R	49B = 3k16	49C = 31k6	49D = 316k	49E = 3M16
50S = 3R24	50R = 32R4	50A = 324R	50B = 3k24	50C = 32k4	50D = 324k	50E = 3M24
51S = 3R32	51R = 33R2	51A = 332R	51B = 3k32	51C = 33k2	51D = 332k	51E = 3M32
52S = 3R4	52R = 34R0	52A = 340R	52B = 3k4	52C = 34k0	52D = 340k	52E = 3M4
53S = 3R48	53R = 34R8	53A = 348R	53B = 3k48	53C = 34k8	53D = 348k	53E = 3M48
54S = 3R57	54R = 35R7	54A = 357R	54B = 3k57	54C = 35k7	54D = 357k	54E = 3M57
55S = 3R65	55R = 36R5	55A = 365R	55B = 3k65	55C = 36k5	55D = 365k	55E = 3M65
56S = 3R74	56R = 37R4	56A = 374R	56B = 3k74	56C = 37k4	56D = 374k	56E = 3M74
57S = 3R83	57R = 38R3	57A = 383R	57B = 3k83	57C = 38k3	57D = 383k	57E = 3M83
58S = 3R92	58R = 39R2	58A = 392R	58B = 3k92	58C = 39k2	58D = 392k	58E = 3M92
59S = 4R02	59R = 40R2	59A = 402R	59B = 4k02	59C = 40k2	59D = 402k	59E = 4M02
60S = 4R12	60R = 41R2	60A = 412R	60B = 4k12	60C = 41k2	60D = 412k	60E = 4M12
61S = 4R22	61R = 42R2	61A = 422R	61B = 4k22	61C = 42k2	61D = 422k	61E = 4M22
62S = 4R32	62R = 43R2	62A = 432R	62B = 4k32	62C = 43k2	62D = 432k	62E = 4M32
63S = 4R42	63R = 44R2	63A = 442R	63B = 4k42	63C = 44k2	63D = 442k	63E = 4M42
64S = 4R53	64R = 45R3	64A = 453R	64B = 4k53	64C = 45k3	64D = 453k	64E = 4M53
65S = 4R64	65R = 46R4	65A = 464R	65B = 4k64	65C = 46k4	65D = 464k	65E = 4M64
66S = 4R75	66R = 47R5	66A = 475R	66B = 4k75	66C = 47k5	66D = 475k	66E = 4M75
67S = 4R87	67R = 48R7	67A = 487R	67B = 4k87	67C = 48k7	67D = 487k	67E = 4M87
68S = 4R99	68R = 49R9	68A = 499R	68B = 4k99	68C = 49k9	68D = 499k	68E = 4M99
69S = 5R11	69R = 51R1	69A = 511R	69B = 5k11	69C = 51k1	69D = 511k	69E = 5M11
70S = 5R23	70R = 52R3	70A = 523R	70B = 5k23	70C = 52k3	70D = 523k	70E = 5M23
71S = 5R36	71R = 53R6	71A = 536R	71B = 5k36	71C = 53k6	71D = 536k	71E = 5M36
72S = 5R49	72R = 54R9	72A = 549R	72B = 5k49	72C = 54k9	72D = 549k	72E = 5M49
73S = 5R62	73R = 56R2	73A = 562R	73B = 5k62	73C = 56k2	73D = 562k	73E = 5M62
74S = 5R76	74R = 57R6	74A = 576R	74B = 5k76	74C = 57k6	74D = 576k	74E = 5M76
75S = 5R9	75R = 59R0	75A = 590R	75B = 5k9	75C = 59k0	75D = 590k	75E = 5M9
76S = 6R04	76R = 60R4	76A = 604R	76B = 6k04	76C = 60k4	76D = 604k	76E = 6M04
77S = 6R19	77R = 61R9	77A = 619R	77B = 6k19	77C = 61k9	77D = 619k	77E = 6M19
78S = 6R34	78R = 63R4	78A = 634R	78B = 6k34	78C = 63k4	78D = 634k	78E = 6M34
79S = 6R49	79R = 64R9	79A = 649R	79B = 6k49	79C = 64k9	79D = 649k	79E = 6M49
80S = 6R65	80R = 66R5	80A = 665R	80B = 6k65	80C = 66k5	80D = 665k	80E = 6M65
81S = 6R81	81R = 68R1	81A = 681R	81B = 6k81	81C = 68k1	81D = 681k	81E = 6M81
82S = 6R98	82R = 69R8	82A = 698R	82B = 6k98	82C = 69k8	82D = 698k	82E = 6M98
83S = 7R15	83R = 71R5	83A = 715R	83B = 7k15	83C = 71k5	83D = 715k	83E = 7M15
84S = 7R32	84R = 73R2	84A = 732R	84B = 7k32	84C = 73k2	84D = 732k	84E = 7M32
85S = 7R5	85R = 75R0	85A = 750R	85B = 7k5	85C = 75k0	85D = 750k	85E = 7M5
86S = 7R68	86R = 76R8	86A = 768R	86B = 7k68	86C = 76k8	86D = 768k	86E = 7M68
87S = 7R87	87R = 78R7	87A = 787R	87B = 7k87	87C = 78k7	87D = 787k	87E = 7M87
88S = 8R06	88R = 80R6	88A = 806R	88B = 8k06	88C = 80k6	88D = 806k	88E = 8M06
89S = 8R25	89R = 82R5	89A = 825R	89B = 8k25	89C = 82k5	89D = 825k	89E = 8M25
90S = 8R45	90R = 84R5	90A = 845R	90B = 8k45	90C = 84k5	90D = 845k	90E = 8M45
91S = 8R66	91R = 86R6	91A = 866R	91B = 8k66	91C = 86k6	91D = 866k	91E = 8M66
92S = 8R87	92R = 88R7	92A = 887R	92B = 8k87	92C = 88k7	92D = 887k	92E = 8M87
93S = 9R09	93R = 90R9	93A = 909R	93B = 9k09	93C = 90k9	93D = 909k	93E = 9M09
94S = 9R31	94R = 93R1	94A = 931R	94B = 9k31	94C = 93k1	94D = 931k	94E = 9M31
95S = 9R53	95R = 95R3	95A = 953R	95B = 9k53	95C = 95k3	95D = 953k	95E = 9M53
96S = 9R76	96R = 97R6	96A = 976R	96B = 9k76	96C = 97k6	96D = 976k	96E = 9M76

If you want an accurate RESISTANCE measurement, remove the resistor from the circuit and use a Digital meter.

SURFACE MOUNT COMPONENTS - PACKS

Talking Electronics has packs of components for the repairman. The following packs are available:

SURFACE MOUNT RESISTOR PACK consists of 1 off each standard value 10 ohms to 1M & 2M2 (60 resistors)

$14.20 including pack and post

SURFACE MOUNT CAPACITOR PACK consists of:
2 - 10p 5 - 47p 5 - 100p 5 - 470p 5 - 1n 5 - 10n 5 - 22n 5 - 100n
5 - 1u 16v electrolytic 5 - 10u 16v electrolytic
(40 components)
$23.80 including pack and post

SURFACE MOUNT DIODE PACK consists of:
5 - 1N 4148 (marked as "A6")
$10.00 including pack and post

SURFACE MOUNT TRANSISTOR PACK consists of:
5 - BC 848 (marked as "1K") NPN
5 - BC858 PNP
$10.00 including pack and post

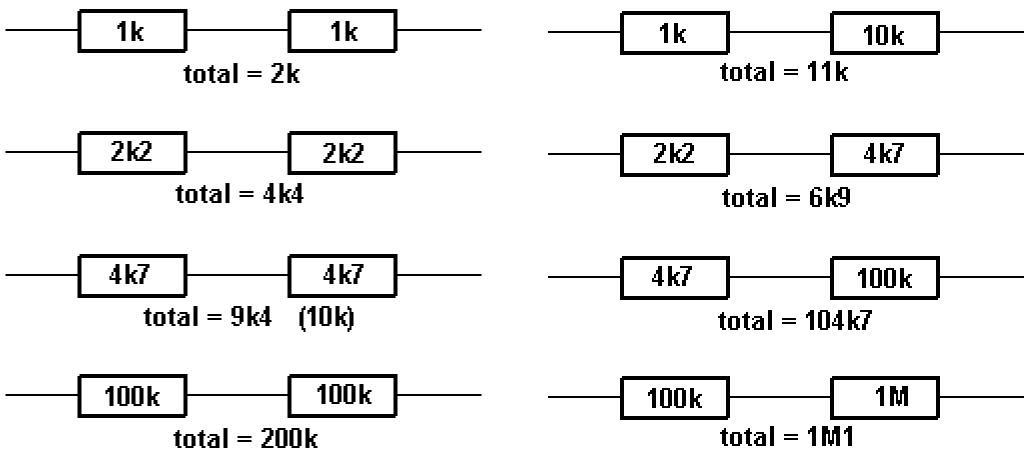
email Colin Mitchell for details on how to pay by credit card or PayPal.

CREATING ANY VALUE OF RESISTANCE

Any value of resistance can be created by connecting two resistors in PARALLEL or SERIES. You can also create a higher wattage resistor by connecting them in SERIES OR PARALLEL. We are only going to cover two EQUAL VALUE resistors in SERIES or in PARALLEL.
If you want to create a "Special Value," simply connect two resistors and read the value with a Digital Meter. Keep changing the values until you get the required value. We are not going into series or Parallel formulae. You can easily find a value with a multimeter.

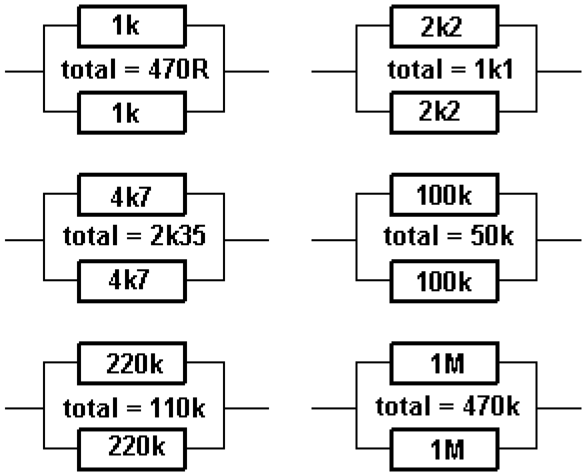
TWO EQUAL-VALUE RESISTORS IN SERIES

Two equal-value resistors IN SERIES creates a value of DOUBLE. You simply ADD the values.
This can be done with any to two values as shown. Three equal-value resistors in series is three times the value.



TWO EQUAL-VALUE RESISTORS IN PARALLEL

Two equal-value resistors IN PARALLEL creates a value of HALF. Three equal-value resistors in parallel is equal to one-third the value.



If you want a particular value and it is not available, here is a chart.
Use 2 resistors in series or parallel as shown:

Required Value	R1	Series/ Parallel	R2	Actual value:
10	4R7	S	4R7	9R4
12	10	S	2R2	12R2
15	22	P	47	14R9
18	22	P	100	18R
22	10	S	12	22
27	22	S	4R7	26R7
33	22	S	10	32R
39	220	P	47	38R7
47	22	S	27	49
56	47	S	10	57
68	33	S	33	66
82	27	S	56	83

There are other ways to combine 2 resistors in parallel or series to get a particular value.
The examples above are just one way. 4R7 = 4.7 ohms

TESTING A RESISTOR

To check the value of a resistor, it should be removed from the circuit. The surrounding components can affect the reading and make it lower.
Resistors **VERY RARELY** change value, but if it is overheated or damaged, the resistance can increase. You can take the reading of a resistor "in-circuit" in one direction then the other, as the surrounding components may have diodes and this will alter the reading.
You can also test a resistor by feeling its temperature-rise. It is getting too hot if you cannot hold your finger on it (some "metal film" resistors are designed to tolerate quite high temperatures).

HOW TO WORK OUT THE VALUE OF A RESISTOR

This is a question from a reader.
"How do I work out the value of a resistor for biasing or illuminating a LED?"
The value of ALL resistors is worked out by the use of Ohm's Law.
Ohm's Law is:

$$I = \frac{V}{R}$$ **Current is equal to voltage divided by resistance.**

Here's one way to work out the resistance:
The first thing you do is decide on the current you want to flow. It may be 1mA for the base current for a transistor or 10mA for a LED. It could be as low as 0.1mA or even 1uA. But you must decide on what we call "**a current-flow**."
Next, you need to know the voltage that will be at the top of the resistor and the voltage at the bottom. Let's say it is 12v at the top and 2v at the bottom.
This means 10v will be across the resistor.
Now we use Ohm's Law: I = V/R In other words, Current = voltage divided by resistance.
In all 3-term formulas, you must know the value of two items to be able to work out the value of the remaining item. These items are called "terms" or "variables"
Here are some examples:
If the resistor is 10,000 ohms (10k) the current will be 1mA
If the resistor is 1,000 ohms (1k) the current will be 10mA
If the resistor is 100 ohms (100R) the current will be 100mA

The base-line for you to remember is this: **one volt across a 10k resistor will allow 1mA to flow.**

For all other values you do not need a calculator.
Just follow these examples:
If 10k will pass 1mA, 4k7 will pass 0.5mA and 3k3 will pass 0.3mA.
If 1k will pass 10mA, 470R will pass 20mA and 330R will pass 30mA.
If 100R will pass 100mA, 47R will pass 200mA and 33R will pass 300mA.

If 1M will pass 1uA, 470k will pass 2uA.

If the voltage is increased to 20v, all the current values will double.
If the voltage is reduced to 5v, the current-values will be halved. No calculator is needed.

If you don't know the voltage across the resistor, you will need to start with a 1M resistor then 100k then 10k then 1k, making sure nothing is getting too hot or being destroyed. This called "trial-and-error" and is the basis of experimenting.

If the resistor is in a high-current circuit, you will also need to work out its wattage.
Normally a 250mW standard through-hole resistor will be suitable for most applications (or a 100mW surface-mount resistor).
But when the current is more than say about 100mA, the resistor will get warm or hot.
You will need to work out the "losses" in the resistor. This is the wattage lost when the current is flowing.
This is called the POWER FORMULA. It is: **Power = volts x amps (answer is watts)**
We are going to keep the discussion simple and only cover the losses of 1watt or more.
When 100mA flows through a resistor and 10v is across the resistor, the wattage lost by the resistor (the dissipation of the resistor) will be:
Power = 10volts times 0.1amp = 1 watt
The formula is: Power = Volts x Amps and the answer is watts.
If the voltage is 10v and the current = 1 amp, the watts dissipated by the resistor will be 10 watts.
This is called HEAT or WASTED ENERGY or HEAT LOSS and it is very difficult to dissipate from your project. You may need a large heat-fin or a fan and is beyond the scope of this discussion.

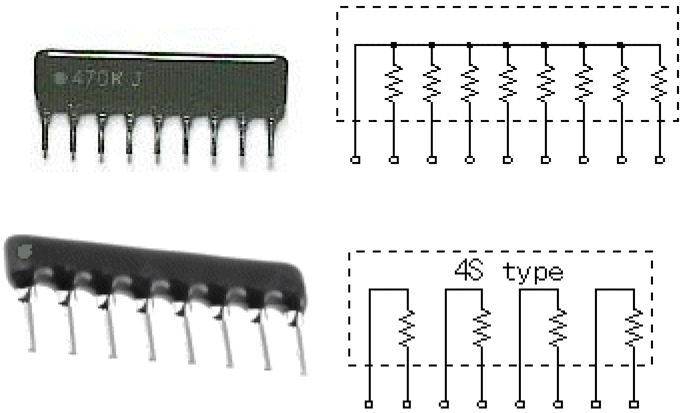
TESTING AN "AC" RESISTOR

There is no such thing as an "AC" resistor. Resistors are just "resistors" and they can be in AC circuits or DC circuits. Resistors can be given names such as "Safety Resistor" "Ballast Resistor" "LOAD Resistor" "Feed Resistor" "Dropper Resistor" or "Supply Resistor." These are just normal resistors with a normal resistance - except a "Safety Resistor."
A safety resistor is made of a flame-proof material such as metal-oxide-film and not carbon-composition. It is designed to "burn out" when too much current flows BUT NOT CATCH FIRE.
It is a low-value resistor and has a voltage-drop across it but this is not intentional. The voltage-drop is

It is a low value resistor and has a voltage drop across it but this is not intentional. The voltage drop is to create a "heating-effect" to burn out the resistor. In all the other types of resistor, the voltage-drop is intentional.
A Ballast resistor is a normal resistor and can be called a Power resistor, Dropper resistor, Supply resistor or Feed resistor. It is designed to reduce the voltage from one source and deliver a lower voltage. It is a form of: "in-line" resistor.
A Load Resistor is generally connected across the output of a circuit and turns the energy it receives, into heat.

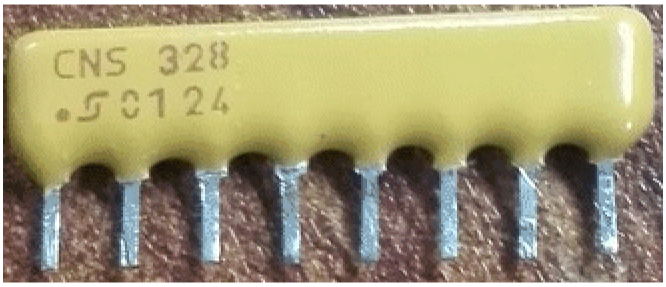
RESISTOR NETWORKS

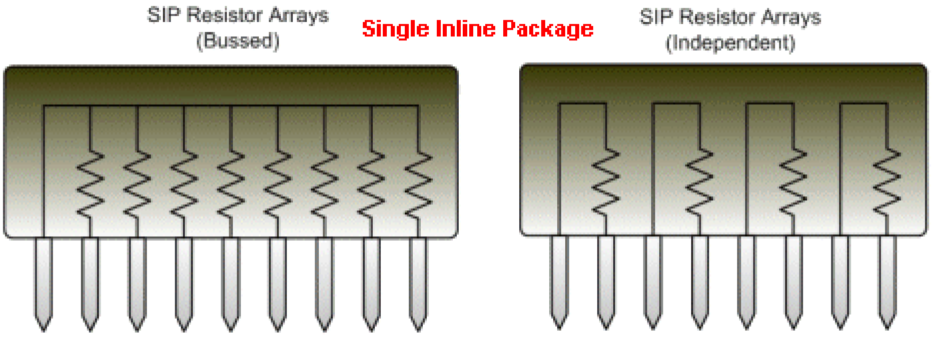
To reduce the number of components in a circuit, some engineers use a set of identical resistors in a package called a Single-In-Line (SIL) resistor network. It is made with many resistors of the same value, all in one package. One end of each resistor is connected all the other resistors and this is the common pin, identified as pin 1 and has a dot on the package.
These packages are very reliable but to make sure all the resistors are as stated, you need to locate pin 1. All values will be identical when referenced to this pin.



RESISTOR NETWORKS

Some resistor networks have a "4S" printed on the component. The 4S indicates the package contains 4 independent resistors that are not wired together inside. The housing has eight leads as shown in the second image.
Independent resistors have an even number of pins and measuring between each pair will produce identical values. Resistance between any pair will indicate leakage and may be a fault. If you know how they are connected, and the value, and you think they are faulty, you can replace an array with 8 small resistors soldered together in a similar way to the diagrams below. The network below has an "in house" number and does not identify any values.





WIRE WOUND RESISTOR

A wire wound resistor is also called a POWER RESISTOR. This type of resistor can have a resistance as low as 0.1 ohms (one-tenth of an ohm) or as high as about 10k.
The image shows a 0.68 ohm resistor as the letter "R" represents the DECIMAL POINT and R68 is the same a .68 and this is 0.68 ohms. The wattage is 9 watts.
This resistor will allow xxx amps to flow.   To work out the current, use the formula:
Power = Current x Current x resistance
   9   = Current x Current x .68
Divide both sides by 0.68
13.2   = Current x Current
Find the square root of 13.2
Current = 3.6 amps

When 3.6 amps flow through the resistor, the voltage appearing across it will be:
V = current x resistance
   = 3.6   x 0.68
   = 2.5v and the wattage (heat) loss will be 9 watts.

The purpose of a resistor like this is to stop or reduce "ripple." Ripple is the noise or hum in an amplifier when the sound is turned up.
There are many reasons why you need to reduce the level of hum and this resistor will remove ripple as large as 2.5v when 3.6 amps is flowing, provided you have filter electrolytics on both side of the resistor to assist in removing the ripple.

If the letter "R" is in a different position, the value of resistance would be:

68R = 68Ω
6R8 = 6.8Ω
R68 = 0.68Ω

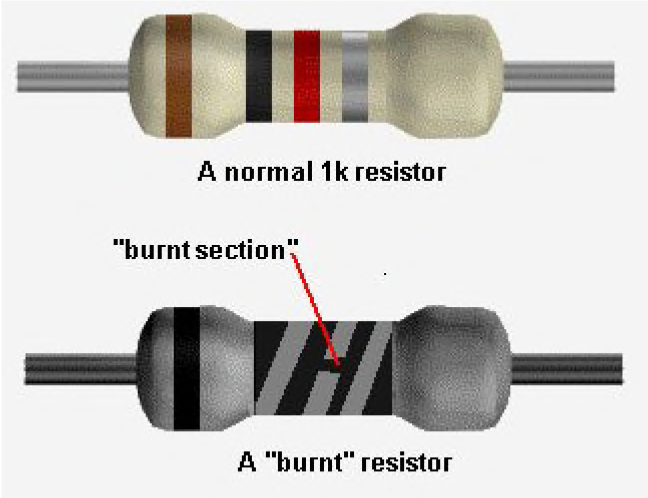
If you replace the R68 resistor a 6R8 resistor by mistake, the voltage across it will rise to 25v and if 3.6 amps flows, the wattage will be: 90 watts!!!
The resistor will glow red and burn out.

TESTING A POSISTOR

A Posistor is a resistor that connects in series with the degaussing coil around the picture tube or **Monitor.** When cold, it has a very low resistance and a large current flows when the monitor or TV is switched on. This current heats up the Posistor and the resistance increases. This causes the current to decrease and any magnetism in the shadow mask is removed. The posistor can one or two elements and it is kept warm so the resistance remains high. Many Posistors have a second element inside the case that connects directly to the supply to keep the Positive Temperature Coefficient resistor high so that the current through the degaussing coil falls to almost zero. This constant heat eventually destroys the package.
The heavy current that flows when a set is turned ON also causes the posistor to crack and break and this results in poor purity on the screen - as the shadow mask gradually becomes magnetic..
Posistors have different resistance values from different manufacturers and must be replaced with an identical type.
They can be checked for very low resistance when cold but any loose pieces inside the case will indicate a damaged component.

A "BURNT" RESISTOR **- normally and technically called a "burnt-out" resistor.**

The resistance of a "burnt" resistor can sometimes be determined by scraping away the outer coating - if the resistor has a spiral of resistance-material. You may be able to find a spot where the spiral has been damaged.



**Note the spirals of conductive carbon.
The number of spirals has nothing to with the resistance.
It is the amount of carbon particles in the "track" that
determines the resistance. It is also the thickness and width
of the track that determines the resistance.
And then it is the overall size of the resistor that determines the wattage.
And then the size of the leads, the closeness to the PCB and
the size of the lands that eventually determines how hot the resistor
will get.**

Clean the "spot" (burnt section of the spiral) very carefully and make sure you can get a good contact with the spiral and the tip of your probe. Measure from one lead of the resistor to the end of the damaged spiral. Then measure from the other lead to the other end of the spiral.
Add the two values and you have an approximate value for the resistor. You can add a small amount for the damaged section.
This process works very well for damaged wire-wound resistors. They can be pulled apart and each section of the resistance-wire (nichrome wire) measured and added to get the full resistance.

There is another way to determine the value of a damaged resistor.
Get a set of resistors of the same wattage as the damaged component and start with a high value. It's handy to know if the resistor is in the range: 10ohm to 100ohms or 1k to 10k etc, but this is not essential.
Start with a very high value and turn the circuit ON. You can perform voltage tests and if you know the expected output voltage, decrease the resistance until this voltage is obtained.
If you do not know the expected voltage, keep reducing the value of resistance until the circuit works as designed.
This is the best advice in a situation where you do not know the value of a resistor.

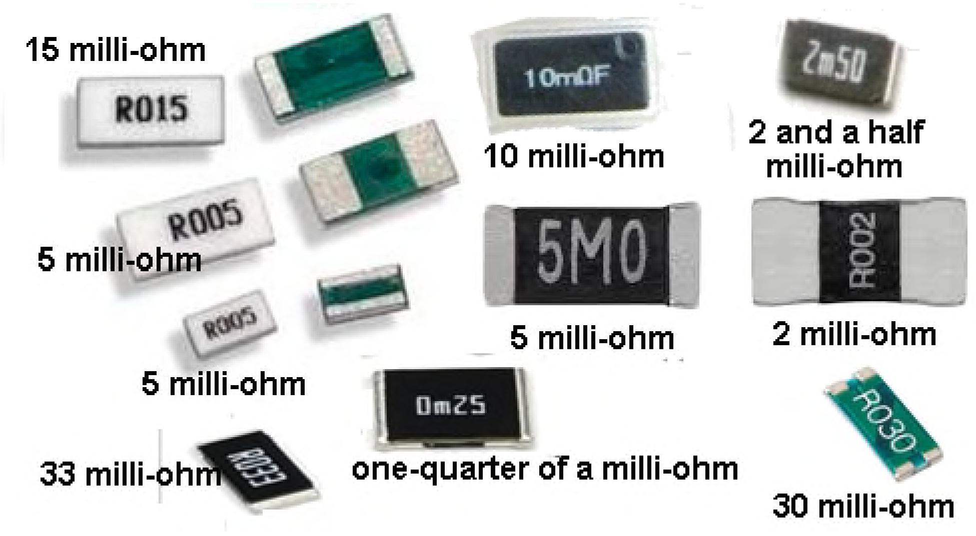
There is a third way to determine the value and this requires measuring the voltage drop across the resistor and the current-flow. By multiplying the two you will get a wattage and this must be less than the wattage of the resistor being replaced.

A "SHUNT" RESISTOR

A SHUNT RESISTOR is a power-resistor and you will find them in multimeters to provide the CURRENT READING.
This type of resistor is also called A CURRENT SHUNT (Current Shunt Resistor) or CURRENT SENSE RESISTOR. You will also find them in many other circuits where the current is required to be measured.
A CURRENT SENSE RESISTOR is always very low resistance so it does not alter the performance of the circuit.
As current flows though the resistor, a voltage is produced across the resistor and this voltage is measured by a detecting circuit and the designer of the circuit already knows how much current is flowing for each mV developed across the resistor.
But, if too much current flows, these resistors can burn-out and it is impossible to work out the value of the resistor. Mainly because the resistance can be as low as 0.1 ohms.
But there is an easy way to replace the resistor.
You will need a set of resistors and the cheapest way to start is with one ohm resistors (0.25watt).
Place two of them in parallel and connect the project in series with a multimeter set to 10 amp range and then place a 10 ohm wire-wound resistor in series with the two instruments and a 12v supply.
You know the current should be about 1.2 amps and if the reading on your damaged instrument is reading 3 amps, you will need to place another one-ohm resistor in parallel with the other two. Keep doing this until the reading on the damaged meter corresponds to the reading on the functioning meter.
You can add 2 or 3 one-ohm resistors in series to get a fine adjustment.
When you have finished, you can work out the value of the combination by realising two resistors in parallel is equal to 0.5 ohms and 3 is 0.33 ohms and 4 is 0.25 ohms.
You may be able to buy shunt resistors of the required value or maybe use surface mount resistors but you also have to take into account the size of the original resistor. You must match the size.

MILLI-OHM RESISTORS

Many SHUNT RESISTORS have a very low resistance, mainly because the resistor is measuring a high current and you don't want a lot of heat to be created by the resistor and you don't want the voltage you are measuring to reduce in value.
That's why many SHUNT RESISTORS have a resistance in the MILLI-OHM range.
A milliohm is ONE THOUSANDTH OF AN OHM and if one amp is flowing through the resistor, one-millivolt will be developed across it.
If you go through all the samples below, the same reasoning produces 5mV for a 5 milli-ohm resistor and one quarter of a milli-volt for a 0m25 resistor. Thus 4 amp through this resistor produces 1mV.
Because a high current will flow through the resistor and through the tracks, there will be some degree of heating and these resistors can get warm/hot and even overheat and melt the solder. They can also go open and that's where your skill comes in . . to replace them with the correct value and wattage.



TESTING AND MEASURING MILLI-OHM RESISTORS

Very low-ohm resistors can be measured in two ways.
Digital multimeters will measure resistors from 0.1 ohms but the leads add 0.3 ohms to the reading.
You can double-check the reading by adding a 1 ohm resistor and measuring the milli-ohm resistor with the 1 ohm and with it removed.
If the milliohm resistor is less than 0.1 ohm, you can place the resistor in series with a multimeter set to current (1 amp) and add an 8 ohm wire wound resistor in series.
Connect the circuit to a variable power supply and increase the current to exactly 1 amp.
Now measure the voltage across the milli-ohm resistor with a multimeter set to say 2,000mA.
Each mV will represent 1milliohm.
For example, if the reading is 200mV, the resistor is 200milli-ohm (0.2 ohm).
If the reading is 1,000mV (1volt) the resistor will be 1,000milli-ohm (1 ohm)
A 0m25 resistor (shown above) will show 0.25mV on the multimeter.
A 5M0 resistor above will show 5mV on the multimeter.
A R015 resistor will show 15mV on the multimeter.

SAFETY RESISTOR

Finally we come to the use of a resistor as a SAFETY RESISTOR.
Whenever you are testing a circuit, you need to use a supply that will not deliver a high current. This will prevent things "going up in smoke" and burning the PCB tracks. The easiest is to use "dry cells" (AA) and even though the motor or output device may not work correctly, you can be sure a short-circuit is not present.
If you are going to use a 12v battery, you need to include a one-ohm (0.25watt) resistor in series with the positive lead.
This resistor ill allow 250mA to pass with damage. At 500mA the resistor will get very hot and any current above this will burn out the resistor.
You will be able to work out how quickly the resistor "goes up in smoke" and compare it to the current requirement of the circuit.
If you leave the resistor permanently in the positive line, it becomes a SAFETY RESISTOR, but don't forget it will drop a small voltage and if the circuit takes peaks of current, this resistor can fail.
For the cost of one-cent you can protect a project and make sure it is working before connecting it permanently to the supply.

FUSIBLE RESISTOR

A fusible resistor is a low value resistor and should be made of non-combustible materials.
The value is chosen so it does not get hot during normal operation but if twice the current flows, it "burns out."
Sometimes it is housed in a non-combustible sleeve.
If you think it has burnt out for no reason, replace it with a one-ohm resistor (0.25 watt) and feel its temperature. If it is in a DC line, the voltage across it will be 250mV max.

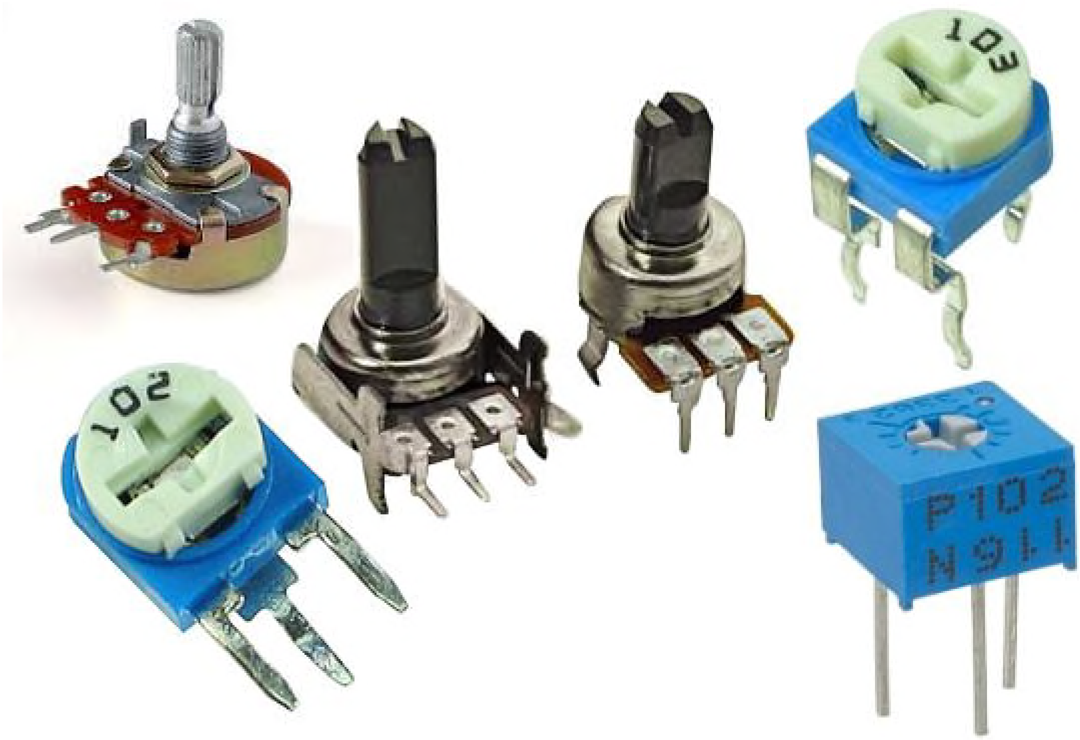
SUBSTITUTING A RESISTOR

You can get a resistor substitution box for $18.00 plus postage.
I bought one 40 years ago and have only used it ONCE.
Just get a a resistor on jumper leads and if it burns out, you have only lost 10 cents.
When designing a circuit, you may need to go 10% higher or lower to see the effect.
That's why it is best to try a resistor on leads.

Cost: $18.00 plus postage. Just use an individual resistor on jumper leads. Save $20.00

TESTING POTENTIOMETERS (variable resistors)

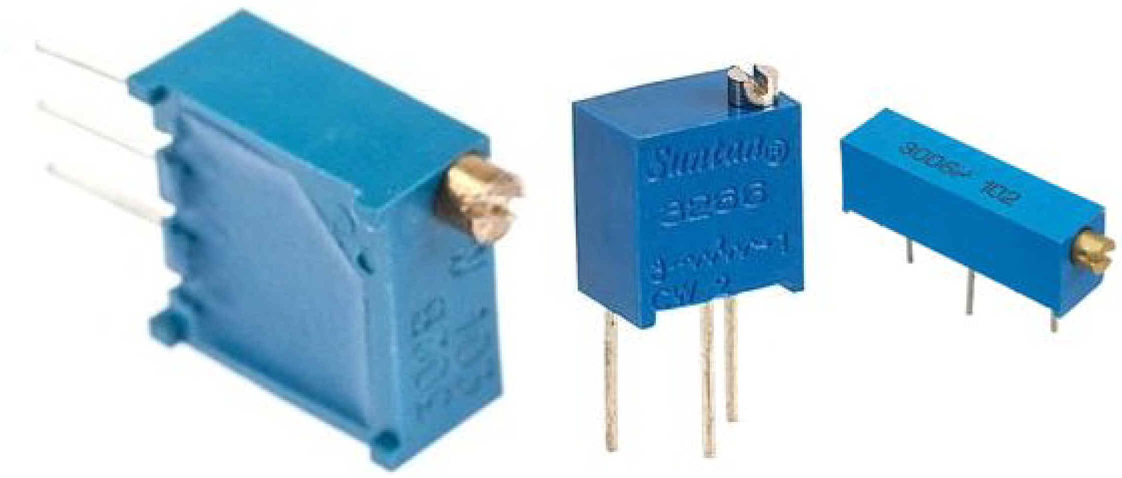
To check the value of a variable resistor, it should be removed from circuit or at least 2 legs should be removed. A Rheostat is a variable resistor using only one end and the middle connected to a circuit. The resistance between the two outside pins is the value marked on the component and the centre leg will change from nearly zero to the full resistance as the shaft is rotated.
To find out if the pot is linear or log, simply turn it to half-way and measure the resistance. It should be half-resistance for a linear pot.
"Pots" generally suffer from "crackle" when turned and this can be fixed by spraying up the shaft and into the pot via the shaft with a tube fixed to a can of "spray-lubricant" (contact cleaner).
"Pre-set pots" and "trim pots" are miniature versions of a potentiometer and they are all tested the same. The photo shows a pot, two mini pots and 3 mini trim pots.



10-Turn POTS

A 10-turn pot is one of the worst items to be designed. I remove them immediately from any design.
You don't know the position of the wiper. You don't know which way you are turning the

You don't know the position of the wiper. You don't know which way you are turning the wiper and you can't remember which way you turned the post "the last time." The screwdriver always falls out of the slot.
If you need fine adjustment, place fixed resistors on each side of the pot and use a normal mini trim pot with much less resistance.



FOCUS POTS
Focus pots are the pots on old-style Cathode Ray TV test or Cathode Ray Oscilloscopes and adjusted the high voltage to the focus anode of the tube. Quite often they get a spot of dirt where the wiper touches the track. Cleaning with spray fixes the bad focus but if the pot is leaking to chassis from inside the pot (due to the high voltage on the terminals) simply remove it from the chassis and leave it floating (this will restore the high voltage to the picture tube) or you can use one from an old chassis.

MAKING YOUR OWN RESISTOR, CAPACITOR, INDUCTOR or DIODE
Quite often you will not have the exact value of resistance or capacitance for a repair.
We have already covered placing resistors and capacitors in parallel and series:

Resistors in Parallel and/or Series
Capacitors in Parallel and/or Series

Here are some extras:

RESISTORS
Two 1k 0.5watt resistors in parallel produces a 470R 1watt resistor.
Two 1k 0.5watt resistors in series produces a 2k 1watt resistor.

CAPACITORS
Two 100n 100v capacitors in series produces a 50n capacitor @200v

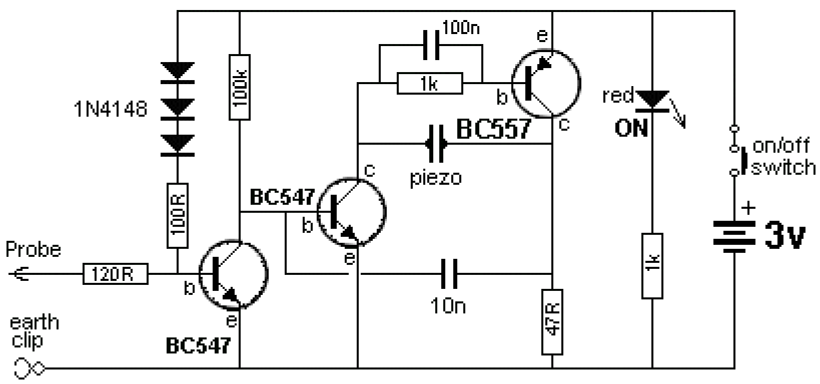
INDUCTORS: Two inductors in series - **ADD THE VALUES**

DIODES: Two 1Amp 400v diodes in series produces a 1Amp 800v diode
Two 1Amp 400v diodes in parallel produces a 2Amp 400v diode

ZENER DIODES: Zener diodes can be connected in series to get a higher voltage.
Two 12v zener diodes in series produces a 24v zener.

CONTINUITY

Some multimeters have a "buzzer" that detects when the probes are touching each other or the resistance between the probes is very LOW. This is called a CONTINUITY TESTER.
You can use the resistance scale "x1" or "x10" to detect low values of resistance.
Set the pointer to "0" (right end of the scale) by touching the probes together and adjusting the "zero ohms" control.
When taking a reading, you will have to decide if a low value of resistance is a short-circuit or an "operating value."
For instance, the cold resistance of a 12v car globe is very low (about 2 ohms) and it increases (about 6 times) to 12 ohms when hot.
The "resistance of a circuit" may be very low as the electrolytics in the circuit are uncharged. This may not indicate a true "short-circuit."
The measurement across a diode is not a resistance-value but a "voltage-drop" and that is why the needle swings nearly full-scale.
Leads and wires and cords have a small resistance and depending on the length of the lead, this small resistance may be affecting a circuit.
Remember this:
When a circuit takes 1 amp, and the resistance of the leads is 1 ohm, the voltage drop across the leads will be 1v.
That's why a 12v battery supplying a circuit with these leads will have 11v at the circuit.
Note:
Turn off the equipment before making any continuity tests. The presence of even a small voltage (from an electrolytic) can give a false reading.
You can determine the resistance of a lead very accurately by taking the example above and applying it to your circuit.
If the battery is 12.6v and the voltage across the circuit is 10v, when the current is 2.6 amps, the resistance of the "leads" is 12.6 - 10 = 2.6 R=V/I = 2.6/2.6 = 1ohm. By making the lead shorter or using thicker wire, the resistance will be less and the voltage on the project will increase.
When taking readings in a circuit that has a number of diodes built-into IC's (Integrated Circuits) and transistors, some Continuity Testers will beep and give a false reading.
The following circuit has the advantage of providing a beep when a short-circuit is detected but does not detect the small voltage drop across a diode. This is ideal when testing logic circuits as it is quick and you can listen for the beep while concentrating on the probe. Using a multimeter is much slower.



CONTINUITY TESTER

You can build the circuit on Matrix Board and add it to your Test Equipment.
You will need lots of "Test Equipment" and they can be built from circuits in this eBook.

TESTING FUSES, LEADS AND WIRES

Before I start this section, let me say this: FUSES DON'T PROTECT ANYTHING. In most cases, when a fuse "blows" many of the components in the circuit will be damaged too.
If these components are regulators, diodes, thyristors or transistors; you will also have to find out what caused them to be damaged. Just replacing the damaged parts may not be successful. They will just "blow" again.

This is just a notification.
You may be lucky. The fuse may "worn out" or just "died" but a one amp fuse will BLOW very quickly if a short-circuit is present and trip a 15 amp circuit breaker !!!

Testing fuses, leads and wires comes under the heading TESTING for CONTINUITY. Turn off all power to the equipment before testing for shorts and continuity. Use the low resistance "Ohms Scale" or CONTINUITY range on your multimeter. All fuses, leads and wires should have a low, very low or zero resistance. This proves they are working.

A BLOWN FUSE

The appearance of a fuse after it has "blown" can tell you a lot about the fault in the circuit.
If the inside of the glass tube (of the fuse) is totally blackened, the fuse has been damaged very quickly. This indicates a very high current has passed through the fuse.
Depending on the rating of the fuse, (current rating) you will be able to look for components that can pass a high current when damaged - such as high power transistors, FETs, coils, electrolytics. Before re-connecting the supply, you should test the "SUPPLY RAILS" for resistance. This is done by measuring them on a low OHMs range in one direction then reverse the leads to see if the resistance is low in the other direction.
A reading can be very low at the start because electrolytics need time to charge-up and if the reading gradually increases, the power rail does not have a short. An overload can occur when the supply voltage rises to nearly full voltage, so you sometimes have to fit a fuse and see how long it takes to "blow."
If the fuse is just slightly damaged, you will need to read the next part of this eBook, to see how and why this happens:

FAST AND SLOW BLOW FUSES

There are many different sizes, shapes and ratings of a fuse. They are all current ratings as a fuse does not have a voltage rating. Some fuses are designed for cars as they fit into the special fuse holders. A fuse can be designed for 50mA, 100mA, 250mA, 315mA, 500mA, 1Amp, 1.5amp, 2amp, 3amp, 3.15amp 5amp, 10amp, 15amp, 20amp, 25amp, 30amp, 35amp, 50amp and higher.
Some fuses are fast-blow and some are slow-blow.
A "normal" fuse consists of a length of thin wire. Or it may be a loop of wire or a strip of thin sheet that is thin near the middle of the fuse. This is the section that will "burn-out."
A "normal" fuse is a fast-blow fuse. For instance, a 1amp fuse will remain intact when up to 1.25 amp flows. When a circuit is turned on, it may take 2-3 amps for a very short period of time and a normal 1 amp fuse will get very hot and the wire will stretch but not "burn-out." You can see the wire move when the supply turns on.
If the current increases to 2amps, the fuse will still remain intact. It needs about 3 amp to heat up the wire to red-hot and burn out.
If the current increases to 5 amp, the wire VOLATILISES (burns-out) and deposits carbon-black on the inside of the glass tube.
A slow-blow fuse uses a slightly thicker piece of wire and the fuse is made of two pieces of wire joined in the middle with a dob of low-temperature solder. Sometimes one of the pieces of wire is a spring and when the current rises to 2.5 amp, the heat generated in the wire melts the solder and the two pieces of wire "spring apart."
A slow-blow fuse will allow a higher current-surge to pass through the fuse and the wire will not heat up and sag.
Thus the fuse is not gradually being damaged and it will remain in a perfect state for a long

period of time.
A fuse does not protect electronic equipment from failing. It acts AFTER the equipment has failed.
It will then protect a power supply from delivering a high current to a circuit that has failed.
If a slow-blow fuse has melted the solder, it could be due to a slight overload, slight weakening of the fuse over a period of time or the current-rating may be too low.
You can try another fuse to see what happens.
You can replace a fast-acting fuse (normal fuse) with a slow blow if the fast-acting fuse has been replaced a few times due to deterioration when the equipment is turned on.
But you cannot replace a slow-blow fuse with a fast acting fuse as it will be damaged slightly each time the equipment is turned on and eventually fail.

100mA FUSES

Fuses below about 100mA are very hard to make and very unreliable.
Many circuits take a high current when turned to charge the electrolytics and a 100mA (or 50mA or 63mA fuse) will bow and stretch and change shape, every time the equipment is turned ON.
Eventually it will break, due to it heating-up and stretching.
To produce a reliable fuse below 100mA, some manufacturers have placed a resistor inside the fuse and connected it to a spring. One end of the resistor is soldered to a wire with low-temperature metal and when the resistor gets hot, the metal softens and the spring pulls the resistor away from the wire.
Quite often you can heat up the metal and connect the wire and the fuse is perfect.
This type of fuse is called a DELAY fuse and the current rating is shown on the end-cap.
The value of the resistor determines the current rating.
There is a small voltage across this type of fuse and it means the circuit sees a slightly lower voltage than the supply voltage.
The third photo shows the "pot of solder" or low-temp metal and a wire connected to a spring. The heat generated in the wire is passed to the solder and it softens. The spring pulls the two components apart.
You can smash the glass and set up the fuse in the two fuse-holders and repair the fuse while you wait for a new fuse to arrive.

TESTING COILS, INDUCTORS and YOKES

Coils, inductors, chokes and yokes are just coils (turns) of wire. The wire may be wrapped around a core made of iron or ferrite.
It is labeled "L" on a circuit board.
You can test this component for continuity between the ends of the winding and also make sure there is no continuity between the winding and the core.
The winding can be less than one ohm, or greater than 100 ohms. A coil of wire is also called

an INDUCTOR and it might look like a very simple component, but it can operate in a very complex way.
The way it works is a discussion for another eBook. It is important to understand the turns are insulated but a slight fracture in the insulation can cause two turns to touch each other and this is called a "SHORTED TURN" or you can say the inductor has "SHORTED TURNS."
When this happens, the inductor allows the circuit to draw MORE CURRENT. This causes the fuse to "blow."
The quickest way to check an inductor is to replace it, but if you want to measure the inductance, you can use an INDUCTANCE METER. You can then compare the inductance with a known good component.
An inductor with a shorted turn will have a very low or zero inductance, however you may not be able to detect the fault when it is not working in a circuit as the fault may be created by a high voltage generated between two of the turns.
Faulty yokes (both horizontal and vertical windings) can cause the picture to reduce in size and/or bend or produce a single horizontal line.
A TV or monitor screen is the best piece of Test Equipment as it has identified the fault. It is pointless trying to test the windings further as you will not be able to test them under full operating conditions. The fault may not show up when a low voltage (test voltage) is applied.

MEASURING AND TESTING INDUCTORS

Inductors are measured with an INDUCTANCE METER but the value of some inductors is very small and some Inductance Meters do not give an accurate reading.
The solution is to measure a larger inductor and note the reading. Now put the two inductors in SERIES and the values ADD UP - just like resistors in SERIES. This way you can measure very small inductors. VERY CLEVER!

Question from a reader: *Can I add an inductor to stop a fuse blowing?*

Basically, an inductor NEVER prevents a fuse blowing because an inductor prevents spikes on one lead (we will call the INPUT lead), appearing on its other lead.
This is the detection and prevention of current that exists for a very short period of time.
A fuse detects an excess of current that occurs over a very long period of time and they are entirely two different "detectors."
One cannot assist the other in any way.

An inductor is basically a coil of wire. It may be thick or thin wire. The value of the inductor is a combination of the number of turns and the material on which the wire is wound.
The value of an inductor does not change over say a period of 20 years but it can go faulty by the enamel cracking and two turns touching. This can also be due to the difference in voltage between the two turns creating a spark between the turns and creating a "short."
When you test it, the high voltage is not present and it will test ok.
You may not think a few turns of wire will have any effect on improving a circuit, but spikes are very high frequency and the inductor will have a very big effect on reducing them.
An inductor (say 100uH) can be produced in many different sizes and the thickness of the wire will be important as it determines the current that can flow through the inductor.
The term "inductor" also includes those with two or more windings and these components are called TRANSFORMERS. These devices can get "shorts" and "leaks" between the windings and sparks can be seen between the windings. These sparks do not occur when you are testing them on test-equipment so the only way to guarantee success is to replace it with an identical replacement.

TESTING SWITCHES and RELAYS

Switches and relays have contacts that open and close mechanically and you can test them for CONTINUITY. However these components can become intermittent due to dirt or pitting

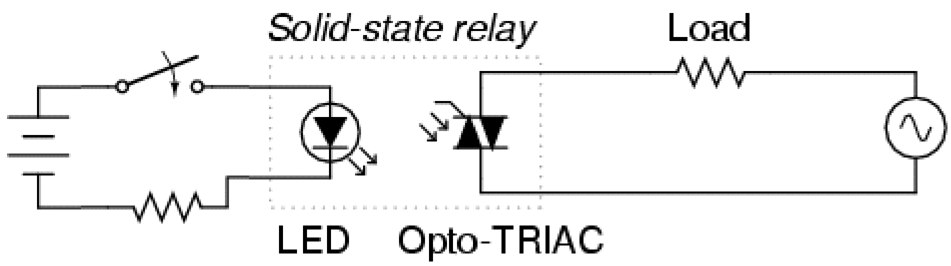
of the surface of the contacts due to arcing as the switch is opened.
It is best to test these items when the operating voltage and current is present as they quite often fail due to the arcing. A switch can work 49 times then fail on each 50th operation. The same with a relay. It can fail one time in 50 due to CONTACT WEAR.
If the contacts do not touch each other with a large amount of force and with a large amount of the metal touching, the current flowing through the contacts will create HEAT and this will damage the metal and sometimes reduce the pressure holding the contact together.
This causes more arcing and eventually the switch heats up and starts to burn. Switches are the biggest causes of fire in electrical equipment and households.

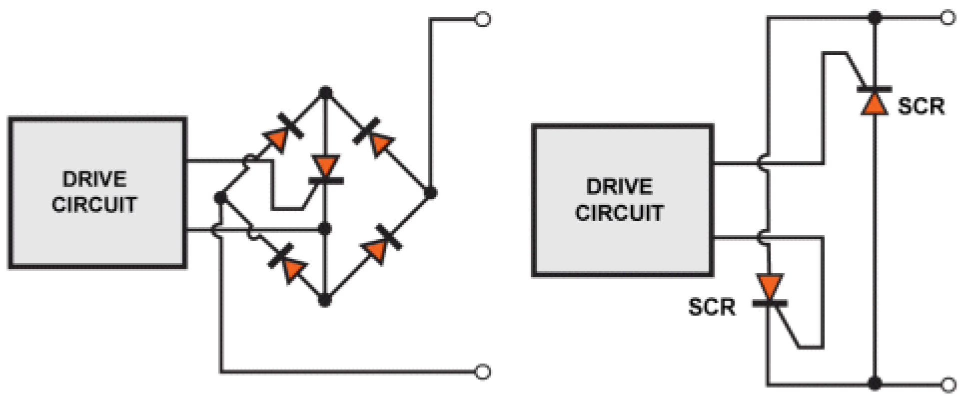
A relay also has a set of contacts that can cause problems.
There are many different types of relays and basically they can be put into two groups.
1. An electromagnetic relay is a switch operated by magnetic force. This force is generated by current through a coil. The relay opens and closes a set of contacts.
The contacts allow a current to flow and this current can damage the contacts. Connect 5v or 12v to the coil (or 24v) and listen for the "click" of the points closing. Measure the resistance across the points to see if they are closing.
You really need to put a load on the points to see if they are clean and can carry a current.
The coil will work in either direction.

If not, the relay is possibly a CMOS relay or Solid State relay.

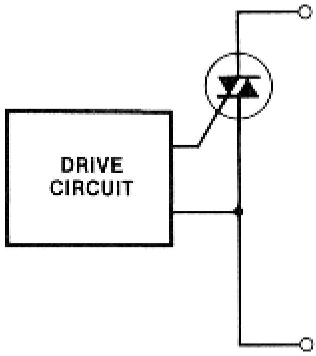
SSR RELAY

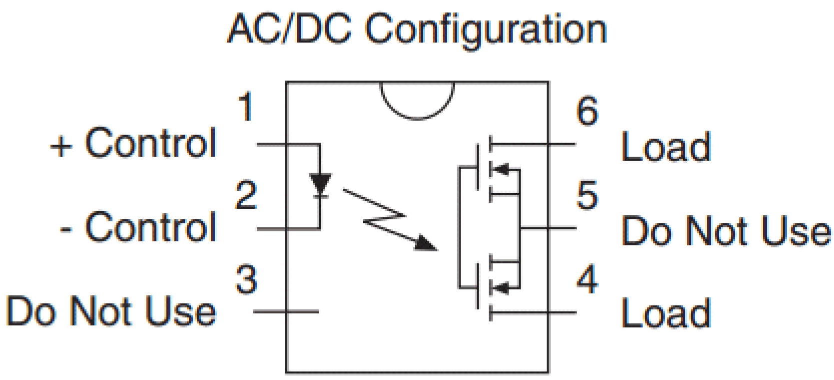
2. An electronic relay (Solid State Relay) does not have a winding. It works on the principle of an opto-coupler and uses a LED and Light Activated SCR or Opto-TRIAC to produce a low resistance on the output. The two pins that energise the relay (the two input pins) must be connected to 5v (or 12v) around the correct way as the voltage is driving a LED (with series resistor). The LED illuminates and activates a light-sensitive device.

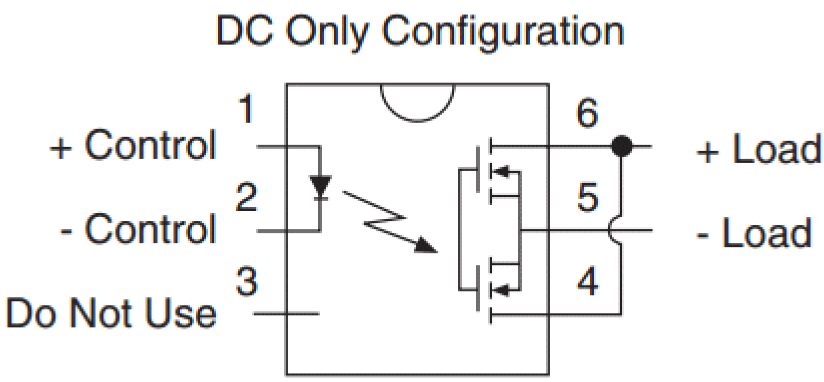




SSR Replacement - for testing purposes





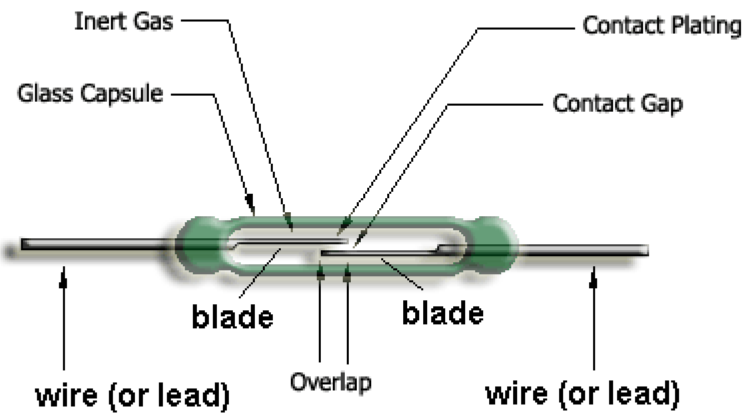


In most cases you do not know what is inside a Solid State Relay and two things can fail.
The LED can be damaged and the OPTO TRIAC may have failed.
Firstly you have to make sure if the SSR is the faulty item.
You can replace with another of the same type but if this is not possible, you can make one of the circuits above and see if closing the output terminals will allow the project to operate.
The next test is to measure the voltage across the input.
If it is between 2v and 4v, the LED is possibly working.
If it is above 5v, the SSR may have an internal resistor.
You will then have to measure the current entering the input terminals. This current will be between 7mA and 25mA.
You also bridge across the output terminals to determine if the project is correctly connected to the SSR.
All this requires CARE as the output terminals may be live to the mains, while the input terminals are electrically isolated from the output with an SSR that is optically connected between input and output.

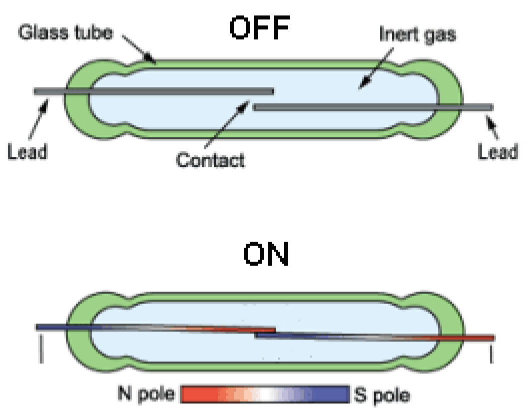
between input and output.

TESTING REED SWITCHES

A reed switch is generally contained in a long glass tube:



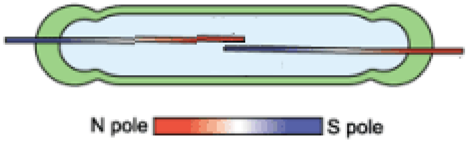
A wire or lead comes out each end for soldering to the reed switch to the project. The two "blades" inside the switch are made from a material that can be magnetised but does not retain its magnetism. This effect is called "temporally magnetised" (not permanently magnetised) and really only "passes" magnetism from one end to the other when in the presence of a magnet. One of the blades is made of a soft material and it will bend very easily. The other one is much stiffer.



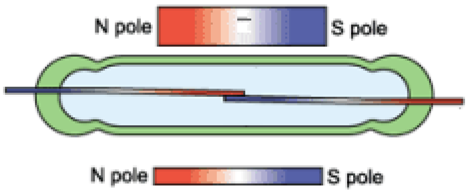
When a magnet is placed under the two blades (or on top), the magnetism from the magnet is passed to the two blades (INDUCTION or MUTUAL INDUCTION - commonly called INDUCED) and it produces a very weak magnet (in the blade) that is identical to the powerful magnet as far as the position of the north and south poles are concerned). Initially it produces a N-S and N-S set of poles and this makes the two blades click together because the top blade will be South at the contact and the bottom blade will be North.
When the two blades click together the magnetism runs through the two blades and keeps them together. The two blades attract and the switch is closed. When the magnet is removed, the magnetism in the two blades ceases and the two blades move apart.
Since there is a very small amount of movement in the top blade, this switch has a limited number of operations. Eventually it will fail. It is a mechanical device and is not suited for detecting a spinning shaft as 100,000 revolutions will very quickly weaken the switch.
If the switch does not make contact or remains closed, the moveable blade can be cracked or broken. This can be very hard to see. So replace the switch.

LATCHING REED SWITCH

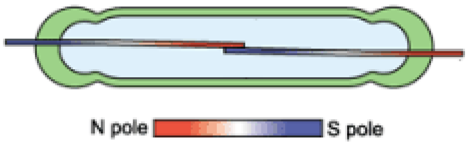
A "normal" reed switch can be converted into a **LATCHING REED SWITCH** by carefully placing a magnet below the switch and moving it away so the two blades open. Now move it slightly closer but do not allow the blades to close.
This is called putting a "SET" on the switch and the two blades will have a small magnetic effect "induced" in them but not enough to close the contacts:



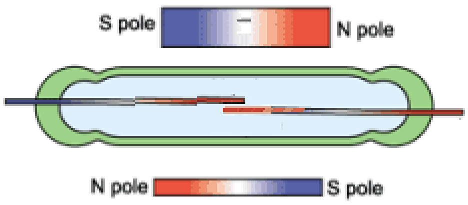
Now bring a strong magnet up to the reed switch on the other side of the glass tube with the north pole above the north of the lower magnet. This effect will increase the INDUCED MAGNETISM in the blades and close the contacts:



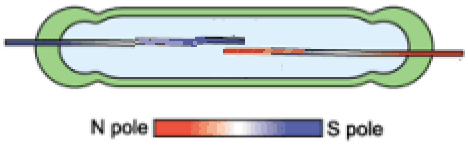
Remove the top magnet and the lower magnet will induce enough magnetism into the blades to keep them closed:



Now bring the upper magnet near the reed switch with the south pole above the north pole of the lower magnet. (In other words: AROUND THE OTHER WAY) This will have the effect of reducing the induced magnetism in the blades and a point will be reached when the two contacts will separate:

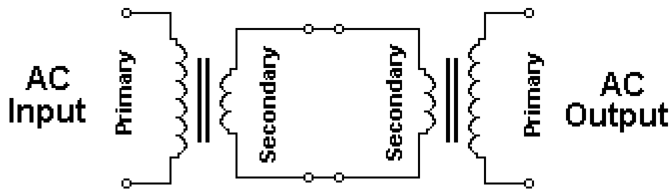


Remove the top magnet and the switch will remain separated because the lower magnet will not have sufficient influence on the blades to close the contact:



SAFETY (when testing ANYTHING)

You have to apply complete safety measures when testing ANYTHING. Even a 5watt cell-phone charger that plugs into the wall needs "protection measures" when "pulling it apart." I use two 15VA transformers (or 30VA) connected "back-to-back" to produce 240v AC output but with a voltage that is totally isolated from the mains and has a very small current capability. When a short-circuit occurs, you can hear the transformers "hum" so you can disconnect the problem. But nothing "blows up."



This is called an ISOLATION TRANSFORMER and prevents things "blowing up in your face" if a short-circuit is present.
The same approach applies to testing all sorts of modules and devices that operate on 6v, 9v, or 12v. Test them with a weak battery and preferably not alkaline cells as they can still deliver 2 amps or more and this can cause damage.
The battery should be weak (500mA or less) and when you have tested the project, you can connect a quality battery.
Even a "current limiting" power supply is not a suitable supply as the voltage drops when a load is present and the project will fail to work.

CAPACITORS

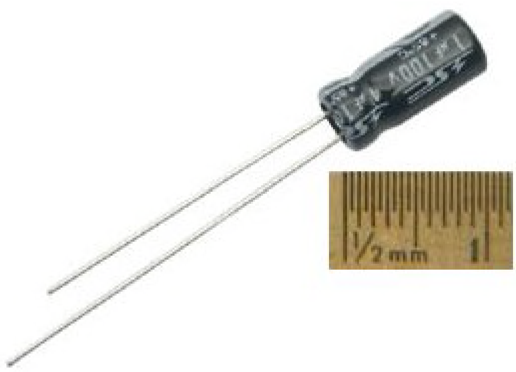
Capacitors are one of the most difficult things to test. That's because they don't give a reading on a multimeter and their value can range from 1p to 100,000u.
A faulty capacitor may be "open" when measured with a multimeter, and a good capacitor will also be "open."
You need a piece of test equipment called a CAPACITANCE METER to measure the value of a capacitor.

HOW A CAPACITOR WORKS

There are two ways to describe how a capacitor works. Both are correct and you have to combine them to get a full picture.
A capacitor has INFINITE resistance between one lead and the other **(an electrolytic has a high resistance when it is fully charged).**
This means no current flows **through** a capacitor. But it works in another way.
Suppose you have a strong magnet on one side of a door and a piece of metal on the other. By sliding the magnet up and down the door, the metal rises and falls.
The metal can be connected to a pump and you can pump water by sliding the magnet up and down.
A capacitor works in exactly the same way.
If you raise a voltage on one lead of a capacitor, the other lead will rise to the same voltage.
This needs more explaining - we are keeping the discussion simple.
It works just like the magnetic field of the magnet through a door.
The next concept is this:
Capacitors are equivalent to a tiny rechargeable battery.
They store energy when the supply-voltage is present and release it when the supply drops.
These two concepts can be used in many ways and that's why capacitors perform tasks such as filtering, time-delays, passing a signal from one stage to another and create many different effects in a circuit.

CAPACITOR VALUES
The basic unit of capacitance is the FARAD. (C) This is the value used in all equations, but it is a very large value. A one FARAD capacitor would be the size of a car if made with plates and paper. Most electronic circuits use capacitors with smaller values such as 1p to 1,000u. 1p is about equal to two parallel wires 2cm long. 1p is one picofarad.

The easiest way to understand capacitor values is to start with a value of 1u. This is one microfarad and is one-millionth of a Farad. A 1 microfarad capacitor is about 1cm long and the diagram shows a 1u electrolytic.



Smaller capacitors are ceramic and they look like the following. This is a 100n (0.1u) ceramic:

To read the value on a capacitor you need to know a few facts.

The basic value of capacitance is the FARAD.
1 microfarad is one millionth of 1 farad.
1 microfarad is divided into smaller parts called nanofarad.
1,000 nanofarad = 1 microfarad
Nanofarad is divided into small parts called picofarad
1,000 picofarad = 1 nanofarad.

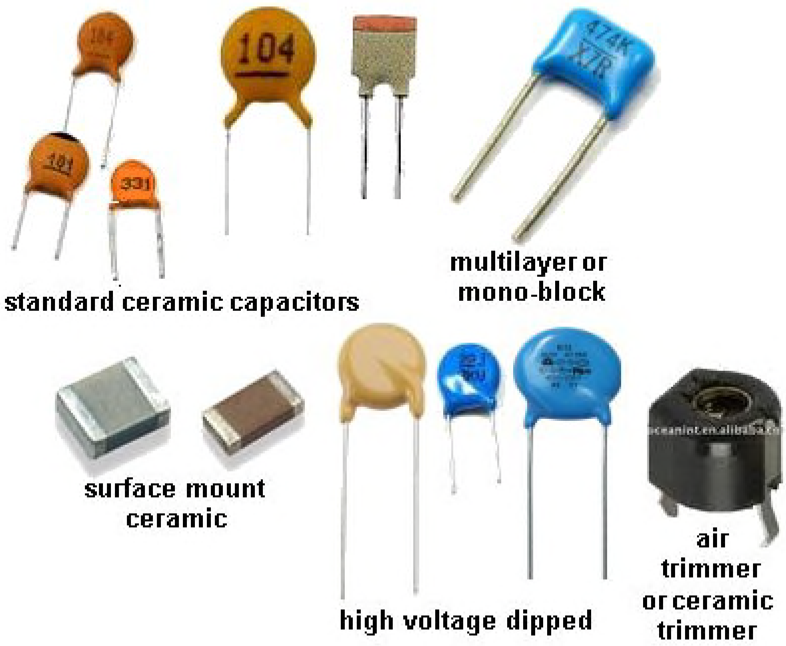
Recapping:
1p = 1 picofarad.   1,000p = 1n (1 nanofarad)
1,000n = 1u (1 microfarad)
1,000u = 1millifarad
1,000,000u = 1 FARAD.

Examples:
All ceramic capacitors are marked in "p" (puff")
A ceramic with 22 is 22p = 22 picofarad
A ceramic with 47 is 47p = 47 picofarad
A ceramic with 470 is 470p = 470 picofarad
A ceramic with 471 is 470p = 470 picofarad
A ceramic with 102 is 1,000p = 1n
A ceramic with 223 is 22,000p = 22n
A ceramic with 104 is 100,000p = 100n = 0.1u

TYPES OF CAPACITOR
For testing purposes, there are two types of capacitor.
Capacitors from 1p to 100n are non-polar and can be inserted into a circuit around either way.
Capacitors from 1u to 100,000u are electrolytics and are polarised. They must be fitted so the positive lead goes to the supply voltage and the negative lead goes to ground (or earth).
There are many different sizes, shapes and types of capacitor. They are all the same. They consist of two plates with an insulating material between. The two plates can be stacked in layers or rolled together.
The important factor is the insulating material. It must be very thin to keep things small. This gives the capacitor its VOLTAGE RATING.

If a capacitor sees a voltage higher than its rating, the voltage will "jump through" the insulating material or around it.
If this happens, a carbon deposit is left behind and the capacitor becomes "leaky" or very low resistance, as carbon is conductive.

CERAMIC CAPACITORS
Nearly all small capacitors are **ceramic capacitors** as this material is cheap and the capacitor can be made in very thin layers to produced a high capacitance for the size of the component. This is especially true for surface-mount capacitors.
All capacitors are marked with a value and the basic unit is: "p" for "puff" However NO surface mount capacitors are marked and they are very difficult to test.

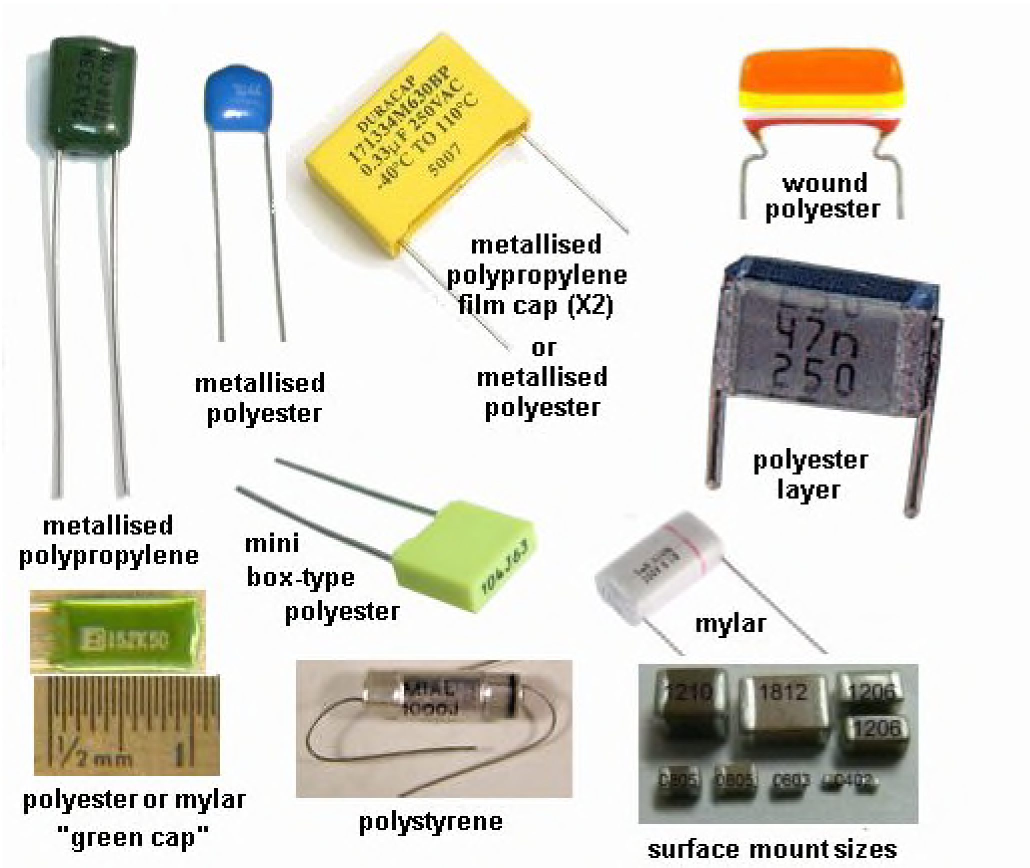


VALUE:	VALUE WRITTEN ON THE COMPONENT:
0.1p	0p1
0.22p	0p22
0.47p	0p47
1.0p	1p0
2.2p	2p2
4.7p	4p7
5.6p	5p6
8.2p	8p2
10p	10 or 10p
22p	22 or 22p
47p	47 or 47p
56p	56 or 56p
100p	100 on 101
220p	220 or 221
470p	470 or 471
560p	560 or 561
820p	820 or 821
1,000p (1n)	102

2200p (2n2)	222
4700p (4n7)	472
8200p (8n2)	822
10n	103
22n	223
47n	473
100n	104
220n	224
470n	474
1u	105

POLYESTER, POLYCARBONATE, POLYSTYRENE, MYLAR, METALLISED POLYESTER, ("POLY") , MICA and other types of CAPACITOR

There are many types of capacitor and they are chosen for their reliability, stability, temperate-range and cost.
For testing and repair work, they are all the same. Simply replace with exactly the same type and value.

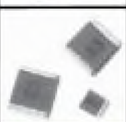
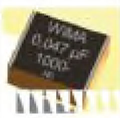


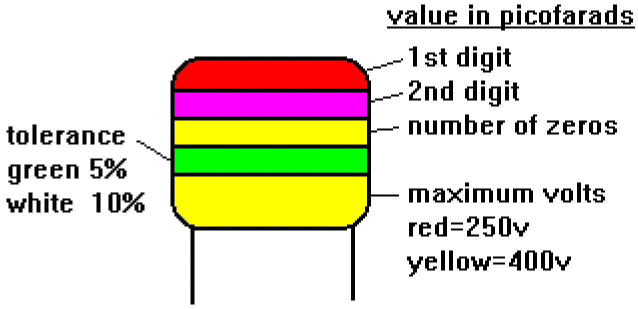
Capacitor Colour Code Table

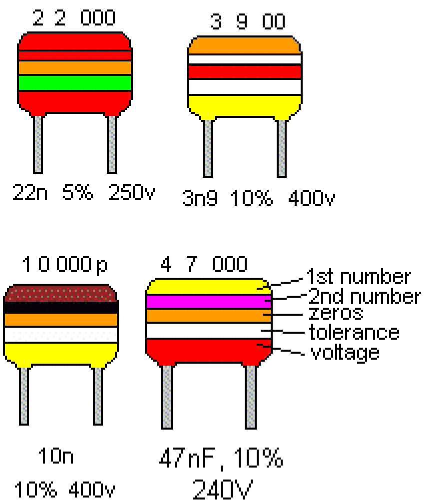
Colour	Digit A	Digit B	Multiplier D	Tolerance (T) > 10pf	Tolerance (T) < 10pf	Temperature Coefficient (TC)
Black	0	0	x1	± 20%	± 2.0pF	
Brown	1	1	x10	± 1%	± 0.1pF	-33x10^{-6}
Red	2	2	x100	± 2%	± 0.25pF	-75x10^{-6}

Orange	3	3	x1,000	± 3%		-150x10^{-6}
Yellow	4	4	x10,000	± 4%		-220x10^{-6}
Green	5	5	x100,000	± 5%	± 0.5pF	-330x10^{-6}
Blue	6	6	x1,000,000			-470x10^{-6}
Violet	7	7				-750x10^{-6}
Grey	8	8	x0.01	+80%,-20%		
White	9	9	x0.1	± 10%	± 1.0pF	
Gold			x0.1	± 5%		
Silver			x0.01	± 10%		

Pico Farads (pF)	Nano Farads (nF)	Micro Farads (µF)
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1
10,000,000	10,000	10
100,000,000	100,000	100

Type ⊕ = polarized	Pic	Cap Range
Ceramic		pF - µF
Mica (silver mica)		pF - nF
Plastic Film (polyethylene polystyrene)		few µFs
Tantalum ⊕		µFs
OSCON ⊕		µFs
Aluminum Electrolytic ⊕		high µFs

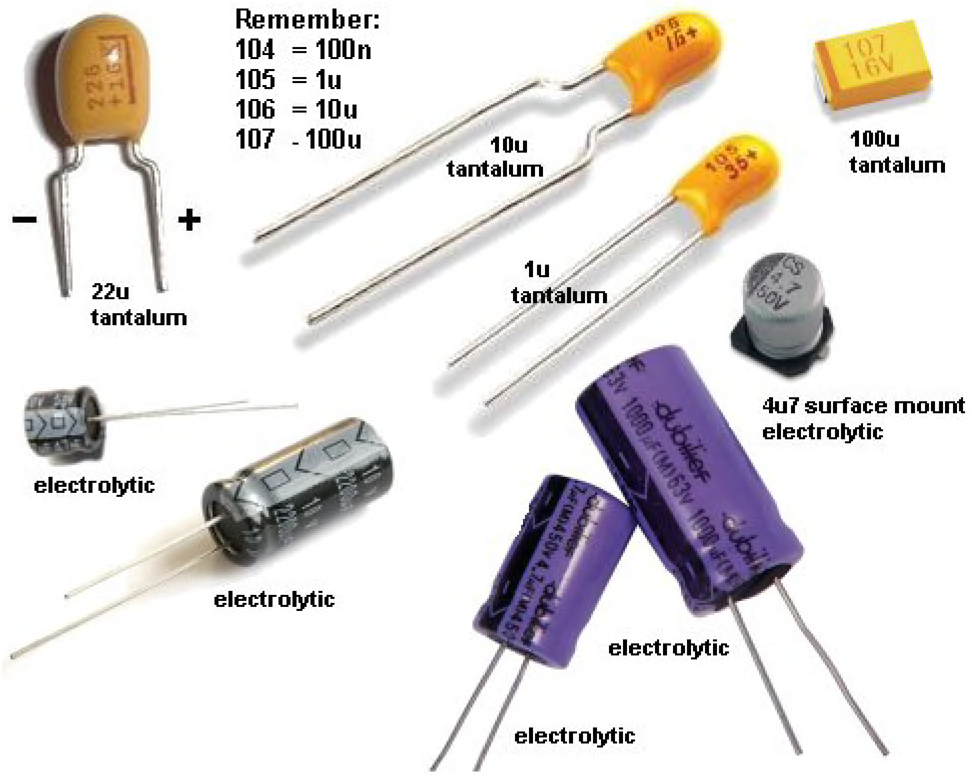


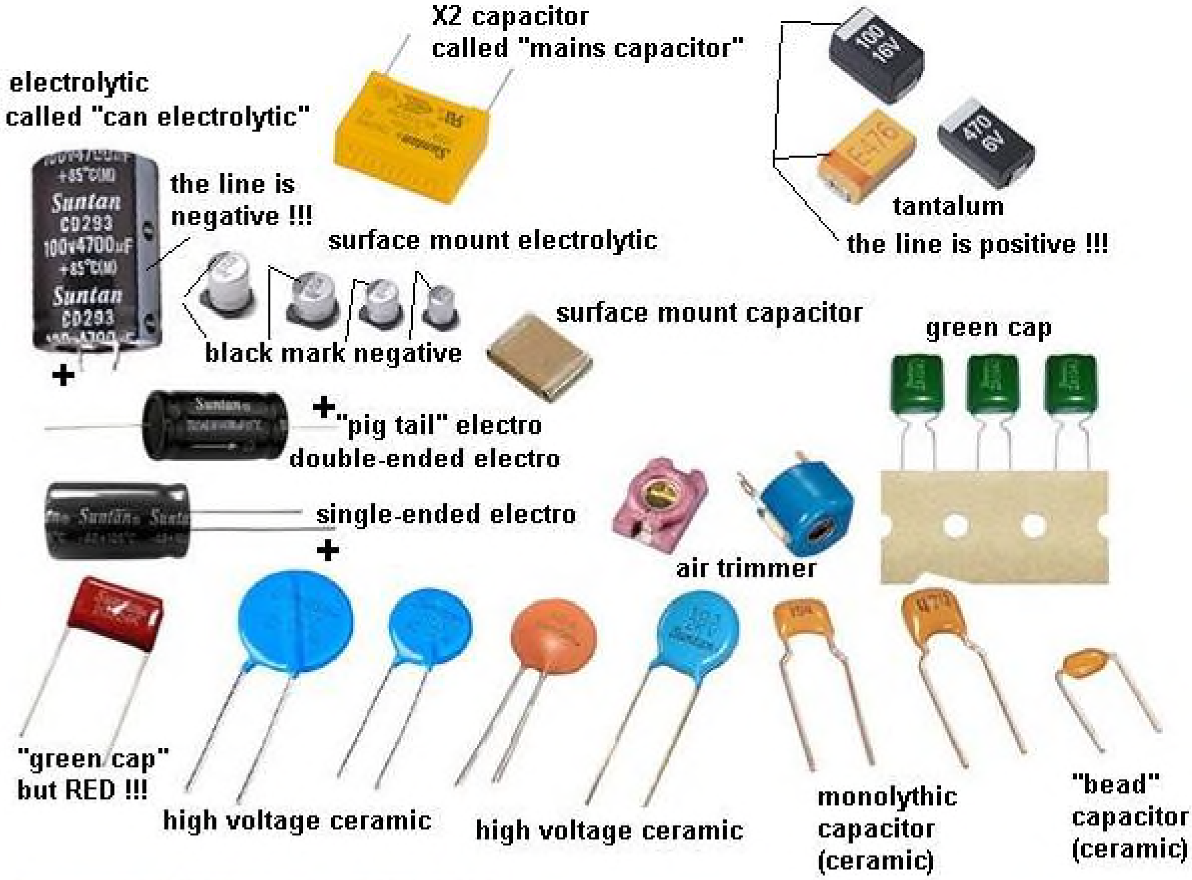


Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

ELECTROLYTIC and TANTALUM CAPACITORS
Electrolytics and Tantalums are the same for testing purposes but their performance is slightly different in some circuits. A tantalum is smaller for the same rating as an electrolytic and has a better ability at delivering a current. They are available up to about 1,000u, at about 50v but their cost is much higher than an electrolytic. A tantalum is know for short-circuiting for no apparent reason in some TV sets. It may have been due to the faulty manufacture.

Electrolytics are available in 1u, 2u2 3u3 4u7 10u, 22u, 47u, 100u, 220u, 330u, 470u, 1,000u, 2,200u, 3,300u, 4,700u, 10,000u and higher.
The "voltage" or "working voltage" can be: 3.3v, 10v, 16v, 25v, 63v, 100v, 200v and higher. Do not exceed the voltage marked on the electrolytic by any more than a few volts.
A 1,000u 25v electro was subjected to 35v and it got hot and exploded!!
There is also another important factor that is rarely covered in text books. It is RIPPLE FACTOR.
This is the amount of current that can enter and leave an electrolytic. This current heats up the electrolytic and that is why some electrolytics are much larger than others, even though the capacitance and voltage-ratings are the same. Ripple factors are very hard to determine, so the size of the electrolytic is your best decision.
If you replace an electrolytic with a "miniature" version, it will heat up and have a very short life. This is especially important in power supplies where current (energy) is constantly entering and exiting the electrolytic as its main purpose is to provide a smooth output from a set of diodes that delivers "pulsing DC." (see "Power Diodes").
A miniature version of an electrolytic will have a lower ripple factor - it will be capable of handling less current entering and leaving. This value is very important in a power supply. A miniature version will get too hot.


Remember:
104 = 100n
105 = 1u
106 = 10u
107 - 100u
22u
tantalum
10u
tantalum
1u
tantalum
100u
tantalum
4u7 surface mount
electrolytic
electrolytic
electrolytic
electrolytic
electrolytic



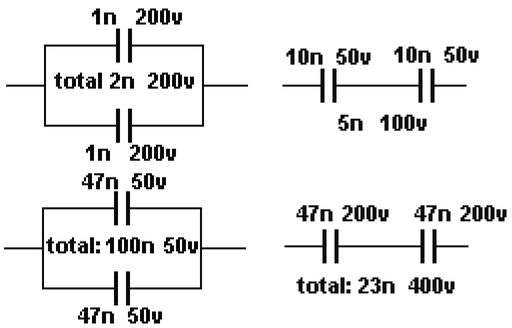
tantalum capacitors can
"go up in smoke"

"bead" tantalum

PARALLEL and SERIES CAPACITORS

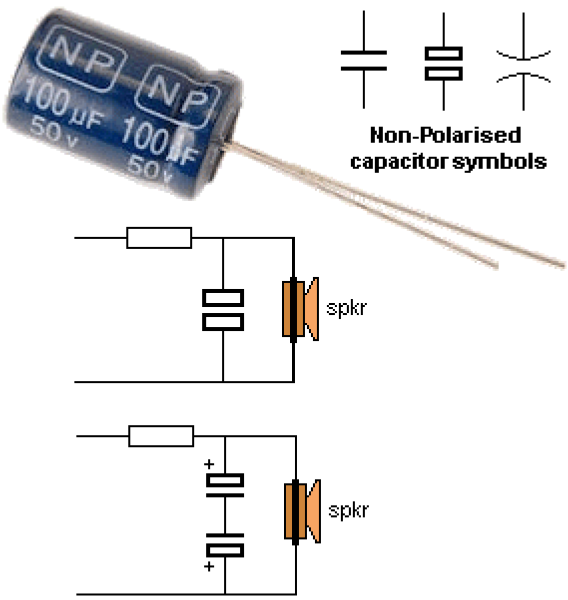
Capacitors can be connected in PARALLEL and/or SERIES for a number of reasons.
1. If you do not have the exact value, two or more connected in parallel or series can produce the value you need.
2. Capacitors connected in series will produce one with a higher voltage rating.
3. Capacitors connected in parallel will produce a larger-value capacitance.

Here are examples of two equal capacitors connected in series or parallel and the results they produce:

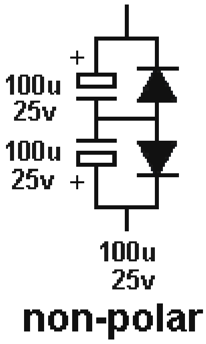


NON-POLAR CAPACITORS (ELECTROLYTICS)

Electrolytics are also available in non-polar values. It sometimes has the letters "NP" on the component. Sometimes the leads are not identified.
This is an electrolytic that does not have a positive and negative lead but two leads and either lead can be connected to the positive or negative of the circuit.
These electrolytics are usually connected to the output of an amplifier (such as in a filter near the speaker) where the signal is rising and falling.
A non-polar electrolytic can be created from two ordinary electrolytics by connecting the negative leads together and the two positive leads become the new leads.
For example: two 100u 63v electrolytics will produce a 47u 63v non-polar electrolytic.
In the circuit below, the non-polar capacitor is replaced with two electrolytics.

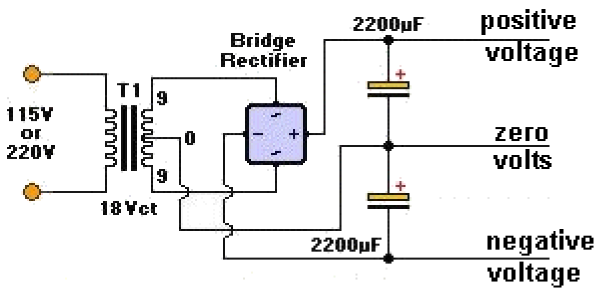


MAKING A NON-POLAR ELECTROLYTIC



A normal electrolytic must be connected the correct way in a circuit because it has a thin insulating layer covering the plates that has a high resistance.
If you connect the electrolytic around the wrong way, this layer "breaks-down" and the resistance of the electrolytic becomes very small and a high current flows. This heats up the electrolytic and the current increases. Very soon the capacitor produces gasses and explodes.
One big mistake in many text books shows how to make a non-polar electrolytic by connecting two "back-to-back."
They claim 2 x 100u connected back-to-back is equal to 47u.
This appears to be case when testing on a meter but the meter simply charges them for a short period of time to get a reading.
If you allow them to charge fully you will find the reverse electrolytic has a very small voltage across it.
Secondly, when you are charging them, you are putting a high current through the reverse electrolytic and damaging the layer.
To prevent this, you need to add two diodes as shown in the diagram.
In addition, 2 x 100u "back-to-back" is very near 100u.
If you are using 2 capacitors back-to-back in a low voltage circuit (without the two diodes), the result will be 47u because a capacitor in reverse will produce its full capacitance, even though it is being charged in the wrong direction. This will only the case when a low voltage is applied and the leakage is very small.
If these two capacitors are left for a long period of time, the "reverse electro" will leak due to the fact that the isolating layer inside the electro is seeing a reverse voltage. This means the current flowing though it will also flow through the other electro and the correctly placed electro will keep charging so that the whole supply voltage will eventually appear across the correctly placed electro.

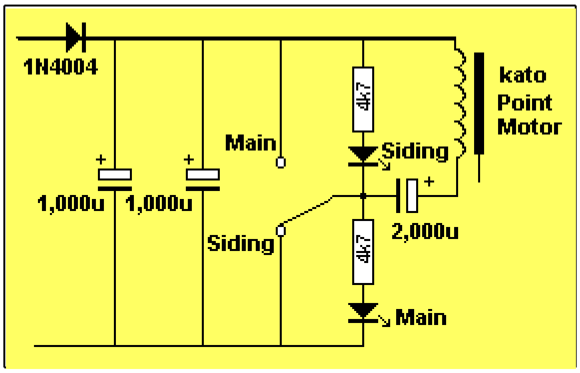
Here is a question from a reader:
I have an amplifier with 2 x2,200u electrolytics on the output of a bridge. Can I replace them with a single 10,000u?

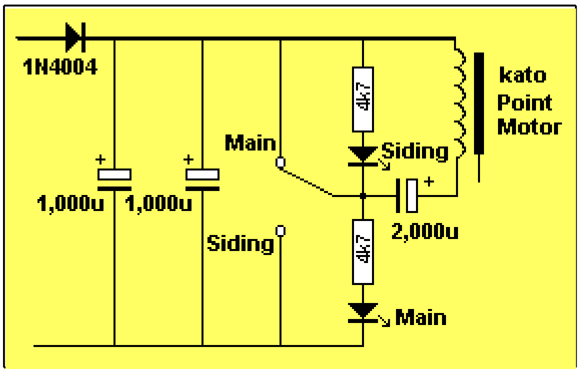


You need to look at the circuit of your amplifier. The two 2,200u electrolytics are possibly connected as shown in the circuit above and you will notice they are joined to produce a positive rail and a negative rail with zero (called earth) in the centre.
This forms two different circuits with the top electrolytic filtering the positive rail and the bottom electro filtering the negative rail. They must be connected to the zero volts rail.
A single 10,000u cannot be connected to the 0v rail and cannot be substituted for the two electro's.
You can easily determine if the two electro's are connected as shown above.

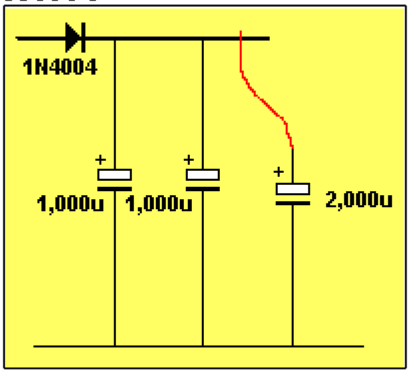
You can easily determine if the two electro's are connected as shown above.
Test the positive terminal of each electro by placing the negative of the meter on the chassis.
If the positive of one electro has zero volts, it will be the lower electro in the diagram above. The negative terminal of the lower electro will have a minus voltage on it.

CAPACITORS IN SERIES
Here is a problem. The circuit operates a solenoid for a short period of time with the current that flows through the 2,000u electrolytic when it is charging (when the switch is in the "siding" position).





When the switch is in the "Main" position, the energy in the 2,000u electrolytic is passed to the solenoid and it operates much more strongly than when the switch is in the other position.
WHY?



When you connect the uncharged 2,000u electrolytic across the other two fully charged electrolytics, the charging current is so high that the power supply cannot deliver nearly enough current and it takes a lot of the charging current from the two 1,000u electros.
This means the "two full buckets of water" and going to be dumped into the "empty bucket" with the result that the voltage is going to drop to about half-voltage at the beginning of the cycle. The only thing that is going to raise the voltage to full voltage is the energy from the power supply. But this will take a long time and the solenoid will only see about half the energy passing between the electros. To solve this problem, the two 1,000u electros need to be replaced with 2,200u and now you can work out how much the energy will rise.

RIPPLE CURRENT
When an electrolytic is in a power supply, the voltage entering the electrolytic is rising and falling. This is called UNFILTERED DC. This voltage is rising to the peak and falling to zero, either 100 or 120 times per second. The electrolytic charges and this rising and falling voltage "disappears from view" because the electrolytic stores the maximum voltage and the diode on the power supply prevents the voltage going back into the "mains."
After a while, the incoming voltage only has a tiny effect on charging the

electrolytic a few millivolts on each cycle to replace the tiny amount of charge lost in the electrolytic due to leakage.
But when you take current from the power supply, the incoming voltage will deliver this current during the time when it is as high as the voltage you are getting from the power supply, but when it is falling, the electrolytic delivers the energy.
The electrolytic is not as "strong" as the incoming energy and that's why the output voltage drops a few volts on each half cycle.
This means current is entering and leaving the electrolytic and the electrolytic has a very small internal resistance.
By simple ohm's law, the heat generated inside the electro is determined by I^2R and this heats the electro.
You can get small, medium and large electrolytics with exactly the same capacity and voltage rating.
The only difference is the temperature rise (and the ripple factor - discussed below). A small electro will heat up to a higher temperature.

It is impossible to predict what will happen so you need to fit the smallest and cover it with something so that it heat up. Feel the temp after an hour. Then fit the other different sizes and compare your results.
Testing 1,000u electrolytics may show they all have the same 80milliohm internal impedance, so it is just the heat dissipation from the can that will reduce the temperature rise.

VOLTAGE RATING OF CAPACITOR
Capacitors have a voltage rating, stated as WV for working voltage, or WVDC. This specifies the maximum voltage that can be applied across the capacitor without puncturing the dielectric. Voltage ratings for "poly," mica and ceramic capacitors are typically 50v to 500 VDC. Ceramic capacitors with ratings of 1kv to 5kv are also available. Electrolytic capacitors are commonly available in 6v, 10v 16v, 25v, 50v, 100v, 150v, and 450v ratings.

THE SIZE OF A CAPACITOR - RIPPLE FACTOR
The size of a capacitor depends on a number of factors, namely the value of the capacitor (in microfarads etc) and the voltage rating. But there is also another factor that is most important. It is the RIPPLE FACTOR. **Ripple Factor** is the amount of current-fluctuation the capacitor (electrolytic) can withstand without getting too hot.

When current flows in and out of an electrolytic, it gets hot and this will eventually dry-out the capacitor as some of the liquid inside the capacitor escapes through the seal. It's a very slow process but over a period of years, the capacitor looses its capacitance.
If you have two identical 1,000u 35v electrolytics and one is smaller, it will get hotter when operating in a circuit and that's why it is necessary to choose the largest electrolytic.

CAUTION
If a capacitor has a voltage rating of 63v, do not put it in a 100v circuit as the insulation (called the dielectric) will be punctured and the capacitor will "short-circuit." It's ok to replace a 0.22uF 50WV capacitor with 0.22uF 250WVDC.
An electrolytic will withstand 110% voltage - that is 10% higher than the marked value, but a voltage above this will leak through the oxide insulation and eventually create a pin-hole short-circuit.

SAFETY
A capacitor can store a charge for a period of time after the equipment is turned off. High voltage electrolytic caps can pose a safety hazard. These capacitors are in power supplies and some have a resistor across them, called a bleed resistor, to discharge the cap after power is switched off.
If a bleed resistor is not present the cap can retain a charge after the equipment is unplugged.

How to discharge a capacitor
Do not use a screwdriver to short between the terminals as this will damage the capacitor internally and the screwdriver.
Use a 1k 1 watt or 3watt or 5watt resistor on jumper leads (or held with pliers) and keep them connected for up to 15 seconds to fully discharge the electro. You can even go as low as 100 ohms or 10 ohms for a 25v or 35v electrolytic and watch the spark. Then test it with a voltmeter to make sure all the energy has been removed.

Before testing any capacitors, especially electrolytics, you should look to see if any are damaged, overheated or leaking. Swelling at the top of an electrolytic indicates heating (and pressure inside the case) and will result in drying out of the electrolyte. Any hot or warm electrolytic indicates leakage and ceramic capacitors with portions missing indicates something has gone wrong (such as it being "blown apart").

Here is a 120u 330v electrolytic from a flash circuit in an old-fashioned film camera.
If the flash does not "fire," the electrolytic will be charged to about 350 volts !!

Use a 1k resistor (held with pliers) to slowly discharge it. It may take 15 seconds to fully discharge.

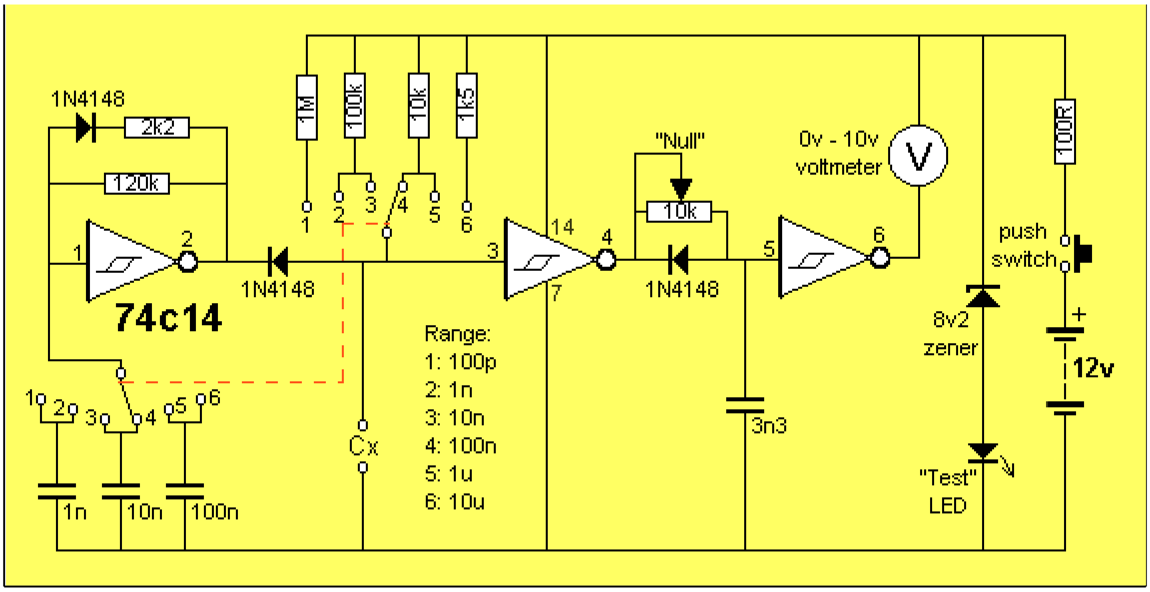
TESTING A CAPACITOR
There are two things you can test with a multimeter:
1. A short-circuit within the capacitor
2. Capacitor values above 1u.

You can test capacitors in-circuit for short-circuits. Use the x1 ohms range.
To test a capacitor for leakage, you need to remove it or at least one lead must be removed. Use the x10k range on an analogue or digital multimeter.
For values above 1u you can determine if the capacitor is charging by using an analogue meter. The needle will initially move across the scale to indicate the cap is charging, then go to "no deflection." Any permanent deflection of the needle will indicate leakage.
You can reverse the probes to see if the needle moves in the opposite direction. This indicates it has been charged. Values below 1u will not respond to charging and the needle will not deflect.
This does not work with a digital meter as the resistance range does not output any current and the electrolytic does not charge.

Rather than spending money on a capacitance meter, it is cheaper to replace any suspect capacitor or electrolytic.
Capacitors can produce very unusual faults and no piece of test equipment is going to detect the problem.
In most cases, it is a simple matter to solder another capacitor across the suspect component and view or listen to the result.
This saves all the worry of removing the component and testing it with equipment that cannot possibly give you an accurate reading when the full voltage and current is not present.
It is complete madness to even think of testing critical components such as capacitors, with TEST EQUIPMENT. You are fooling yourself. If the Test Equipment says the component is ok, you will look somewhere else and waste a lot of time.

FINDING THE VALUE OF A CAPACITOR

If you want to find the value of a surface-mount capacitor or one where the markings have been removed, you will need a CAPACITANCE METER. Here is a simple circuit that can be added to your meter to read capacitor values from 10p to 10u.
The full article can be found HERE.



ADD-ON CAPACITANCE METER

CAPACITOR SUBSTITUTION BOX

Cost: $18.00 plus postage. Just use individual capacitors and solder them directly to the board.

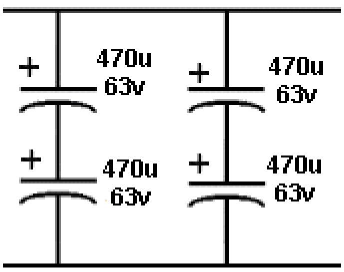
You can get a kit or a ready-made piece of test gear called **CAPACITOR SUBSTITUTION BOX** and also **RESISTOR SUBSTITUTION BOX**.
I bought one of each 30 years ago and I have only used them ONCE.
They appear to be very handy but when you are testing a circuit, you want the component next to the other parts.
It is just as easy to pick the component you need from your junk box and connect it to the circuit via jumper leads. If the resistor burns out, you can throw it away.

REPLACING A CAPACITOR

Always replace a capacitor with the exact same type.
A capacitor may be slightly important in a circuit or it might be extremely critical.
A manufacturer may have taken years to select the right type of capacitor due to previous failures.

failures.
A capacitor just doesn't have a "value of capacitance."
It may also has an effect called "tightening of the rails."
In other words, a capacitor has the ability to react quickly and either absorb or deliver energy to prevent spikes or fluctuations on the rail.
This is due to the way it is constructed. Some capacitors are simply plates of metal film while others are wound in a coil. Some capacitors are large while others are small.
They all react differently when the voltage fluctuates.
Not only this, but some capacitors are very stable and all these features go into the decision for the type of capacitor to use.
You can completely destroy the operation of a circuit by selecting the wrong type of capacitor.
No capacitor is perfect and when it gets charged or discharged, it appears to have a small value of resistance in series with the value of capacitance. This is known as "ESR" and stands for EQUIVALENT SERIES RESISTANCE. This effectively makes the capacitor slightly slower to charge and discharge.
We cannot go into the theory on selecting a capacitor as it would be larger than this eBook so the only solution is to replace a capacitor with an identical type.
However if you get more than one repair with identical faults, you should ask other technicians if the original capacitor comes from a faulty batch.
The author has fixed TV's and fax machines where the capacitors have been inferior and alternate types have solved the problem.
Some capacitor are suitable for high frequencies, others for low frequencies.
With high frequency circuits, you cannot substitute a capacitor by connecting it to long jumper leads. The capacitor MUST be soldered directly into the circuit.

We get a lot of enquiries about replacing a capacitor in say an e-bike with 470u 80v. Many electronics shops only supply 35v or 63v and the voltage rating needs to be about 80v to cater for the high voltage battery packs.
The only solution I can come up with is parallel/series. This will not guarantee equal division of the voltage across all capacitors but will be acceptable. For a 470u 80v we need four 470u at 63v, connected like this:



You need four because the first two on the left are in series to obtain 120v capability and this produces 235u. The second string adds 235u to get 470u at over 100v

The volume of the 4 capacitors (electrolytics) must be equal or greater than the original to maintain the same ripple-factor.

DECOUPLING CAPACITORS

A Decoupling Capacitor can severe one, two or three functions. You need to think of a decoupling capacitor as a miniature battery with the ability to deliver a brief pulse of energy when ever the line-voltage drops and also absorb a brief pulse of energy when ever the line voltage rises (or spikes).
Decoupling capacitor can range from 100n to 1,000u.
100n capacitors are designed to absorb spikes and also have the effect of tightening-up the rails for high frequencies. They have no effect on low frequencies such as audio frequencies.
These capacitors are generally ceramic and have very low internal impedance and thus they can operate at high frequencies.
Capacitors above about 10u are used for decoupling and these are nearly always electrolytics.
Decoupling means "tightening-up the power rails." The electrolytic acts just like a miniature rechargeable battery, supplying a small number of components in a circuit with a smooth

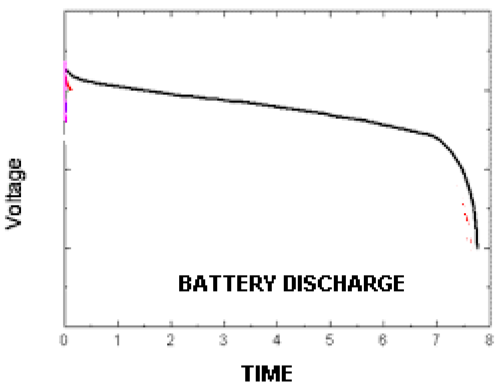
and stable voltage.
The electrolytic is usually fed from a dropper resistor and this resistor charges the electrolytic and adds to the ability of the electrolytic to create a "separate power supply." These two components help remove spikes as an electrolytic cannot remove spikes if connected directly to the supply rails - it's internal impedance is high and the spikes are not absorbed.
Decoupling capacitors are very difficult to test.
They rarely fail but if a project is suffering from unknown glitches and spikes, it is best to simply add more 100n decoupling caps on the underside of the board and replace all electrolytics.
Some small electrolytics will dry out due to faulty manufacture and simply replacing every one on a board will solve the problem.
Some of the functions of a decoupling capacitor are:
Removing ripple - hum or buzz in the background of an amplifier
Removing glitches or spikes.
Separating one stage from another to reduce or remove MOTOR-BOATING - a low frequency sound due to the output putting a pulse on the power rails that is picked up by the pre-amplifier section and amplified.

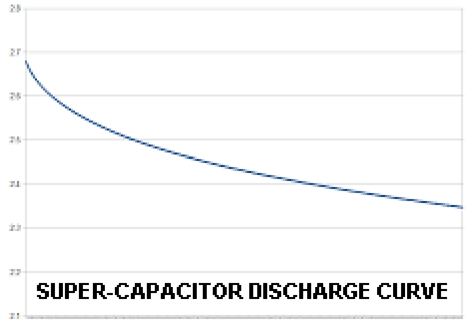
SUPER CAPACITORS

Super-capacitors are coming on the market with surprisingly high capacitance but still in the low-voltage range. They are suitable for some applications but not for: **JUMP-STARTER PACKS.**

A super capacitor does not take the place of a rechargeable battery. It may be able to deliver a very high current for a short period of time, (for say a spot welder) but some manufacturers sell a JUMP STARTER PACK for a car, using super-capacitors.
Don't be tricked by the output voltage and huge current of these packs. There is more to learn out jump-starting a car.
Jump-starting a car uses a very clever trick in the first place.
If your car does not start on a cold morning, it will be due to the battery as starting to get old and its voltage will drop when a high current is required. This is due to the chemical on the plates increasing in resistance. When the voltage drops by 1, 2 3 or 4 volts, the current drops as well due to the simple fact of Ohm's Law coming into the equation. The combination of these two lower values causes the starter motor to revolve as a lower RPM and the car does not start.
A jump-starter pack connects across your battery and it does deliver some of the current but more important is the fact that it keeps the VOLTAGE at a higher value. This is the secret. It keeps the VOLTAGE high. You can also say it "raises" the voltage.
A jump-starter pack containing a rechargeable battery will keep the voltage high for more than 30 seconds.
This is because it contains a NEW battery (very similar in construction to your car battery) and the cells will maintain an output of 2.1v for at least 30 seconds.
But a super capacitor will only deliver its full rated voltage for less than one second and the voltage drops very quickly.
This means a **super-capacitor jump starter pack** is totally unsuitable for jump-starting a car. The following two graphs show the voltage of a rechargeable battery remains fairly high for a long period of time. The super-capacitor voltage drops very quickly (after a fraction of a second). The super-cap helps the car battery but only for a fraction of a second. It may take 5 to 10 seconds to start the car and the super-cap will not help.
There are other technical points to this discussion including the amount of energy in a super-cap and a jump-start battery pack. The energy in a super-cap starter pack is less than a pack of torch cells. If 8 Alkaline cells could deliver the current, eight "D" cells would start your car 10 times. (432,000watt-sec from the cells and the starter motor takes 42,000watt-sec). A 1,000F supercap @12v only delivers 70watt-secs but its useful delivery is only for the portion that is between 12v and down to 9v and this is just 15watt-seconds.

So you can see the uselessness of a super-capacitor for this application.





TESTING DIODES

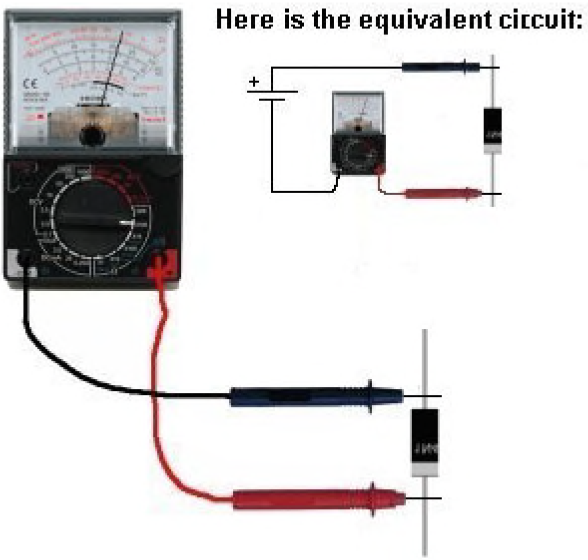
Diodes can have 4 different faults.
1. Open circuit in both directions.
2. Low resistance in both directions.
3. Leaky.
4. Breakdown under load.

TESTING A DIODE ON AN ANALOGUE METER

Testing a diode with an **Analogue Multimeter** can be done on any of the resistance ranges. [The high resistance range is best - it sometimes has a high voltage battery for this range but this does not affect our testing]
There are two things you must remember.
1. When the diode is measured in one direction, the needle will **not move at all**. The technical term for this is the diode is **reverse biased**. It will not allow any current to flow. Thus the needle will not move.
When the diode is connected around the other way, the needle will swing to the right (move up scale) to about 80% of the scale. This position represents the voltage drop across the junction of the diode and is NOT a resistance value. If you change the resistance range, the needle will move to a slightly different position due to the resistances inside the meter. The technical term for this is the diode is **forward biased**. This indicates the diode is not faulty.
The needle will swing to a slightly different position for a "normal diode" compared to a Schottky diode. This is due to the different junction voltage drops.
However we are only testing the diode at very low voltage and it may break-down when fitted to a circuit due to a higher voltage being present or due to a high current flowing.

2. The leads of an **Analogue Multimeter** have the positive of the battery connected to the black probe and the readings of a "good diode" are shown in the following two diagrams:

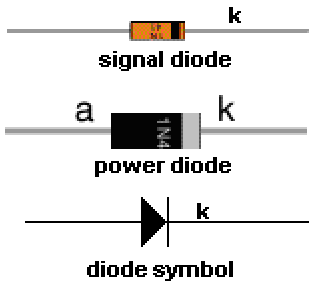
The diode is REVERSE BIASED in the diagram above and diodes not conduct.



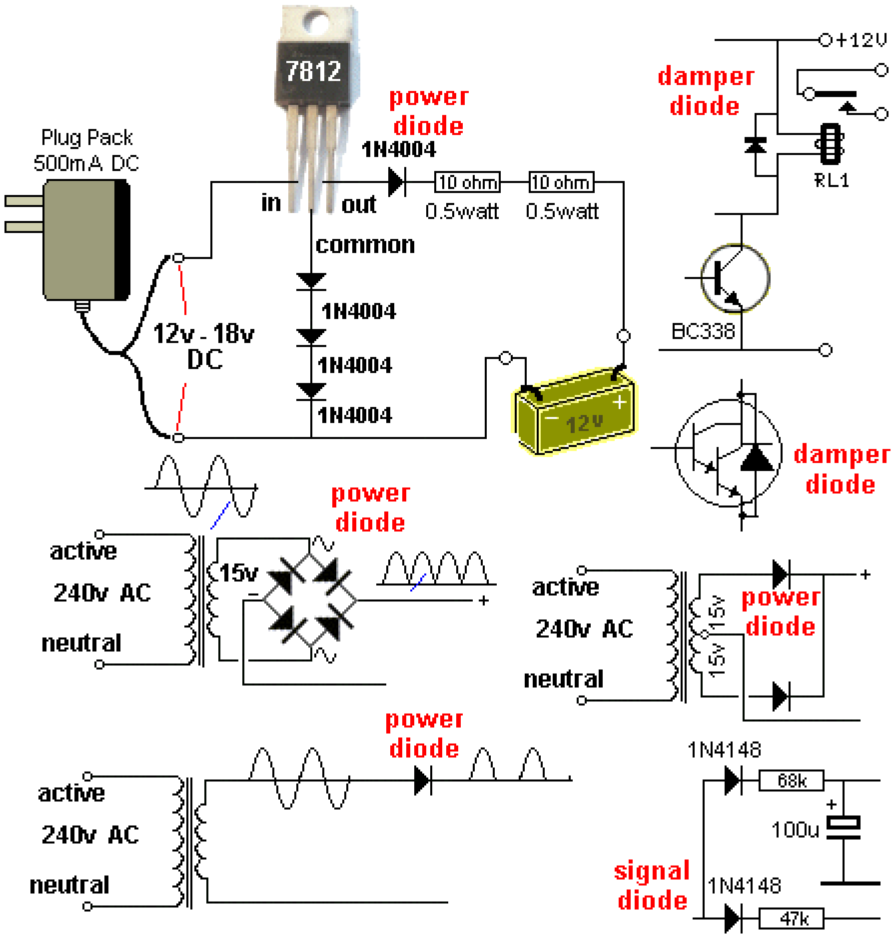
The diode is FORWARD BIASED in the diagram above and it conducts

TESTING A DIODE ON A DIGITAL METER

Testing a diode with a Digital Meter must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.



The best thing to do with a "suspect" diode is to replace it. This is because a diode has a number of characteristics that cannot be tested with simple equipment. Some diodes have a fast recovery for use in high frequency circuits. They conduct very quickly and turn off very quickly so the waveform is processed accurately and efficiently.
If the diode is replaced with an ordinary diode, it will heat up as does not have the high-speed characteristic.
Other diodes have a low drop across them and if an ordinary is used, it will heat up.
Most diodes fail by going: SHORT-CIRCUIT. This can be detected by a low resistance (x1 or x10 Ohms range) in both directions.
A diode can also go OPEN CIRCUIT. To locate this fault, place an identical diode across the diode being tested.
A leaky diode can be detected by a low reading in one direction and a slight reading the other direction.
However this type of fault can only be detected when the circuit is working. The output of the circuit will be low and sometimes the diode heats up (more than normal).
A diode can go open under full load conditions and perform intermittently.
Diodes come in pairs in surface-mount packages and 4 diodes can be found in a bridge. They are also available in pairs that look like a 3-leaded transistor.
The line on the end of the body of a diode indicates the cathode and you cannot say "this is the positive lead." The correct way to describe the leads is to say the "cathode lead." The other lead is the anode. The cathode is defined as the electrode (or lead) through which an electric current flows out of a device.
The following diagrams show different types of diodes:



POWER DIODES

To understand how a power diode works, we need to describe a few things. This has NEVER been described before, so read carefully.

The 240v AC (called the "mains") consists of two wires, one is called the ACTIVE and the other is NEUTRAL. Suppose you touch both wires. You will get a shock. The neutral is connected to an earth wire (or rod driven into the ground or connected to a water pipe) at the point where the electricity enters the premises and you do not get a shock from the NEUTRAL.

But the voltage on the active is rising to +345v then goes to -345v at the rate of 50 times per second (for a complete cycle).

345v is the peak voltage of 240v. You never get a 240v shock. (It is a 345v shock.)

In other words, if you touch the two wires at a particular instant, you would get a POSITIVE 345v shock and at another instant you would get a negative 345v shock. This is shown in the diagram below.

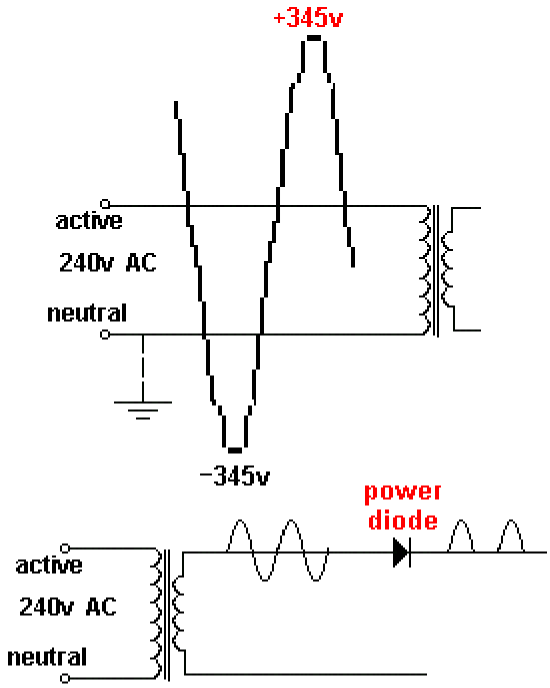
We now transfer this concept to the output of a transformer. The diagram shows an AC waveform on the output of the secondary.

This voltage is rising 15v higher than the bottom lead then it is 15v LOWER than the bottom lead. The bottom lead is called "zero volts." You have to say one lead or wire is not "rising and falling" as you need a "reference" or starting-point" or "zero point" for voltage measurements.

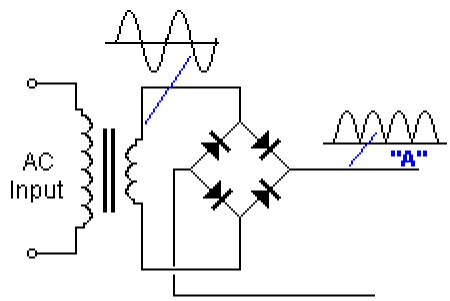
The diode only conducts when the voltage is "above zero" (actually when it is 0.7v above zero) and does not conduct (at all) when the voltage goes below zero.

This is shown on the output of the Power Diode. Only the positive peaks or the positive parts of the waveform appear on the output and this is called "pulsing DC." This is called "half-wave" and is not used in a power supply. We have used it to describe how the diode works.

The electrolytics charge during the peaks and deliver energy when the diode is not delivering current. This is how the output becomes a steady DC voltage.
Power supplies use FULL WAVE rectification and the other half of the AC waveform is delivered to the output (and fills in the "gaps") and appears as shown in "A."



Half-wave rectifier

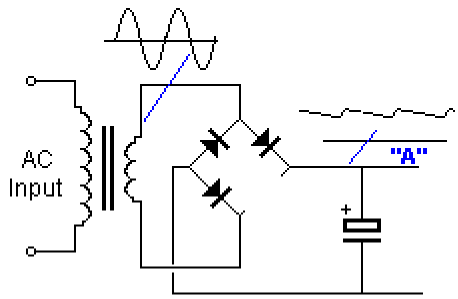


Full-wave rectifier

ONE FAULTY DIODE

One diode in a bridge can go open (any of the 4 diodes will produce the same effect) and produce an output voltage that can be slightly lower than the original voltage. The actual "voltage-drop" will depend on the current taken by the circuit and the ability of the transformer to produce the required voltage and current during half-wave operation. The voltage during each half cycle (when none of the diodes is delivering any energy to the circuit) is maintained by the electrolytic and its size (relative to the current taken by the circuit) will determine the size of the ripple that will result when the diode fails. The ripple will be 100 to 1,000 times greater after the failure of a diode, depending on the value of the filter capacitor.
To locate the faulty diode, simply get a diode and place it across each of the diodes in the bridge (in turn) when the circuit is working.
For a bridge rectifier, the ripple-frequency will be twice the mains frequency and its ripple will be very small if the electrolytic is the correct value. When a diode fails, the ripple-frequency will be equal to mains-frequency and the amplitude will increase considerably.

You may even hear background hum from audio equipment.
If you cannot find a faulty diode, the filter capacitor will be at fault. Turn off the equipment and connect an electrolytic across the filter capacitor via jumper leads. Turn the power ON and see if the hum has reduced.



One diode "burnt-out"

DAMPER DIODES

A damper diode is a diode that detects a high voltage and SQUELCHES IT (reduces it - removes it). The signal that it squelches is a voltage that is in the opposite direction to the "supply voltage" and is produced by the collapsing of a magnetic field. Whenever a magnetic filed collapses, it produces a voltage in the winding that is opposite to the supply voltage and can be much higher. This is the principle of a flyback circuit or EHT circuit. The high voltage comes from the transformer.
The diode is placed so that the signal passes through it and less than 0.5v appears across it.
A damper diode can be placed across the coil of a relay, incorporated into a transistor or FET or placed across a winding of a flyback transformer to protect the driving transistor or FET.
It can also be called a "Reverse-Voltage Protection Diode," "Spike Suppression Diode," or "Voltage Clamp Diode."
The main characteristic of a Damper Diode is HIGH SPEED so it can detect the spike and absorb the energy.
It does not have to be a high-voltage diode as the high voltage in the circuit is being absorbed by the diode.

SILICON, GERMANIUM AND SCHOTTKY DIODES

When testing a diode with an analogue meter, you will get a low reading in one direction and a high (or NO READING) in the other direction. When reading in the LOW direction, the needle will swing nearly full scale and the reading is not a resistance-value but a reflection of the characteristic voltage drop across the junction of the diode. As we mentioned before, a resistance reading is really a voltage reading and the meter is measuring the voltage of the battery minus the voltage-drop across the diode.
Since Silicon, Germanium and Schottky Diodes have slightly different characteristic voltage drops across the junction, you will get a slightly different reading on the scale. This does not represent one diode being better than the other or capable of handling a higher current or any other feature.
The quickest, easiest and cheapest way to find, fix and solve a problem caused by a faulty diode is to replace it.
There is no piece of test equipment capable of testing a diode fully, and the circuit you are working on is actually the best piece of test equipment as it is identifying the fault UNDER LOAD.

Only very simple tests can be done with a multimeter and it is best to check a diode with an ANALOGUE MULTIMETER as it outputs a higher current though the diode and produces a more-reliable result.

A Digital meter can produce false readings as it does not apply enough current to activate the junction.

Fortunately almost every digital multimeter has a **diode test mode.** Using this, a silicon diode should read a voltage drop between 0.5v to 0.8v in the forward direction and open in the reverse direction. For a germanium diode, the reading will be lower, around 0.2v - 0.4v in the forward direction. A bad diode will read zero volts in both directions.

REPLACING A DIODE

It is always best to replace a diode with the same type but quite often this is not possible. Many diodes have unusual markings or colours or "in-house" letters.

This is only a general guide because many diodes have special features, especially when used in high-frequency circuits.

However if you are desperate to get a piece of equipment working, here are the steps:

Determine if the diode is a signal diode, power diode, or zener diode.

For a signal diode, try 1N4148.

For a power diode (1 amp) try 1N4004. (for up to 400v)

For a power diode (3 amp) try 1N5404. (for up to 400v)

For a high-speed diode, try UF4004 (for up to 400v)

If you put an ordinary diode in a high-speed application, it will get very hot very quickly.

To replace an unknown zener diode, start with a low voltage such as 6v2 and see if the circuit works.

The size of a diode and the thickness of the leads will give an idea of the current-capability of the diode.

Keep the leads short as the PC board acts as a heat-sink.

You can also add fins to the leads to keep the diode cool.

DIODE BRIDGE

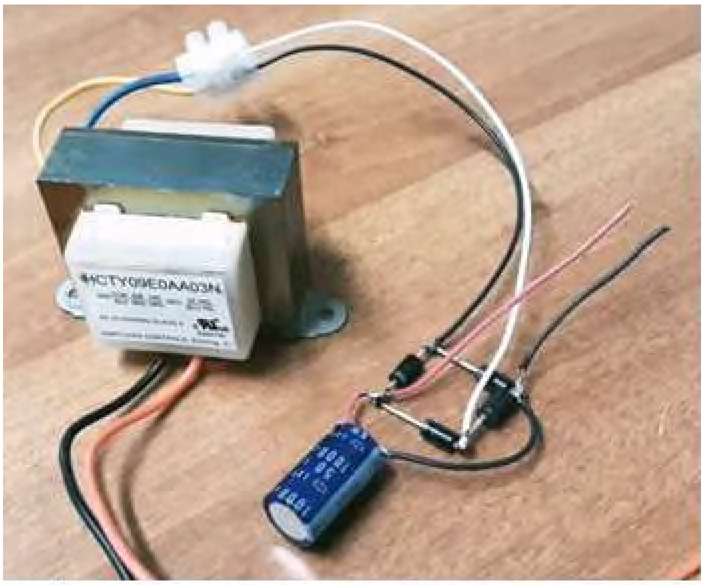
The rating of a diode depends on the way it is connected to a printed circuit board via the two leads. It does not matter if the diode is rated a 1 amp or 3 amp, if it is connected "in the air" it will dissipate less than 1 watt and since a diode has a characteristic voltage drop across it when full current is flowing, it will only pass less than 1 amp.

If we take a 1 watt resistor, it will only dissipate 1 watt when it is connected directly to the tracks of a PC board. These tracks are enormously important as two 330R resistors in series in a project I was fixing had one resistor burn out. Now this is theoretically impossible when they are passing the same current. But after a lot of investigation the failed resistor had narrower and shorter tracks.

A 1 amp diode may be the same size but when connected "in the air" it will dissipate much less than 1 watt.

Here we see 2 projects from YouTube, claiming to be a 3 amp bridge. These bridges will have about 1 amp capability. Even though each diode will be active for only 50% of each cycle, the first image uses 1amp diodes and the maximum you can expect them to pass is 1 amp for each half cycle. This will create a lot of heat in the leads and the heat will not be able to go anywhere because another diode connects to the lead. On top of this the voltage drop of each diode will be greater than 1.1v when 1 amp is flowing.

A 1 amp diode is really only suitable for 700mA max. As the current increases from 700mA to 1 amp, the temperature rises enormously because the wattage dissipated rises as the square of the current $P=I^2R$



The image above shows 3 amp diodes in a bridge. But the limiting factor is the heat generated. If you cannot hold your fingers on a component, it is getting too hot. This bridge is limited to 1.5 amp due to the heat it will generate. If you maintain more than 1.5 amp, I am sure the solder will soften and the diodes will fall off!

LIGHT EMITTING DIODES (LEDs)

Light Emitting Diodes (LEDs) are diodes that produce light when current flows from anode to cathode. The LED does not emit light when it is revered-biased. It is used as a low current indicator in many types of consumer and industrial equipment, such as monitors, TV's, printers, hi-fi systems, machinery and control panels.

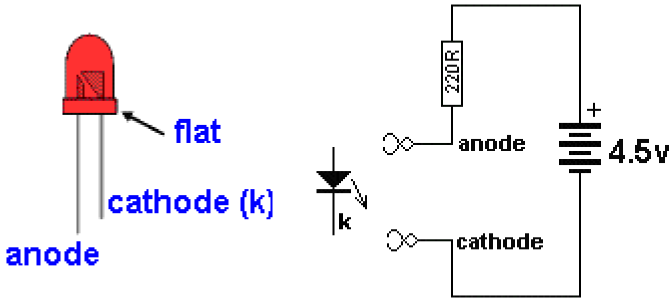
The light produced by a LED can be visible, such as red, green, yellow or white. It can also be invisible and these LEDs are called Infrared LEDs. They are used in remote controls and to see if they are working, you need to point a digital camera at the LED and view the picture on the camera screen.

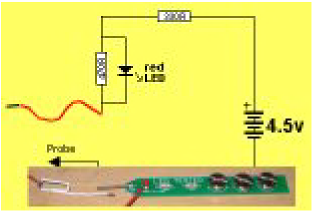
An LED needs about 2v - 3.6v across its leads to make it emit light, but this voltage must be exact for the type and colour of the LED. The simplest way to deliver the exact voltage is to have a supply that is higher than needed and include a voltage-dropping resistor. The value of the resistor must be selected so the current is between 2mA and 25mA.

The cathode of the LED is identified by a flat on the side of the LED. The life expectancy of a LED is about 100,000 hours. LEDs rarely fail but they are very sensitive to heat and they must be soldered and de-soldered quickly. They are one of the most heat-sensitive components.

Light emitting diodes cannot be tested with most multimeters because the characteristic voltage across them is higher than the voltage of the battery in the meter.

However a simple tester can be made by joining 3 cells together with a 220R resistor and 2 alligator clips:





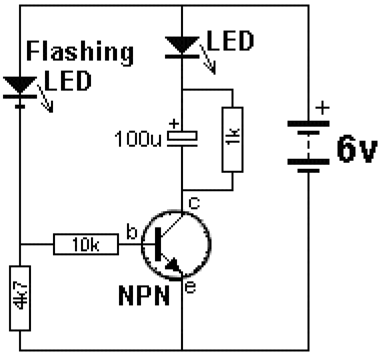
LED TESTER

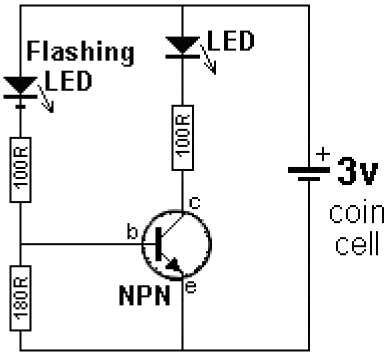
LED TESTER is a very simple project from Talking Electronics that tests LEDs and diodes and continuity. It is one of the most useful projects to add to your TEST EQUIPMENT.
Connect the clips to a LED and it will illuminate in only one direction.
The colour of the LED will determine the voltage across it. You can measure this voltage if you want to match two or more LEDs for identical operation.
Red LEDs are generally 1.7v to 1.9v. - depending on the quality such as "high-bright"
Green LEDs are 1.9v to 2.3v.
Orange LEDs are about 2.3v and
White LEDs and IR LEDs are about 3.3v to 3.6v.
The illumination produced by a LED is determined by the quality of the crystal. It is the crystal that produces the colour and you need to replace a LED with the same quality to achieve the same illumination.
Never connect a LED across a battery (such as 6v or 9v), as it will be instantly damaged. You must have a resistor in series with the LED to limit the current.

The LED TESTER also identifies a very unusual property of some LEDS. Some of the powerful LEDs illuminate in a display but fail to illuminate when tested with **LED Tester**. When they are replaced, the current take by the display reduces considerably. It seems the faulty LEDs will illuminate but take excess current.

FLASHING LEDs

An ordinary LED can be flashed by using one of the following circuits. This allows a very bright LED to flash and give a special effect. The secret is to use a flashing LED to prove the on/off operation.
The flashing LED can be 3mm 5mm or SURFACE MOUNT.
These LEDs have an inbuilt resistor so the applied voltage can be as low as 3v and up to 7v.
You can use them to illuminate a brighter LED with the following single transistor circuits. The second circuit operates on 3v from a coin cell. It is only suitable for red LEDs.





Here is an 0805 flashing LED.

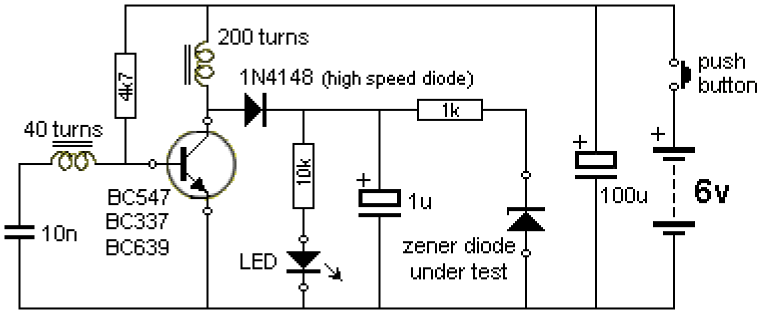
0805 SM Chip

The oscillator inside the case is so small, it cannot be seen.
These devices are the same price as an ordinary surface mount LED and need no other components.
They will operate from 3v to 7v and have an internal dropper-resistor.
The flash rate is about 1- 2 Hz and are available in red, green, blue and white.
You can also get 3mm LEDs red, green, blue flashing and random flashing and flickering orange LEDs.
These are all available on eBay. Most of them work on 3v to 7v and take about 10mA to 20mA. You can connect a piezo diaphragm across them and listen to the oscillator "clocking."
To find out the maximum supply voltage, connect the LED to a variable supply and put a milliamp meter in the positive line. Read the current (as the voltage is increased) and when it reaches 20mA to 25mA you have found the maximum supply voltage.

ZENER DIODES

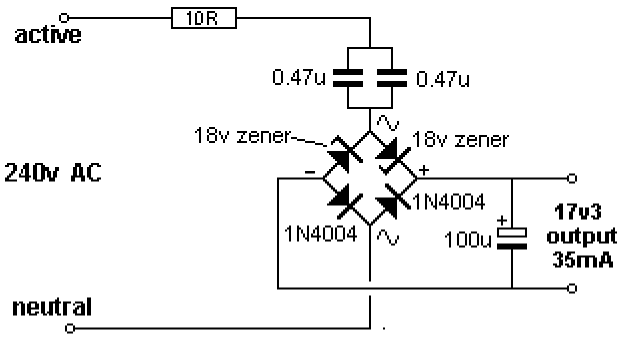
All diodes are Zener diodes. For instance a 1N4148 is a 120v zener diode as this is its reverse breakdown voltage.
And a zener diode can be used as an ordinary diode in a circuit with a voltage that is below the zener value.
For instance, 20v zener diodes can be used in a 12v power supply as the voltage never reaches 20v, and the zener characteristic is never reached.
Most diodes have a reverse breakdown voltage above 100v, while most zeners are below 70v. A 24v zener can be created by using two 12v zeners in series and a normal diode has a characteristic voltage of 0.7v. This can be used to increase the voltage of a zener diode by 0.7v. See the diagram above. It uses 3 ordinary diodes to increase the output voltage of a 3-terminal regulator by 2.1v.
To tests a zener diode you need a power supply about 10v higher than the zener of the diode. Connect the zener across the supply with a 1k to 4k7 resistor and measure the voltage across the diode. If it measures less than 1v, reverse the zener.
If the reading is high or low in both directions, the zener is damaged.

Here is a zener diode tester. The circuit will test up to 56v zeners.



ZENER DIODE TESTER

TRANSFORMERLESS POWER SUPPLY
Here's a circuit that uses zener diodes in a power supply to show how they work. This clever design uses 4 diodes in a bridge to produce a fixed voltage power supply capable of supplying 35mA.
If we put 2 zener diodes in a bridge with two ordinary power diodes, the bridge will break-down at the voltage of the zener. This is what we have done. If we use 18v zeners, the output will be 17v4.



SUPPLY USING ZENER DIODES

When the incoming voltage is positive at the top, the left zener provides 18v limit (and the other zener produces a drop of 0.6v). This allows the right zener to pass current just like a normal diode. The output is 17v4. The same with the other half-cycle.
You cannot use this type of bridge in a normal power supply as the zener diode will "short" when the input voltage reaches the zener value. The concept only works in the circuit above.

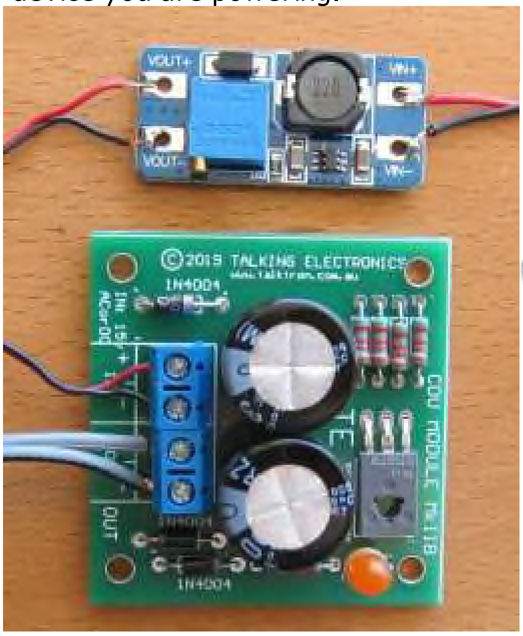
VOLTAGE REGULATORS

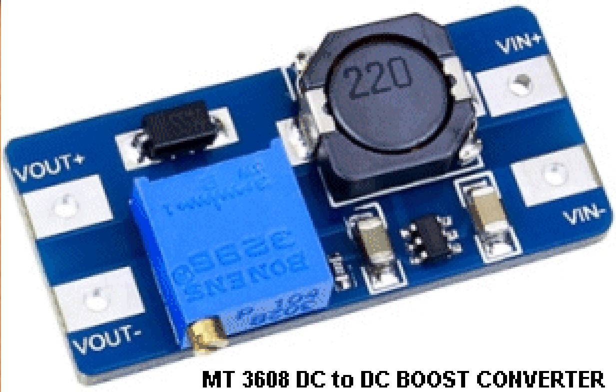
A Voltage Regulator takes a high input voltage and delivers a fixed output voltage. Providing the input voltage is 4v above the output voltage, the regulator will deliver a fixed output voltage with almost no ripple.
Voltage regulators are also called "3-TERMINAL REGULATORS" or "REGULATOR IC's" - although this name is not generally used.
In most cases, a voltage regulator gets quite hot and for this reason it has a high failure-rate.
If a regulator is not getting hot (or warm) it has either failed or the circuit is not operating.
A regulator can only decrease the voltage. It cannot increase the current. This means the

current being supplied to a circuit must also be available from the circuit supplying the regulator.
All regulators have different pin-outs, so you need to find the input pin and output pin and make sure the voltage-difference is at least 4v. Some regulators will work with a difference as low as 1v, so you need to read the specifications for the type you are servicing.
Some regulators are called "negative voltage regulators" and the input voltage will be negative and the output will be negative.
You need to test a voltage regulator with the power "ON".
Make sure you do not allow the probes to short any of the pins together as this will destroy the regulator or the circuit being supplied.
With the power turned off or the regulator removed from the circuit, you can test it with a multimeter set to resistance to see if it is ok. If any resistance readings are very low or zero ohms, the regulator is damaged.

PRE-VOLTAGE REGULATORS

There is a new module on the market called a **DC-DC CONVERTER.** I say "new" because they have come down in price to a point where they sell for less than the cost of buying the components separately.
And they solve a lot of problems.
Suppose you have a power supply for an amplifier or other device and need to increase the voltage slightly to get better performance.
This is the perfect application for a **DC-DC CONVERTER.** The converter shown below is a **BOOST CONVERTER** and will increase say 12v to produce an output of 15v.
It is also ideal for converting almost any voltage from say 5v to 15v to deliver an output voltage 26.5v to a Capacitor Discharge Unit.
It is also capable of handling currents up to 3 amp. But it does not have an input protection diode and will "blow up" if the reverse voltage is applied to the input.
This happened to a number of our customers and when you are installing a new module that connects to a power supply, it is best to put a 10R to 47R in series with one of the input leads. Turn the supply On and OFF very quickly and feel the resistor. If it is not getting hot, try for longer. If it gets hot, see if the load is taking a high current. Once you are certain it is connected correctly, remove the resistor and adjust the 10-turn pot with a screwdriver in the ANTI-CLOCKWISE direction to INCREASE the voltage. Monitor the output voltage and make sure it does not exceed the allowable input voltage of the device you are powering.

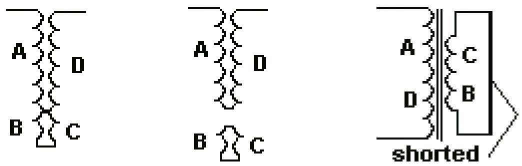




MT 3608 DC to DC BOOST CONVERTER
Input 5v to 20v
Output 5v to 37v
Output will be higher than input
Current - up to 3 amps

TRANSFORMERS

All transformers and coils are tested the same way. This includes chokes, coils, inductors, yokes, power transformers, EHT transformers (flyback transformers), switch mode transformers, isolation transformers, IF transformers, baluns, and any device that has turns of wire around a former. All these devices can go faulty.
The coating on the wire is called insulation or "enamel" and this can crack or become overheated or damaged due to vibration or movement. When two turns touch each other, a very interesting thing happens. **The winding becomes two separate windings.**



We will take the case of a single winding such as a coil. This is shown in the first diagram above and the winding is wound across a former (a former is a bobbin or plastic molding or something to hold the winding) and back again, making two layers. The bottom and top layers touch at the point shown in the diagram and the current that originally passed though A, B, C, D now passes though A & D.

Winding B C becomes a separate winding as shown in the second diagram.
In other words the coil becomes a TRANSFORMER with a SHORT CIRCUIT on the secondary winding as shown in the third diagram.
When the output wires of a transformer are shorted together, it delivers a very high current because you have created a SHORT-CIRCUIT. This short-circuit causes the transformer to get very hot.
That's exactly what happens when any coil or transformer gets a "shorted turn."
The shorted turns can be a single turn or many turns.
It is not possible to measure a fault like this with a multimeter as you don't know the exact resistance of a working coil or winding and the resistance of a faulty winding may be only 0.001 ohms less.
However when a transformer or coil is measured with an inductance meter, an oscillating voltage (or spike) is delivered into the core as magnetic flux, then the magnetic flux collapses and passes the energy into the winding to produce a waveform. The inductance meter reads this and produces a value of inductance in Henry (or milliHenry or microHenry.)
This is done with the transformer removed from the circuit and this can be a very difficult thing to do, as most transformers have a number of connections.
If the coil or transformer has a shorted turn, the energy from the magnetic flux will pass into the turns that are shorted and produce a current. Almost no voltage will be detected from winding.
The reading from the inductance meter will be low or very low and you have to work out if it is correct.
However there is one major problem with measuring a faulty transformer or coil.
It may only become faulty when power is applied.
The voltage between the turns may be sparking or jumping a gap and creating a problem. A tester is not going to find this fault.
Secondly, an inductance meter may produce a reading but you do not know if the reading is correct. An improved tester is a RING TESTER.
The circuit for a ring tester can be found here:

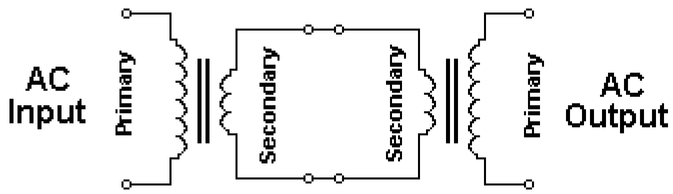
http://www.flippers.com/pdfs/k7205.pdf

It sends a pulse to the coil and counts the number of returning pulses or "rings." A faulty coil (or winding) may return one pulse but nearly all the energy will be passed to the shorted turns and you will be able to see this on the scale. You will only get one or two return pulses, whereas a good winding will return more pulses.

One way to detect a faulty power transformer is to connect it to the supply and feel the temperature-rise (when nothing is connected to the secondary).
It should NOT get hot.
Detecting shorted turns is not easy to diagnose as you really need another identical component to compare the results.
Most transformers get very hot when a shorted turn has developed. It may deliver a voltage but the heat generated and a smell from the transformer will indicate a fault.

ISOLATION TRANSFORMER

An isolation transformer is a piece of **Test Equipment** that provides "Mains Voltage" but the voltage is "floating." You will still get a shock if you touch the two output leads, but it has a special use when testing unknown equipment.
Many electrical appliances are fully insulated and only have two leads connected to the mains.
When you take these appliances apart, you do not know which end of say a heating element is connected to the "live" (active) side of the mains and which end connects to the neutral.
I am not suggesting you carry out the following tests, but they are described to show how an isolation transformer works.
If you touch a soldering iron on the "live" (active) end of the heating element it will create a short-circuit.
However when the appliance is connected to the mains via an **isolation transformer**, you can touch an earthed soldering iron on either end of the heater as both leads from the isolation transformer are "floating."
Note: As soon as you earth one lead of the output an isolation transformer, the other lead becomes "active."
You can make your own **Isolation Transformer** by connecting two identical transformers "back-to-back."
The following diagram shows how this is done:

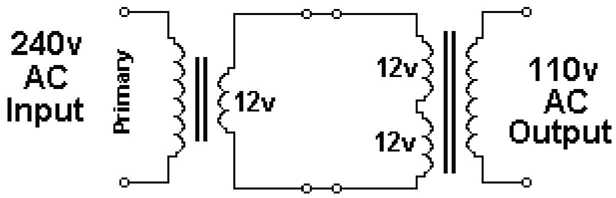


You can use any transformers providing the primary and secondary voltages are the same. The current capability of the secondary winding does not matter. However if you want a supply that has almost the same voltage as your "Mains," you need two transformers with the same voltages.

the same voltages.
This handy isolation transformer will provide you with "Mains Voltage" but with a limited current.
In other words it will have a limited capability to supply "wattage." If you are using two 15VA transformers, you will only be able to test an appliance rated at 15 watts.
This has some advantages and some disadvantages.
If you are working on a project, and a short-circuit occurs, the damage will be limited to 15 watts.
If you are using two transformers with different VA ratings, the lower rating will be the capability of the combination.
If the secondaries are not equal, you will get a higher or lower "Mains Voltage."
If you get two transformers from TVs or Monitors, with a rating on the compliance plate of 45 watts, or 90 watts, you can assume the transformers are capable of delivering this wattage and making an isolation transformer will enable you to test similar items with the safety of being isolated from the mains.
Colin Mitchell designs a lot of "LED lighting lamps" that are connected directly to the mains. He always works with an isolating transformer, just to be safe. Working on exposed "mains" devices is extremely nerve-wracking and you have to be very careful.
The isolation transformer will prevent a BIG EXPLOSION.

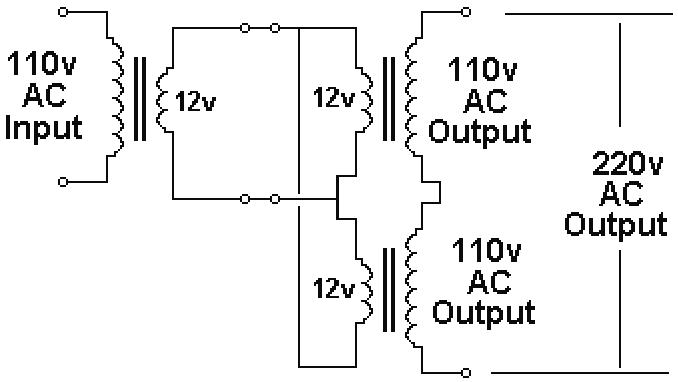
DETERMINING THE SPECS OF A TRANSFORMER
Suppose you have a "mains transformer" with unknown output voltages and unknown current capability.
You must be sure it is a mains transformer designed for operation on 50Hz or 60Hz. Switch-Mode transformers operate at frequencies 40kHz and higher and are not covered in this discussion.
To be on the safe-side, connect the unknown transformer to the output of your isolating transformer.
Since the transformer will take almost no current when not loaded, the output voltages it produces will be fairly accurate. Measure the input AC voltage and output AC voltage.
If the transformer has loaded your isolating transformer it will be faulty.
Mains transformers are approx 15VA for 500gm, 30VA for 1kgm 50VA for 2kgm and and 100VA for 2.5kgm.
VA stands for Volts-Amps and is similar to saying watts. Watts is used for DC circuits, while VA refers to AC circuits.
Once you have the weight of the transformer and the output voltage, you can work out the current capability of the secondary.
For transformers up to 30vA, the output voltage on no-load is 30% higher than the final "loaded voltage."
This is due to the poor regulation of these small devices.
If the transformer is 15VA and the output voltage is 15v AC, the current will be 1 amp AC.
You can check the "quality" of the transformer, (the regulation) by fully loading the output and measuring the final voltage. If the transformer has a number of secondaries, the VA rating must be divided between all the windings.

240v to 110v ISOLATION TRANSFORMER
Here's how to create a 110v isolating transformer:
Find a 240v:12v transformer.
Now find a transformer that has two secondary windings, such as 240v:12v+12v.



Connect the two transformers as shown in the circuit above. If the output is zero, connect ONE of the 12v windings of the second transformer around the other way.

110v to 240v ISOLATION TRANSFORMER

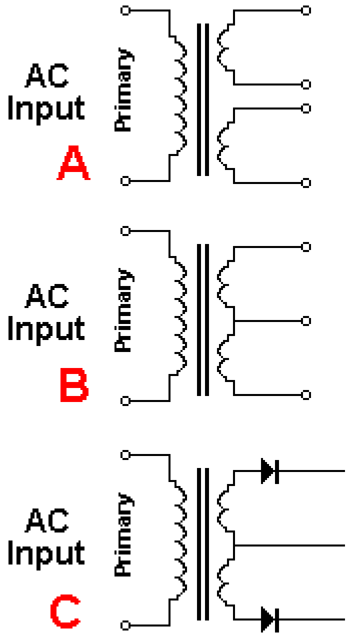


A 110v to 240v isolation transformer can be created by connecting 3 identical transformers as shown in the diagram above. If the output is zero, connect one of the outputs around the other way.

TRANSFORMER RATINGS

Question from a reader:
I have a 28v - 0 - 28v transformer @3amps. Does this mean each side is 1.5 amps?
The transformer is called CENTRE TAPPED and is shown in figures B and C.
It is designed to be connected to two diodes so each winding takes it in turn to deliver the current as shown in diagram C and the output will be 28v AC at 3 amps.
Each winding is delivering up to 3 amps for half-cycle and nothing for the next half-cycle.
The 28v and 3 amp are both AC values.
If you connect across both outside wires, the output will be 56v at 1.5 amp.
This is because the transformer has a VA rating of 28 x 3 = 84VA. This is very similar to the term "watts."
When the 28v AC is rectified and smoothed, it becomes 28 x 1.4 = 39v (minus 0.6v across the diode) and since the transformer has a rating of 84 VA, the current must be reduced to 84/39 = 2.1 amps to maintain the VA rating. So, you will only get 2.1 amps DC and 39v DC from the two diodes.
Some transformers are specified as say: 12v - 0 - 12v, but the wiring diagram is shown as "A." This transformer should be specified as 12v + 12v as the secondaries are separate.
12v - 0 - 12v means the two secondary windings are NOT separate.
It does not make any difference to the output voltage and current, if the windings are separate or joined. The only difference is 12v +12v can be turned into two separate 12v outputs.
If you do not know the output current for a particular transformer, go to the website of electronic parts suppliers and compare the weight of your transformer with others. This will give you a VA rating and you can work out the current, once you know the output voltage.
Note: the output current finishes up ONLY 60% of the rating on the transformer tag because the rating is an **AC RATING**.

With 2 separate secondaries, you can parallel the outputs to get double the current, but don't forget 12v + 12v @ 3amp means 12v in parallel with 12v will provide 2amp DC and the DC voltage will be about 17v.



CURRENT TRANSFORMER

A Current Transformer is really an ordinary transformer.
All transformers produce a CURRENT output and a VOLTAGE output.
If you put an ammeter across the secondary, the current will increase through the meter when the primary voltage is increased.
This is because the output voltage will increase and this voltage will allow a higher current to flow.

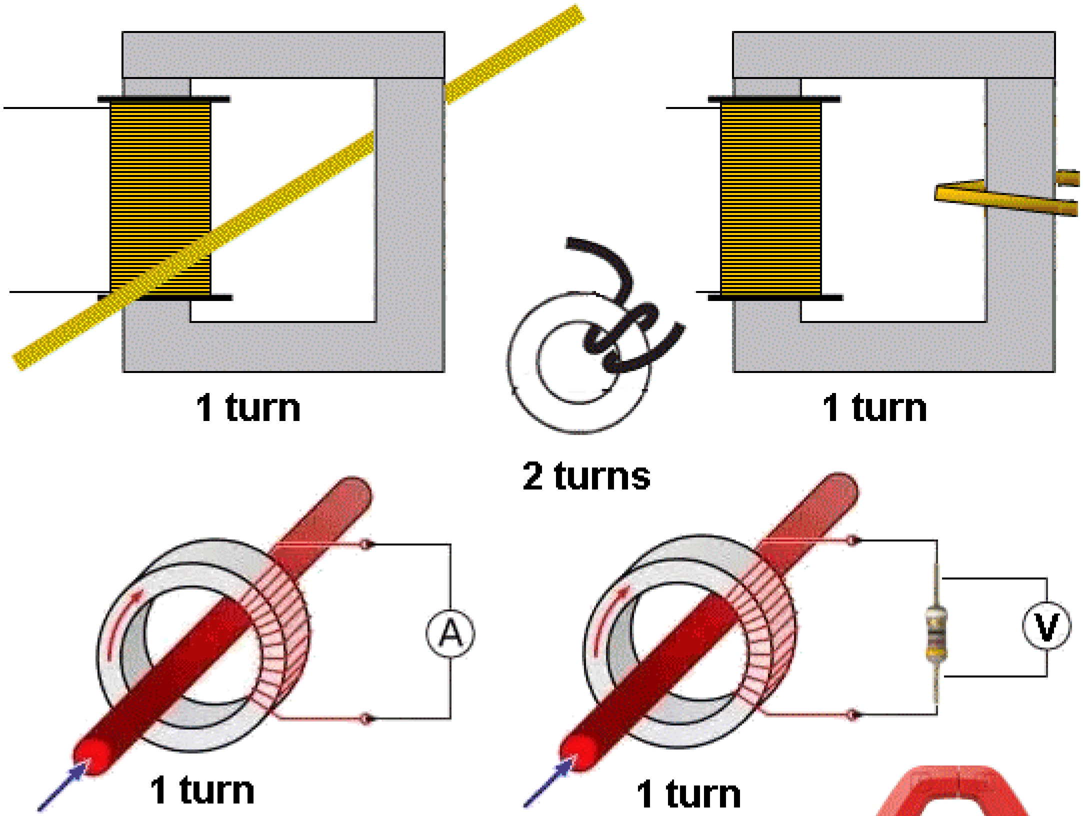
WHY DETECT CURRENT? Why not voltage?

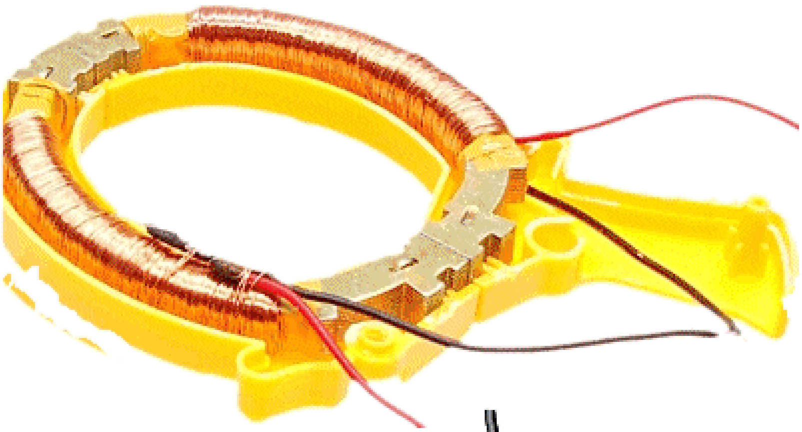
Because the voltage of say the "240v AC" is always 240v but the current can increase from say 1 amp to nearly 15 amps, depending what appliance is connected. So it is pointless measuring voltage.
A Current Transformer is a step-up transformer. When we say step-up and step-down, we are referring to the voltage - comparing the primary voltage to the secondary voltage. (Most transformers on the "mains" are step-down transformers and are used as power supplies to laptops, phone chargers etc.) Even a welding transformer is a step-down device and produces about 20v to 70v, while the current can be as high as 100 amps. This current is higher than the mains will deliver and is needed to melt the metal at the point of contact of the probe and the item being welded.
A Current Transformer is a step-up transformer. The primary consists of a single turn (or maybe 2 - 5 turns) and the secondary has 100 turns (or more).
This means the voltage seen by the primary will be increased 100 times and appear as anything from a few hundred millivolts to a few volts, depending on the quality of the coupling. (the magnetic coupling between the wire through the centre of the core, the quality of the core to transfer this magnetic flux to the secondary turns.) This voltage is then passed to a low value resistor, where the voltage is reduced to a level that suits the detection circuit and the resulting millivolts is interpreted as current in the wire being tested.

Recapping:

The reading on the secondary has no relation to the current in the primary. We need to add a LOAD RESISTOR and create a table before we can use the transformer.

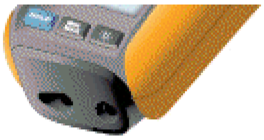
a LOAD RESISTOR and create a table before we can use the transformer.
There is no such thing as a CURRENT TRANSFORMER. It is really an INSTRUMENT TRANSFORMER and the scale has been marked in units of CURRENT after measurements have been made. (INSTRUMENT TRANSFORMER means it is a device that helps us to produce a connection between current flowing through a wire and a reading on a meter or display).
If we connect a load to the secondary, (say an ammeter), it will produce a reading that increases when the current through the single primary turn is increased. That's because the ammeter is a LOAD. But the reading is meaningless until be calibrate the scale.
Now, lets look at the primary.
A wire (or cable) through the centre of the core is counted as one turn. If the turn is wrapped around the core, the coupling will be improved, but if we always use a straight wire, it does not matter where it is positioned inside the centre of the core.
It does not matter if the magnetic interaction of the flux from the wire is good or bad, we just have to keep to the same way of using the transformer.
The calibration can be done with any poor coupling and the result will be accurate for all future readings.
If a low-value resistor is placed across the secondary, the voltage across this resistor will increase and also the current through it will increase. But we are not going to measure the current through the resistor. We are going to measure the voltage across the resistor and by taking lots of reading we will finish up with a scale or table and this is called CALIBRATION. The results will be equated to the current flowing through the primary wire (primary turn).
A clamp meter uses a current transformer and the jaws must be closed completely and cleanly for the flux to flow around the core and produce a reading in the secondary.
Dirt in the jaws will reduce the reading considerably.
You cannot measure the current in a "power cord" because it contains both the active and neutral wires.
Even though the current is a maximum in both conductors at the same time, the current is flowing in two different directions and the magnetic flux produced by one conductor is clockwise and the other is anticlockwise and they are cancelled by each other.


1 turn
2 turns
1 turn
A
V
1 turn
1 turn



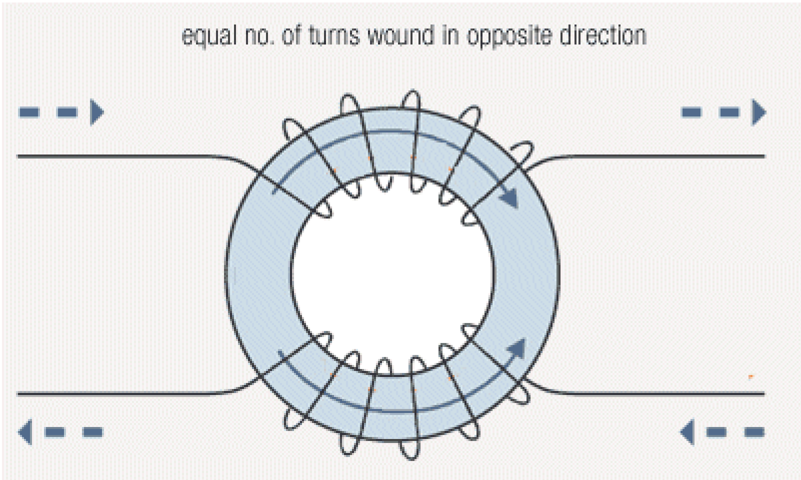

FLUKE
600.0

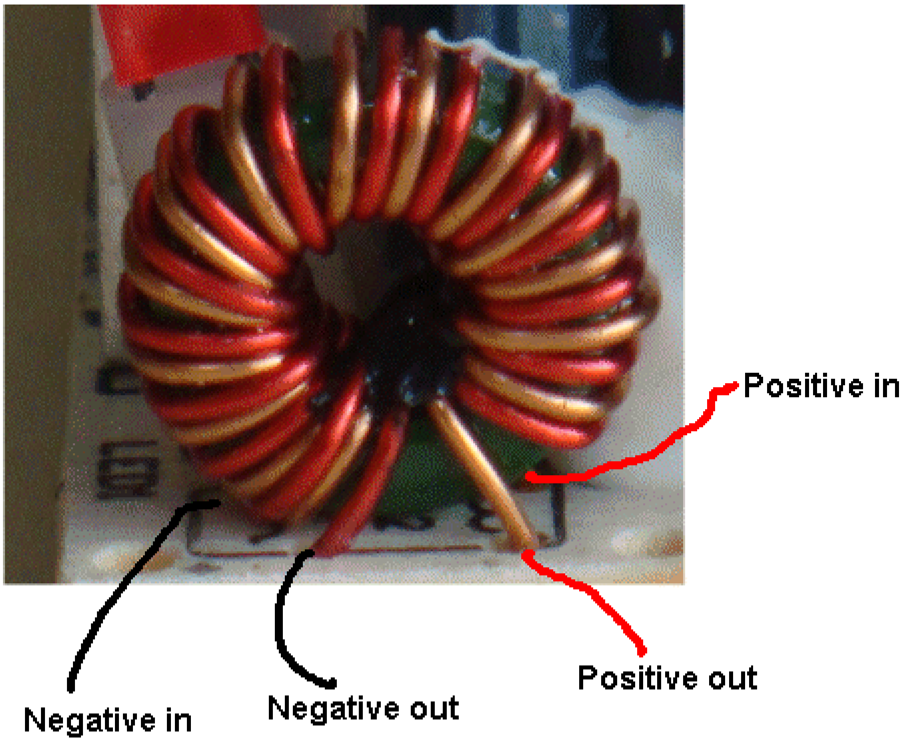

30.00



Identifying ONE TURN.
The quality (the coupling) of a single STRAIGHT wire through the centre of a core is very poor but if all readings are taken with this amount of coupling, the readings will be accurate, as the calibrations have been done with this arrangement.

COMMON MODE TRANSFORMER -really COMMON MODE CHOKE





The negative wire is RED. The positive wire is "Copper"

This component is very small but it has a big effect because the magnetic flux produced by one winding is in the opposite direction to the flux produced by the other winding. This means there is a resulting almost zero flux in the core.
In the lower image, the red winding and "copper" winding are wound around the core and back to the starting point.
This means the two red wires are on the left.
Now, to work out which way the flux is being created in the core you have to see which way the turns are wound and also understand the direction of the current because one winding is in the positive lead and the other is in the negative lead.
When you have zero final flux, the windings are correct.
Only two things can go wrong with this component. Either a wire breaks at the termination or two turns burn together due to the high voltage.
Suppose a pulse or spike appears on the positive line. This will create magnetic flux.
This magnetic flux will pass to the negative winding and try to produce a voltage in it. Buy because there is a current flowing through the negative winding, the winding will appear a shorted-turn or at least a turn that will absorb the flux. This means the spike will not get through the choke. It will not come out the positive lead and not appear in the negative lead.
In fact this small component will have a very big effect on removing spikes due to the "shorted-turn" effect of the other winding.

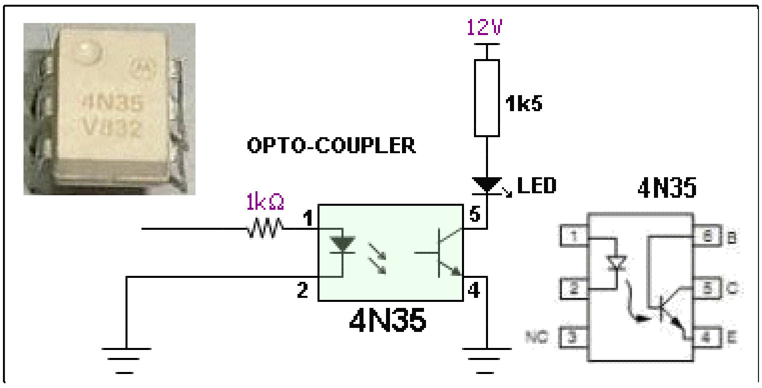
OPTO Components   Including LDRs, Photo Electric Cells (PE Cells) Photo Transistors, IR transistors and solar cells.

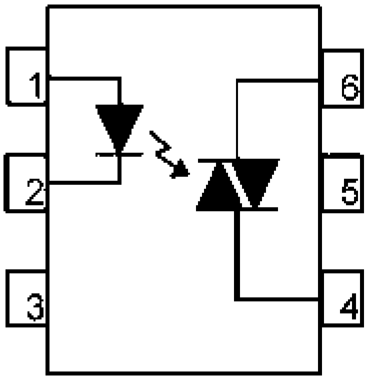
All the components we are going to cover respond to light, sun-light, room light, LED light, torch light or Infra Red light.
Most of these components have 2 leads and the simplest way to test them is with an analogue multimeter as the meter has an inbuilt 1.5v or 3v supply to operate the pointer on the meter when the leads are connected to a component and the scale is set to the highest ohms range.
The first thing you do is add alligator clips so your hands do not change the reading on the scale and place the component in front of a lamp, light or the sun.

scale and place the component in front of a lamp, light or the sun.
The needle should not move when in darkness and move almost fully across the scale when in bright light.
This proves the component is responding to the light.
If the component does not respond or has 3 leads or a dark body, you will have to reverse the leads and only responds to sun-light.
Put your hand in front of the component to see the difference between full light and random light to see how sensitive the device is. This gives you some idea of its SENSITIVITY.
If it only works around one way, it is transistor device - PHOTO TRANSISTOR - and can be a normal Photo Transistor that picks up room light or an IR (Infra Red) transistor that picks up Infra-Red illumination.
A solar cell produces a voltage and current when exposed to light and you can use the 10 volt scale and the 500mA scale to determine these values. Using the 500mA scale across the solar cell (pr solar panel) does not do any damage and gives you some idea of the current it will produce when in full sunlight.
You can also test LEDs with the high ohms scale or the microamps scale and see the very small voltage and current it produces.
Once the component moves the pointer on a multimeter, you can put it in a circuit and find out its sensitivity.
All we are doing at the moment is sorting out components that are light detecting.

OPTO ISOLATORS and OPTO COUPLERS

Opto Isolators and Opto Couplers are the same thing. A common opto-coupler is 4N35. It is used to allow two circuits to exchange signals yet remain electrically isolated. The signal is applied to the LED, which shines on a silicon NPN photo-transistor in the IC.
The light is proportional to the signal, so the signal is transferred to the photo transistor to turn it on a proportional amount. Opto-couplers can have Light Activated SCR's, photodiodes, TRIAC's and other semiconductor devices as an output. The 4N35 opto-coupler schematic is shown below:





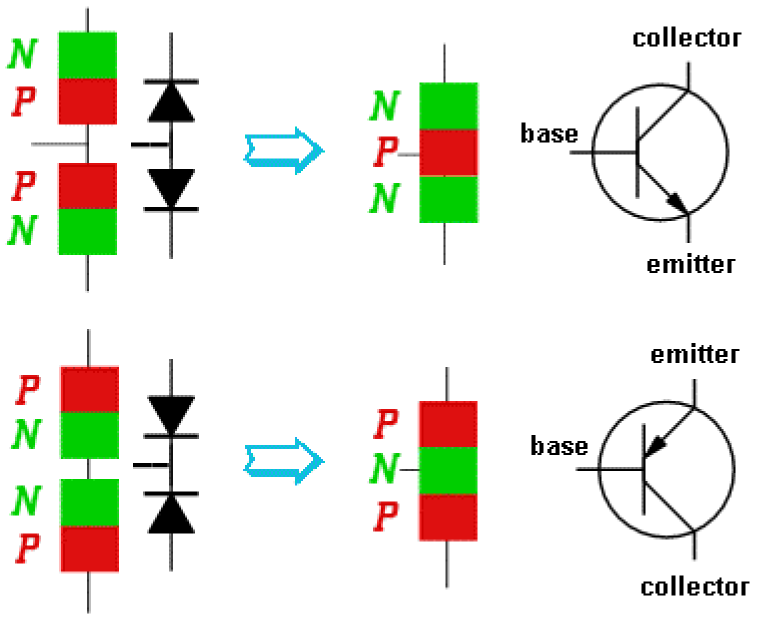
An opto-Coupler using a TRIAC
Note: the pinout is different to 4N35

TESTING AN OPTO COUPLER

Most multimeters cannot test the LED on the input of an opto-coupler because the ohms range does not have a voltage high enough to activate the LED with at least 2mA.
You need to set-up the test-circuit shown above with a 1k resistor on the input and 1k5 on the output. When the 1k is connected to 12v, the output LED will illuminate.
The opto-coupler should be removed from circuit to perform this test.

TRANSISTORS

Transistors are solid-state devices and although they operate completely differently to a diode, they appear as two back-to-back diodes when tested.
There are basically 2 types of transistor NPN and PNP.
A transistor is sometimes referred to as BJT (Bi-polar Junction Transistor) to distinguish it from other types of transistor such as Field Effect transistor, Programmable Unijunction Transistor and others.
In the following diagram, two diodes are connected together and although the construction of a transistor is more complex, we see the transistor as two diodes when testing it.



A TRANSISTOR APPEARS AS TWO DIODES WHEN TESTING IT

A TRANSISTOR APPEARS AS TWO DIODES WHEN TESTING IT

All transistors have three leads. Base (b), Collector (c), and Emitter (e).
For an NPN transistor, the arrow on the emitter points away from the base.
It is fortunate that the arrow on both symbols points in the direction of the flow of current (Conventional Current) and this makes it easy to describe testing methods using our simplified set of instructions. The symbols have been drawn exactly as they appear on a circuit diagram.

All transistors **are the same** but we talk about digital and analogue transistors. There is no difference between the two.
The difference is the circuit. And the only other slight difference between transistors is the fact that some have inbuilt diodes and resistors to simplify the rest of the circuit.
All transistors work the same way. The only difference is the amount of amplification they provide, the current and voltage they can withstand and the speed at which they work. For simple testing purposes, they are all the same.

NPN transistors are the most common and for an NPN transistor, the following applies. (the opposite applies for PNP)
To test a transistor, there is **one thing** you have to know:
When the base voltage is higher than the emitter, current flows though the collector-emitter leads.
As the voltage is increased on the base, nothing happens until the voltage reaches 0.55v. At this point a very small current flows through the collector-emitter leads. As the voltage is increased, the current-flow increases. At about 0.75v, the current-flow is a MAXIMUM. (can be as high as 0.9v). That's how it works. A transistor also needs **current** to flow into the base to perform this amplifying function and this is the one feature that separates an ordinary transistor from a FET.

If the voltage on the base is 0v, then instantly goes to 0.75v, the transistor initially passes NO current, then FULL current. The transistor is said to be working in its two states: OFF then ON (sometimes called: "cut-off" and "saturation"). These are called digital states and the transistor is said to be a **DIGITAL TRANSISTOR** or a **SWITCHING TRANSISTOR** , working in **DIGITAL MODE.**

If the base is delivered 0.5v, then slowly rises to 0.75v and slowly to 0.65v, then 0.7v, then 0.56v etc, the transistor is said to be working in ANALOGUE MODE and the transistor is an **ANALOGUE TRANSISTOR**.
Since a transistor is capable of amplifying a signal, it is said to be an active device.
Components such as resistors, capacitors, inductors and diodes are not able to amplify and are therefore known as passive components.

In the following tests, use your finger to provide the **TURN ON** voltage for the base (this is 0.55v to 0.7v) and as you press harder, more current flows into the base and thus more current flows through the collector-emitter terminals. As more current flows, the needle of the multimeter moves UP-SCALE.

TESTING A TRANSISTOR - DETERMINING THE GAIN OF A TRANSISTOR

A transistor is used in a circuit because it has a GAIN. In other words it has an **AMPLIFICATION FACTOR**. In other words the current on or through the output section of the transistor is higher than the current entering the stage (or transistor).
The gain (the Amplification factor) of a transistor can be between 2 and 1,000.
But measuring this value is very difficult.
And the reading you get is very inaccurate.
Here are 4 different types of instruments (test gear) to measure the gain of a transistor:

A $190 piece of equipment that can show a number of parameters of a transistor.

A $10.00 piece of equipment that tests transistors, inductors, capacitors, resistors

A dedicated tester for transistors

The item above is a normal "standard" Digital Multimeter. It can be used to determine the gain of the transistor if you follow the steps below.

I must admit I have all these pieces of test gear and I have never used any of them. They were supplied as samples from suppliers.
The gain of a transistor when testing it on a tester above may show a value of 120.
But this is when the current through the device "under test" is very small. It may be 1mA.
But when the transistor is placed in a circuit and 10mA flows through the collector-emitter section, the gain will drop to say 70. And if the current is 100mA, the gain may drop to 40.
And the components around the transistor may reduce the gain to 30 or less.
That means testing it out-of-circuit does not tell you anything.

So, what do you do?

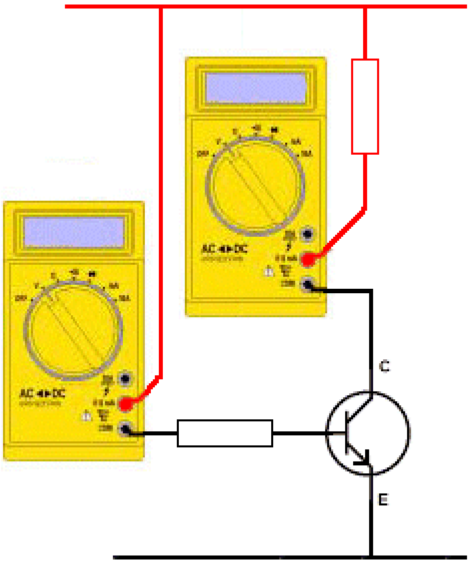
The only way to test a transistor is this:
In most cases we need to test a transistor when it is driving a relay or globe or solenoid.
We need to know if the components and the driving current is sufficient when all the transistors in a batch are used in a product.
It's simple. Cut the track on the base and insert a milliamp meter. Measure the current.
Now connect a resistor from the power rail to the meter (remove one lead so this can be done accurately) so that the same current flows into the base. Suppose the value of this resistor is 10k. Now use a 22k resistor and see if the relay or lamp or solenoid works the same as before. If not, use 15k.
We are attempting to work out the tolerance between the circuit working and not working.
You should have an allowance of at least 50%. In other words, the circuit must work with a value of 15k. If not, replace the 10k resistor on the printed circuit board with 8k2 or lower.

The Gain of a Transistor:

All the pieces of Test Gear above use the same procedure and the same formula.
They measure the current into the base (normally one-tenth of a milliamp) and at the same time measure the current through a resistor connected to the collector.
This is called the DC current gain and is the same as you will obtain from a circuit operating a relay or globe.
If the circuit is passing a signal, the transistor is oscillating and the current through it is increasing and decreasing during each cycle.
As the frequency of the the circuit increases, the ability for a transistor to provide an amplification-factor DECREASES. As soon as this decrease reaches a gain of say 2, the maximum frequency for the transistor is determined. But what is the point of having a circuit that only has a gain of 2 or 3 !!!!
That's why the value of gain is such an unknown value.

Working out the Gain of a Transistor

You can work out the gain of a transistor with a single multimeter (either digital or analogue) or use two multimeters.
Basically you are using the circuit described above (with the relay) and it will look like this:



The current into the base of the transistor is adjusted so that it is 0.1mA and the value of the red load resistor is adjusted so the current is 10mA. If the voltage across the transistor is less and 0.5v, the transistor is fully turned ON and the gain is 100 or greater. If you decrease the value of the red resistor to half the previous value and the voltage across the transistor remains less than 0.5v, the gain will be 200.
The voltage of the supply for the test circuit above should be 5v to 12v,
We are not going into this test in any more detail because the numerical value for the gain of a transistor is not very important. All you need to know is the success of the circuit and the fact that all the transistors in a batch will work perfectly.
You can use the previous test to see if the "drive current" you are supplying to the transistor in the project you are testing is sufficient for all the transistors in a batch.

The following discussion detects the C, B E leads of a transistor and detects if the junctions are no damaged. It does not test the "quality" of a transistor or the current it will deliver or the maximum voltage it will operate at. These are all things you have to get from a data sheet.

TESTING A TRANSISTOR ON A DIGITAL METER

Testing a transistor with a **Digital Meter** must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.
The "DIODE" setting must be used for diodes and transistors. It should also be called a "TRANSISTOR" setting.

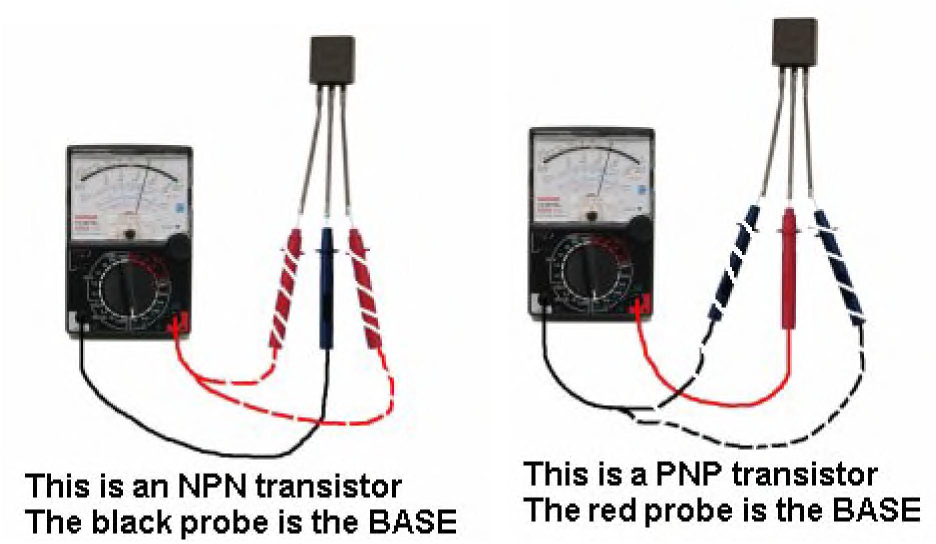
TESTING AN unknown TRANSISTOR

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also want to perform a test to find out if it is NPN or PNP.
That's what this test will provide.
You need a cheap multimeter called an ANALOGUE METER - a multimeter with a scale and pointer (needle).
It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings. It may have ranges such as "x10" "x100" "x1k" "x10"

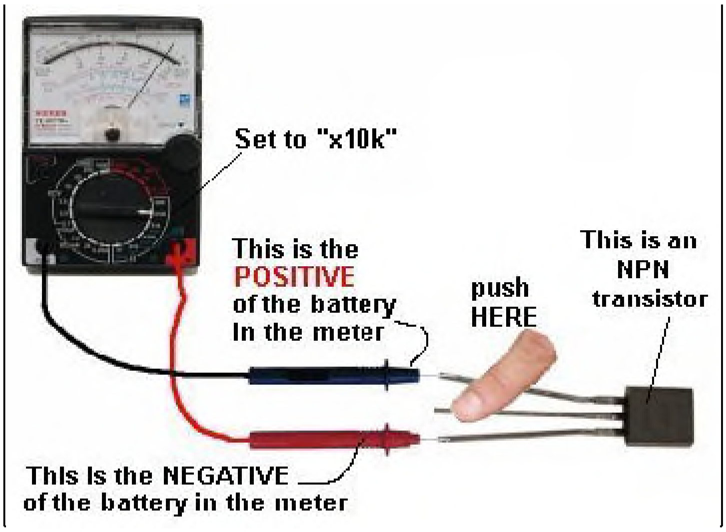
Look at the resistance scale on the meter. It will be the top scale.
The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales.
When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

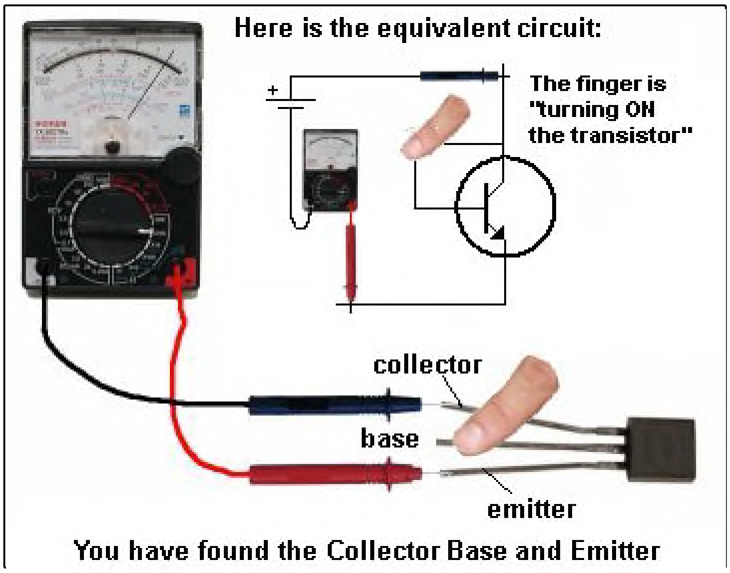
How to read: "x10" "x100" "x1k" "x10"
Up-scale from the zero mark is "1"
When the needle swings to this position on the "x10" setting, the value is 10 ohms.
When the needle swings to "1" on the "x100" setting, the value is 100 ohms.
When the needle swings to "1" on the "x1k" setting, the value is 1,000 ohms = 1k.
When the needle swings to "1" on the "x10k" setting, the value is 10,000 ohms = 10k.
Use this to work out all the other values on the scale.
Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

Step 1 - FINDING THE BASE and determining NPN or PNP
Get an unknown transistor and test it with a multimeter set to "x10"
Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an NPN transistor. The black probe is BASE
If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a PNP transistor. The red probe is BASE
If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is **FAULTY**.

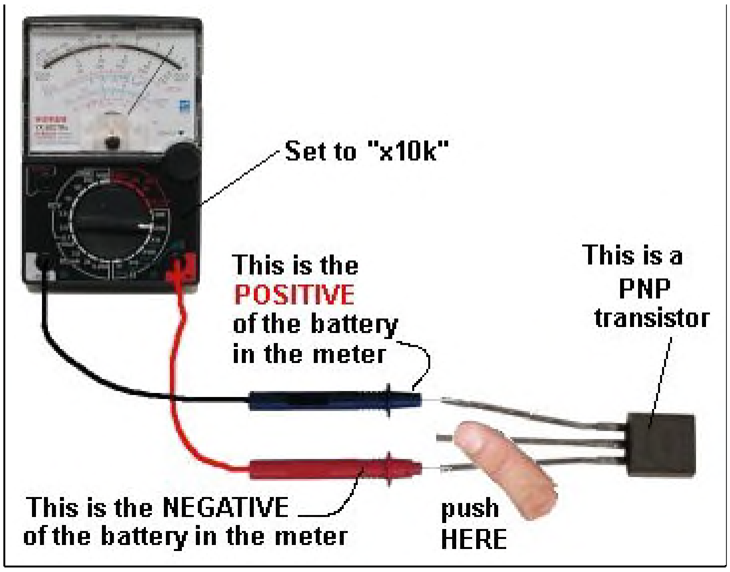


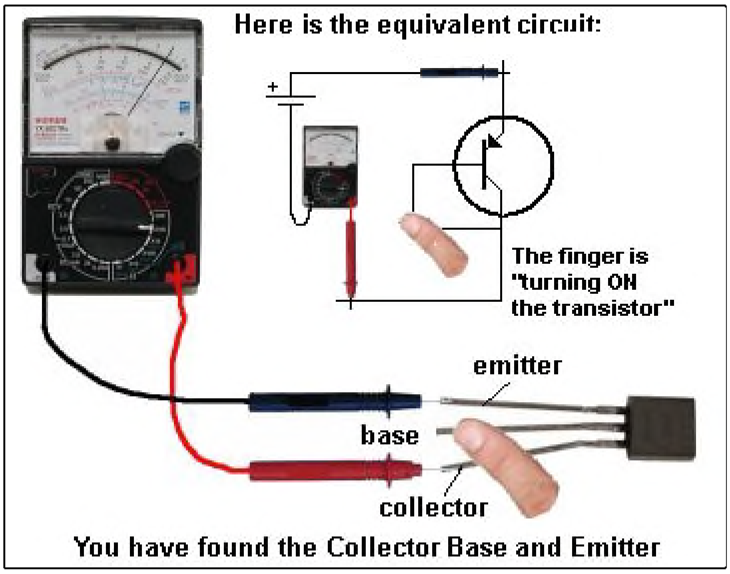
Step 2 - FINDING THE COLLECTOR and EMITTER
Set the meter to "x10k."
For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.



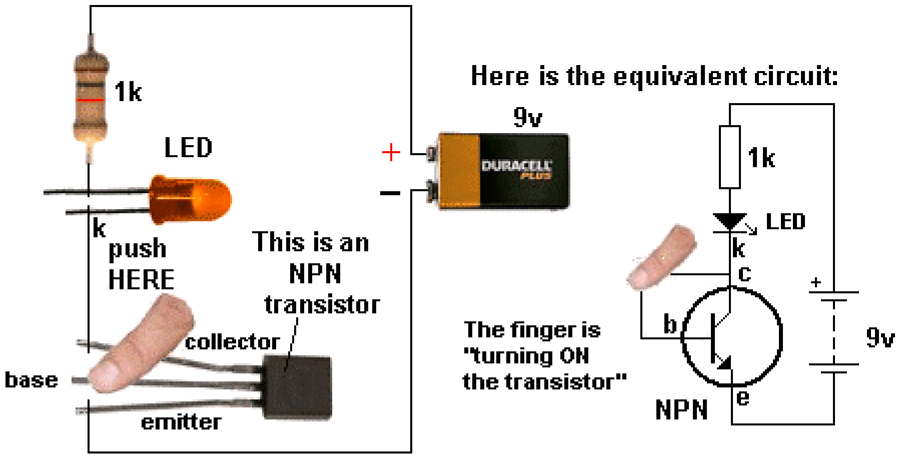


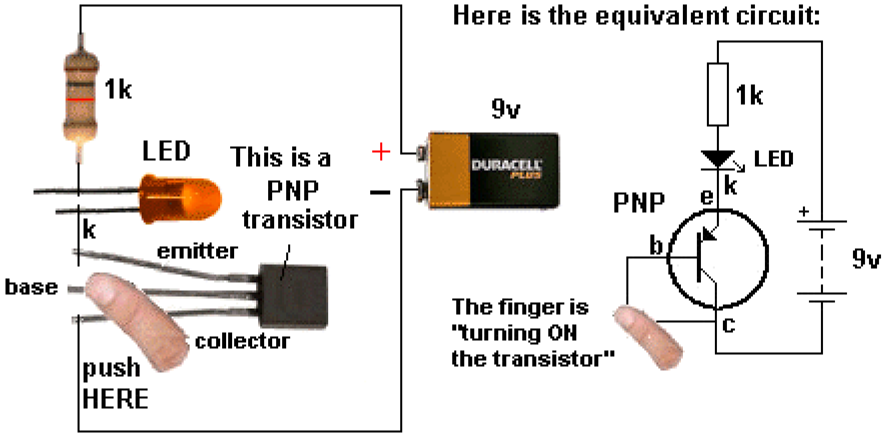
For a PNP transistor, set the meter to "x10k" place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.



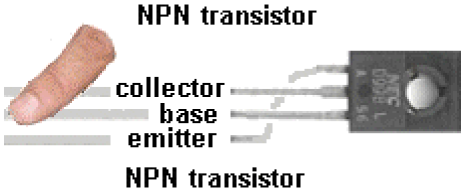


SIMPLEST TRANSISTOR TESTER
The simplest transistor tester uses a 9v battery, 1k resistor and a LED (any colour). Keep trying a transistor in all different combinations until you get one of the circuits below. When you push on the two leads, the LED will get brighter.
The transistor will be NPN or PNP and the leads will be identified:





The leads of some transistors will need to be bent so the pins are in the same positions as shown in the diagrams. This helps you see how the transistor is being turned on. This works with NPN, PNP transistors and Darlington transistors.



HEATSINKING

Heat generated by current flowing between the collector and emitter leads of a transistor causes its temperature to rise. This heat must be conducted away from the transistor otherwise the rise may be high enough to damage the P-N junctions inside the device. Power transistors produce a lot of heat, and are therefore usually mounted on a piece of aluminium with fins, called a **HEATSINK**.
This draws heat away, allowing it to handle more current. Low-power signal transistors do not normally require heat sinking. Some transistors have a metal body or fin to connect to a

larger heatsink. If the transistor is connected to a heatsink with a mica sheet (mica washer) , it can be damaged or cracked and create a short-circuit. (See Testing Mica Washers). Or a small piece of metal may be puncturing the mica. Sometimes white compound called **Heatsink Compound** is used to conduct heat through the mica. This is very important as mica is a very poor conductor of heat and the compound is needed to provide maximum thermal conduction.

TRANSISTOR FAILURE

Transistor can fail in a number of ways. They have forward and reverse voltage ratings and once these are exceeded, the transistor will ZENER or conduct and may fail. In some cases a high voltage will "puncture" the transistor and it will fail instantly. In fact it will fail much faster via a voltage-spike than a current overload.

It may fail with a "short" between any leads, with a collector-emitter short being the most common. However failures will also create shorts between all three leads.
A shorted transistor will allow a large current to flow, and cause other components to heat up.
Transistors can also develop an open circuit between base and collector, base and emitter or collector and emitter.
The first step in identifying a faulty transistor is to check for signs of overheating. It may appear to be burnt, melted or exploded. When the equipment is switched off, you can touch the transistor to see if it feels unusually hot. The amount of heat you feel should be proportional to the size of the transistor's heat sink. If the transistor has no heat sink, yet is very hot, you can suspect a problem.
DO NOT TOUCH A TRANSISTOR IF IT IS PART OF A CIRCUIT THAT CARRIES 240VAC. Always switch off the equipment before touching any components.

TRANSISTOR REPLACEMENT

If you can't get an exact replacement, refer to a transistor substitution guide to identify a near equivalent.

The important parameters are:
- Voltage
- Current
- Wattage
- Maximum frequency of operation

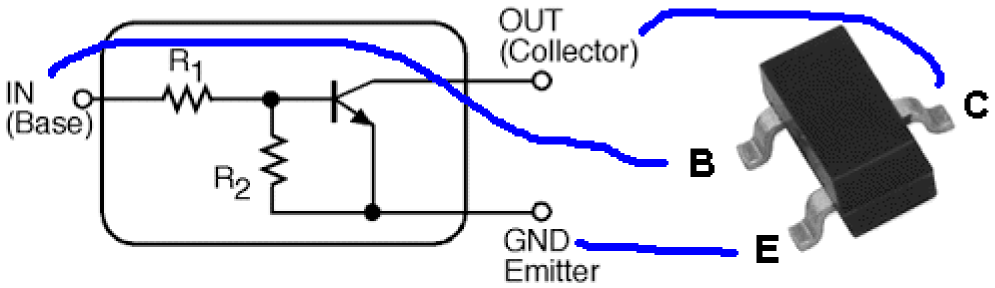
The replacement part should have parameters equal to or higher than the original.

Points to remember:
- Polarity of the transistor i.e. PNP or NPN.
- At least the same voltage, current and wattage rating.
- Low frequency or high frequency type.
- Check the pinout of the replacement part
- Use a desoldering pump to remove the transistor to prevent damage to the printed circuit board.
- Fit the heat sink.
- Check the mica washer and use heat-sink compound
- Tighten the nut/bolt - not too tight or too loose.
- Horizontal output transistors with an integrated diode should be replaced with the same type.

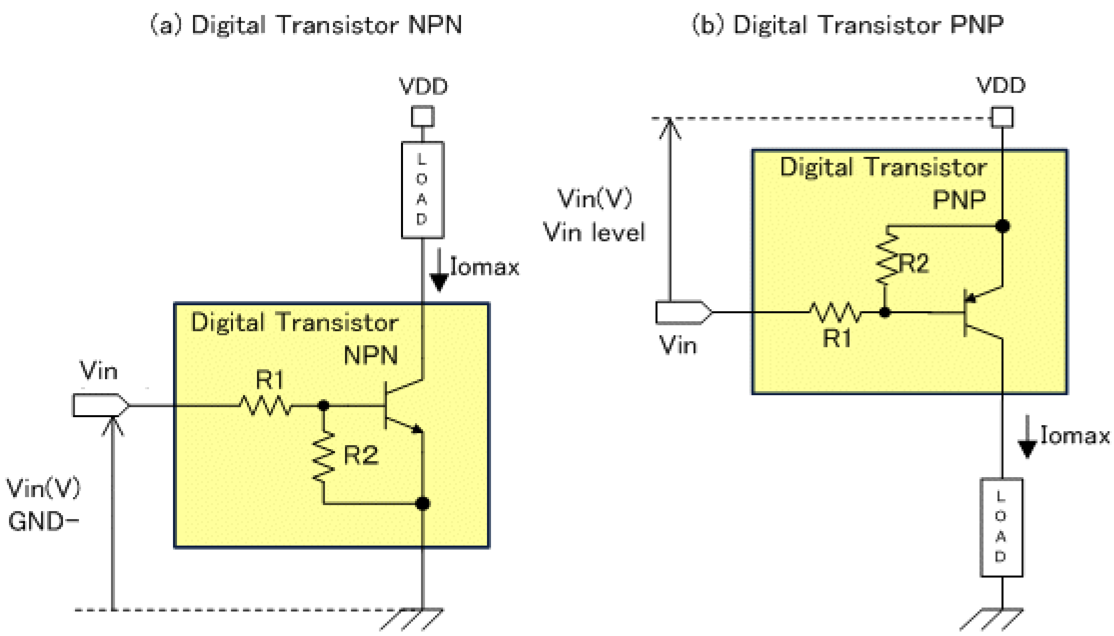
DIGITAL TRANSISTORS

There is no such thing as a DIGITAL TRANSISTOR or an AUDIO TRANSISTOR.
All transistors are just "TRANSISTORS" and the surrounding components as well as the type of signal, make the transistor operate in DIGITAL MODE or ANALOGUE MODE.

But we have some transistors that have inbuilt resistors to make them suitable for connecting to a digital circuit without the need for a base resistor.
Here is the datasheet for an NPN transistor BCR135w and PNP datasheet for BCR185w.
These transistors are called "Digital Transistors" because the "base lead" can be connected directly to the output of a digital stage. This "lead" or "pin" is not really the base of the transistor but a 4k7 (or 10k) resistor connected to the base allows the transistor to be connected to the rest of a digital circuit.
You cannot actually get to the base. The resistor(s) are built into the chip and the transistor is converted into a "Digital Transistor" because it will accept 5v on the "b" lead.
The 47k is not really needed but it makes sure the transistor is fully turned OFF if the signal on the "b" lead is removed (in other words - if the input signal is converted to a high-impedance signal - see tri-state output from microcontrollers for a full explanation).
This transistor is designed to be placed in a circuit where the input changes from low to high and high to low and does not stop mid-way. This is called a DIGITAL SIGNAL and that is one reason why the transistor is called a digital transistor. (However you could stop half-way but the transistor may heat up and get too hot).
Any transistor placed in a digital circuit can be called a "digital transistor" but it is better to say it is operating in DIGITAL MODE.



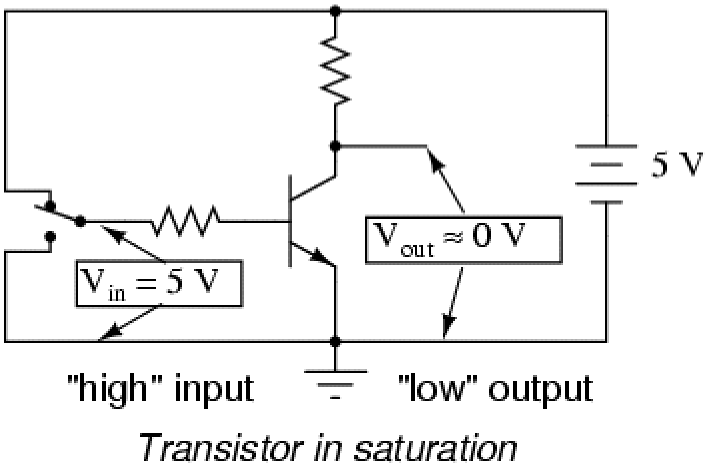
The digital transistor has two resistors included inside the case
R1 is about 10k and R2 is approx 47k



Equivalent circuit of the digital transistor

These transistors can be made to work in analogue circuits because they are ordinary transistors with a 10k base resistor.

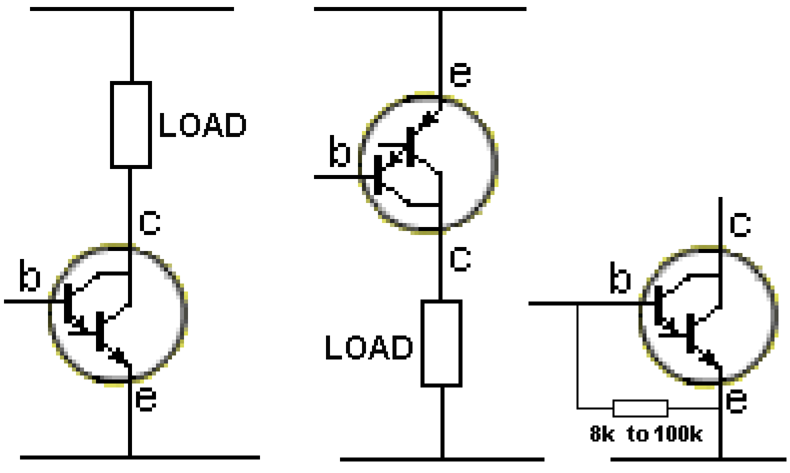
but you will have to know what you are doing.



The circuit above shows the digital transistor is designed to allow a voltage of 5v to be supplied to the "base" pin and the transistor will Fully Conduct.
This type of transistor saves putting a base resistor on the PC board.
It can be tested just like a normal transistor but the resistance between base and emitter will be about 5k to 50k in both directions. If the collector-emitter is low in both directions the transistor is damaged.
Here's how to look at how the transistor works:
The 10k resistor on the base will allow 0.5mA to flow into the base. But the 47k will reduce this to 0.4mA. If the transistor has a gain of 100, the collector-emitter current can be 40mA.
To determine the current capability of the transistor, connect 100R load and turn the transistor ON. This will allow about 100mA for the collector-emitter current. Measure the collector-emitter voltage. If it is more than 0.5v, the transistor is OVER-LOADED.

DARLINGTON TRANSISTORS

A DARLINGTON TRANSISTOR is two transistors in a single package with three leads. They are internally connected in cascade so the gain of the pair is very high. This allows a very small input signal to produce a large signal at the output. They have three leads (Base, Collector and Emitter and can be PNP or NPN) and are equivalent to the leads of a standard individual transistor, but with a very high gain. The second advantage of a Darlington Transistor is its high input impedance. It puts very little load on the previous circuit.
Some Darlington transistors have a built-in diode and/or built-in resistor and this will produce a low reading in both directions between the base and emitter leads.



NPN Darlington PNP Darlington

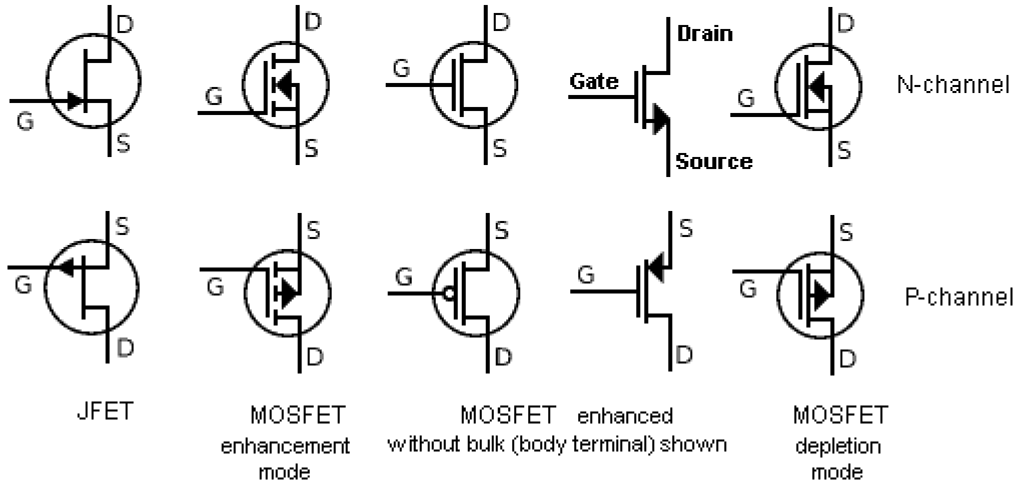
Darlington transistors are tested the same as an ordinary transistor and a multimeter will produce about the same deflection, even though you will be measuring across two junctions, (and a base-emitter resistor is present).

HORIZONTAL OUTPUT TRANSISTORS, SWITCH-MODE TRANSISTORS, FLYBACK TRANSISTORS, POWER TRANSISTORS, VERTICAL TRANSISTORS . . . .

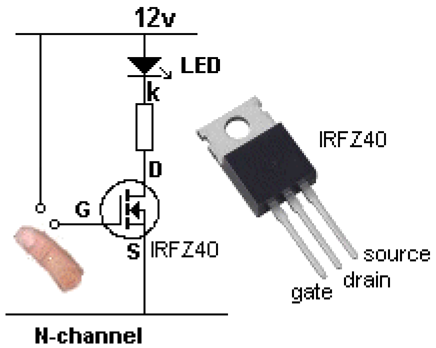
These are all names given to a transistor when it is used in a particular circuit. ALL these transistors are the same for testing purposes.
We are not testing for gain, maximum voltage, speed of operation or any special feature.
We are just testing to see if the transistor is completely faulty and SHORTED.
A transistor can have lots of other faults and the circuit **using the transistor** is the best piece of TEST EQUIPMENT as it is detecting the fault.

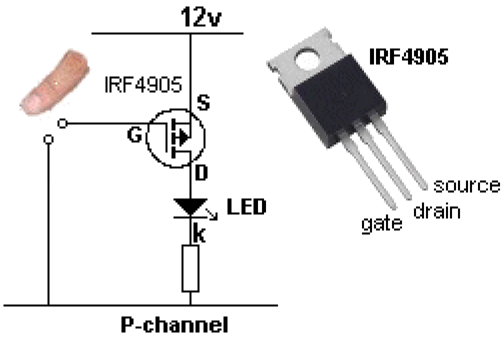
TESTING MOSFETs and FETs

MOSFETs and **JFETs** are all part of the **FET** family.
MOSFET stands for **Metal Oxide Semiconductor Field Effect Transistor.**
FETs operate exactly the same as a "normal" transistor except they have different names for the input and output leads and the voltage between the gate and the source has to between 2v to 5v for the device to turn on fully. A FET requires almost NO CURRENT into the Gate for it to turn on and when it does, the voltage between drain and source is very low (only a few mV). This allows them to pass very high currents without getting hot. There is a point where they start to turn on and the input voltage must rise higher than this so the FET turns on FULLY and does not get hot.
Field Effect Transistors are difficult to test with a multimeter, but "fortunately" when a power **MOSFET** blows, it is completely damaged. All the leads will show a short circuit. 99% of bad **MOSFETs** will have GS, GD and DS shorted.
The following symbols show some of the different types of MOSFETs:



Most **MOSFET** transistors cannot be tested with a multimeter. This due to the fact that the Gate needs 2v - 5v to turn on the device and this voltage is not present on the probes of either meter set to any of the ohms ranges.
You need to build the following Test Circuit:



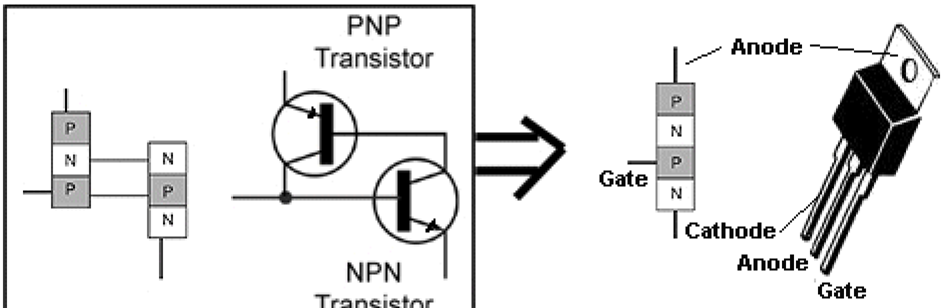


Touching the Gate will increase the voltage on the Gate and the MOSFET will turn ON and illuminate the LED. Removing your finger will turn the LED off.
Large devices such as the TO-220 types shown above do not like static electricity on the gate and you have to be careful not to "spike" the gate with any static. Generally this type of device is not "super sensitive" and you can use your finger or a large value resistor.
When replacing one of these devices, there are 2 things to match-up.
Voltage and Current.
In most cases, the "turn-ON" resistance (the resistance between Source and Drain) will be

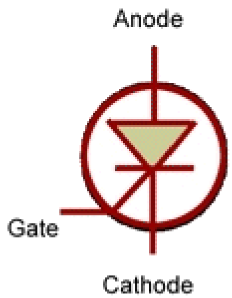
the same (something like 22 milli ohms) and the speed of operation will be ok.
Check the voltage needed to turn the gate ON and make sure you can supply the required voltage.

SILICON CONTROLLED RECTIFIERs (SCR)

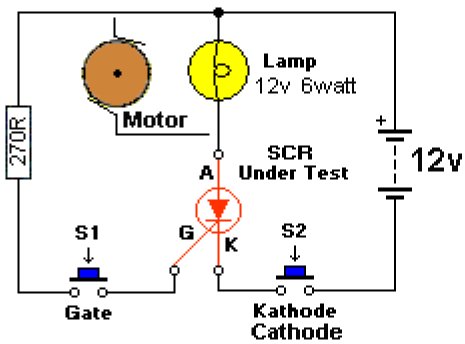
The **Silicon Controlled Rectifier** (SCR) is a semiconductor device that is a member of a family of control devices known as **Thyristors**. It is a 3-leaded device and when a small current enters the Gate, the **thyristor** turns on. AND STAYS ON. It only conducts current between Anode and Cathode in one direction and it is mainly only used in DC circuits. When it is used with AC, it will only conduct for a maximum of half the cycle.



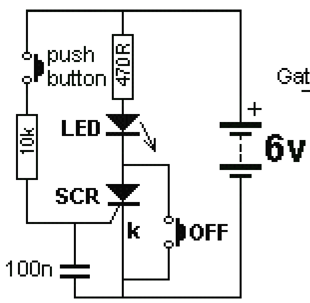
THYRISTOR or SCR



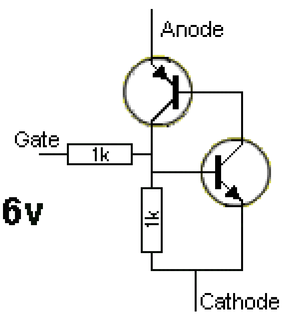
SCR
Silicon Controlled Rectifier



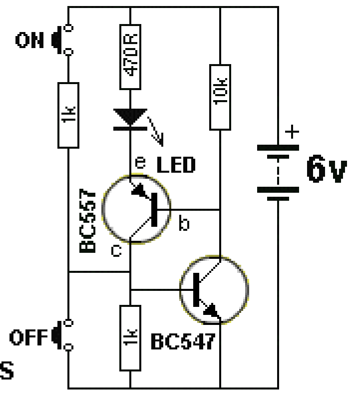
SCR TESTER



A



SCR WITH TRANSISTORS



B

To understand how an SCR "latches" when the gate is provided with a small current, we can replace it with two transistors as shown in diagram B above. When the ON button is pressed, the BC547 transistor turns on. This turns ON the BC557 and it takes over from the action of the switch.
To turn the circuit off, the OFF button removes the voltage from the base of the BC547.

Testing an SCR

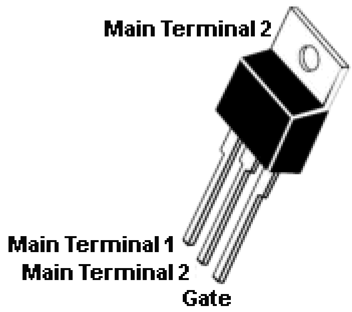
An **SCR** can be tested with some multimeters but a minimum current Anode-to-Cathode is needed to keep the device turned on. Some multimeters do not provide this amount of current and the **SCR Tester** circuit above is the best way to test these devices.
Shorted SCRs can usually be detected with an ohmmeter check (SCRs usually fail shorted rather than open).
Measure the anode-to-cathode resistance in both the forward and reverse direction; a good SCR should measure near infinity in both directions.
Small and medium-size SCRs can also be gated ON with an ohmmeter (on a digital meter use the Diode Check Function). Forward bias the SCR with the ohmmeter by connecting the black (-) lead to the anode and the red (+) lead to the cathode (because the + of the battery is connected to the negative lead, in most analogue multimeters). Momentarily touch the gate lead to the anode while the probes are still touching both leads; this will provide a small positive turn-on voltage to the gate and the cathode-to-anode resistance reading will drop to a low value. Even after removing the gate voltage, the SCR will stay conducting. Disconnecting the meter leads from the anode or cathode will cause the SCR to revert to its non-conducting state.
When making the above test, the meter impedance acts as the SCR load. On larger SCRs, it may not latch ON because the test current is not above the SCR holding current.

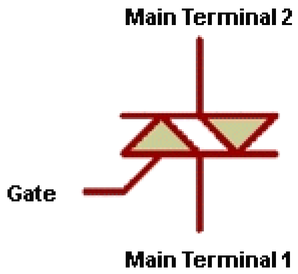
Using the SCR Tester

Connect an SCR and press Switch2. The lamp should not illuminate. If it illuminates, the SCR is around the wrong way or it is faulty.
Keep Switch 2 PRESSED. Press Sw1 very briefly. The lamp or motor will turn ON and remain ON. Release Sw 2 and press it again. The Lamp or motor will be OFF.

TRIACs

A triac is a bidirectional, three-terminal dual, back-to-back thyristor (SCR) switch. This device will conduct current in both directions when a small current is constantly applied to the Gate.
If the gate is given a small, brief, current during any instant of a cycle, it will remain triggered during the completion of the cycle until the current though the Main Terminals drops to zero.
This means it will conduct both the positive and negative half-cycles of an AC waveform. If it is tuned on (with a brief pulse) half-way up the positive waveform, it will remain on until the wave rises and finally reaches zero. If it is then turned on (with a brief pulse) part-way on the negative wave, the result will be pulses of energy and the end result will be about 50% of the full-energy delivered at a rate of 100 times per second for a 50HZ supply.
TRIACs are particularly suited for AC power control applications such as motor speed control, light dimmers, temperature control and many others.

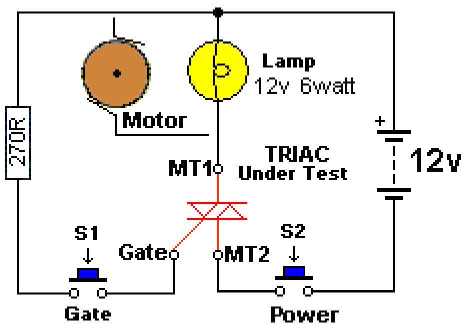




TRIAC (2 SCR's)
TRIode for Alternating Current

Using the TRIAC Tester

Connect a TRIAC and press Switch2. The lamp should not illuminate. If it illuminates, the TRIAC is faulty.
Keep Switch 2 PRESSED. Press Sw1 very briefly. The lamp or motor will turn ON and remain ON. If the lamp does not turn on, reverse the TRIAC as the current into the gate must produce a slight voltage between **Gate** and **Main Terminal 1**.
Release Sw 2 and press it again. The Lamp or motor will be OFF.



TRIAC TESTER

MICA WASHERS AND INSULATORS

Plastic insulating sheets (washers) between a transistor and heatsink are most often made from mica but some are plastic and these get damaged over a period of time, turn dark and become cracked.
The plastic eventually becomes carbonized and conducts current and can affect the operation of the appliance. You can see the difference between a mica sheet (washer) and plastic by looking where it extends from under the transistor. Replace all plastic insulators

as they eventually fail.

SPARK GAPS

Some TV's and monitors with a CRT (picture tube), have spark gaps either on the socket at the end of the tube or on the chassis.
These can consist of two wires inside a plastic holder or a glass tube or special resistive device.
The purpose of a spark gap is to take any flash-over (from inside the tube), to earth. This prevents damage to the rest of the circuit.
However if the tube constantly flashes over, a carbon track builds up between the wires and effectively reduces the screen voltage. This can cause brightness and/or focus problems.
Removing the spark-gap will restore the voltage.
These are not available as a spare component and it's best to get one from a discarded chassis.

CO-AX CABLES

Co-Ax cables can produce very high losses and it seems impossible that a few metres of cable will reduce the signal. The author has had a 3 metre cable reduce the signal to "snow" so be aware that this can occur. Faults can also come from a splitter and/or balun as well as dirty plugs and sockets. This can result in very loud bangs in the sound on digital reception.

TESTING EARTH LEAKAGE DETECTORS or Residual Current Devices or Ground Fault Circuit Interrupters or GFCI

An Earth Leakage Detector or Sensor is a circuit designed to continuously monitor the imbalance in the current in a pair of load carrying conductors.
These two conductors are normally the Active and Neutral. Should the imbalance current reach 30mA the sensor will "trip" and remove the voltage (and current) from the line being monitored.
Some detectors will trip at 15mA.
You cannot alter the sensitivity of the device however there are a number of faults in these devices that can be fixed.
In some devices the contact pressure for the 10Amp or 15 Amp contacts is very weak and they arc and produce an open circuit. The result is this: When you press the rest button, power is not restored to the output.
Clean the contacts with a small file and bend the metal strips to the contacts so they make a very strong contact.
The other fault is the trip mechanism.
The magnetism from the coil does not allow the pin to move and "trip" the contacts. It may be due to a small metal filing or the pin not moving freely enough.
All good Earth Leakage Detectors have a TEST BUTTON. This connects a resistor between the active line and earth so that 15mA or 30mA flows.
The detector should trip immediately. Make sure the trigger mechanism trips when the test button is pressed.
None of the electronics in the detector can be replaced however you can test the mechanical operation and the pressure on the contacts when the unit is removed from the power. Do not work on the device when it is connected to the mains.

TESTING CELLS AND BATTERIES

There is an enormous number of batteries and cells on the market and a number of "battery testers." Instead of buying a battery tester that may give you a false reading, here is a method of testing cells that is guaranteed to work.
There are two types of cell: a **rechargeable** cell and a non-rechargeable cell

There are two types of cell: a **rechargeable** cell and a non rechargeable cell.

The easiest way to test a **rechargeable** cell is to put a group of them in an appliance and use them until the appliance "runs down" or fails to work. If you consider the cells did not last very long, remove them and check the voltage of each cell. The cell or cells with the lowest voltage will be faulty. You can replace them with new cells or good cells you have in reserve.
There is no other simple way to test a rechargeable cell.
You cannot test the "current of a cell" by using an ammeter. A rechargeable cell can deliver 10 amps or more, even when nearly discharged and you cannot determine a good cell from a faulty cell.
However you can test them under a heavy load by placing a 1R (one ohm) 5 watt wire wound resistor across a cell and measure the voltage of the cell after a short period of time.

Dry cells are classified as "non-rechargeable" cells.
DRY CELLS and MANGANESE CELLS are the same thing. These produce 1.5v per cell (manganese means the Manganese Dioxide depolariser inside the cell. All "dry cells" use manganese dioxide).
ALKALINE CELLS produce between 2 - 10 times more energy than a "dry cell" and produce 1.5v per cell.
Dry cells - LeClanche cells - the first cell to be produced in quantity as they found how to make the electrolyte - the water between the positive and negative plates (electrodes) into a thick paste and put everything into a zinc case and seal the top with bitumen - the same material on a road - and it would not leak.
This meant the cells could be put in torches and moved at any angle.
A "dry cell" and an "alkaline cell is identical in construction and they are basically identical.
But the acidity of the electrolyte of a dry cell has been replaced with an alkaline chemical. An alkaline chemical is called a BASE - as referred to in the ACIDS and BASES table with water being in the middle of the table with a value of "7" and this table is also called the "pH" table with acids having a value of "0 to 6" and bases "7 to 14."
Most diagrams don't show an accurate "cut" of a dry cell. The centre rod is carbon and it touches the Manganese Dioxide depolariser to create the positive terminal. The manganese dioxide has carbon powder added to reduce the internal resistance and allow the battery to deliver a high current.
A thin layer of Ammonium Chloride is spread on the inside of a zinc case and then a paper tube is added. A cardboard disk is placed in the bottom of the zinc case.
Now the case is filled with Manganese dioxide/carbon and a carbon rod. This black powder must not touch the zinc case as this will cause the battery to "self discharge" and it will be dead in a few months.
An alkaline cell is identical and could be constructed in the same way with Potassium Hydroxide as the electrolyte.
But the limitations of a cell producing a high current is the resistance of the depolariser. When a cell delivers a current, bubbles of gas are created in this mix and they are non-conducting. The depolariser gradually converts them to water and that's why the battery recovers.
But with an alkaline cell it was found that the zinc electrode could be made into fine powder and added to the depolariser. This means the negative electrode could be a steel nail and now the centre of the cell is negative. The energy form a cell comes from changing (dissolving) the zinc into zinc oxide.
But zinc oxide is a very good insulator and that's why the current reduces as the cell gets older.
But in an alkaline cell the zinc is not attacked as much with a BASE (Potassium Hydroxide) and that's why its shelf-life is much longer.
Alkaline cells can fail for no reason at any stage in their life and are not recommended for emergency situations.
The output voltage of some Alkaline cells can fall to 0.7v or 0.9v for not apparent reason.
There are lots of other cells including "button cells," hearing-aid cells, air cells, and they

produce from 1.2v to 3v per cell.

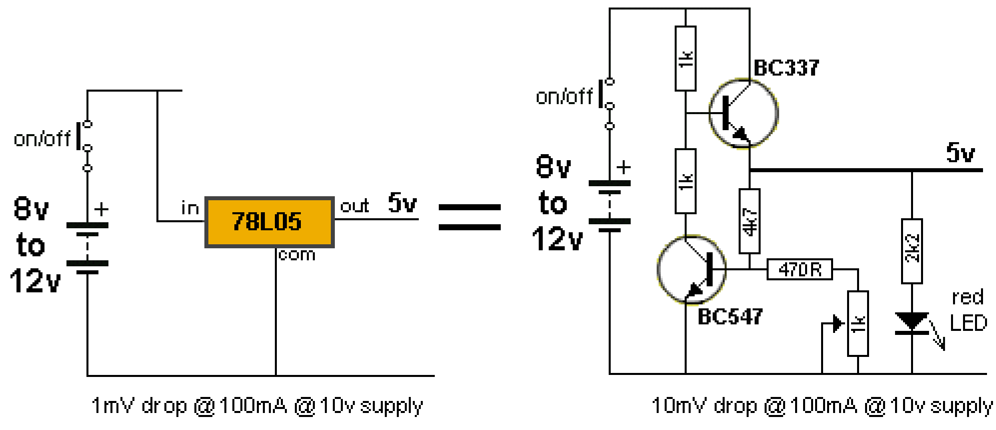
Note:
Lithium cells are also called "button cells" and they produce 3v per cell.
Lithium cells are non-rechargeable (they are generally called "button cells") but some Lithium cells can be recharged. These are Lithium-ion cells and generally have a voltage of 3.6v. Some Lithium-ion cells look exactly like 3v Lithium cells, so you have to read the data on the cell before charging.

You cannot test the voltage of a cell and come to any conclusion as to the age of the cell or how much energy remains. The voltage of a cell is characteristic to the chemicals used and the actual voltage does not tell you its condition.
Some "dry cells" deliver 1.5v up to the end of their life whereas others drop to about 1.1v very quickly.
Once you know the name of the cell that drops to 1.1v, avoid them as the operation of the equipment "drops off" very quickly.

However if you have a number of different cells and need to know which ones to keep, here's the solution:

1. Check the voltage and use those with a voltage above 1.1v
2. Next, select 500mA or 10A range on a multi-meter and place the probes on a cell. For a AAA or AA cell, the current should be over 500mA and the needle will swing full scale very quickly.
Keep the testing short as you are short-circuiting the cell but it is the only way to determine the internal impedance (internal resistance) of the cell and this has a lot to do with its stage-of-charge.
This will give you a cell with a good terminal voltage and a good current capability.

This also applies to button cells, but the maximum current they will deliver will be less.
If you want to get the last of the energy out of a group of cells they can be used in the following circuits:



Some 78L05 regulators are "clones" or "copies" and they do not deliver 100mA. If your equipment fails to perform correctly, check this possibility. The author has found this to be a real problem.

Lithium-ion cells need to be charged individually so the charger can be turned off when the cell reaches a certain voltage. This voltage is pre-programmed into the charger.
If you have a faulty battery made up of a number of Li-ion cells, you can detect the faulty cell in a number of ways.
The simplest is to buy a single-cell charger for Aliexpress for $1.50 and connect jumper leads to the output. Clip it onto a cell and the red LED will illuminate on the charger module. When the blue LED illuminates, the cell is charged.

illuminates, the cell is charged.
These chargers generally output about 500mA so a lithium cell of 4AHr will take at least 10 to 12 hours to charge. 18650 cells have a capacity of 1AHr to more than 4AHr, depending on the amount of and length of material wrapped in a spiral inside the cell. A very light cell will have almost nothing inside.
The output voltage can be stated as anything between 3.2v and 3.7v and will have a "floating charge" as high as 4.2v when it is removed from a charger. These voltages are not very important because they will soon drop to between 3.4v and 4.2v for perfectly good cells from different manufacturers.
Even 10AHr battery banks will show just 3.9v after charging.
To test the cell you can put a 10R 5watt wire wound resistor across the cell and include a blue or white LED with 100R resistor across the 10R resistor.
Leave the 10R to discharge the cell and take a note of how long it takes. Do the same with the other cells and you will be able to work out which is the faulty cell. This may take a few days but you will be able to return a dead battery into a good replacement.

BATTERY CHARGER FOR CARS (12v)

Testing a 12v battery for a car battery is a very difficult thing to do if it an automatic charger.
Some of these chargers don't start to charge if the battery is below 5v and some take time to test the battery before starting to charge. If you have one that is failing to charge you can convert it to a simple charger and get rid of the hassles.
If you want to build a charger, here are some of the features you will need to know.
The problem with all chargers is the current they will deliver when the battery voltage is low. Chargers do not have any current-limiting features and the current will be limited to the VA rating of the transformer.
But this means the current will be very high when you touch the two leads together and also when you connect a flat battery. That's why automatic chargers do not start up or they deliver brief pulses to the battery to charge it and it will produce a "floating charge" to oppose the voltage delivered by the charger and then the charger will start to charge it normally. But this all take a lot of electronics.

The normal output voltage of a 12v charger is 17.7v to 18.3v and to measure this voltage you need to connect a 1,000u to 4,700u electrolytic across the leads and measure the DC voltage.
Without the electrolytic the voltage is pulsing DC and the meter will read 11v (which is quite inaccurate).
If you have a charger and it will not start to deliver a voltage, connect 12v set of AA cells across the electrolytic to start the charger and then immediately remove them. Now you can read the DC voltage.
If your automatic charger has failed, you can convert it to a simple charger by re-connecting either the positive or negative wire from the transformer to the positive or negative of the bridge. On the automatic chargers I have converted, the negative lead was connected to the negative terminal of the bridge and the thermal trip and on-board ammeter remained in circuit so the cut-out tripped when excess current is delivered and the MOVING IRON ammeter showed the current flowing.

With all chargers, you should only deliver a maximum of the capacity of the battery and then use the battery to see if it "held its charge."
For example a 40AHr battery should be charged for 12 hours at 4 amps.
Most batteries don't disclose the capacity but give a meaningless CCA (cold crank amp) rating that you are suppose to co-relate to the current required by the starter motor.
The best way to work out the capacity is by the weight of the battery:

1.5kgm	4AHr
5.5kgm	16AHr
6.25kgm	20Ahr
7.2kgm	27AHr
10.3kgm	40AHr
14.5kgm	40AHr
10kgm	50AHr

15.5kgm	75AHr

The smallest capacity 12v battery for a car is 40AHr and a battery can be charged at 10% of its rating for a period of time AFTER it is fully charged and it will produce only a small amount of "gassing." Some batteries have pressure relieve holes or ports or tracks to release this gas but if you are not sure and the battery says: FULLY SEALED - can be used in any position" You need to be very careful as these batteries need a REGULATED charger that stops charging when the battery reaches a terminal voltage of about 14.5v. These type of batteries do not produce any gassing AT ALL below about 15v as they have a plate chemistry that prevents gassing below this voltage and come as MAINTENANCE FREE. But this only applies when the charger is limited to 15v charging voltage.
You have to know what to do. If you don't following this: If you have left the lights ON and the battery is dead, you can give it a boost of 4 hours and start the can and use the car for a 30 minute trip. Or you can charge the battery for a maximum of 12 hours.
If the battery is small and you don't know its condition, charge it for one or two hours and test it.
Be very careful because you don't know the condition of the battery and you are not using a regulated battery charger and you don't know the specified charging current or the shut-off voltage.
The danger comes when you overcharge a battery and don't know the safety relief for the bubbles of gas produced by the plates.

The simplest charger for a 12v battery is a transformer and bridge. Use a 3 to 10 amp bridge with heatsink and any type of transformer. Connect it up and if the bridge gets warm you know current is flowing. For each amp the bridge will dissipate 1.5watts. If you cannot hold your finger on the bridge, it is getting too hot. The same with the transformer.
It does not matter how long it takes to charge a battery. The only problem is charging it too fast or over-charging. Charge for a few hours and test it. If it does not last very long, charge it for longer. This way you can get an idea how long to charge it. Old batteries will be very inefficient in holding a charge.

FIXING A 12V BATTERY

If you are charging a 12v battery and the charging current remains high but the battery does not start the car - the problem will be a faulty cell. When the charged battery is put under load such as turning on the HIGH BEAM lights, the battery voltage will immediately drop to about 10v.
If you want to turn this battery into a DONKEY BATTERY and use it for say your solar array, you can drill through the top plastic cover of the battery until you get to the individual connectors between the cells and fit a self-tapping screw to each connector. You can now measure the individual voltage of each cell and find the problem. Gradually discharge the faulty cell and short across the two screws with wire and you have a good 10v battery. You will need to get another faulty battery with a single cell to produce a 12v battery or you can use it in a high voltage solar array.

SOLAR PANELS

There is quite a lot to learn and understand about solar installations because a Solar Panel is a very "sloppy" power supply and changes its impedance throughout the day according to the illumination it gets.
That's why you can connect them in series and parallel and they will combine their output energy, even though each panel is contributing a varying amount.
The first thing you should know is the advantages of series connection and the advantages of parallel connection.
No matter how you connect them, the charge controller will convert a high voltage at low current into a low voltage at high current to charge the battery pack.
Working with high voltage DC is very dangerous.

Working with high voltage DC is very dangerous.
Solar arrays can be anything from 40v to 80v or 300v to 600v or more.
Anything over 100v DC needs special care and attention.
An 80v AC voltage will give you a "tingle." 100v -150v AC will give you quite a shock.
But you will not be able to feel a 120v DC voltage. That's why DC is so dangerous.
Solar arrays also produce a very high current and the panels need to have the voltage covered to 12v DC or up to 120v DC for storage into batteries or converted to 240v AC for delivery to a household or exported to the mains.
We will not be covering voltages or currents as these vary enormously.
We will be covering the connection of panels in series and in parallel and explaining the faults that may occur.

PANELS IN SERIES
Solar panels can be connected in series and the voltage of each panel is added to produce the output voltage.
Suppose you have a 5kW array and suppose the inverter has a maximum input voltage of 500v. This means the input current will be 5,000/500 = 10 amps.
Most solar panels have an output wattage of about 250 to 300 watts and an output voltage of about 30v. This means the output current will be about 8 to nearly 10 amps. With a 20 panel array the system will produce about 5kW and the inverter will need to have an input voltage capability of up to 700v.
The only problem with series connection is shading. If one panel becomes shaded due to a tree or cloud, the current from the whole system is reduced as well as the voltage.
A small amount of shading can reduce the current considerably. But that's the effect you get when the intensity of the sun changes due to clouds in the sky.
Remember, when installing or servicing the array, the 700v DC will be present or may be present at any part of the wiring because you do not know if any part of the wiring is damaged and touching any of the metal mounting brackets of frames. And this voltage will be present at any part of the day when the sun is shining bright or dull.
The whole system is insulated and isolated and does not have a "ground" connection and no point has zero voltage.
To test a solar panel you need to disconnect it completely from all the other panels and use a LOAD.
The LOAD is a tester made from 3 12v car headlamps of 100watts each. These are connected in series.
Connect the solar panel and observe the brightness.
If the sun has constant brightness you can compare all the panels.
This is the simplest, cheapest and best way to find the faulty panel.

PANELS IN PARALLEL
Solar panels can be connected in parallel and the current of each panel is added to produce the output current.
Panels need to be connected in parallel if you have an inverter that has an input limit of 100v to 200v.
But then you have to make sure the current does not exceed the rating of the inverter.

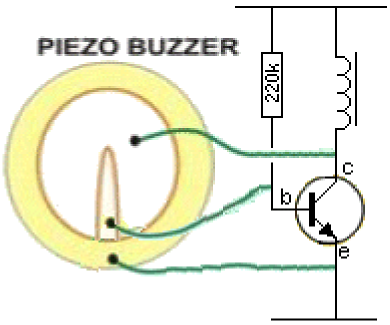
TESTING PIEZO DIAPHRAGMS and PIEZO BUZZERS
There are two types of piezo devices that produce a sound.
They are called **PIEZO DIAPHRAGMS** and **PIEZO BUZZERS**.
A **piezo diaphragm** consists of two metal plates with a ceramic material between. The ceramic expands and contracts when an alternating voltage is placed on the two plates and this causes the main plate to "dish" and "bow."

This creates a high-pitched sound. There are no other components inside the case and it requires an AC voltage of the appropriate frequency to produce a sound.
A **piezo buzzer** has a transistor and coil enclosed and when supplied with a DC voltage, the buzzer produces a sound.
Both devices can look exactly the same and the only way to tell them apart is by connecting a 9v battery. One device may have "+' and "-" on the case to indicate it is a piezo buzzer, but supplying 9v will make the buzzer produce a sound while the piezo diaphragm will only produce a "click."

A piezo diaphragm will produce a click when connected to 9v DC.
A piezo buzzer will produce a tone when connected to a DC voltage.

How a PIEZO BUZZER WORKS

A Piezo Buzzer contains a transistor, coil, and piezo diaphragm and produces sound when a voltage is applied. The buzzer in the circuit above is a PIEZO BUZZER.



The circuit starts by the base receiving a small current from the 220k resistor. This produces a small magnetic flux in the inductor and after a very short period of time the current does not increase. This causes the magnetic flux to collapse and produce a voltage in the opposite direction that is higher than the applied voltage.
3 wires are soldered to pieces of metal on the top and bottom sides of a ceramic substrate that expands sideways when it sees a voltage. The voltage on the top surface is passed to the small electrode and this positive voltage is passed to the base to turn the transistor ON again. This time it is turned ON more and eventually the transistor is fully turned ON and the current through the inductor is not an INCREASING CURRENT by a STATIONARY CURRENT and once again the magnetic flux collapses and produces a very high voltage in the opposite direction. This voltage is passed to the piezo diaphragm and causes the electrode to "Dish" and produce the characteristic sound. At the same time a small amount is "picked-off" and sent to the transistor to create the next cycle.

TESTING A SPEAKER

A speaker (also called a **loud speaker**) has coil of wire wrapped around a magnet but it does not touch the magnet as it is wound on a thin cardboard former so the coil will be pulled closer to the flux produced by the magnet when a current flows in the coil.
When the current flows in the other direction, the coil moves away from the magnetic flux.
This coil is called a voice coil and it is connected to a sheet of thin card called a CONE and as the cone vibrates the speaker reproduces music or noise.

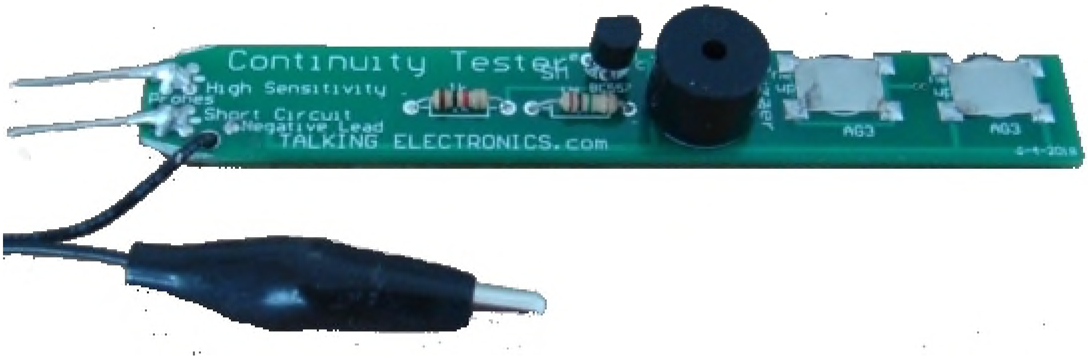
cone vibrates, the speaker reproduces music or noise.
Use a multimeter on a low ohms scale to read the value of resistance of the coil.
It can be as low as 2 ohms or as high as 100 ohms.

REPLACING A SPEAKER

Replacing a speaker is easy. Just get one the same size and impedance and the job is done.
But there is a lot more to understand this simple replacement.
The principle of operation of a speaker is called ELECTROMAGNETISM and the strength of the "Pull" depends on the strength of the PERMANENT MAGNET and the magnetism produced by the coil.
The strength of the coil can be produced in two different ways.
The coil can consist of a few turns and a high current flows. Or it can consist of many turns with a very low current.
When you multiply the number of turns and the current you get a result called AMP-TURNS.
It is the AMP-TURNS that produces the FLUX (called MAGNETIC FLUX) and this flux interacts with the MAGNETIC LINES OF FORCE produced by the PERMANENT MAGNET to produce REPULSION or ATTRACTION.
Here's the amazing part: You can replace an 8-ohm speaker with 16 ohm, 32 ohm or 50 ohm and get the same (or even higher) output. That's because the number of turns on an 8-ohm coil multiplied by the current flowing through the coil may be equal to the number of turns on a 50 ohm coil multiplied by the current flowing through the coil. If the answers are identical, both speakers will produce the same output.
So, don't bypass the possibility of replacing a speaker with one having a higher impedance voice coil (VC). If the new speaker has a super-magnet, the output will be very impressive. A higher impedance will also put less stress on the output of the circuit and it will sometimes allow a higher voltage to be delivered to the speaker and thus allow proportionately higher current to flow.
A speaker with a weak magnet will produce a low output. Throw it out.

CONTINUITY TESTER

Now is an ideal time to introduce a simple piece of test equipment that will test all sorts of devices and circuits.
It is a **CONTINUITY TESTER**



This piece of test equipment is available from Talking Electronics for $2.50 plus postage.
It is very handy handy and very clever because it has 2 levels of continuity.
The "short-circuit" probe detects low resistance and beeper-buzzer produces a noise when a low resistance is present (up to about 50 ohms).
The High Sensitivity probe is amplified by the transistor and will detect up to about 30k.
It's ideal for measuring and comparing a fault project with a project that works as you can hear the different tones from the buzzer and detect quite small differences in resistance.
You don't realise the importance of a simple piece of test gear like this, until you get one. We use it all the time.

Now, back to the speaker discussion:
Most speakers have an 8R voice coil and the actual resistance may be slightly lower than this.
Some speakers have a resistance of 16R, 32R or 50R and even 75 ohms.
You would think putting a 16R speaker in place of 8R would reduce the sound output, but this is not always the case.

You can even use 50R or 75R and get the same performance.
This may sound amazing, but here is the reason.
The cone is deflected a certain amount due to the current flowing and the number of turns.
These two values are multiplied together to produce a value called AMP-TURNS.
If we have an 8R speaker with 80 turns and 100mA, the result is 0.1 x 80 = 8.
If we use a 16R speaker, the average current flow will be 50mA and the number of turns will be about 160. The multiplication of 0.05 x 160 = 8.
The author then tried a 50R speaker and the sound output was equal to 8R and the same with 75R speaker.
This might not apply in all situations, but the 75R speaker was slightly larger and the ticking sound form the **Metal Detector** kit was louder than using an 8R mini speaker.

To see if the cone of a speaker is undamaged, push it slightly and it will move towards the magnet. If it does not move, it is bent or damaged. If the cone is scratchy when pushed, it is rubbing against the magnet.
A cone should be able to be pushed and pulled from its rest-state. If not, it will produce a distorted sound.

TESTING A CIRCUIT

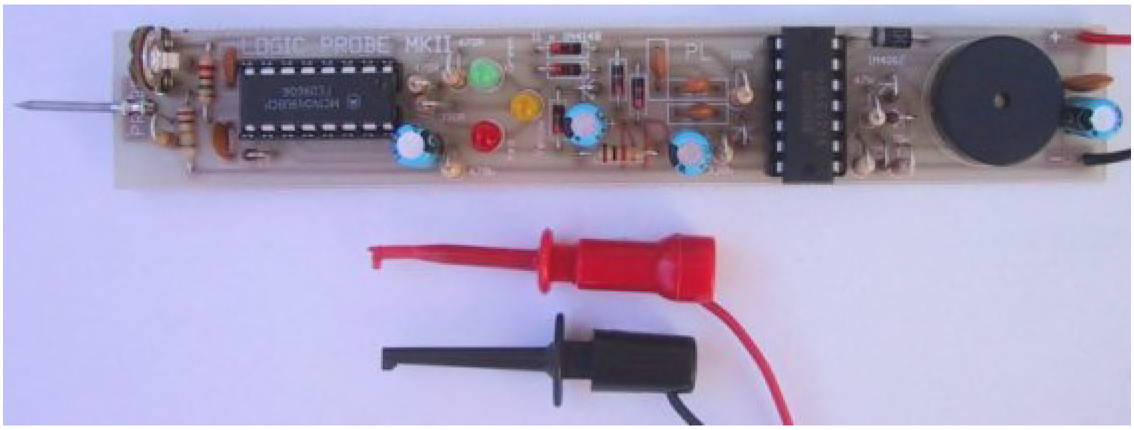
Whenever you test a circuit, the TEST EQUIPMENT puts "a load" or "a change" on it.
It does not matter if the test equipment is a multimeter, Logic Probe, CRO, Tone Injector or simply a LED and resistor.
There are two things you need to know.
1. The IMPEDANCE of the circuit at the location you are testing, and
2. The amount of load you are adding to the circuit via the test equipment.

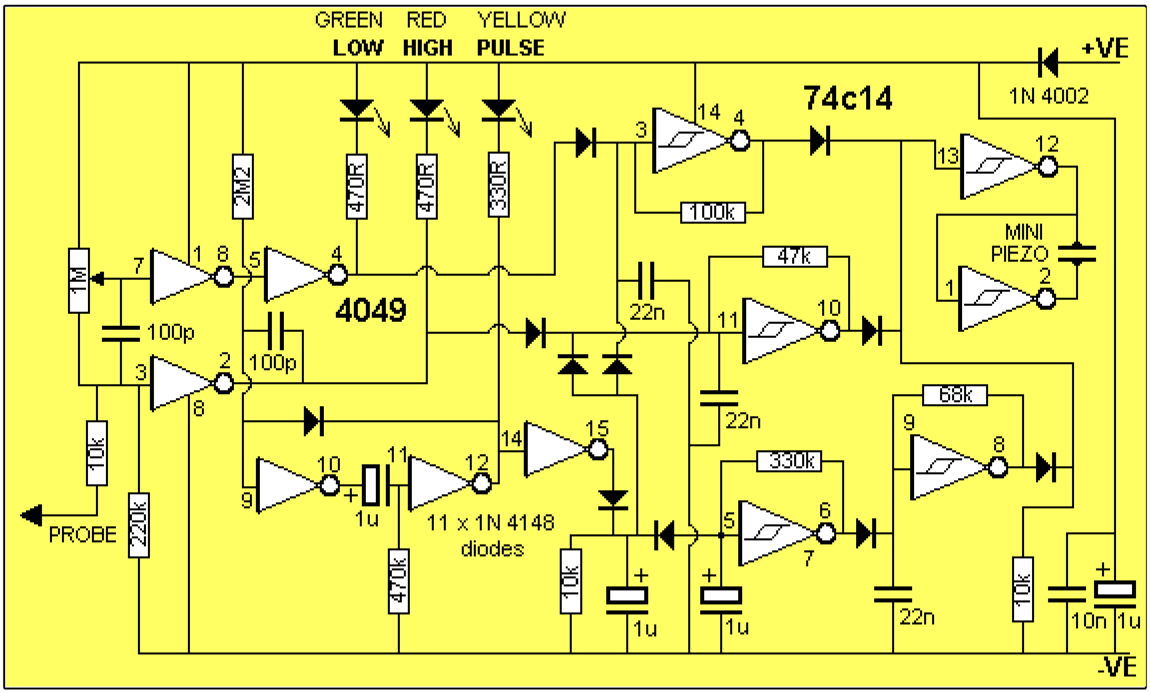
There is also one other hidden factor. The test equipment may be injecting "hum" due to its leads or the effect of your body at absorbing hum from the surroundings or the test equipment may be connected to the mains.
These will affect the reading on the test equipment and also any output of the circuit.
Sometimes the test equipment will prevent the circuit from working and sometimes it will just change the operating conditions slightly. You have to be aware of this.
The last section of this eBook covers High and Low Impedance and understanding impedance is something you need to know.
The point to note here is the fact that the equipment (and the reading) can be upset by hum and resistance/capacitance effects of test equipment. This is particularly critical in high impedance and high frequency circuits.

TESTING INTEGRATED CIRCUITS (IC's)

Integrated Circuits can be tested with a LOGIC PROBE. A Logic Probe will tell you if a line is HIGH, LOW or PULSING.
Most logic circuits operate on 5v and a Logic Probe is connected to the 5v supply so the readings are accurate for the voltages being tested.
A Logic Probe can also be connected to a 12v CMOS circuit.
You can make your own Logic Probe and learn how to use it from the following link:

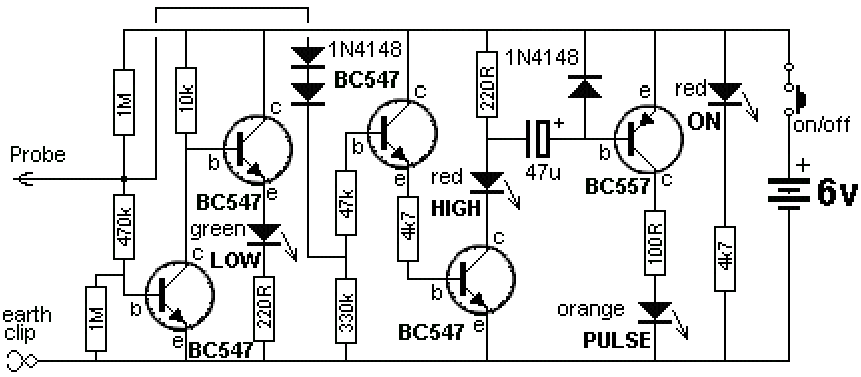
http://www.talkingelectronics.com/projects/LogicProbeMkIIB/LogicProbeMk-IIB.html





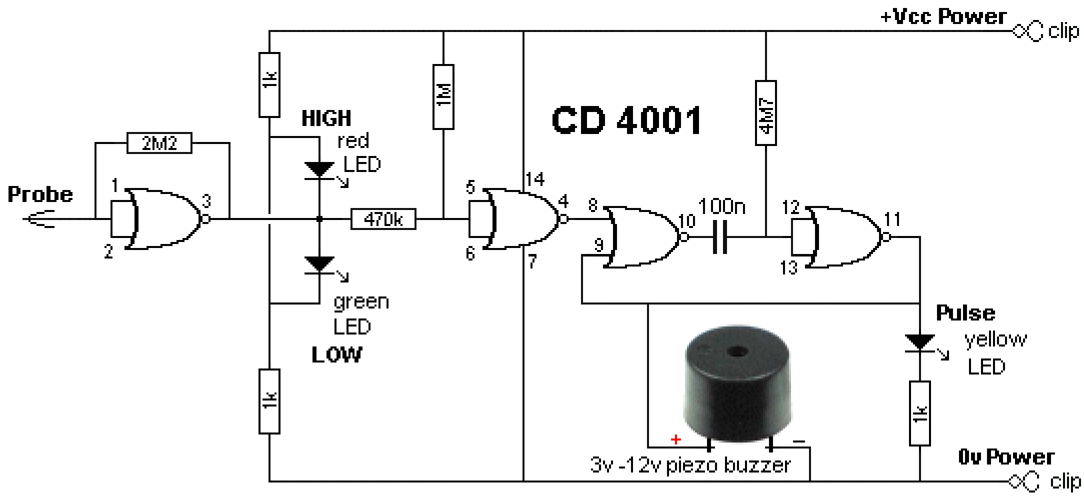
LOGIC PROBE with PULSE

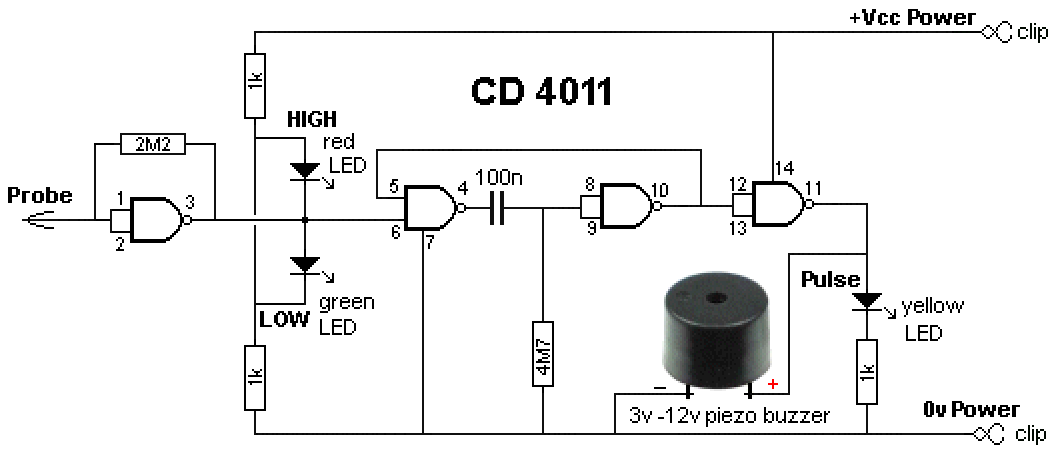
This is a very simple transistor circuit to provide HIGH-LOW-PULSE indication for digital circuits. It can be built for less than $5.00 on a piece of matrix board or on a small strip of copper clad board if you are using surface mount components. The probe will detect a HIGH at 3v and thus the project can be used for 3v, 5v and CMOS circuits.



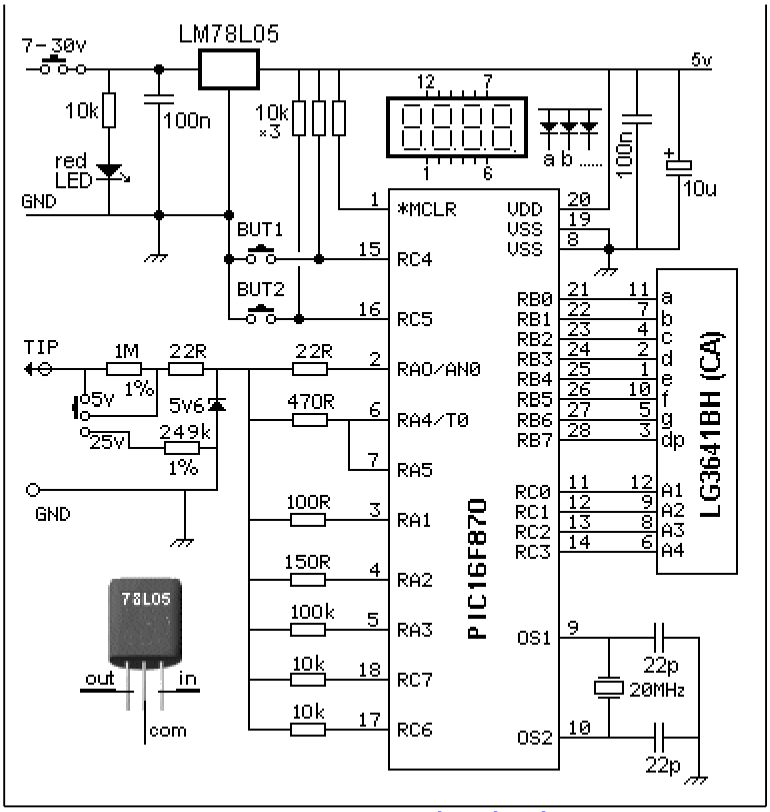
LOGIC PROBE using CD4001 and CD4011

Here is a simple Logic Probe using a single chip. The circuits have been designed for the **CD4001** CMOS quad NOR gate and **CD4011** CMOS NAND gate. The output has an active buzzer that produces a beep when the pulse LED illuminates (the buzzer is not a piezo-diaphragm but an active buzzer containing components).

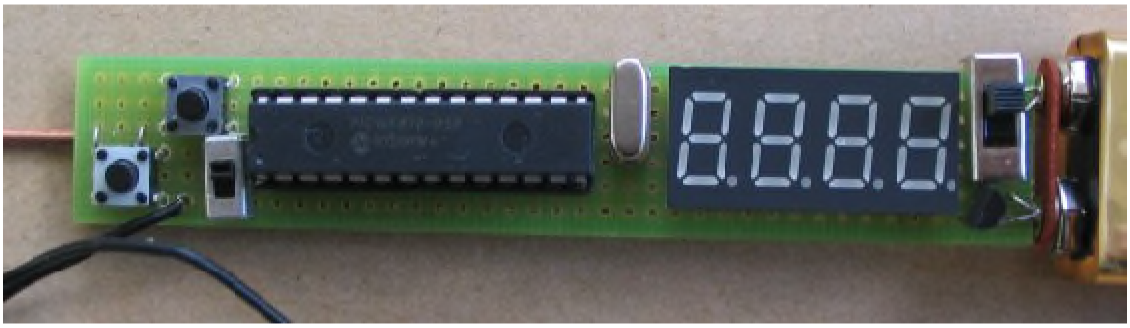




SUPER PROBE MkII has 20 different features including a Logic Probe, capacitance tester, Inductance tester, and more.



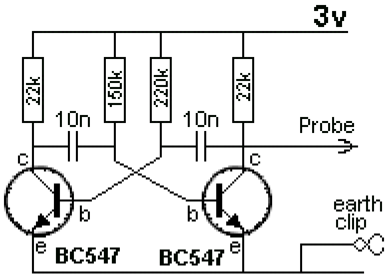
SUPER PROBE MkII Circuit



SUPER PROBE MkII

To test an IC, you need a circuit diagram with waveforms. These diagrams will show the signals and are very handy if a CRO (cathode ray Oscilloscope) is used to diagnose the problem. The CRO will reproduce the waveform and prove the circuit is functioning correctly.
A Logic Probe will just show activity and if an output is not producing a "pulse" or "activity," you should check the power to the IC and test the input line.
It is beyond the scope of this eBook to explain how to diagnose waveforms, however it is important to know if signals are entering and exiting an IC and a Logic Probe is designed for this.

SIGNAL INJECTOR
This circuit is rich in harmonics and is ideal for testing amplifier circuits. To find a fault in an amplifier, connect the earth clip to the 0v rail and move through each stage, starting at the speaker. An increase in volume should be heard at each preceding stage. This Injector will also go through the IF stages of radios and FM sound sections in TV's.



TESTING AUDIO AMPLIFIERS and AUDIO IC's

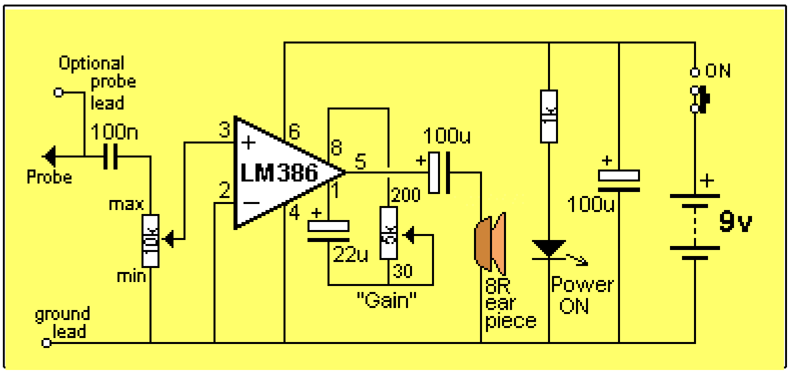
The **Super Probe MII** described above has a "noise" function and a tone function that allows you to inject a signal into an audio stage, amplifier (made from discrete components) or an audio chip, and detect the output on a speaker.
Audio stages are very difficult to work-with if you don't have a TONE GENERATOR or SIGNAL INJECTOR.
The signals are very small and not detected by a multimeter.
You can start anywhere in an amplifier and when a tone is heard, you can keep probing until the signal is not present or louder. From this you can work out which way the signal is travelling.
A Signal Injector is very handy for finding shorts and broken wires in switches, plugs, sockets and especially leads to headphones.
You can determine the gain of a stage (amplification) by probing before and after a chip or transistor and listen for the relative increase in volume from the speaker.
You can also use your finger to produce "hum" or "buzz" if a **Signal Injector** is not available.
Nearly all audio problems are plugs, sockets and cracks in the PC board, but finding them takes a lot of time and skill.

TESTING IC's - also called "CHIPS"
An Integrated Circuit is also called a "chip." It might have 8 pins or as many as 40.
Some chips are ANALOGUE. This means the input signal is rising and falling slowly and the output produces a larger version of the input.
Other chips are classified as DIGITAL and the input starts at 0v and rises to rail voltage very quickly. The output does exactly the same - it rises and falls very quickly.
You might think the chip performs no function, because the input and output voltage has the same value, but you will find the chip may have more than one output and the others only go high after a number of clock-pulses on the input, or the chip may be outputting when a combination of inputs is recognised or the output may go HIGH after a number of clock pulses.

ANALOGUE CHIPS (also see above)
Analogue chips are AUDIO chips or AMPLIFIER chips.
To test these chips you will need three pieces of test equipment:
1. A multimeter - this can be digital or analogue.
2. A Signal Injector
3. A Mini Bench Amplifier.

The Mini Bench Amplifier is available as a kit.

MINI BENCH AMPLIFIER



MINI BENCH AMPLIFIER CIRCUIT

Start by locating the power pin with a multimeter.
If the chip is receiving a voltage, you can use the Mini Bench Amplifier to detect an output.
Connect the Ground Lead of the Mini Bench Amplifier to 0v and touch the Probe tip on each of the pins.
You will hear faint audio on the Input pin and very loud audio on the Output pin.
If no input is detected, you can use a Signal Injector to produce a tone.
Connect the clip of the Signal Injector to 0v and the probe to the input pin of the amplifier chip. At the same time, connect the Mini Bench Amplifier to the output pin and you will hear a very loud tone.
These pieces of test equipment can also be used to diagnose an amplifier circuit constructed with individual components.
Amplifier circuits using discrete components are very hard to trouble-shoot and these pieces of test equipment make it very easy.

DIGITAL CHIPS

It is always best to have data on the chip you are testing, but if this is not available, you will need three pieces of equipment:
1. A multimeter - this can be digital or analogue.
2. A Logic Probe,
3. A logic Pulser.
Firstly test the chip to see if power is being delivered. This might be anything from 3v3 to 15v.
Place the negative lead of the multimeter on the earth rail of the project - this might be the

chassis, or the track around the edge of the board or some point that is obviously 0v.
Try all the pins of the chip and if you get a reading, the chip will have "supply."
Identify pin 1 of the chip by looking for the "cut-out" at the end of the chip and you may find a small dimple below the cut-out (or notch). This is pin 1 and the "power pin" can be directly above or any of the other pins.
Next you need to now if a signal is entering the chip.
For this you will need a LOGIC PROBE.
A Logic Probe is connected to the same voltage as the chip, so it will detect a HIGH and illuminate a red LED.
Connect the Logic Probe and touch the tip of the probe on each pin.
You will not know if a signal is an input or output, however if you get two or more active pins, you can assume one is input and the other is output. If none of the pins are active, you can assume the signal is not reaching this IC.
If only one pin is active, you can assume the chip is called a CLOCK (or Clock Generator). This type of chip produces pulses. If more than two pins are active, you can assume the chip is performing its function and unless you can monitor all the pins at the same time, you don't know what is happening.
This is about all you can do without any data on the chip.

If you have data on the chip, you can identify the input(s) and output(s).
A Logic Probe on each of these pins will identify activity.
A Logic Probe has 3 LEDs. Red LED indicates a HIGH, Green indicates a LOW and Orange indicates a PULSE (activity).
Some Logic Probes include a piezo and you can hear what is happening, so you don't take your eyes off the probe-tip.
It is important not to let the probe tip slip between the pins and create a short-circuit.

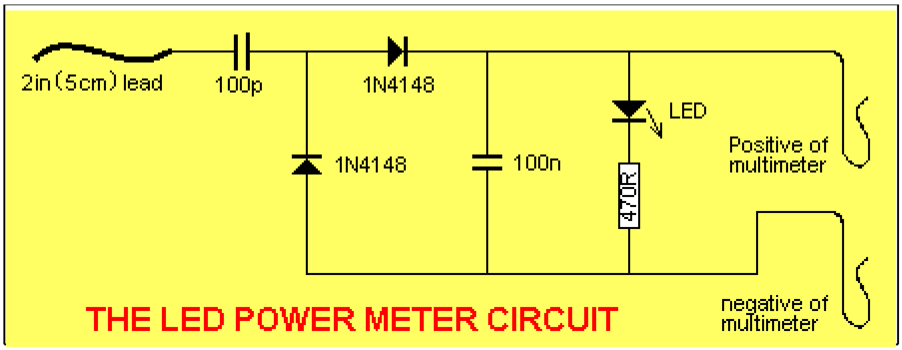
LOGIC PULSER
If you have a board or a single chip and want to create activity (clock pulses), you can use a Logic Pulser. This piece of test equipment will produce a stream of pulses that can be injected into the clock-line (clock input) of a chip.
You can then use a Logic Probe at the same time on the outputs to observe the operation of the chip.

You can also use the Mini Bench Amplifier to detect "noise" or activity on the inputs and outputs of digital chips.
This only applies if the frequency is in the audio range such as scanning a keyboard or switches or a display.

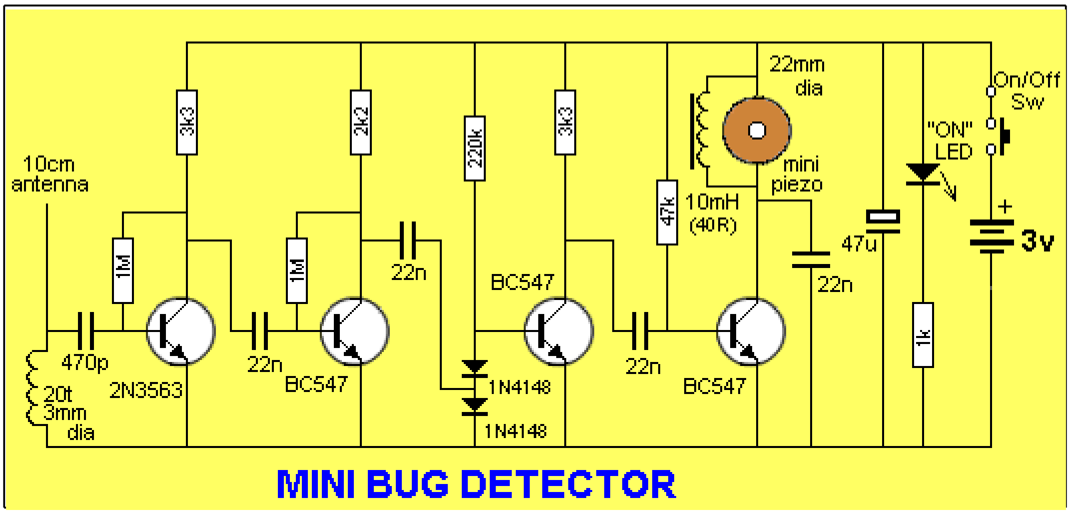
This is how to approach servicing/testing in a general way. There are thousands of digital chips and if you want to test a specific chip for its exact performance, you will need to set-up a "test-bed."

REMOTE CONTROLS

There are two types of remote control - Infrared and RF. Infrared is used for short-range, line-of-sight for TV's DVD's etc.
A few faults can be fixed, but anything complex needs a new remote control.
Check the batteries and battery-contacts. See if the IR LED is illuminating by focusing it into a digital camera and looking on the screen for illumination.
The only other things are a sticky button, a worn-out button or a crack in the PC board.
Water damage is generally too much work to repair.
RF remote controls for cars, garage doors etc need a second working unit to check the power output.
Here is a simple circuit that can be connected to an analog multimeter to detect the signal strength at a very close range:



To hear the tone from a transmitter, the **Mini Bug Detector** circuit can be used:



Any further investigation requires a circuit diagram so you can work out what is actually being sent from the transmitter.
Most of the time it is a faulty switch, battery or contacts. Make sure the setting is correct on the "dip switches" and use a working unit to compare all your testing.

TESTING VOLTAGES ON (in) A CIRCUIT

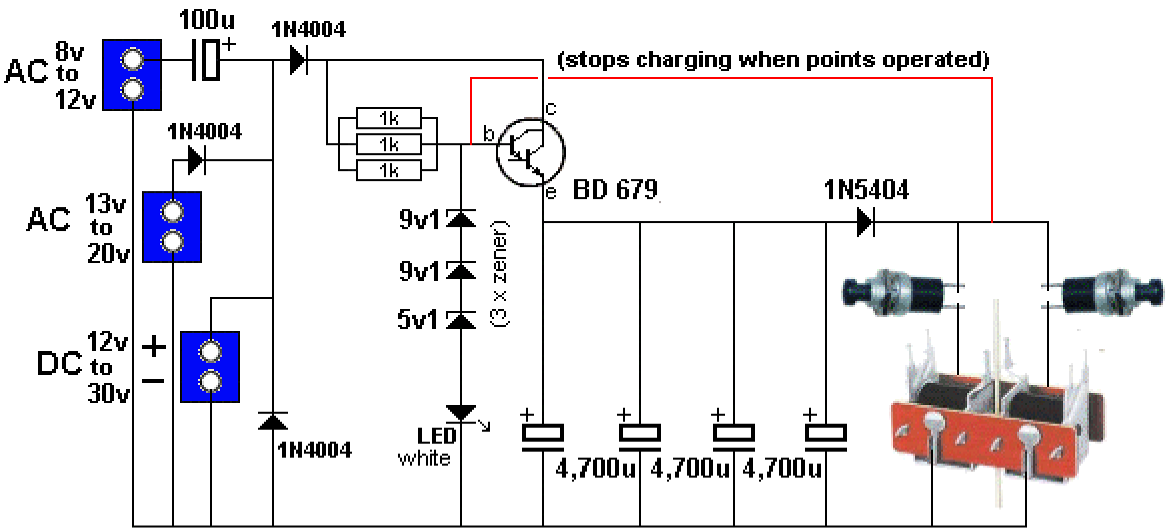
There are basically two different types of circuit.
1. **ANALOGUE CIRCUIT**
An analogue circuit can also be called an AUDIO CIRCUIT and the voltages at different points in a circuit can be measured with a multimeter but the changes (the waveforms) will be quite small or changing at a rapid rate and cannot be detected by a multimeter.
You need a CRO to "see" the signals or a **Signal Injector** to inject a waveform into the circuit and hear the result on the circuit's speaker.

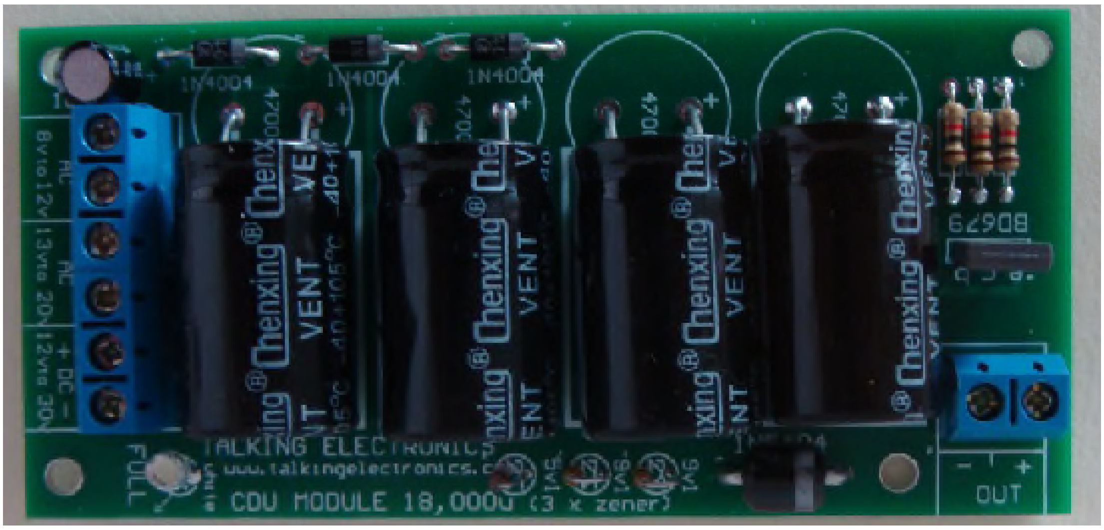
2. **DIGITAL CIRCUIT**
A digital circuit can also be called a "Computer Circuit" or "Logic Circuit" and some of the voltages can be measured with a multimeter (such as supply voltages) but the "signal lines" will be be changing from HIGH to LOW to HIGH very quickly and these signals are detected with a **Logic Probe**.

Here are some circuits with details of how to test the voltages.
Most circuits do not show voltages at various different points and we will explain what to expect on each "stage."

TESTING A MODULE

This is the way to test all modules. You may know what they do but you may know nothing. The point is to be careful. Don't allow any of your probing to create a short-circuit as the energy in large capacitors (electrolytics) will destroy almost anything.
You can see the module has 3 inputs. They all convert the input voltage to 25v (or deliver 25v) to the top diode and this diode turns on a Darlington transistor that gradually rises "higher and higher" (as the 4 electrolytics charge). The transistor is turned ON via the 3 x 1k resistors and the base voltage is monitored by three zeners and a LED. When this voltage gets to 9.1v + 9.1v + 5.1v + 3.3v (for the LED), it cannot rise any further and the emitter reaches 0.6v less than this.
The first thing to do is connect a low voltage to the DC input and see of a voltage appears on the electrolytics.
If not, you measure the voltage on the ends of the 1k resistors and the 3 leads of the transistor. No voltage will mean the wiring or the top diode is not conducting or around the wrong way.
When you have voltage, increase the input voltage to more than 27v and the LED will illuminate. If not the zeners and or LED are faulty. If the LED comes on below 25v, a zener will be faulty.
The 3 voltages on the transistor should be almost the same after a short period of charging. If not, the transistor will be damaged.
Do no short-circuit the output terminals. The high current from the electrolytics will BLOW UP the output power diode.
Touch a 8R 5watt power resistor on the top of the output screw terminals and look for the spark. Or you can use a fairly large 12v motor. If it does not work, the diode is damaged.
The transistor does not pass a high current at any time and is not heat-sinked. When the output is delivery energy to a load, the output voltage drops to a few volts and the red wire on the circuit diagram reduces the voltage on the base to a low value and prevents the circuit charging the capacitors.





This module is used to show how to perform "testing".

A "STAGE"

A stage is a set of components with an input and output. A "stage" can also be called a "Building Block."
Sometimes it has a capacitor on the input and one on the output.
This means the stage is completely isolated as far as DC is concerned.
The stage has a supply (a DC supply) and it is producing its own voltages on various points on the "stage." It can only process (amplify) "AC." (signals).
Sometimes the stage can be given a name, such as small-signal amplifier, push-pull amplifier or output.
If the stage has a link or resistor connected to a previous stage, the previous stage will have a "DC effect" on the stage. In other words it will be biasing or controlling the voltages on the stage. The stage may be called a "timer" or "delay" or "DC amplifier."

It is important to break every circuit into sections. This makes testing easy. If you have a capacitor at the input and output, you know all the problems lie within the two capacitors. In a digital circuit (no capacitors) you need to work on each IC (integrated Circuit) and test the input for activity and all the outputs.

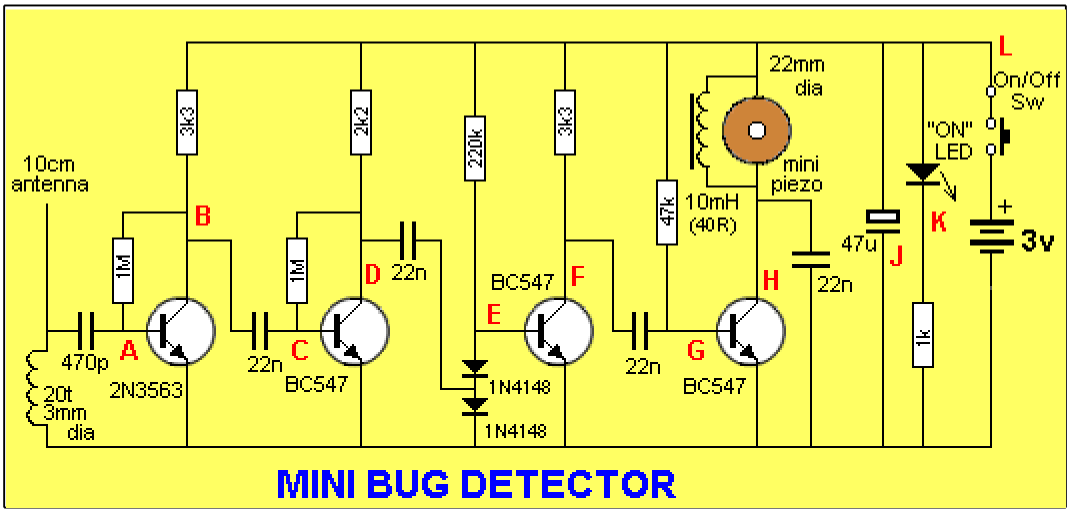
Once you have determined if the circuit is Analogue or Digital, or a combination of both, you have to look at the rail voltage and work out the size or amplitude of the voltage or waveform.
This is done before making a test, so your predictions are confirmed.
You will need a **multimeter** (either Digital or Analogue) a **Logic Probe** and a **Signal Injector** (**Tone Generator**). An analogue meter has the advantage that it will detect slight fluctuations of voltage at a test-point and its readings are faster than a digital meter. A digital meter will produce an accurate voltage-reading - so you should have both available.

HIGH IMPEDANCE AND LOW IMPEDANCE

Every point in a circuit has a characteristic called "IMPEDANCE." This has never been discussed before in any text book. That's why it will be new to you.
In other words, every point will be "sensitive to outside noise."
An audio amplifier is a good example. If you put your finger on the active input, it will produce hum or buzz in the speaker. This is because it is a HIGH IMPEDANCE line or high impedance section of the circuit.
The same applies to every part in a circuit and when you place Test Equipment on a line for

testing purposes, the equipment will "upset" the line. It may be very slight but it can also alter the voltage on the point CONSIDERABLY.
We have already mentioned (above) how a cheap multimeter can produce a false reading when measuring across a 1M resistor. That's why you need high impedance test Equipment so you do not "load" the point you are testing and create an inaccurate reading.
The word **Impedance** really means resistance, but when you have surrounding components such as diodes, capacitors, transistors, coils, Integrated Circuits, supply-voltages and resistors, the combined effect is very difficult to work out as a "resistance" and that's why we call it "Impedance."
The term "**High and Low Impedance**" is a relative term and does not have any absolute values but we can mention a few points to help you decide.
In general, the base of a transistor, FET input of an IC are classified as HIGH IMPEDANCE.
The output of these devices are LOW IMPEDANCE.
Power rails are LOW IMPEDANCE.
An oscillator circuit and timing circuit are HIGH IMPEDANCE.
A LOAD is low impedance.
And it gets tricky: An input can be designed to accept a low-impedance device (called a transducer or pick-up) and when the device is connected, the circuit becomes LOW impedance, but the input circuitry is actually high impedance.
The impedance of a diode or LED is HIGH before the device sees a voltage higher than the junction voltage and then it becomes LOW Impedance.
Impedance is one of the most complex topics however it all comes down to testing a circuit without loading it.
That's why test equipment should have an input impedance higher than 1M.

The first circuit we will investigate is the **Mini Bug Detector**, shown above and below.
Points on the circuit have been labelled A, B, C etc:



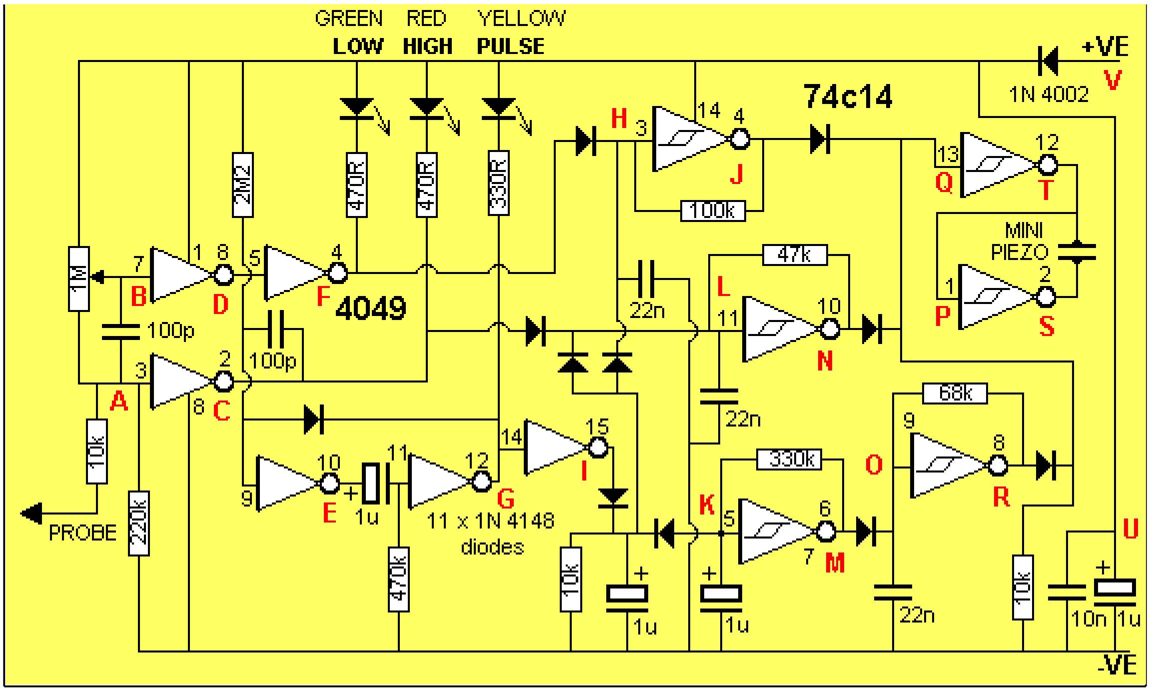
Point A - The first transistor is "self-biased" and will have 0.6v on the base. The antenna is connected to a 20 turn coil and you might think the coil will "short" the signals to earth. But the coil and 470p capacitor form a circuit that oscillates at a high frequency when the antenna wire picks up stray signals. The coil and capacitor actually amplify the signals (see Talking Electronics website: Spy Circuits to see how a TANK CIRCUIT works) and these signals enter the base of the first transistor.
This is classified as a HIGH Impedance section because the signals are small and delicate and any loading via test equipment will kill them. The first transistor amplifies the signals about 70 times and they appear at **Point B**.

The signal passes though a 22n to **Point C** and the transistor amplifies the signal about 70

The signal passes though a 22n to **Point C** and the transistor amplifies the signal about 70 times to **point D**. **Point C** is classified as high impedance as any voltage measurement at this point will upset the biasing of the stage as a few millivolts change in base-voltage will alter the voltage on the collector considerably. **Point D** is classified as low impedance as any voltage-testing will not alter the voltage appreciably.
The output of the second stage passes through a capacitor to the join of two diodes. These two diodes are not turned on because the voltage at **Point E** can never rise above 0.7v as this is the voltage produced by the base-emitter of the third transistor.
The purpose of the two diodes is to remove background noise. Background noise is low amplitude waveforms and even though the transistor is turned on via the 220k, low amplitude signals will not be received. The third transistor works like this: It cannot be turned ON any more because any waveform from the 22n will be "clipped" by the bottom diode and it will never rise above 0.6v.
So, the only signal to affect the transistor is a negative signal - to turn it OFF.
Firstly we have to understand the voltage on the 22n. When the second transistor is sitting at mid-rail voltage, the 22n gets charged via the 2k2 and lower diode. When the transistor gets tuned ON, the collector voltage falls and the left side of the 22n drops. The right side of the 22n also drops and when it drops 0.6v, the top diode starts to conduct and when the voltage on the 22n drops more than 0.6v the third transistor starts to turn OFF. This effect is amplified by the transistor at least 100 times and appears at **Point F.** All the voltages around the two diodes are classified as HIGH Impedance as any piece of test equipment will upset the voltage and change the output.
There are some losses in amplitude of the signal as it passes through the 22n coupling capacitors but the end result is a very high strength signal at **point G.** The 4th transistor drives a 10mH choke and the mini piezo is effectively a 20n capacitor that detects the "ringing" of the inductor to produce a very loud output.
The 22n capacitor on the collector eliminates some of the background noise. The choke and piezo form an oscillatory circuit that can produce voltages above 15v, even though the supply is 3v.
The 47n capacitor at **Point J** is to keep the supply rails "tight" (to create a LOW Impedance) to allow weak cells to operate the circuit.
The "Power-ON" LED tells you to turn the device off when not being used and **Point L** is the power supply - a low impedance line due to the 47u electrolytic.

Testing the Mini Bug Detector
To test the Mini Bug Detector, you will need a Signal Injector.
Place the Injector on **Point G** and you will hear a tone. Then go to **E**, **C** and **A**. The tone will increase in volume. If it does not increase, you have pin-pointed the faulty stage.

The next circuit is a combination of digital and analogue signals. It is a **Logic Probe**:



The voltage on a circuit (to be tested) is detected by the probe at **Point A** of the circuit above and the "tip" is classified as "reasonably high impedance" as it has a 220k resistor between the tip and 0v rail. The 1M reduces the impedance by about 20% but the inputs of the two inverters have no effect on the "tip" impedance as they are extremely high input-impedance devices.
The 1M trim pot is designed to put put a voltage on **point B** that is slightly higher than mid-rail so the green LED is turned off.
Point A will see a voltage below mid-rail and **point C** will be HIGH. **Point C** and **F** are low-impedance outputs.
When the tip of the probe is connected to a LOW voltage, Point B sees a LOW and Point F goes LOW to illuminate the green LED. At the same time it removes the "jamming voltage" produced by the diode between pin 4 of the 4049 and pin 3 of the 74C14 and the oscillator between **points H and J** produces a low-tone via the 100k resistor and 22n to indicate a LOW.
When the probe tip sees a HIGH, a lot more things happen.
Point C goes LOW and turns on the red LED. At the same time the 100p is in an uncharged state and the right lead goes LOW. This takes the left lead LOW as the left lead connects to a HIGH Impedance line and pin 9 goes LOW. This makes **point E** HIGH
and since the 1u is in an uncharged state, pin 11 goes HIGH. This makes **point G** LOW and the diode between pins 9 and 12 keeps pin 9 LOW and takes over from the pulse from the 100p. The yellow LED is illuminated. The 1u starts to charge via the 470k and when it is approx half-charged, pin 11 sees a HIGH and **point G** goes low. This creates the length of pulse for the yellow LED.
At the same time, **Point L** goes LOW because the "jamming diode" from pin 2 of the 4049 goes low and allows the inverter between point L and N to produce a tone for the piezo.
In addition, **Point I** goes HIGH and quickly charges a 1u electrolytic. This removes the effect of the jamming diode on pin 5 of the 74C14 and a low frequency oscillator made up of 68k and 1u between pins 5&6 turns on and off an oscillator between **points O** and **R** to get a beep. The mini piezo is driven n bridge mode via the two gates between **points QT** and **PS**.
Point U is a 1u electrolytic to reduce the impedance of the power rail and **Point V** is a protection diode to prevent damage if the probe is connected to the supply around the wrong way.

Testing the Logic Probe

You can test the Logic Probe with the simple Logic Probe with Pulse project described above. It will let you know if each point in the circuit is HIGH or LOW. You will also find out the difficulty in testing the points that are HIGH Impedance, as the Probe will upset the voltage levels and the reading may be inaccurate.

More circuits will be added here in the future.

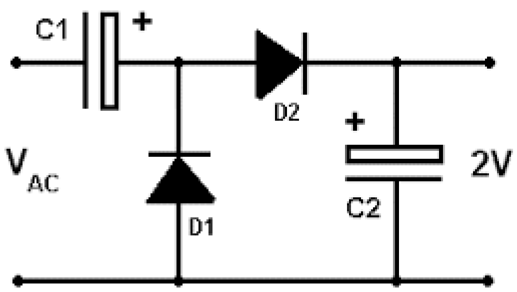
THE VOLTAGE DIVIDER **- this topic could fill a book.**

You need to read lots of other sections in this eBook, including the section on measuring across a resistor with a multimeter, and high impedance circuits, to fully understand the complexities of a VOLTAGE DIVIDER CIRCUIT.
It is one of the most important BUILDING BLOCKS to understand. Even though it may consists of two components, you have to understand what is happening between these two components. You have to realise there is a voltage at their join that will be rising and falling due to one of the components changing RESISTANCE.
Sometimes you can work out the voltage at the join by using Ohm's LAW but quite often it will be impossible as it is changing (rising and falling) during the operation of the circuit.
At the beginning of this discussion we will only dealing with DC circuits and the voltage across a particular component will be due to its RESISTANCE. We are not going into any formulas, as it is very easy to measure the voltages with a multimeter set to VOLTS and you will have an accurate result.
The simplest two components in series are resistors. They always have the same resistance during the operation of a circuit and the voltage across each will not change.
In a further discussion we will cover "resistors" that change value according to the temperature. These are called THERMISTORS. And we have "resistors" that change value according to the light they receive. These are called LIGHT DEPENDENT RESISTORS (LDR's) or PHOTO RESISTORS.
A transistor that is partly or fully turned ON can be considered to be similar to a resistor.
In these 3 cases we need to measure the voltage at the join with a voltmeter as it will be a lot of work to measure the resistance and work out a value.
You can also keep a voltmeter on the joint and watch the voltage change.
Finally we have some components that produce a fixed voltage across them (or nearly fixed) and the remaining voltage is dropped across a resistor. These components MUST have a resistor connected in series to limit the current and allow the component to pass the specified in the datasheet.
These devices include LEDs, diodes and zener diodes. A LED will have a fairly fixed voltage across it from 1.7v to 3.6v depending on the colour. A diode will have a voltage of 0.7v across it when it is connected to a voltage via a resistor. And a zener diode will have a fixed voltage across it when it is connected with the cathode to the positive rail via a resistor. The voltage across it will be as marked on the zener.
The concept of a VOLTAGE DIVIDER is very simple, but it takes a lot of understanding because both VOLTAGE and CURRENT are involved in the UNDERSTANDING-PROCESS.
Each component has a resistance and this can be measured with a multimeter. When two components are connected in series, a current will flow and a voltage will develop across each item.
More voltage will develop across the item with the higher resistance and the addition of each voltage will always equal the supply voltage.
That's the simple answer.
There is a little more involved . . . It is the word CURRENT. Here is an explanation:
Suppose we have a 1k and 2k resistor on a 12v supply. The voltage at the join will be 4v.
In other words, there will be 4v across the 1k and 8v across the 2k.
If we have a 10k and 20k resistors in series, the voltage will also be 4v at the join.
If we have a 100k and 200k resistors, the voltage will also be 4v at the join.
The voltage will be the same in all cases, but the current will be different. The current in the second case will be one-tenth and only one hundredth in the third case.

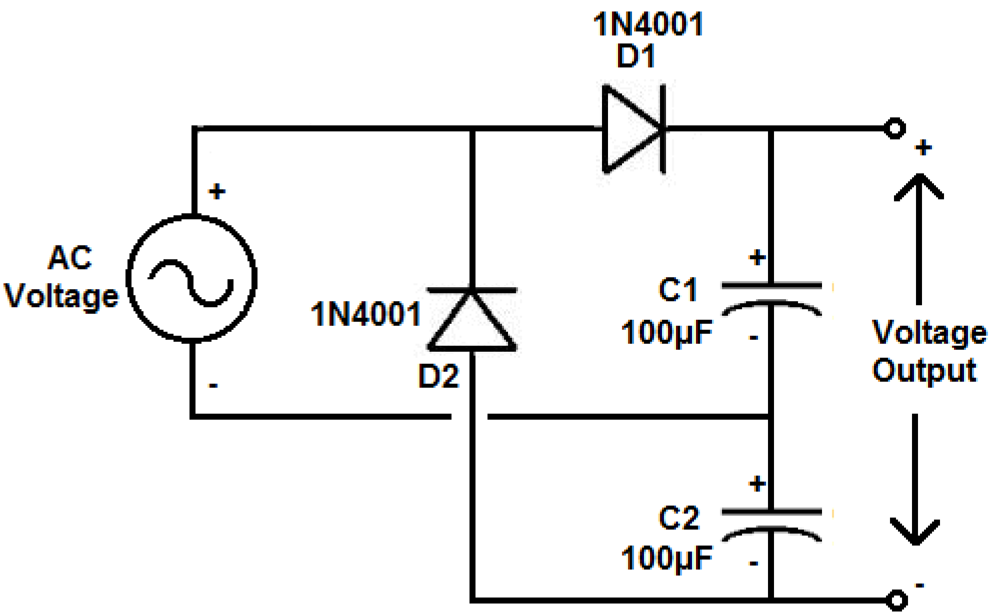
If you want to go further, place a one ohm and two ohm in series and get 4v. But the resistors will get very hot and burn out very quickly.
Why do we have to chose between using 1k, 10k and 100k set-ups? Because different amounts of current will flow in each set-up. This current is called BLEED CURRENT and is basically "WASTED CURRENT." But it may be only way to design a circuit.
How do you choose? Basically you measure the current flowing through the voltage divider and one-fifth of this current will be the current you can "tap-off" to the circuit you are supplying the 4v to. You can turn the circuit around the other way and deliver 8v. In the above example with 1k and 2k, the "bleed current" will be 4mA and you can only supply 1mA to your project.
WHY?
Because the current you take from the voltage divider will make the 4v reduce to a lower voltage (3.5v) and if you take more than 1mA, the voltage will fall to less than 3v.
A voltage divider is like supplying a circuit with a very old and weak battery.

THE VOLTAGE DOUBLER

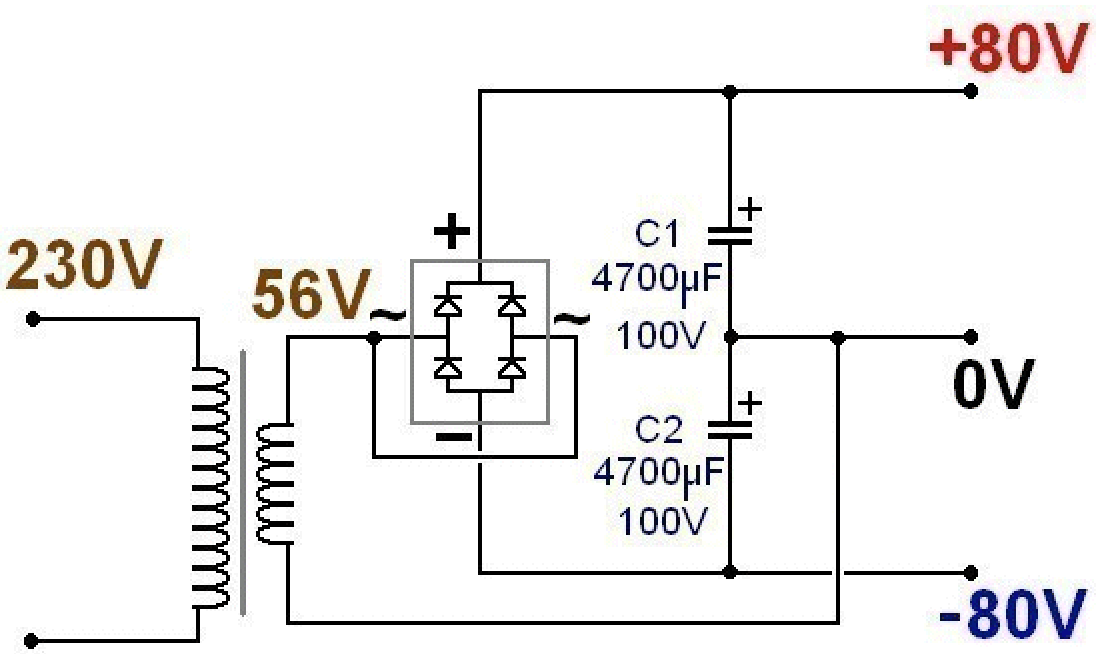
Many circuits use a capacitor to increase the voltage.
Firstly you have to look at a circuit and then realise **"it is designed to increase the voltage"** and then look at the features of this type of circuit.
If the incoming voltage is 12vAC, the peak will be 17v and the output can be as high as 32v. And it will be DC.
The electrolytic used in this type of circuit may get hot or warm, depending on the current and it will gradually dry out. This will reduce the output voltage -the voltage will sag when a load is applied.
This is the first component to replace.
The simplest voltage doubler is called a **CAPACITOR INPUT** VOLTAGE DOUBLER:



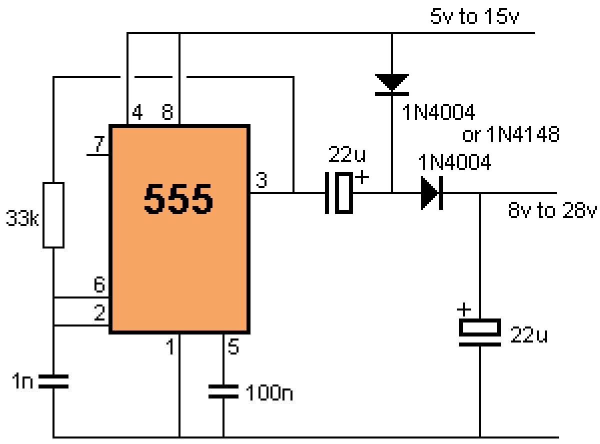
If the output voltage is very high, you can use 2 electrolytics:



The same circuit can be used to produce a positive and negative output:



If the input voltage to the doubler section is DC, as shown in the following 555 VOLTAGE DOUBLER circuit, you will have to "jack-up" the voltage on the electrolytic by taking the negative lead of the electrolytic to the negative rail to charge it and then take the negative lead to the positive rail to deliver the voltage to the output section:



VOLTAGE DOUBLER

The amount of current that can be delivered by this type of circuit depends on the value of the electrolytic and the frequency at which the circuit operates.

SOLDERING

Here are three 30-minute videos on soldering.
1. **TOOLS**
2. **Soldering components**
3. Soldering **SURFACE MOUNT** components
Soldering skills is one of the most important skills for an electronics person.
I have many projects brought in for repair and the only fault has been a poorly soldered connection.
You must use a temperature controlled soldering iron and it is a simple matter to adjust the temperature correctly.
Turn the temperature down and let the iron heat up. Gradually increase the temperature until the solder JUST MELTS.
This is your starting point. Increase the temperature slightly and if the joint is taking too long to melt the solder, increase the temperature slightly.
There are two points of view on this subject.
One school of thought says to keep the temperature low to prevent damaging the components and the other says to increase the temperature considerably and perform the operation VERY QUICKLY.
I have followed both methods and have not damaged a component in 40 years.
So, it all boils down to quick and efficient soldering and taking the least time to complete each joint.
But here's something that has never been covered before.
Some Chinese solder is marketed as 60/40 solder with rosin core. When this was tried at the normal temperature of soldering, the solder did not melt quickly and formed lumps and you could watch it harden with a very dull finish.
The soldering iron had to be turned up to full heat to get it to melt quickly.
THIS IS NOT THE SORT OF SOLDER TO USE.
This sort of solder WILL damage a component because the temperature is HIGH and the time is LONG.
For the same cost you can buy Chinese Eutectic solder 63/37 and it melts at a very definite point that is equal to the quality solder available in Australia.

Soldering relies on CONDUCTION -heat conduction, cleanliness and speed.
Repairing items needs skill in removing components, testing them and replacing them or using a new component.
In the process you don't want to damage a good component or the PC board.

So you have to be careful.
You can pull a component off a board with your fingers or a pointed-nose pair of pliers if you are quick and heat all the leads at the same time.
To do this, you need to add solder to each joint so the iron will get heat conduction to all the joints at the same time.
You must use resin (rosin) cored solder so the solder and iron is clean and ready to do the desoldering.
Another way to prepare the component for removal is to buy a bottle of solder flux and dab it onto each joint and then use a clean piece of de-solder wick to remove all the solder.
When you touch the desolder wick with the iron, the flux will splutter and heat up and then you will see the solder flowing onto and into the wick. Do this to all the joints and then move the wire with pliers so it is disconnected from the hole.
You can remove solder from a hole by adding more solder than dab the solder flux on the hole and use a new piece of desolder wick.
You can also remove solder from a hole by feeding tinned copper wire into the hole with a hot soldering iron and letting the tinned copper wire absorb the solder.
Or you can feed enamelled wire into the hole and make sure the enamel is not removed from the wire so the enamelled wire will push and pull into the hole and remove the solder while heating the hole with a soldering iron.
The third method is to use a needle that does not accept solder and push and pull it through the hole while heating the hole with a soldering iron.
Finally, you can heat up the solder in a hole and tap the board on the bench very hard and the hole will be clean.
If you want to remove a chip, you can place the board over a gas stove and heat up the underside of the board and remove the chip with long nose pliers . . . VERY QUICKLY.
Some solder flux is highly conductive, so remove it with acetone before fitting a new component or you will think the new component is "leaky."

TESTING A MOTOR

Strictly speaking, a motor is not an electronic component, but since a website gave a useless description on testing motors, I have decided to supply the correct information.
The only REAL way to test a motor is to have two identical motors and check the torque by connecting them to a low voltage and trying to stop the shaft with your fingers. This will give you two results. Firstly it will let you know the torque of the motor.
This is the twisting effect of the shaft. There is no way to determine the torque by knowing the voltage or current.
The unknown factor is the strength of the field magnets (permanent magnets) and this determines the torque.
Secondly, feeling the shaft will let you know if the torque is even for a complete revolution.
By having two identical motors, you can see if one has a lower torque.
Almost nothing can go wrong with a motor except for the brushes. If the brushes wear out, additional resistance will be produced at the interface between the brush and commutator and this can be detected by allowing the shaft to rotate slowly and feeling the resistance as it revolves. A 3-pole motor will have six places where the strength is greatest. A 5-pole motor will have 10 places of strength, when the motor is not powered. When the motor is powered, this changes to 3 places and 5 places.
If the strength is weak or not uniform, the motor is faulty.
You cannot test a motor with a multimeter as the resistance of the armature winding is very low and if you spin the motor with your fingers, the back voltage produced by the spinning, increases the reading on the meter and is false.
The best way to test a motor is to supply a low voltage and put an ammeter in series with the positive lead. You will see the current change as the shaft is held slightly with your fingers.
Micro motors have a coreless armature. This means the 3 windings for the armature are wound on a machine then bent slightly into shape and glued. A circular magnet with 3 poles is in the centre and the armature rotates around this.

This type of motor is reasonably efficient because the armature is the greatest distance from the point of rotation, and the motor reaches full RPM very quickly because the armature has very little inertia.
I have not heard of the armature-winding flying apart but if you hear any scraping noise, it may be the winding.
3-pole, 5-pole and micro motors can be found in printers, eject mechanisms of CD players, toys, RC helicopters, cars etc and they rarely fail.
Motors do not work on "voltage." They actually work on CURRENT and as you increase the voltage, more current will flow and produce a stronger magnetic field (by the winding on each pole). This magnetic field will be attracted by the permanent magnet surrounding the armature and repelled by the surrounding permanent magnet, depending on where the face of the pole is, during each revolution.
If the permanent magnet is not very strong, the interaction of the magnetic fields will be very weak and thus the torque will be small, but the motor will increase to a higher RPM in an attempt to generate sufficient back-voltage.
Because motors work on "current" you must have a high current available when you increase the voltage as the motor will require short bursts of high current during part of each revolution.
It is the combination of voltage and current (called watts) that gives the motor "strength" (torque) as well as the "strength" of the permanent magnets (called the field magnets) and the number of turns of wire on each pole (and the gauge of wire).
Basically, if a motor is hard to spin, and has 3 "hard spots" on each revolution, it will be powerful.
A 2-pole motor does not self-start and will spin in either direction. But a 3-pole motor will self-start and you can control the direction of rotation.
A 5-pole motor has a lower RPM. It is slightly smoother in output but may not be more powerful than a 3-pole version.
A 3-pole motor will have an RPM in the range of 10,000 to 30,000 RPM. A 5 pole motor can be as low as 6,000 to 8,000 RPM. The RPM of a 5-pole motor (and 3-pole) can be reduced by supplying a lower voltage. Some 5-pole motors will reduce to 600RPM when the voltage is reduced from 12v to 6v. The torque from a 5-pole motor is the same as a 3-pole motor if the armature diameter is the same and the strength of the permanent magnets are the same and the air gap is the same and the magnetic field produced by the armature is the same. A certain voltage and current cannot produce greater torque, just because the motor has more poles.
Basically, the RPM of a motor when not loaded will increase until the energy required to rotate the armature equals the energy being delivered by the voltage and current. At the beginning, the energy input is very high and the motor increases in RPM. As it increases in RPM, the energy required to do this increases and at the same time the increase in back voltage it produces causes the incoming energy to reduce. Eventually these two become equal and the RPM is maintained. If a motor has very few turns on each pole, it will need to achieve a higher RPM to produce the back voltage needed to achieve equilibrium. If the magnets are weak, the RPM is also higher.
A coreless motor has a very light armature and it does not require very much energy to rotate it. That's why it achieves a very high RPM.
The RPM is also very high because the "back-voltage" - voltage produced when the windings pass a magnet - is not very high. With the motor having an armature, the armature not only concentrates the magnetic flux produced by the winding but it also receives the magnetic flux from the permanent magnets and this flux is in the opposite direction to that produced by the winding and puts a reverse voltage on the input voltage and thus the current decreases. With a coreless motor, the winding has to revolve at a much higher RPM to active this reverse voltage as the magnetic flux from the magnet has to actually pass though the copper wire of the winding to produce the back-voltage and this is not nearly as efficient as having a metal core.
A motor with "permanent magnets" is called a DC motor as it will not work on AC. If the magnets are replaced with a coil, it will work on AC and it will be called a "shunt wound" motor if the field coil is connected across the same terminals as the brushes or a "series

wound" motor if the field coil is in series with the armature.
By reversing the two wires to the field winding, the motor will reverse.
If the armature is long, the motor will produce more torque because the interaction between the magnetism of the pole and the associated field of the permanent magnet is greater.
With a 3-pole motor, one pole is receiving full voltage and it will be NORTH. The other two poles will be in series and producing less magnetic flux and will be SOUTH. The combination of attraction of one pole and repulsion of two poles produces a "pulling" and "pushing" effect, that causes the armature to rotate in the clockwise direction.
You cannot predict, design or work out the RPM of a motor because it depends on so many things.
Things like the strength of the permanent magnets, the distance between the poles and the magnets (called the air gap), the effectiveness of the faces of the poles and obvious things like the number of turns, the voltage and the number of poles.
You simply build a motor and change the number of turns and do this 4 or more times and generate a list of results. Then you can change the alnico magnets (ferrite magnets) for super-magnets and the size of the armature and then work out where you want to go.

THE SECRET

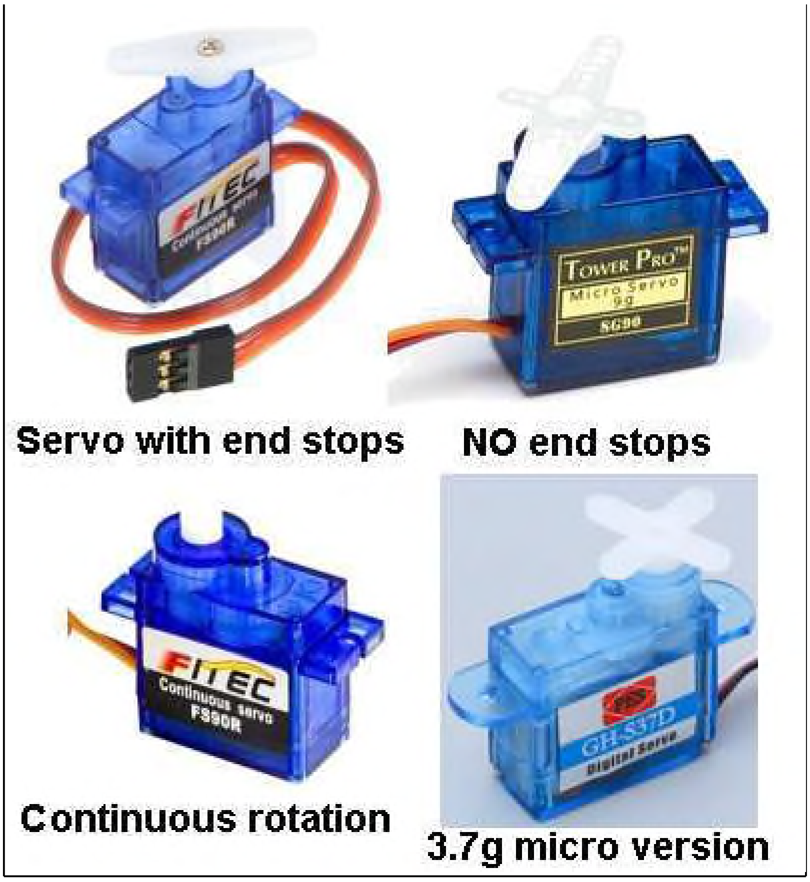
Now we come to a secret that no-one has ever mentioned.
As you increase the voltage to a motor, the current will increase and the attraction and repulsion of the magnetic field between the pole and the permanent magnets will increase and the motor will have more torque and this will give it a higher RPM. But a point will be reached where the magnetic field produce by the winding on a pole will be greater than the magnetic field produce by the permanent magnet and suppose the magnet is N-pole and the winding produces a North pole. As the flux from the armature increases, the repulsion increases but when it is greater than the permanent magnet, the repulsion reaches a maximum and now the armature sees the permanent magnet as a piece of material that it can be attracted-to. Thus the torque of the motor has reached a maximum.

EMF

When a motor is revolving, you can see sparks between the brushes and the segments of the commutator. These sparks are due to the voltage produced by the coils on each pole. This voltage is called "back voltage" or "spike voltage" can be very high - up to 100 times higher than the supply voltage and this voltage can damage the driver transistor. This voltage has very little current but transistors are very susceptible to voltages and can be damaged instantly.
The name given to this voltage is called BACK EMF. It is generally considered to be a voltage that has very little current. In other words it cannot do any "work." But it can damage a transistor instantly. Sometimes a capacitor across the terminals of the motor will reduce the voltage and protect the driver transistor.

The Servo

The servo is a very low-cost item due to the enormous quantity produced and you have to expect some defective units are sold from the sellers on the web. For $3.00 you cannot expect every unit to be perfect and here are some of the defects and tests.



There are 4 different types of low-cost plastic-gear SERVOS. The first model to be produced allowed the arm (called a HORN) to be rotated 270° and the arm stopped at the point via a "stop" inside the servo. The electronics inside the servo did not allow the arm to pass beyond this point but sometimes the servo got jammed and would not come out of this jammed position.
The next model to be produced had no stops and if you rotated the arm past the point where the "stop" would normally be located, the electronics would rotate the arm to a position in the range of 0° to about 270°. This prevented the problem of "jamming." The model with no end stops has the ID: SG90.
A more-expensive model has now been produced with a completely different program in the microcontroller and the arm will rotate 360° and the microcontroller will accept a program to rotate the arm in a continuous rotation mode. The cost about $10.00 with shipping and you need to have a project that sends the correct signals for continuous rotation.
Some of the servos fail to work and it could be the wiper on the potentiometer not making good contact. If the arm jitters as it moves, the wiper on the pot is most likely the problem.
Finally a micro version is also available for about $10.00 with stops.
All these servos can be taken apart and the microcontroller removed and the motor connected to 2 wires so the servo becomes a motor and gearbox. This is the cheapest and smallest motor and gearbox for all sorts of applications and the internal stop needs to be removed to get continuous rotation.
If you find the plastic gears are wearing out in your application, you can buy the metal-gears version.
I have bought hundreds of servos and the ones that did not work were converted to motor/gearbox versions.
All the servos work on 4.5v to 6v and have a 3.3v regulator inside. The motor is most powerful on 6v and the supply should not be increased above 6v or 8.5v (according to spec sheets).

TESTING COMPONENTS "IN-CIRCUIT"

You can test components while they are IN CIRCUIT, but the surrounding components will have an effect on the results.
You can get all sorts of "In-Circuit" testers. They are expensive and offer little more accuracy than a multimeter.
In-Circuit testing with a multimeter can give you the same results as a tester.
All you have to do is turn the project ON and use a multimeter (set to voltage) to determine the voltage at various points. It is best to have a circuit of the equipment so you can what to expect at each point.
Only major departures from the expected can be located in this way.
Obviously the first thing to look for is burnt-out components. Then feel components such as transistors for overheating.
The look for electrolytics that may be dry. Sometimes these have changed colour or are slightly swollen.
If they are near hot components, they will be dry.
For the cost of a few dollars I change ALL THE ELECTROLYTICS in some pieces of equipment, as a dry electrolytic is very difficult to detect.
Testing a transistor "in-circuit" is firstly done with the supply ON. That's because it is quicker.
Measure the voltage between ground and collector.
In most cases you should get a voltage of about half-rail. If it is zero, or close to rail voltage, you may have a problem.
Turn off the supply and use the multimeter on low-ohms to measure all six resistances between the leads.
A low resistance in both directions on two leads will indicate a fault.
Resistors almost NEVER go "HIGH." For instance, a 22k will never go to 50k. However a low-value resistor will "burn-out" and you will read the value of the surrounding components.
Don't forget, some low-value resistors are designed to burn-out (called fusible resistors) and anytime you find a damaged low-value resistor, you will need to look for the associated semiconductor.
You can replace the resistor quickly and turn the circuit ON to see it burn out again.
Alternatively you can trace though the circuit and find the shorted semiconductor.
It's always nice to "see the fault" then "fix the fault."
Sometimes a transistor will only break-down when a voltage is present, or it may be influenced by other components.
When the piece of equipment is turned OFF, you can test for resistance values. The main thing you are looking for is "dry joints" and continuity. Dry joints occur around the termination of transformers and any components that get hot. Rather than wasting time checking for dry joints, it is better to simply go over the connections with a hot iron and fresh solder.
You may need to check the continuity of a track (trace) and it may go from one side of the PC board to the other.
Use a multimeter set to low-ohms and make sure the needle reads "zero-ohms."
It is very dangerous to do any testing on a project using a multimeter set to "amps" or "milliamps."
You cannot test "current flowing through a component" by placing the probes across a component. You will simply over-load the rest of the circuit and create a problem.
To find out if current is flowing though a circuit or a low-value resistor, turn the project ON and measure the voltage either across the component or the voltage on one end then the other.
A voltage-drop indicates current is flowing.
That's about it for testing "in-circuit." Use the rest of this eBook to help you with diagnosis.
Don't think an IN-CIRCUIT COMPONENT TESTER is going to find a fault any faster than a multimeter. They all use a multimeter principle.

SHORT CIRCUIT

SHORT CIRCUIT

Nearly every component can fail and produce an effect called a SHORT CIRCUIT.
This basically means the component takes more current than normal and it may fail completely or simply take more current and the operation of the circuit may be reduced only a small amount.
The resistance of the component may reduce a very small amount but this may have a very large effect on the operation of the circuit.
For instance, two turns in the horizontal or vertical winding of a yoke on the picture tube or monitor may arc and weld together and reduce the size of the picture on the screen, but measuring the winding will not detect the difference in resistance.
The same with the windings on a motor and a short between two winding in a transformer.
If the "short" is between two near-by turns, the change in resistance will be very small. If the "short" is between to different layers, the resistance will be reduced and it may be detected.
When a "short" occurs, the winding turns into a transformer. To be exact, an AUTO-TRANSFORMER.
In the following diagram you can see a normal winding in fig A:

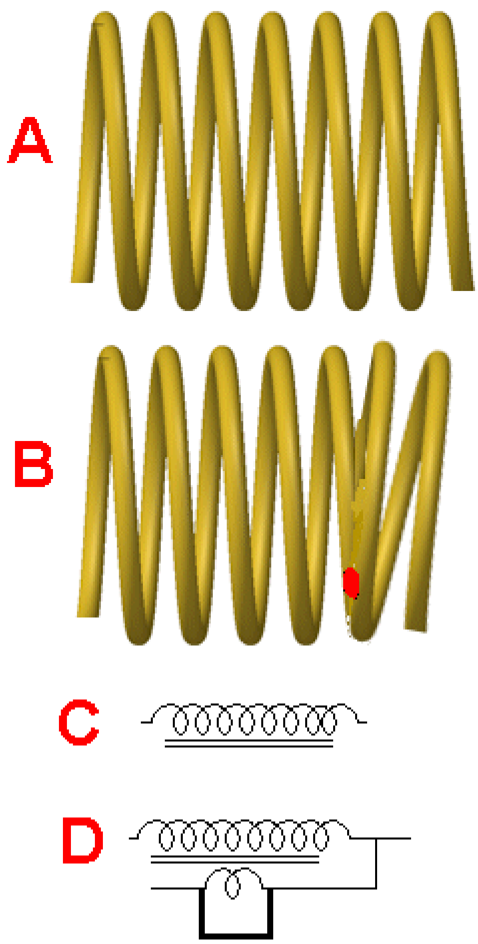


Fig B shows two turns touching each other and if the wire is enamelled, the coating has been damaged so the copper wire from the two turns is touching. This is called a SHORTED TURN.
In fig C you can see two turns touching.
In fig D the shorted-turn has been moved to the other side of the symbol to show the effect it has on the operation of the winding.

The shorted-turn is exactly like the secondary of a transformer with a "jumper" across the output.
This will produce a very high current in the secondary.
A very high current flows through the shorted turn and this changes the operation of the rest of the winding.

1. In most cases a SHORT CIRCUIT can be detected by feeling the additional heat generated by the component.
2. Next, turn off the supply and measure the resistance of the component. If it is lower than expected, the component will be faulty.
3. Next, measure the voltage across the component. If it is lower than normal, the component will be faulty.
4. Next, measure the current taken by the component. If it is higher than normal, the component will be faulty.
5. If the component is an inductor, such as a motor, coil or transformer, you can use an inductance meter. Compare a good winding with a faulty winding. Sometimes the fault will disappear because an arc develops across the fault when the component is operating.

INTERNAL AND EXTERNAL SHORTS

An **internal short** refers to two windings shorting together and the winding has a very high resistance between the winding and the frame on which it is wound. An external short refers to a winding shorting to the frame of the component - such as one of the armature windings shorting to the metal core, around which the wire is wound.
This may not be important unless another winding shorts to the metal frame and creates "**inter winding**" problems (**inner winding** problems is within the same winding).

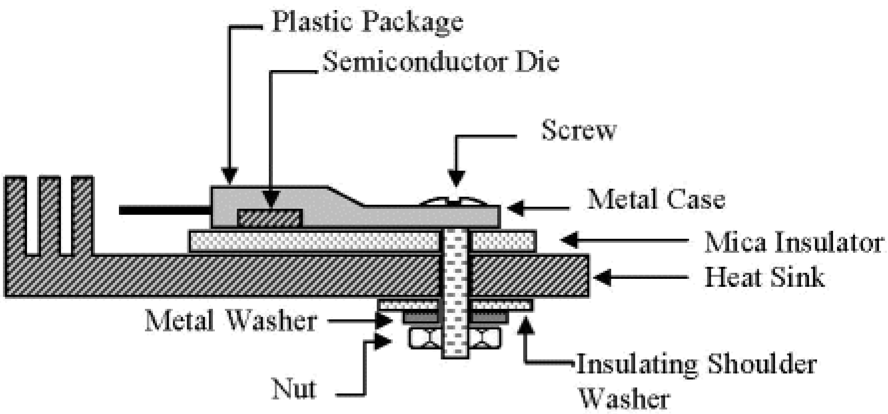
The opposite to a short circuit is an OPEN CIRCUIT.

This is generally a broken lead or contact or a wire that has "burnt-out" or been "eaten-away" by acid attack or galvanic action by water and voltage (current).
1. No current will flow when an OPEN CIRCUIT exists.
2. The voltage on each end of the OPEN CIRCUIT will not be the same.
3. Measure the current across the OPEN CIRCUIT and determine if excess current is flowing.
4. Join the two ends of the OPEN CIRCUIT and see if the circuit operates normally.

HEATSINKS

This is not an electronic component but it can certainly affect the operation of a circuit.
If you cannot hold your fingers on a heatsink, it is getting too hot. This is because the actual location where the heat is being generated is much hotter than the part you are touching.
Transistors and IC's can withstand a high temperature but if they go above this temp, they BLOW UP.
They also have a shorter life when operating at a high temperature.
The secret to a good heatsink is called an INFINITE HEATSINK.
This is the metal frame of a case.
There are lots of charts and data on choosing a heatsink but they don't take into account two factors:
Sometimes a circuit takes a very high current for a short time and this creates a high temperature gradient. This will cause the transistor to get very hot and fail.
The solution is to have two or more transistors in parallel to separate the "heat spots."
The second problem with designing a heatsink is the unknown location of the heatsink and the air-flow. Products placed on a shelf or in a cupboard will get very little air-flow.
Remember: some transistors are mounted on thermal insulators. This means the transistor will have a voltage on it but the heatsink will be zero voltage.
The temperature of the transistor will be MUCH HIGHER than the heatsink under the transistor and the transfer of the heat from the transistor to the heatsink will be very slow.
This can be the cause of the transistor failing. Sometimes the transistor will fail because

This can be the cause of the transistor failing. Sometimes the transistor will fail because insulation is high temp plastic and it gets brittle. The plastic can carbonise and leak and sometimes a voltage can flash through the insulator. Some amazing things have happened under these transistors and you may need to pull it apart and replace all the insulation.
Finally, feel the heatsink after 15 minutes and feel right up to the transistor. If you cannot touch the transistor, increase the thickness of the heatsink or use two transistors to dissipate the heat.
To design a heatsink, you have to have some idea of the size of a heatsink for the application.
Charts and data can send you in the wrong direction.
Start with a heatsink twice the recommended size and feel the temp after 15 minutes. Put the project in a cupboard and see how the temperature rises.
If possible, connect the heatsink to the metal case to get added dissipation and if you include fan-cooling, remember the fan will eventually gather dust and reduce its efficiency.
It is very difficult to explain how heat passes through a mica washer or plastic washer, but if the transistor has a copper base, the heat transfer has a value of 400. For aluminium it is 200. If it is steel, the transfer has a value of 50. For a mica sheet it is 1 and for plastic it is 0.1
Even though the sheet is very thin, the transfer is a lot less than metal-to-metal transfer.
Most references state the temperature difference is about one degree C for each watt of heat generated by the transistor.
Don't believe anything you read.
Feel the temperature yourself and if you cannot hold your finger on the transistor, fix the problem.



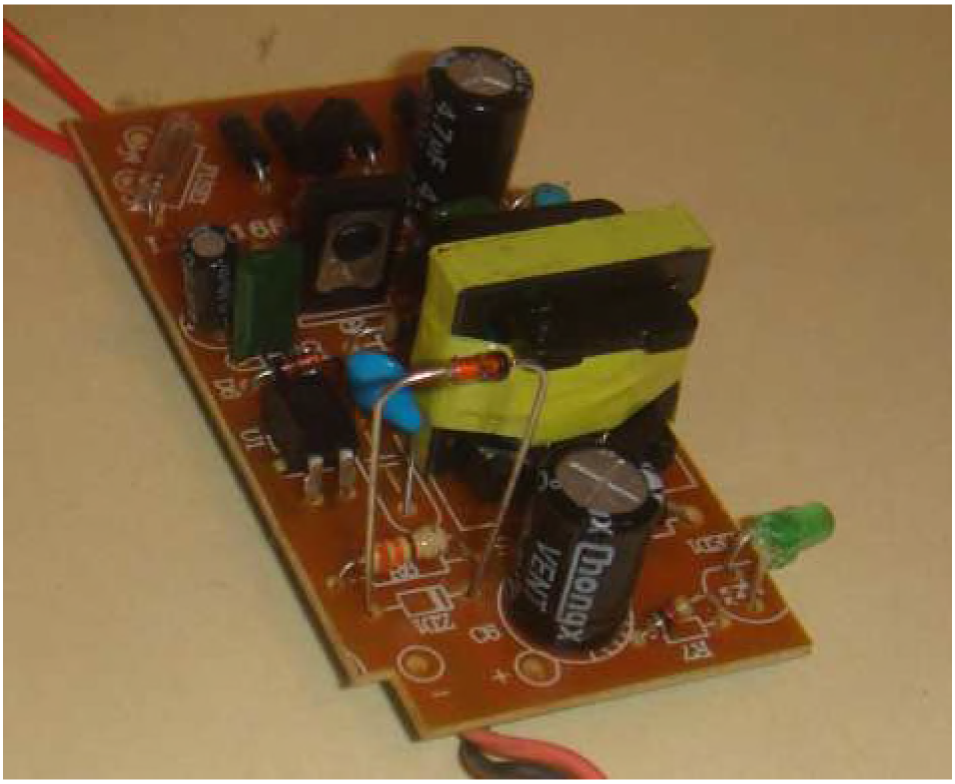
In the end, use a heatsink 50% larger than recommended.

TESTING PLUG PACKS

I do not recommend servicing a plugs pack when you can get them on eBay for a few dollars.
But there are couple of interesting things you can do with them.
Most of them have to be smashed apart, but some have screws and the 12v plug pack shown below cost just $2.50 posted.

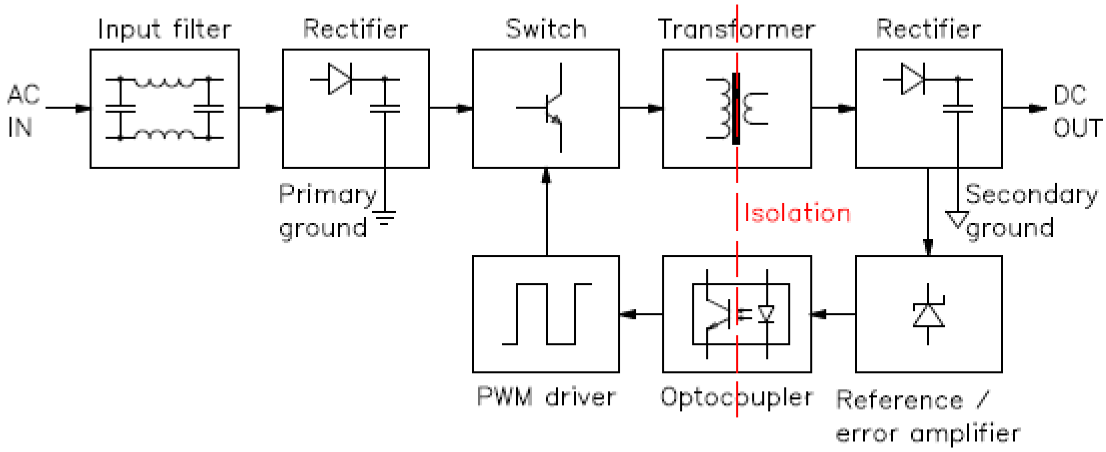
The high voltage transistor used in these circuits is a MJE13003 and I have replaced a number of these transistors in power supplies for 40 watt electronic ballasts and the circuit worked perfectly. They were not "blown-up" but just produced a faulty flickering operation.
The same transistor is used in low-voltage supplies and the output voltage is determined by a zener, (shown in the photo below) and this was changed from 12v to 15v to produce a 15v plug pack for a train throttle.
As soon as the output voltage reaches 12v or 15v, (the voltage of the zener) the circuit produces extra voltage and this is passed to a LED in an opto-coupler to turn off the

oscillator slightly on the "mains" side of the transformer. The opto-coupler provides feedback for the output-to-input and the 5,000v isolation of the opto-coupler and the insulation of the transformer produces the isolation needed to make sure the plug pack is safe to use.
When you load the output, the voltage will remain constant and the current will rise as the load increases. Theoretically this current will rise until of the transformer is reached and the increase in current on the primary side of the transformer passes through a 3.3 ohm resistor. When the load current reaches 1 amp, the current through this 3R3 resistor (I do not know the value) begins to turn off the oscillator on the mains side of the circuit and this is how both voltage and current regulating is achieved.
The first fault with these plug packs is the electros drying out and reducing capacitance.
If the high voltage transistor has blown up, its time to throw out the plug pack . . . too many parts will be damaged.
If you have spare transistors, you need to replace all the transistors in the circuit and the signal diodes and check the power diodes and electros.
Test it on the **isolating transformer** described above as it is dangerous to work on as it is a LIVE circuit and if you change lots of parts, including the fuse, it may blow up in your face if the short-circuit still exists. The isolating transformer will prevent an explosion.
These plug packs are very good for teaching you how **switch-mode circuits** work and after working on a dozen of them you will have more experience than any text book can give you.



The 3R3 current-sensing resistor is just behind the large transistor. The far electro is 4u7 @400v and the close electro is 470u @16v.

Here is a block diagram of a Switch Mode Power Supply:



The mains is converted to DC and this becomes about 315v for 240v AC mains.
We now have an oscillator that gets turned ON for a very short period of time during a cycle. It is operating on this 315v DC supply.
To start to understand how it works, the oscillator operates at 50kHz. This frequency does not change.
The transistor driving the transformer gets turned ON fully for a very short period of time and is then turned OFF.
This causes a current to flow in the primary of the transformer but because the transformer is an INDUCTOR, it takes a relatively long time for the current to increase to a high value. So, in effect, only a very small amount of current actually flows. If we kept the transistor ON, the current would increase to more than 100 amps because we have 300v available and the resistance of the transformer is only a few ohms.
So we have a real challenge. We only want the amount of energy to be equal to 12v x 1amp = 12 watts MAXIMUM.
That's what the feedback circuit via the opto-coupler does. It turns off the transistor when the output voltage reaches 12v. At the moment, no output current will be flowing so the actual wattage needed will be about 10 MILLIWATTS. And that's what the control circuit will do. It will shut off the power transistor when the output voltage reaches 12v. When we load the output, the voltage will drop slightly and the feedback circuit will increase the ON time of the power transistor to regain the 12v output.
Theoretically you can keep loading the output until more than 1 amps flows because the circuit has no detection. But this will start to overheat the transformer because it cannot pass more than a certain wattage from the primary to the secondary due to the limiting factor of the ferrite core.
So, the circuit has a current sensing resistor (in this case 3R) and as the current increases, the voltage across this resistor increases and it turns down one of the oscillator transistors.

If you still want to learn more about Switch Mode Power supplies, here's a link

http://www.giangrandi.ch/electronics/smpsfix/smpsfix.shtml

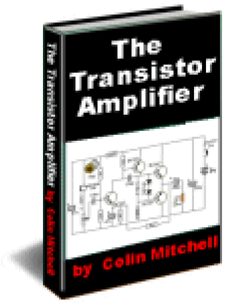
THE END

This is not the full story to learning about servicing. It is just the beginning.
We have only covered the simplest tests and shown how 90% of faults can be found by checking voltages, waveforms and looking for obvious things such as burnt out components, cracks in PC boards.
The author has fixed over 35,000 TV's, radios, stereos, VCRs and all those things that were on the market 30 years ago.
Things have not changed. It's just that some repairs cost nearly as much as buying a new product and half the customers opt for dumping a faulty item and buying the latest "flat

screen" version. That's why you have to get things through the workshop as fast and as cheaply as possible, to make a living.

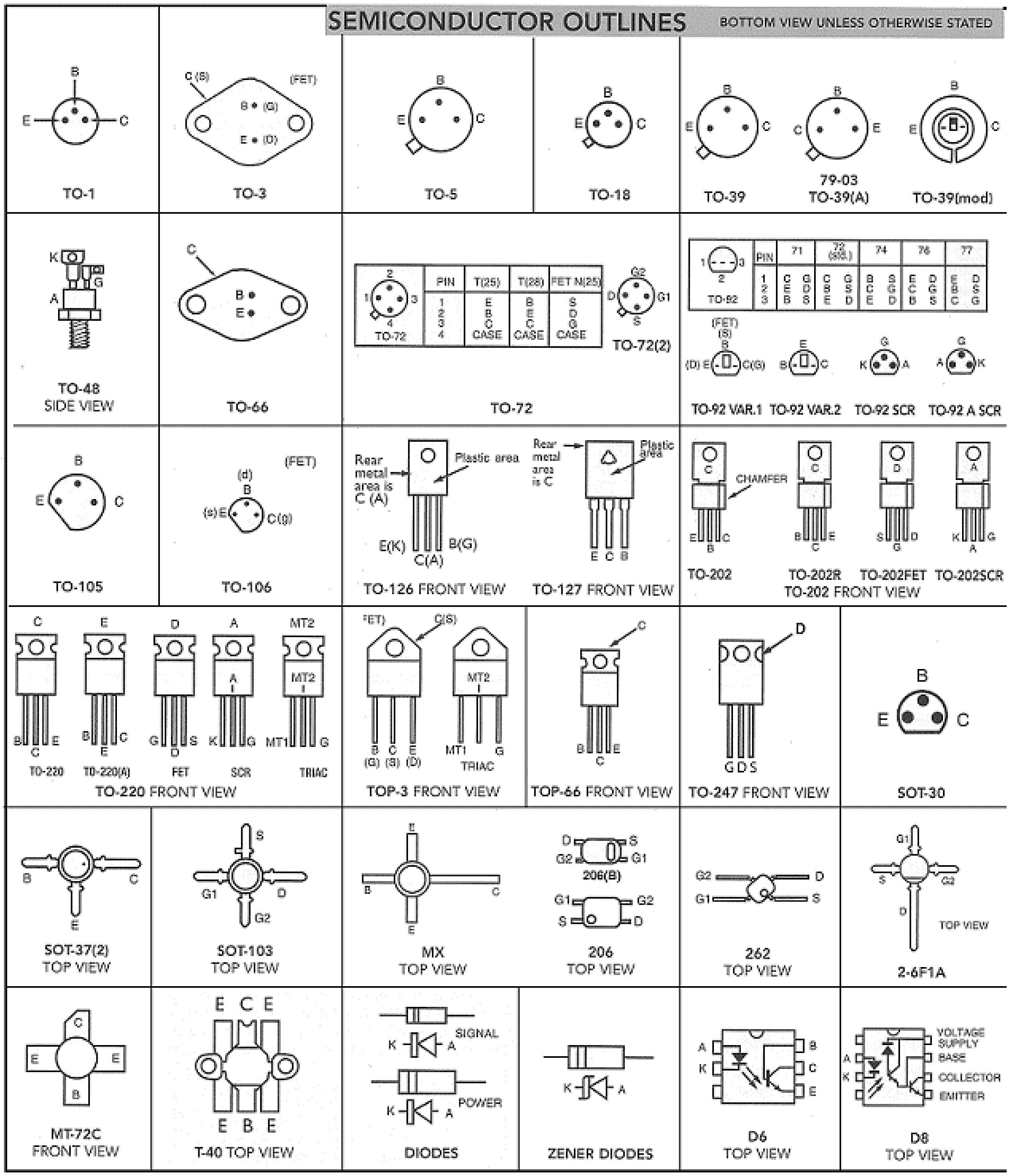
If you want any more devices added to this list, email **Colin Mitchell**.

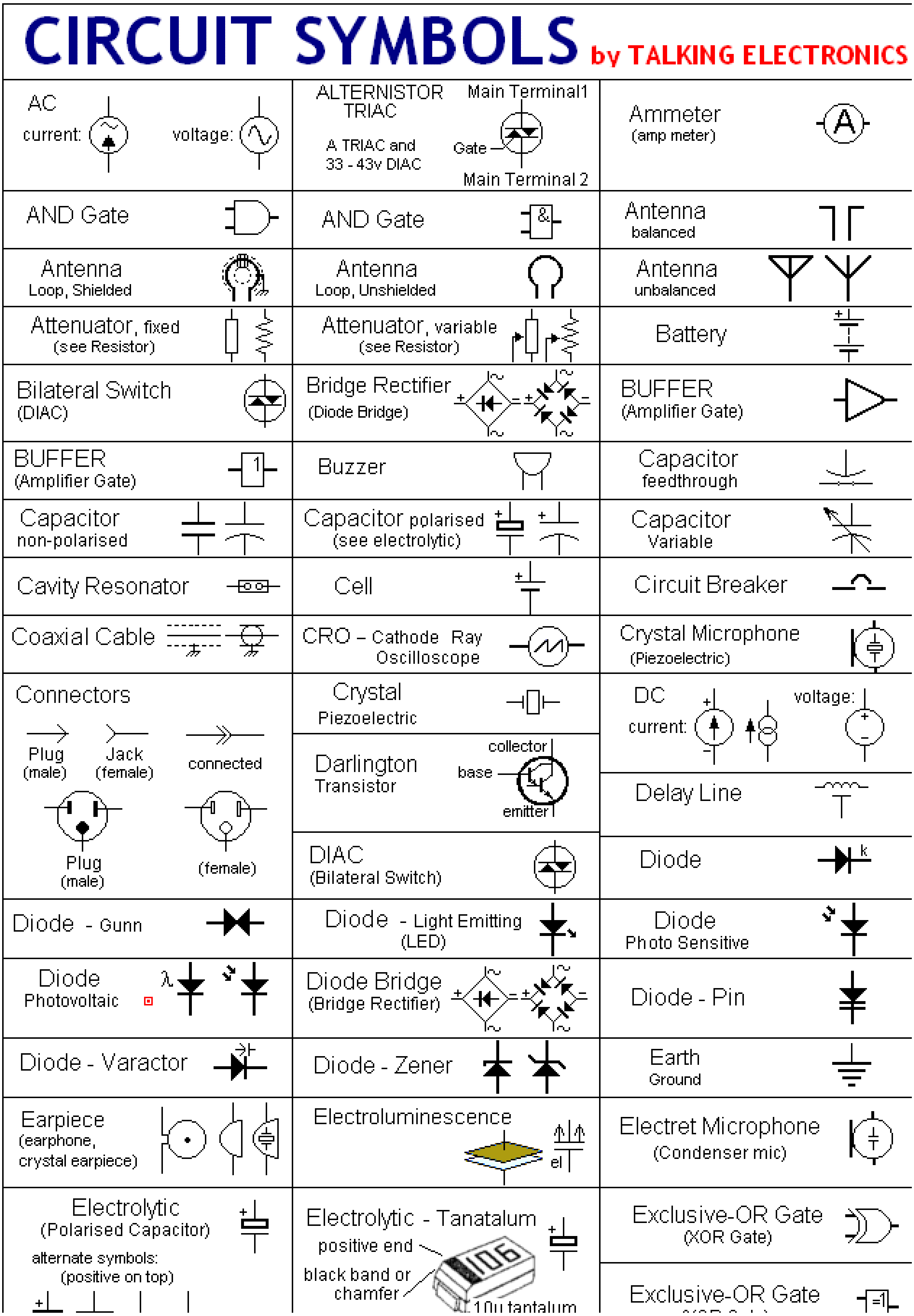
To help with understanding how a transistor circuit works, we have produced an eBook: **The Transistor Amplifier.** It covers a whole range of circuits using a transistor.

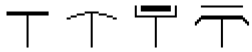
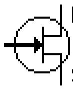
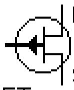
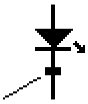


See the enormous amount of information on Talking Electronics website.

16-3-2023-


SEMICONDUCTOR OUTLINES
BOTTOM VIEW UNLESS OTHERWISE STATED
TO-1
TO-3
TO-5
TO-18
TO-39
79-03
TO-39(A)
TO-39(mod)
TO-48
SIDE VIEW
TO-66
PIN
T(25)
T(28)
FET N(25)
CASE
TO-72
TO-72(2)
TO-92
TO-92 VAR.1
TO-92 VAR.2
TO-92 SCR
TO-92 A SCR
TO-105
TO-106
Rear metal area is C (A)
Plastic area
TO-126 FRONT VIEW
Rear metal area is C
TO-127 FRONT VIEW
CHAMFER
TO-202
TO-202R
TO-202FET
TO-202SCR
TO-202 FRONT VIEW
TO-220
TO-220(A)
FET
SCR
TRIAC
TO-220 FRONT VIEW
TOP-3 FRONT VIEW
TOP-66 FRONT VIEW
TO-247 FRONT VIEW
SOT-30
SOT-37(2)
TOP VIEW
SOT-103
TOP VIEW
MX
TOP VIEW
206(B)
206
TOP VIEW
262
TOP VIEW
TOP VIEW
2-6F1A
MT-72C
FRONT VIEW
T-40 TOP VIEW
SIGNAL
POWER
DIODES
ZENER DIODES
D6
TOP VIEW
VOLTAGE SUPPLY
BASE
COLLECTOR
EMITTER
D8
TOP VIEW


CIRCUIT SYMBOLS by TALKING ELECTRONICS
AC
current:
voltage:
ALTERNISTOR
TRIAC
A TRIAC and
33 - 43v DIAC
Main Terminal1
Gate
Main Terminal 2
Ammeter
(amp meter)
A
AND Gate
AND Gate
&
Antenna
balanced
Antenna
Loop, Shielded
Antenna
Loop, Unshielded
Antenna
unbalanced
Attenuator, fixed
(see Resistor)
Attenuator, variable
(see Resistor)
Battery
Bilateral Switch
(DIAC)
Bridge Rectifier
(Diode Bridge)
BUFFER
(Amplifier Gate)
BUFFER
(Amplifier Gate)
1
Buzzer
Capacitor
feedthrough
Capacitor
non-polarised
Capacitor polarised
(see electrolytic)
Capacitor
Variable
Cavity Resonator
Cell
Circuit Breaker
Coaxial Cable
CRO – Cathode Ray
Oscilloscope
Crystal Microphone
(Piezoelectric)
Connectors
Plug
(male)
Jack
(female)
connected
Plug
(male)
(female)
Crystal
Piezoelectric
DC
current:
voltage:
Darlington
Transistor
collector
base
emitter
Delay Line
DIAC
(Bilateral Switch)
Diode
k
Diode - Gunn
Diode - Light Emitting
(LED)
Diode
Photo Sensitive
Diode
Photovoltaic
λ
Diode Bridge
(Bridge Rectifier)
Diode - Pin
Diode - Varactor
Diode - Zener
Earth
Ground
Earpiece
(earphone,
crystal earpiece)
Electroluminescence
el
Electret Microphone
(Condenser mic)
Electrolytic
(Polarised Capacitor)
alternate symbols:
(positive on top)
Electrolytic - Tanatalum
positive end
black band or
chamfer
106
10u tantalum
Exclusive-OR Gate
(XOR Gate)
Exclusive-OR Gate
=1

		(XOR Gate)
Field Effect Transistor (FET) n-channel also: N-Channel J FET Gate  Drain Source	Field Effect Transistor (FET) p-channel also: P-Channel J FET Gate  Drain Source	Flashing LED (Light Emitting Diode) (Indicates chip inside LED) 

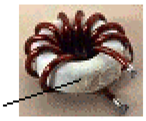
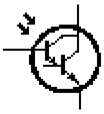
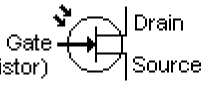
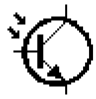
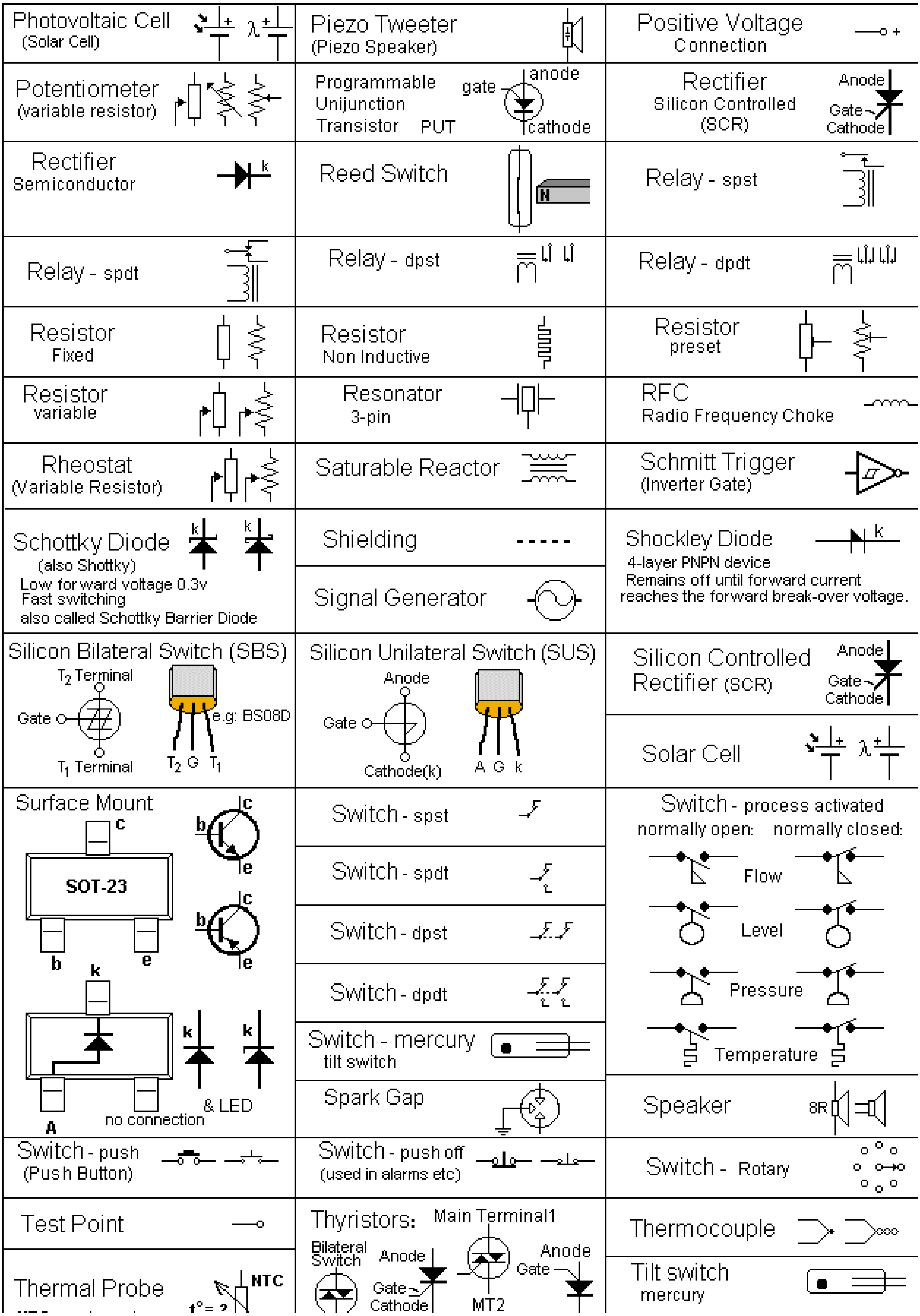
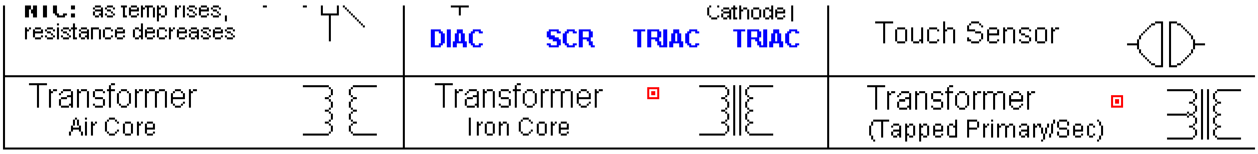
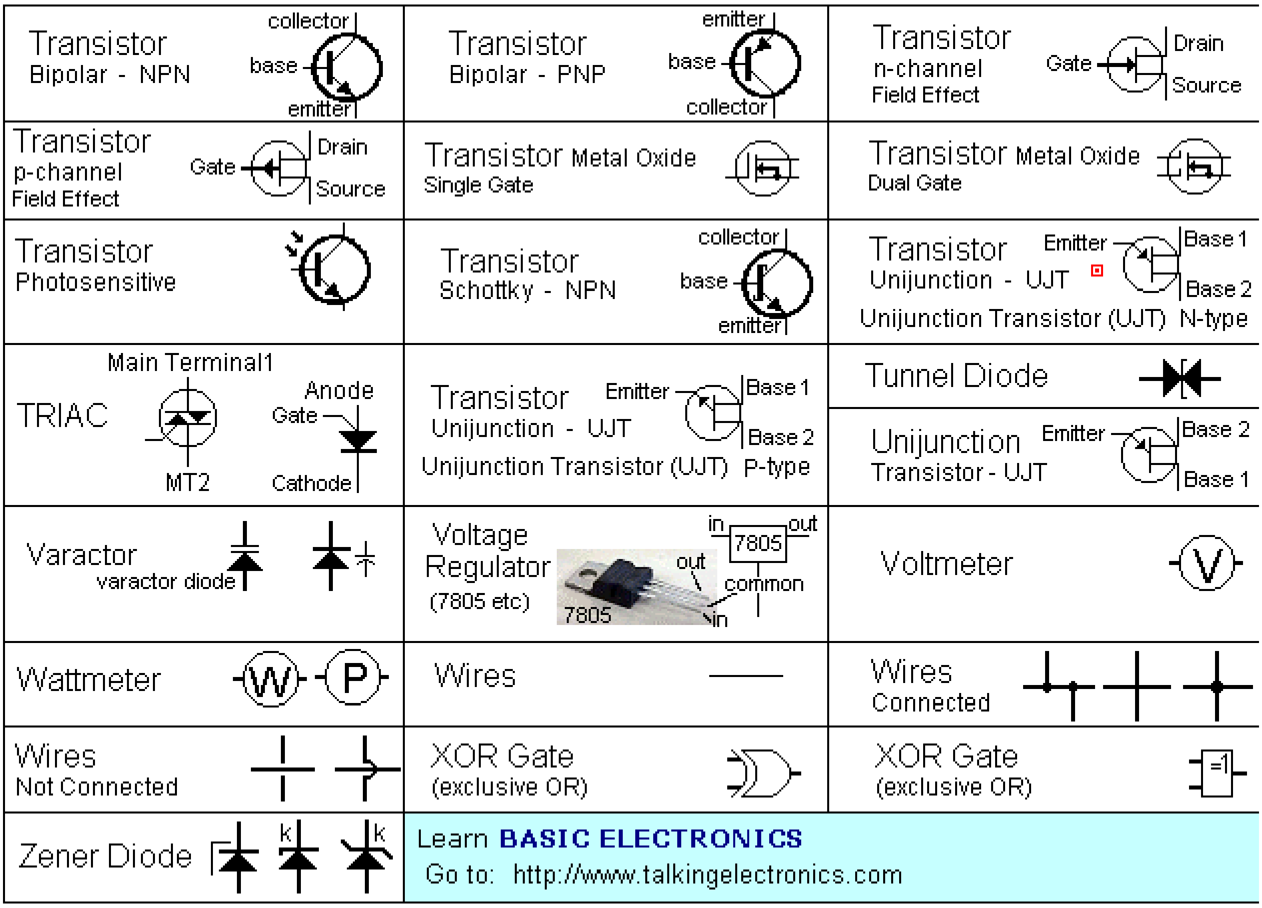
Ferrite Bead	Fuse	Galvanometer G
Globe	Ground Chassis	Ground Earth
Heater (immersion heater) (cooker etc)	IC Integrated Circuit power ground	Inductor Air Core
Headphone		Inductor Iron Core or ferrite core 
Inductor Tapped	Inductor Variable	Integrated Circuit 
Inverter (NOT Gate)	INVERTER (NOT Gate) 1	
Jack Co-axial	Jack Phone (Phone Jack)	Jack Phone (Switched)
Jack Phone (3 conductor)	Key Telegraph (Morse Key)	Lamp Incandescent
Lamp - Neon	LASCR (Light Activated Silicon Controlled Rectifier)	LDR (Light Dependent Resistor)
LASER diode laser diode photo diode	Light Emitting Diode (LED) 	Light Emitting Diode (LED - flashing) (Indicates chip inside LED)
Mercury Switch	Micro-amp meter (micro-ammeter) µA	Microphone (see Electret Mic) 
Microphone (Crystal - piezoelectric)	Milliamp meter (milli-ammeter) mA	Motor MOT
NAND Gate	NAND Gate &	Nitinol wire "Muscle wire"
Negative Voltage Connection	NOR Gate	NOR Gate
NOT Gate Inverter	NOT Gate Inverter 1	Ohm meter Ω
Operational Amplifier (Op Amp)	Optocoupler (Transistor output)	Opto Coupler (Opto-isolator) a c k e Photo-transistor output
Optocoupler (Darlington output)	Opto Coupler (Opto-isolator) a c k e TRIAC output	OR Gate
OR Gate	Oscilloscope see CRO	Outlet (Power Outlet)
Piezo Diaphragm	Photo Cell (photo sensitive resistor)	Photo Diode

Photo Darlington Transistor		Photo FET (Field Effect Transistor)		Photo Transistor	


Photovoltaic Cell
(Solar Cell)
Piezo Tweeter
(Piezo Speaker)
Positive Voltage
Connection
Potentiometer
(variable resistor)
Programmable
Unijunction
Transistor PUT
gate
anode
cathode
Rectifier
Silicon Controlled
(SCR)
Anode
Gate
Cathode
Rectifier
Semiconductor
k
Reed Switch
N
Relay - spst
Relay - spdt
Relay - dpst
Relay - dpdt
Resistor
Fixed
Resistor
Non Inductive
Resistor
preset
Resistor
variable
Resonator
3-pin
RFC
Radio Frequency Choke
Rheostat
(Variable Resistor)
Saturable Reactor
Schmitt Trigger
(Inverter Gate)
Schottky Diode
(also Shottky)
Low forward voltage 0.3v
Fast switching
also called Schottky Barrier Diode
k
Shielding
Signal Generator
Shockley Diode
4-layer PNPN device
Remains off until forward current
reaches the forward break-over voltage.
Silicon Bilateral Switch (SBS)
T2 Terminal
Gate
T1 Terminal
e.g: BS08D
T2 G T1
Silicon Unilateral Switch (SUS)
Anode
Gate
Cathode(k)
A G k
Silicon Controlled
Rectifier (SCR)
Anode
Gate
Cathode
Solar Cell
Surface Mount
SOT-23
c
b
e
k
A
no connection
& LED
Switch - spst
Switch - spdt
Switch - dpst
Switch - dpdt
Switch - mercury
tilt switch
Spark Gap
Switch - process activated
normally open:
normally closed:
Flow
Level
Pressure
Temperature
Speaker
8R
Switch - push
(Push Button)
Switch - push off
(used in alarms etc)
Switch - Rotary
Test Point
Thyristors:
Main Terminal1
Bilateral
Switch
Anode
Gate
Cathode
MT2
Thermocouple
Thermal Probe
NTC
Tilt switch
mercury


resistance decreases
DIAC
SCR
TRIAC
TRIAC
Cathode
Touch Sensor
Transformer
Air Core
Transformer
Iron Core
Transformer
(Tapped Primary/Sec)


Transistor
Bipolar - NPN
collector
base
emitter
Transistor
Bipolar - PNP
emitter
base
collector
Transistor
n-channel
Field Effect
Gate
Drain
Source
Transistor
p-channel
Field Effect
Gate
Drain
Source
Transistor Metal Oxide
Single Gate
Transistor Metal Oxide
Dual Gate
Transistor
Photosensitive
Transistor
Schottky - NPN
collector
base
emitter
Transistor
Unijunction - UJT
Emitter
Base 1
Base 2
Unijunction Transistor (UJT) N-type
Main Terminal1
TRIAC
MT2
Anode
Gate
Cathode
Transistor
Unijunction - UJT
Emitter
Base 1
Base 2
Unijunction Transistor (UJT) P-type
Tunnel Diode
Unijunction
Transistor - UJT
Emitter
Base 2
Base 1
Varactor
varactor diode
Voltage
Regulator
(7805 etc)
7805
out
in
in
out
7805
common
Voltmeter
Wattmeter
W
P
Wires
Wires
Connected
Wires
Not Connected
XOR Gate
(exclusive OR)
XOR Gate
(exclusive OR)
=1
Zener Diode
k
k
Learn BASIC ELECTRONICS
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2-3-2024