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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**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 Multimeter (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.

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 20,000 ohms/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."

MEASURING VOLTAGE
Most of the readings taken 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).
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.

![Diagram of voltage measurements](image)

**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 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
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.
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.

<table>
<thead>
<tr>
<th>THIRD BAND</th>
<th>FIRST BAND</th>
<th>SECOND BAND</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOLD</td>
<td>GREY</td>
<td>BLACK</td>
<td>100k</td>
</tr>
<tr>
<td>SILVER</td>
<td>GREY</td>
<td>BLACK</td>
<td>10k</td>
</tr>
<tr>
<td>BLACK</td>
<td>GREY</td>
<td>BLACK</td>
<td>1k</td>
</tr>
<tr>
<td>RED</td>
<td>GREY</td>
<td>BLACK</td>
<td>0.1k</td>
</tr>
<tr>
<td>YELLOW</td>
<td>GREY</td>
<td>BLACK</td>
<td>100R</td>
</tr>
<tr>
<td>GREEN</td>
<td>GREY</td>
<td>BLACK</td>
<td>10R</td>
</tr>
<tr>
<td>ROSE</td>
<td>GREY</td>
<td>BLACK</td>
<td>1R</td>
</tr>
</tbody>
</table>

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%)

<table>
<thead>
<tr>
<th>1R0</th>
<th>10R</th>
<th>100R</th>
<th>1k0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1R2</td>
<td>12R</td>
<td>120R</td>
<td>1k2</td>
</tr>
<tr>
<td>1R5</td>
<td>15R</td>
<td>150R</td>
<td>1k5</td>
</tr>
<tr>
<td>1R8</td>
<td>18R</td>
<td>180R</td>
<td>1k8</td>
</tr>
<tr>
<td>2R2</td>
<td>22R</td>
<td>220R</td>
<td>2k2</td>
</tr>
<tr>
<td>2R7</td>
<td>27R</td>
<td>270R</td>
<td>2k7</td>
</tr>
<tr>
<td>3R3</td>
<td>33R</td>
<td>330R</td>
<td>3k3</td>
</tr>
<tr>
<td>3R9</td>
<td>39R</td>
<td>390R</td>
<td>3k9</td>
</tr>
<tr>
<td>4R7</td>
<td>47R</td>
<td>470R</td>
<td>4k7</td>
</tr>
<tr>
<td>5R6</td>
<td>56R</td>
<td>560R</td>
<td>5k6</td>
</tr>
<tr>
<td>6R8</td>
<td>68R</td>
<td>680R</td>
<td>6k8</td>
</tr>
<tr>
<td>8R2</td>
<td>82R</td>
<td>820R</td>
<td>8k2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10R</th>
<th>100k</th>
<th>1M0</th>
<th>10M</th>
</tr>
</thead>
<tbody>
<tr>
<td>12k</td>
<td>120k</td>
<td>1M2</td>
<td>22M</td>
</tr>
<tr>
<td>15k</td>
<td>150k</td>
<td>1M5</td>
<td></td>
</tr>
<tr>
<td>18k</td>
<td>180k</td>
<td>1M8</td>
<td></td>
</tr>
<tr>
<td>22k</td>
<td>220k</td>
<td>2M2</td>
<td></td>
</tr>
<tr>
<td>27k</td>
<td>270k</td>
<td>2M7</td>
<td></td>
</tr>
<tr>
<td>33k</td>
<td>330k</td>
<td>3M3</td>
<td></td>
</tr>
<tr>
<td>39k</td>
<td>390k</td>
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</tr>
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<td>47k</td>
<td>470k</td>
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<td>56k</td>
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<td>68k</td>
<td>680k</td>
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<td></td>
</tr>
<tr>
<td>82k</td>
<td>820k</td>
<td>8M2</td>
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</table>

<table>
<thead>
<tr>
<th>0R0</th>
<th>0R1</th>
<th>R22</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

zero ohm (link)
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: 1R0 = 1 ohm  2R2 = 2 point 2 ohms  22R = 22 ohms
2k2 = 2,200 ohms  100k = 100,000 ohms
2M2 = 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          - colour of increasing temperature
brown
red
orange
yellow
green
blue
(indigo - that part of the spectrum between blue and violet)
violet
gray
white

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

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.**

<table>
<thead>
<tr>
<th>Value</th>
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<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10R</td>
<td>121R</td>
<td>806R</td>
<td>3k83</td>
<td>7k15</td>
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</table>

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

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<td>47k</td>
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<td>390R</td>
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### Surface Mount Resistors

<table>
<thead>
<tr>
<th>Value</th>
<th>Image</th>
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<th>Image</th>
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<tbody>
<tr>
<td>3R3</td>
<td><img src="image1.png" alt="Image" /></td>
<td>22R</td>
<td><img src="image2.png" alt="Image" /></td>
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<td>3R9</td>
<td><img src="image3.png" alt="Image" /></td>
<td>110R</td>
<td><img src="image4.png" alt="Image" /></td>
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<tr>
<td>4R7</td>
<td><img src="image5.png" alt="Image" /></td>
<td>560R</td>
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<tr>
<td>12R</td>
<td><img src="image23.png" alt="Image" /></td>
<td>560k</td>
<td><img src="image24.png" alt="Image" /></td>
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</tbody>
</table>

#### 1206 and 0805 SURFACE MOUNT RESISTORS
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 0 00 = 2,200 = 2k2
473 = 47 0 000 = 47,000 = 47k
474 = 47 0 0000 = 470,000 = 470k
105 = 10 0 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.

THE COMPLETE RANGE OF SM RESISTOR MARKINGS

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

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

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:

<table>
<thead>
<tr>
<th>Three Digit Examples</th>
<th>Four Digit Examples</th>
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</thead>
<tbody>
<tr>
<td>330 is 33 ohms - not 330 ohms</td>
<td>1000 is 100 ohms - not 1000 ohms</td>
</tr>
<tr>
<td>221 is 220 ohms</td>
<td>4992 is 49 900 ohms, or 49k9</td>
</tr>
<tr>
<td>683 is 68 000 ohms, or 68k</td>
<td>1623 is 162 000 ohms, or 162k</td>
</tr>
<tr>
<td>105 is 1 000 000 ohms, or</td>
<td>0R56 or R56 is</td>
</tr>
</tbody>
</table>
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.

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<td>422</td>
<td>77</td>
<td>619</td>
</tr>
<tr>
<td>14</td>
<td>137</td>
<td>30</td>
<td>200</td>
<td>46</td>
<td>294</td>
<td>62</td>
<td>432</td>
<td>78</td>
<td>634</td>
</tr>
<tr>
<td>15</td>
<td>140</td>
<td>31</td>
<td>205</td>
<td>47</td>
<td>301</td>
<td>63</td>
<td>442</td>
<td>79</td>
<td>649</td>
</tr>
<tr>
<td>16</td>
<td>143</td>
<td>32</td>
<td>210</td>
<td>48</td>
<td>309</td>
<td>64</td>
<td>453</td>
<td>80</td>
<td>665</td>
</tr>
</tbody>
</table>

The multiplier letters are as follows:

<table>
<thead>
<tr>
<th>letter</th>
<th>mult</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>100000</td>
</tr>
<tr>
<td>E</td>
<td>10000</td>
</tr>
<tr>
<td>D</td>
<td>1000</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>X or S</td>
<td>0.1</td>
</tr>
<tr>
<td>Y or R</td>
<td>0.01</td>
</tr>
</tbody>
</table>

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:
Chip resistors come in the following styles and ratings:

<table>
<thead>
<tr>
<th>Power Rating</th>
<th>EIA marking code for surface mount (SMD) resistors</th>
</tr>
</thead>
<tbody>
<tr>
<td>01S = 1R</td>
<td>01F = 10M</td>
</tr>
<tr>
<td>02S = 1R02</td>
<td>18F = 15M</td>
</tr>
<tr>
<td>03S = 1R05</td>
<td>30F = 20M</td>
</tr>
<tr>
<td>04S = 1R07</td>
<td></td>
</tr>
<tr>
<td>05S = 1R1</td>
<td></td>
</tr>
<tr>
<td>06S = 1R13</td>
<td></td>
</tr>
<tr>
<td>07S = 1R15</td>
<td></td>
</tr>
<tr>
<td>08S = 1R18</td>
<td></td>
</tr>
<tr>
<td>09S = 1R21</td>
<td></td>
</tr>
<tr>
<td>10S = 1R24</td>
<td></td>
</tr>
<tr>
<td>11S = 1R27</td>
<td></td>
</tr>
<tr>
<td>12S = 1R3</td>
<td></td>
</tr>
<tr>
<td>13S = 1R33</td>
<td></td>
</tr>
<tr>
<td>14S = 1R37</td>
<td></td>
</tr>
<tr>
<td>15S = 1R4</td>
<td></td>
</tr>
<tr>
<td>16S = 1R43</td>
<td></td>
</tr>
<tr>
<td>17S = 1R47</td>
<td></td>
</tr>
<tr>
<td>18S = 1R5</td>
<td></td>
</tr>
<tr>
<td>19S = 1R54</td>
<td></td>
</tr>
<tr>
<td>20S = 1R58</td>
<td></td>
</tr>
<tr>
<td>21S = 1R62</td>
<td></td>
</tr>
<tr>
<td>22S = 1R65</td>
<td></td>
</tr>
<tr>
<td>23S = 1R69</td>
<td></td>
</tr>
<tr>
<td>24S = 1R74</td>
<td></td>
</tr>
<tr>
<td>25S = 1R78</td>
<td></td>
</tr>
<tr>
<td>26S = 1R82</td>
<td></td>
</tr>
<tr>
<td>27S = 1R87</td>
<td></td>
</tr>
<tr>
<td>28S = 1R91</td>
<td></td>
</tr>
<tr>
<td>29S = 1R96</td>
<td></td>
</tr>
<tr>
<td>30S = 2R0</td>
<td></td>
</tr>
<tr>
<td>31S = 2R05</td>
<td></td>
</tr>
<tr>
<td>32S = 2R10</td>
<td></td>
</tr>
<tr>
<td>33S = 2R15</td>
<td></td>
</tr>
<tr>
<td>34S = 2R21</td>
<td></td>
</tr>
<tr>
<td>35S = 2R26</td>
<td></td>
</tr>
<tr>
<td>36S = 2R32</td>
<td></td>
</tr>
<tr>
<td>37S = 2R37</td>
<td></td>
</tr>
<tr>
<td>38S = 2R43</td>
<td></td>
</tr>
<tr>
<td>39S = 2R49</td>
<td></td>
</tr>
<tr>
<td>40S = 2R55</td>
<td></td>
</tr>
<tr>
<td>41S = 2R61</td>
<td></td>
</tr>
<tr>
<td>42S = 2R67</td>
<td></td>
</tr>
<tr>
<td>43S = 2R74</td>
<td></td>
</tr>
<tr>
<td>44S = 2R80</td>
<td></td>
</tr>
<tr>
<td>45S = 2R87</td>
<td></td>
</tr>
<tr>
<td>46S = 2R94</td>
<td></td>
</tr>
<tr>
<td>47S = 3R01</td>
<td></td>
</tr>
<tr>
<td>48S = 3R09</td>
<td></td>
</tr>
<tr>
<td>49S = 3R16</td>
<td></td>
</tr>
<tr>
<td>50S = 3R24</td>
<td></td>
</tr>
</tbody>
</table>

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.

Tolerance: 0.1%, 0.5%, 1%, 5%

Temperature Coefficient: 25ppm 50ppm 100ppm
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:

<table>
<thead>
<tr>
<th>SURFACE MOUNT RESISTOR PACK</th>
<th>$14.20</th>
<th>including pack and post</th>
</tr>
</thead>
<tbody>
<tr>
<td>SURFACE MOUNT CAPACITOR PACK</td>
<td>$23.80</td>
<td>including pack and post</td>
</tr>
<tr>
<td>SURFACE MOUNT DIODE PACK</td>
<td>$10.00</td>
<td>including pack and post</td>
</tr>
<tr>
<td>SURFACE MOUNT TRANSISTOR PACK</td>
<td>$10.00</td>
<td>including pack and post</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Required Value</th>
<th>R1</th>
<th>Series/Parallel</th>
<th>R2</th>
<th>Actual value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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).

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 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 resistors 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.
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.

**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.
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.

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.
"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.

FOCUS POTS
Focus pots quite often 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  \( R=V/I = 2.6/2.6 = 1\) ohm. 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 Diagram]

**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**

All these components come 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 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.

TESTING COILS, INDUCTORS and YOKES

Coils inductors and yokes are just an extension of a length 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, however 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.

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!

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.

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.

**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. 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. 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.

![Capacitor Diagram](image)

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

![Capacitor Diagram](image)

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.
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

<table>
<thead>
<tr>
<th>Colour</th>
<th>Digit A</th>
<th>Digit B</th>
<th>Multiplier</th>
<th>Tolerance (T) &gt; 10pf</th>
<th>Tolerance (T) &lt; 10pf</th>
<th>Temperature Coefficient (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>x1</td>
<td>± 20%</td>
<td>± 2.0pF</td>
<td></td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>x10</td>
<td>± 1%</td>
<td>± 0.1pF</td>
<td>-33x10^{-6}</td>
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<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>x100</td>
<td>± 2%</td>
<td>± 0.25pF</td>
<td>-75x10^{-6}</td>
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<tr>
<td>Orange</td>
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<td>3</td>
<td>x1,000</td>
<td>± 3%</td>
<td></td>
<td>-150x10^{-6}</td>
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<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>x10,000</td>
<td>± 4%</td>
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<td>-220x10^{-6}</td>
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<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>x100,000</td>
<td>± 5%</td>
<td>± 0.5pF</td>
<td>-330x10^{-6}</td>
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<tr>
<td>Blue</td>
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<td>6</td>
<td>x1,000,000</td>
<td></td>
<td></td>
<td>-470x10^{-6}</td>
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<tr>
<td>Violet</td>
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<td></td>
<td></td>
<td>-750x10^{-6}</td>
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<td>Grey</td>
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<td>8</td>
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<td>+80%, -20%</td>
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<td></td>
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<td>White</td>
<td>9</td>
<td>9</td>
<td>x0.1</td>
<td>± 10%</td>
<td>± 1.0pF</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
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<td></td>
<td>x0.1</td>
<td>± 5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver</td>
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<td></td>
<td>x0.01</td>
<td>± 10%</td>
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<tr>
<td>Pico Farads (pF)</td>
<td>Nano Farads (nF)</td>
<td>Micro Farads (μF)</td>
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<td></td>
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<tr>
<td>100</td>
<td>0.1</td>
<td>0.001</td>
<td></td>
<td></td>
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<tr>
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<td>10,000,000</td>
<td>10,000</td>
<td>100</td>
<td></td>
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<tr>
<td>100,000,000</td>
<td>100,000</td>
<td>100</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Pic</th>
<th>Cap Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>✽ = polarized</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Ceramic
- Mica
  (silver mica)
- Plastic
  Film
  (polyethylene
  polystyrene)
- Tantalum
  ✽
- OSCON
  ✽
- Aluminum
  Electrolytic
  ✽
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.

Electrolytics are available in 1u, 2u, 3u, 4u, 7u, 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.

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The "voltage" or "working voltage" can be: 3.3v, 10v, 16v, 25v, 63v, 100v, 200v and higher.

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.
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")
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.

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:

| Capacitor 1 | Capacitor 2 | Total
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1n 200v</td>
<td>1n 200v</td>
<td>2n 200v</td>
</tr>
<tr>
<td>1n 200v</td>
<td>10n 50v</td>
<td>10n 50v</td>
</tr>
<tr>
<td>47n 50v</td>
<td>5n 100v</td>
<td></td>
</tr>
<tr>
<td>47n 200v</td>
<td>47n 200v</td>
<td>23n 400v</td>
</tr>
</tbody>
</table>

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.

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.

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 3watt or 5watt resistor on jumper leads and keep them connected for a few seconds to fully discharge the electro.
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.

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](image)

**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. 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.

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.

Here is the equivalent circuit:

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."

---

**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.

**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:

[Diagram of LED tester]

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.

**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.
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.

![Circuit diagram](image)

**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.

**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 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 through A, B, C, D now passes through 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 (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:


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 cause a short-circuit.

However when the appliance is connected to the main 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:

![Diagram of isolation transformer](image)

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.

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 old TV's 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 very careful.

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
If the transformer has loaded your isolating transformer it will be faulty. Mains transformers are approx 15 VA for 500gm, 30VA for 1kgm 50VA for 2kgm 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 will be 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.

**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:

![Opto Coupler Schematic](image)

**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 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.

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 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, however some transistors are available with built-in resistors between base and emitter (to save space on the board) and these transistors are often used in digital circuits. The transistor will amplify analogue signals but when the signal is 0v then immediately goes to a voltage above 0.7v, the transistor is in a DIGITAL CIRCUIT and the transistor is called a DIGITAL TRANSISTOR. It is tested like an ordinary transistor but the low value resistor between base and emitter will produce a low reading in both directions.

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.

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 be 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.

**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-leded 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.
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

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**SCR Tester**

![SCR Tester Diagram]

**SCR with Transistors**

![SCR with Transistors Diagram]
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.

**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.

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**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.

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**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.

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**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.

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**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.

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 for a faulty cell.

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. 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 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 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:

**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."

**PIEZO DIAPHRAGM**  **PIEZO BUZZER**
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.
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/LogicProbeMkIIIB/LogicProbeMk-IIIB.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

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.

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**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 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 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."

**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 through 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](#):

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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 in 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.

**SOLDERING**
Here are three 30-minute videos on soldering.
1. **TOOLS**
2. Soldering components
3. Soldering [SURFACE MOUNT](#) components

**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 through 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.

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.

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See the enormous amount of information on Talking Electronics website.
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<tr>
<td>Ferrite Bead</td>
<td><img src="image" alt="Ferrite Bead" /></td>
<td>Fuse</td>
<td><img src="image" alt="Fuse" /></td>
<td>Galvanometer</td>
<td><img src="image" alt="Galvanometer" /></td>
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<tr>
<td>Globe</td>
<td><img src="image" alt="Globe" /></td>
<td>Ground Chassis</td>
<td><img src="image" alt="Ground Chassis" /></td>
<td>Ground Earth</td>
<td><img src="image" alt="Ground Earth" /></td>
</tr>
<tr>
<td>Heater (immersion heater) (cooker etc)</td>
<td><img src="image" alt="Heater" /></td>
<td>IC Integrated Circuit</td>
<td><img src="image" alt="IC Integrated Circuit" /></td>
<td>Inductor Core</td>
<td><img src="image" alt="Inductor Core" /></td>
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<tr>
<td>Headphone</td>
<td><img src="image" alt="Headphone" /></td>
<td>Inductor Variable</td>
<td><img src="image" alt="Inductor Variable" /></td>
<td>Integrated Circuit</td>
<td><img src="image" alt="Integrated Circuit" /></td>
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<tr>
<td>Inductor Tapped</td>
<td><img src="image" alt="Inductor Tapped" /></td>
<td>INVERTER (NOT Gate)</td>
<td><img src="image" alt="INVERTER (NOT Gate)" /></td>
<td>Jack Phone (Switched)</td>
<td><img src="image" alt="Jack Phone (Switched)" /></td>
</tr>
<tr>
<td>Jack Co-axial</td>
<td><img src="image" alt="Jack Co-axial" /></td>
<td>Jack Phone (Phone Jack)</td>
<td><img src="image" alt="Jack Phone (Phone Jack)" /></td>
<td>Lamp Incandescent</td>
<td><img src="image" alt="Lamp Incandescent" /></td>
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<tr>
<td>Jack Phone (3 conductor)</td>
<td><img src="image" alt="Jack Phone (3 conductor)" /></td>
<td>Key Telegraph (Morse Key)</td>
<td><img src="image" alt="Key Telegraph (Morse Key)" /></td>
<td>LASCR (Light Activated Silicon Controlled Rectifier)</td>
<td><img src="image" alt="LASCR (Light Activated Silicon Controlled Rectifier)" /></td>
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<tr>
<td>Lamp - Neon</td>
<td><img src="image" alt="Lamp - Neon" /></td>
<td>Light Emitting Diode (LED)</td>
<td><img src="image" alt="Light Emitting Diode (LED)" /></td>
<td>Light Emitting Diode (LED - flashing)</td>
<td><img src="image" alt="Light Emitting Diode (LED - flashing)" /></td>
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<tr>
<td>LASER diode</td>
<td><img src="image" alt="LASER diode" /></td>
<td>Micro-amp meter (micro-ammeter)</td>
<td><img src="image" alt="Micro-amp meter (micro-ammeter)" /></td>
<td>Microphone (see Electret Mic)</td>
<td><img src="image" alt="Microphone (see Electret Mic)" /></td>
</tr>
<tr>
<td>Mercury Switch</td>
<td><img src="image" alt="Mercury Switch" /></td>
<td>Milliamp meter (milli-ammeter)</td>
<td><img src="image" alt="Milliamp meter (milli-ammeter)" /></td>
<td>Motor</td>
<td><img src="image" alt="Motor" /></td>
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<tr>
<td>Microphone (Crystal - piezoelectric)</td>
<td><img src="image" alt="Microphone (Crystal - piezoelectric)" /></td>
<td>NAND Gate</td>
<td><img src="image" alt="NAND Gate" /></td>
<td>NOR Gate</td>
<td><img src="image" alt="NOR Gate" /></td>
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<tr>
<td>Negative Voltage Connection</td>
<td><img src="image" alt="Negative Voltage Connection" /></td>
<td>NOT Gate Inverter</td>
<td><img src="image" alt="NOT Gate Inverter" /></td>
<td>Ohm meter</td>
<td><img src="image" alt="Ohm meter" /></td>
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<tr>
<td>Operational Amplifier (Op Amp)</td>
<td><img src="image" alt="Operational Amplifier (Op Amp)" /></td>
<td>Optocoupler (Transistor output)</td>
<td><img src="image" alt="Optocoupler (Transistor output)" /></td>
<td>Opto Coupler (Opto-isolator)</td>
<td><img src="image" alt="Opto Coupler (Opto-isolator)" /></td>
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<tr>
<td>Optocoupler (Darlington output)</td>
<td><img src="image" alt="Optocoupler (Darlington output)" /></td>
<td>Oscilloscope see CRO</td>
<td><img src="image" alt="Oscilloscope see CRO" /></td>
<td>Outlet (Power Outlet)</td>
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<tr>
<td>OR Gate</td>
<td><img src="image" alt="OR Gate" /></td>
<td>Photo Cell (photo sensitive resistor)</td>
<td><img src="image" alt="Photo Cell (photo sensitive resistor)" /></td>
<td>Photo Diode</td>
<td><img src="image" alt="Photo Diode" /></td>
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<tr>
<td>Piezo Diaphragm</td>
<td><img src="image" alt="Piezo Diaphragm" /></td>
<td>Photo FET (Field Effect Transistor)</td>
<td><img src="image" alt="Photo FET (Field Effect Transistor)" /></td>
<td>Photo Transistor</td>
<td><img src="image" alt="Photo Transistor" /></td>
</tr>
<tr>
<td>Photovoltaic Cell (Solar Cell)</td>
<td>Piezo Tweeter (Piezo Speaker)</td>
<td>Positive Voltage Connection</td>
<td></td>
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</tr>
<tr>
<td>Potentiometer (variable resistor)</td>
<td>Programmable Unijunction Transistor PUT</td>
<td>Rectifier Silicon Controlled (SCR)</td>
<td></td>
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<tr>
<td>Rectifier Semiconductor</td>
<td>Reed Switch</td>
<td>Anode - cathode</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Relay - spdt</td>
<td>Relay - dpst</td>
<td>Relay - dpst</td>
<td></td>
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</tr>
<tr>
<td>Resistor Fixed</td>
<td>Resistor Non Inductive</td>
<td>Resistor preset</td>
<td></td>
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<tr>
<td>Resistor variable</td>
<td>Resonator 3-pin</td>
<td>RFC Radio Frequency Choke</td>
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<tr>
<td>Rheostat (Variable Resistor)</td>
<td>Saturable Reactor</td>
<td>Schmitt Trigger (Inverter Gate)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schottky Diode (also Shottky)</td>
<td>Shielding</td>
<td>Shockley Diode 4-layer PNPN device remains off until forward current reaches the forward break-over voltage.</td>
<td></td>
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<tr>
<td>Silicon Bilateral Switch (SBS)</td>
<td>Silicon Unilateral Switch (SUS)</td>
<td>Silicon Controlled Rectifier (SCR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Mount</td>
<td>Switch - spst Switch - dpst Switch - dpdt</td>
<td>Switch - process activated normally open: normally closed:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Point</td>
<td>Thyristors: Main Terminal1</td>
<td>Thermocouple Tilt switch mercury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Probe NTC: as temp rises, resistance decreases</td>
<td>Diac SCR TRIAC TRIAC</td>
<td>Touch Sensor</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Transformer Air Core</td>
<td>Transformer Iron Core (Tapped Primary/Secondary)</td>
<td>Transformer (Tapped Primary/Secondary)</td>
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</tbody>
</table>
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