

South Bristol Amateur Radio Club

Lesson 13 - Construction

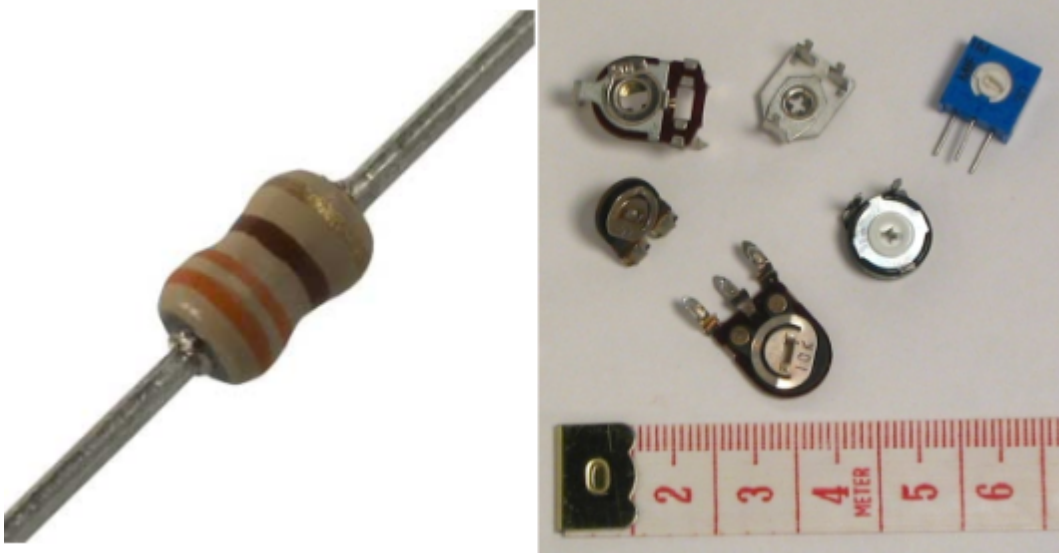
Syllabus 10a.1, 10b.1, 10b.2 10b.3, 10b.4, 10b.5, 10c.1

Component Recognition

There is no simple way to cover this, and in truth the exam will not show you a picture of something and ask you to identify it. Essentially if you develop an interest in the construction or repair of equipment you will get used to recognising the common components. The construction project that you are completing on your own will help as will the following practical sessions.

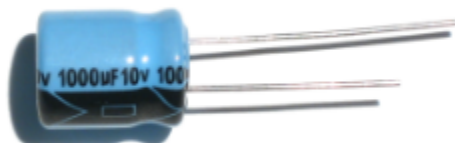
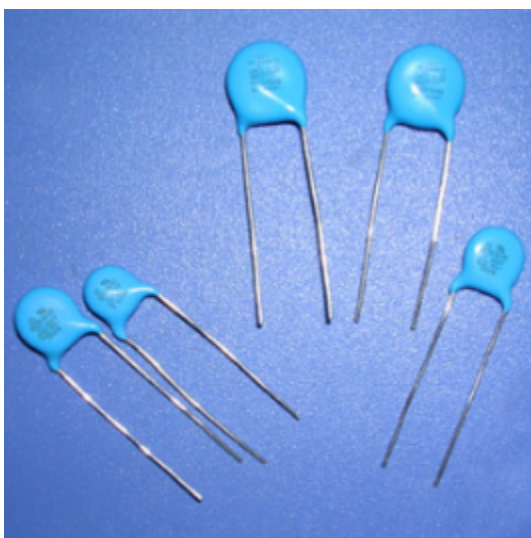
Note that there are an almost infinite variety of forms that similar components can take and therefore it is not possible to provide a definitive set of images. However common forms have been included as an aide memoir.

At times components can be very similar. In the club air band receiver kit construction many of us, including highly experienced members confused a fixed inductor with a resistor, so be warned.

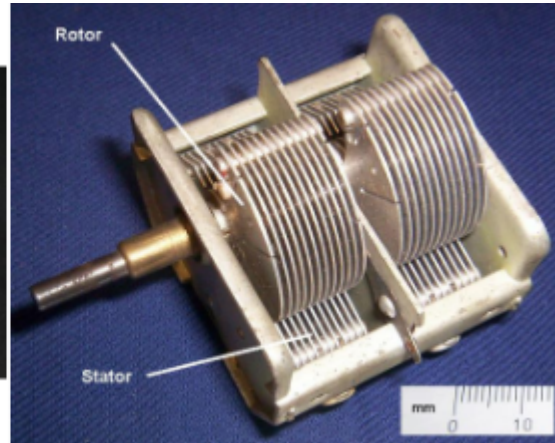


Above Left: Fixed Resistor

Above Right: Variable Resistors and Potentiometers



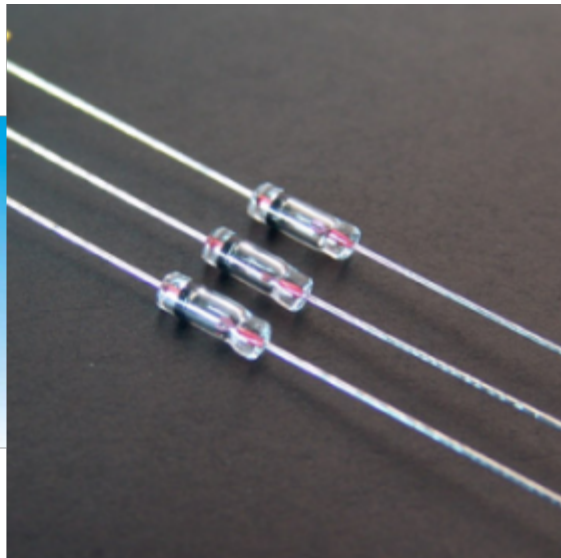
Above Left: Ceramic Capacitors
Above Right: Electrolytic Capacitor



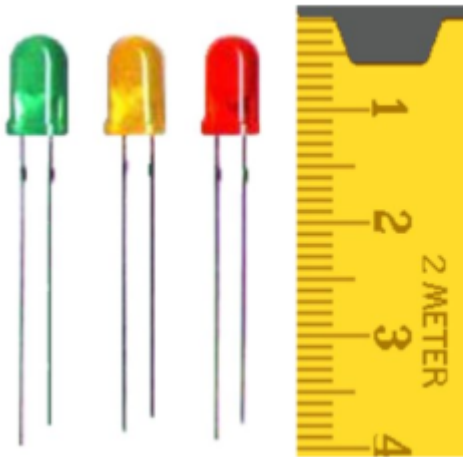
Above Left: Selection of Capacitors
Above Right: Variable Capacitor



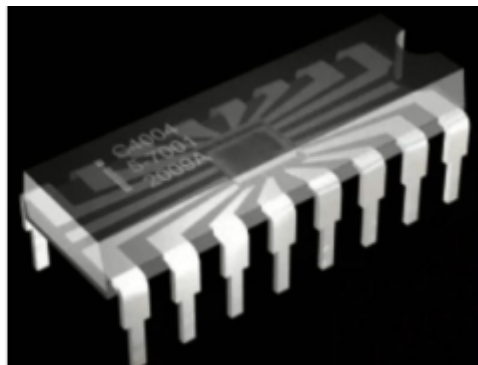
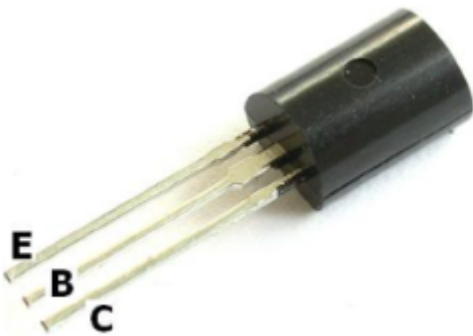
Above Left: Transformer
Above Right: Inductors



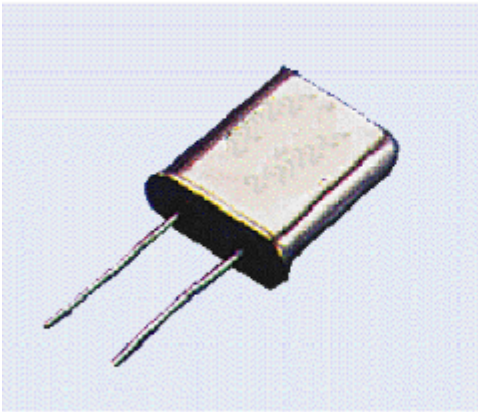
Above Left: Selection of Transformers
Above Right: Germanium Diodes



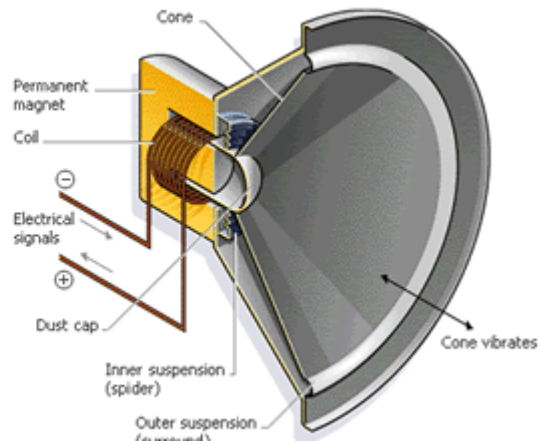
Above Left: Light Emitting Diodes
Above Right: Varicap Diode



Above Left: Bipolar Transistor
Above Right: Integrated Circuit



Above Left: Crystal
Above Right: Microphone



Above Left: Loudspeakers
Above Right: Speaker Cut-Away

Soldering

Syllabus 10b.1

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a relatively low melting point. Soft soldering is characterized by the melting point of the filler metal, which is below 400°C (800°F). The filler metal used in the process is called solder.

In a soldering process, heat is applied to the parts to be joined, causing the solder to melt and be drawn into the joint by capillary action and to bond to the materials to be joined by wetting action. After the metal cools, the resulting joints are not as strong as the base metal, but have adequate strength, electrical conductivity, and water-tightness for many uses. Soldering is an ancient technique mentioned in the Bible and there is evidence that it was employed up to 5000 years ago in Mesopotamia.

For hand soldering of electronic components, the heat source tool should be selected to provide

adequate heat for the size of joint to be completed. A 100 watt soldering iron will provide too much heat for printed circuit boards, while a 15 watt iron will not provide enough heat for large electrical connectors. Using a tool with too high a temperature can damage sensitive components, but protracted heating by a tool that is too cool or under powered can also cause extensive heat damage. Typically general purpose soldering irons around 25watts are the best starting point.

Solders

Syllabus 10b.2

Soldering filler materials are available in many different alloys for differing applications. In electronics assembly, the eutectic alloy of 63% tin and 37% lead (or 60/40, which is almost identical in performance to the eutectic) has been the alloy of choice, although new Health & Safety regulations are outlawing this.

A eutectic formulation has several advantages for soldering; chief among these is the coincidence of the liquidus and solidus temperatures, i.e. the absence of a plastic phase. This allows for quicker wetting out as the solder heats up, and quicker set up as the solder cools. A non-eutectic formulation must remain still as the temperature drops through the liquidus and solidus temperatures. Any differential movement during the plastic phase may result in cracks, giving an unreliable joint. Additionally, a eutectic formulation has the lowest possible melting point, which minimizes heat stress on electronic components during soldering.

Common solder alloys are mixtures of tin and lead, respectively:

63/37: melts at 183°C (361.4°F) (eutectic: the only mixture that melts at a point, instead of over a range)

60/40: melts between 183–190°C (361–374°F)

50/50: melts between 185–215°C (365–419°F)

Lead-free solder alloys melt around 250°C (482°F), depending on their composition.

For environmental reasons, 'no-lead' solders are becoming more widely used. Unfortunately most 'no-lead' solders are not eutectic formulations, making it more difficult to create reliable joints with them.

Lead-free electronic soldering

More recently environmental legislation has specifically targeted the wide use of lead in the electronics industry. The RoHS directives in Europe require many new electronic circuit boards to be lead free by 1 July 2006, mostly in the consumer goods industry, but in some others as well.

Many new technical challenges have arisen with this endeavour. For instance, traditional lead-free solders have a significantly higher melting point than lead-based solders, which renders them unsuitable for use with heat-sensitive electronic components and their plastic packaging. To overcome this problem, solder alloys with a high silver content and no lead have been developed with a melting point slightly lower than many lead-free solders, but still much higher than traditional tin/lead solders.

Lead-free construction has also extended to components, pins, and connectors. Most of these pins used copper frames, and either lead, tin, gold or other finishes. Tin finishes are the most popular of lead-free finishes. Nevertheless, this brings up the issue of how to deal with tin whiskers.

Flux

In high-temperature metal joining processes (welding, brazing and soldering), the primary purpose of flux is to prevent oxidation of the base and filler materials. Tin-lead solder, for example, attaches very well to copper, but poorly to the various oxides of copper, which form quickly at soldering temperatures. Flux is a substance which is nearly inert at room temperature, but which becomes strongly reducing at elevated temperatures, preventing the formation of metal oxides. Secondly, flux acts as a wetting agent in the soldering process, reducing the surface tension of the molten solder and causing it to better wet out the parts to be joined.

Fluxes currently available include water-soluble fluxes (no VOC's required for removal) and 'no-clean' fluxes which are mild enough to not require removal at all. Performance of the flux needs to be carefully evaluated; a very mild 'no-clean' flux might be perfectly acceptable for production equipment, but not give adequate performance for a poorly-controlled hand-soldering operation.

Traditional rosin fluxes are available in non-activated (R), mildly activated (RMA) and activated (RA) formulations. RA and RMA fluxes contain rosin combined with an activating agent, typically an acid, which increases the wettability of metals to which it is applied by removing existing oxides. The residue resulting from the use of RA flux is corrosive and must be cleaned off the piece being soldered. RMA flux is formulated to result in a residue which is not significantly corrosive, with cleaning being preferred but optional.

Soldering Different Metals

Syllabus 10b.3

Not all metals are easy to work with when soldering. Metals such as tin, copper and brass are good whereas aluminium and steel can be problematic and require special techniques. Fortunately in radio we are usually dealing with the more amenable metals so the problems associated with aluminium and steel rarely crop up or can be avoided.

Applications and Basic Soldering Techniques

Syllabus 10b4, 10b5

One of the most frequent application of soldering is assembling electronic components to printed circuit boards (PCBs). Jewellery components are assembled and repaired by soldering. Soldering is also used to join lead came and copper foil in stained glass work.

Some examples of solder types and their applications are tin-lead (general purpose), tin-zinc for joining aluminium, lead-silver for strength at higher than room temperature, cadmium-silver for strength at high temperatures, zinc-aluminium for aluminium and corrosion resistance, and tin-silver and tin-bismuth for electronics.

Methods

Soldering operations can be performed with hand tools, one joint at a time, or en masse on a production line. Hand soldering is typically performed with a soldering iron, soldering gun, or a torch, or occasionally a hot-air pencil. All soldered joints require the same elements of:

- cleaning of the metal parts to be joined;
- fitting up the joint;
- heating the parts;

- applying flux (tinning);
- applying the filler (solder);
- removing heat and holding the assembly still until the filler metal has completely solidified.

Depending on the nature of flux material used, cleaning of the joints may be required after they have cooled.

The process of *tinning* should be enlarged upon. It is the application of a small amount of solder or flux to both the clean tip of the soldering iron and the legs of the component being fitted.

The tip of the soldering iron is cleaned with a wet sponge and then a small amount of flux or a multi-cored solder containing flux is applied to the tip. Similarly the legs of the components are also cleaned and similarly and individually treated. This pre-application helps with heat transfer and prevents oxides forming on the tip of the soldering iron.

When making a solder joint, it is important to ensure that the joint is adequately heated without overheating. Many electronic components have plastic surrounds which are not tolerant of prolonged exposure to high temperatures. Too much heat may damage the components, but too little heat and the solder won't melt and flow correctly resulting in a dry joint. These dry joints can be particularly difficult to track down.

A heat sink may be used on the leads of heat sensitive components to reduce heat transfer to the component. This is especially applicable to germanium parts. (Note the heat sink will mean the use of more heat to complete the joint.) If all metal surfaces are not properly fluxed and brought above the melting temperature of the solder in use, the result will be an unreliable 'cold soldered' joint.

To simplify soldering, beginners are usually advised to apply the soldering iron and the solder separately to the joint, rather than the solder being applied direct to the iron. When sufficient solder is applied, the solder wire is removed. When the surfaces are adequately heated, the solder will flow around the joint. The iron is then removed from the joint.

Since non-eutectic solder alloys have a small plastic range, the joint must not be moved until the solder has cooled down through both the liquidus and solidus temperatures. Visually, a good solder joint will appear smooth and shiny, with the outline of the soldered wire clearly visible. A matte grey surface is a good indicator of a joint that was moved during soldering. Too little solder will result in a dry and unreliable joint; too much solder (the 'solder blob' very familiar to beginners) is not necessarily unsound, but tends to mean poor wetting. With some fluxes, flux residue remaining on the joint may need to be removed, using water, alcohol or other solvents compatible with the process. Excess solder and unconsumed flux and residue is sometimes wiped from the soldering iron tip between joints. The tip of the iron is kept wetted with solder ("tinned") when hot to minimize oxidation and corrosion of the tip itself.

Soldering defects

Various problems may arise in the soldering process which lead to joints which are non functional either immediately or after a period of use. The most common defect when hand-soldering results from the parts being joined not exceeding the solders liquidus temperature, resulting in a "cold solder" joint. This is usually the result of the soldering iron being used to heat the solder directly, rather than the parts themselves. Properly done, the iron heats the parts to be connected, which in

turn melt the solder, guaranteeing adequate heat in the joined parts for thorough wetting.

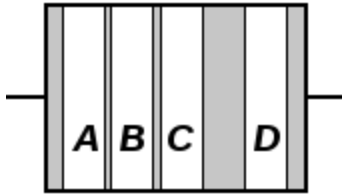
An improperly selected or applied flux can cause joint failure, or if not properly cleaned off the joint, may corrode the metals in the joint over time and cause eventual joint failure. Without flux the joint may not be clean, or may be oxidized, resulting in an unsound joint.

Movement of metals being soldered before the solder has cooled will cause a highly unreliable cracked joint.

Resistor Colour Codes

Syllabus 10c.1

Resistor values are always coded in Ω and represented by a series of colour bands.



- Band A is first significant figure of component value
- Band B is the second significant figure
- Band C is the decimal multiplier
- Band D if present, indicates tolerance of value in percent (no colour means $\pm 20\%$)

Resistors manufactured for military use may also include a fifth band which indicates component failure rate (reliability), however we can ignore this for all practical purposes.

Tight tolerance resistors may have three bands for significant figures rather than two, and/or an additional band indicating temperature coefficient, in units of ppm/K, again though these are rare enough to be ignored at this stage.

All colour coded components will have at least two value bands and a multiplier; other bands are optional.

The Standard EIA colour Code Table per EIA-RS-279 is as follows:

Colour	1 st Band	2 nd Band	3 rd Band (Multiplier)	4 th Band (Tolerance)
Black	0	0	$\times 10^0$ (0 noughts)	
Brown	1	1	$\times 10^1$ (1 nought)	+/- 1% (F)
Red	2	2	$\times 10^2$ (2 noughts)	+/- 2% (G)
Orange	3	3	$\times 10^3$ (3 noughts)	
Yellow	4	4	$\times 10^4$ (4 noughts)	
Green	5	5	$\times 10^5$ (5 noughts)	+/- 0.5% (D)
Blue	6	6	$\times 10^6$ (6 noughts)	+/- 0.25% (C)
Violet	7	7	$\times 10^7$ (7 noughts)	+/- 0.1% (B)
Gray	8	8	$\times 10^8$ (8 noughts)	+/- 0.05% (A)
White	9	9	$\times 10^9$ (9 noughts)	
Gold			$\times 10^{-1}$ (1 tenth)	+/- 5% (J)
Silver			$\times 10^{-2}$ (1 hundredth)	+/- 10% (K)
None				+/- 20% (M)

Note: red to violet are the colours of the rainbow where red is low energy and violet is higher energy.

Now let's consider a couple of examples:

Let us take a resistor with bands of yellow – violet – red - gold will have first digit 4 (yellow in table), second digit 7 (violet), followed by 2 (red) zeros: 4,700 Ω , sometimes written as 4k7 Ω . Gold signifies that the tolerance is $\pm 5\%$, so the real resistance could lie anywhere between 4,465 and 4,935 Ω .

Now consider a resistor which (read left to right) displays the colours yellow, violet, yellow, brown. We take the first two bands as the value, giving us 4, 7. Then the third band, another yellow, gives us the multiplier 104. Our total value is then 47 x 104 Ω , totalling 470,000 Ω or 470kilo Ω . Our brown is then a tolerance of $\pm 1\%$, giving a range of 465,300 Ω – 474,700 Ω .

A much older resistor colour coding scheme, still to be found on components in vintage radios, is known as 'body-tip-spot'. Here the colour of the resistor body was the first digit, the colour of one tip or end of the resistor was the second, and the colour of the spot on the body was the multiplier.

Many resistors now utilise a 4 band value as opposed to the three band system described above. Reading these resistors is no more complicated than reading three band resistors, it is only the number of significant figures in the value that differs.

When reading a 4 band resistor the first three bands are the value and the 4th band is the multiplier and the 5th band the tolerance. Thus a resistor which shows red – red – black – brown – brown. The first 4 bands give the value and the fifth band gives the tolerance. Red-red-black gives 2-2-0 and brown gives x10 or 2200 Ω which is 2.2k Ω . The brown tolerance gives +/- 1%.

Next Lesson

Practical sessions covering the construction of a basic circuit and the making of measurements to check out the theories we've been using to date.

Lesson 13 – Summary

At the end of this lesson you should be able to:

- Identify resistors, capacitors including fixed, variable and electrolytic types, inductors, transformers, diodes, transistors, integrated circuits, crystals, microphones and loudspeakers.
- Understand that soldering is a method of joining metal wires and components using a hot soldering iron to melt the solder.
- Recall that many solders contain a flux to help the solder to flow and to remove the layer of oxide on the surfaces to be joined.
- Recall that some metals are easy to solder and some are difficult.
- Understand that the tip of the soldering iron has to be cleaned to help remove any oxide and then "tinned" to prevent the oxide reforming and to improve the conduction of heat to the joint.
- Recall the reason for tinning wires prior to soldering.
- Recall that it is necessary to make joints reasonably quickly to avoid damage to components, and that most construction faults stem from poor (dry) joints.
- Recall the resistor colour code, colours 0 – 9 with gold as multiplier. Recall silver (10%) and gold (5%) as tolerance bands. Identify the value of a resistor between 1 Ω and 9M Ω from the E12 series.