Material here presented is taken from the CD-ROM 'The COMPLETE GUIDE to Vintage Radios' by TONY THOMPSON BSc, Cert. Ed., available from Vintage Radio World www.vintageradioworld.co.uk

SAFETY NOTICE
All vintage radios should be considered to be inherently unsafe until they can be tested to prove otherwise. You are STRONGLY ADVISED to read and understand the safety information provided before ANY set is connected to power or ANY work begins.

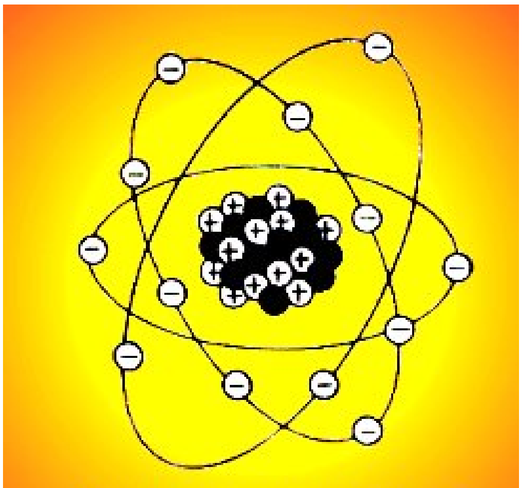
SECTION 1: BASIC THEORY

The CONDUCTOR AND INSULATOR

All matter is made from atoms. Atoms are so small that even the most powerful microscope cannot see them. Grouped together, atoms form molecules from which everything in the universe is made.

Here is a simplified view of the atom. The central nucleus is built up from protons and neutrons, around which spin a varying number of electrons. Protons are said to carry a positive electrical charge, neutrons no charge at all, and electrons a negative charge.

Typically, the number of protons in the central core balances the number of electrons and as the protons are positive, there exists an equal and opposite charge to that of the negative electrons. The result, on the average, is zero charge on the atom as a whole because the equal and opposite polarities cancel each other.


A simplified representation of an atom

Materials classed as insulators have tightly packed clouds of electrons and there are very few electrons capable of leaving the parent atom. In conducting materials such as metals, electrons are more loosely bound to the individual atom and those in the outer orbits are free to move at random from one atom to another. When an atom loses an electron to another atom, it becomes positively charged due to the loss of that electron's quantity of negative charge. Atoms so charged are said to be ionised. Because opposite charges attract and like charges repel, another electron will be attracted from a nearby atom. This happens continually with all the atoms of conducting materials. So, although there may be individual atoms with a positive charge, over a group of atoms there is effectively neither a positive or negative charge. This is a state we call neutral.

Remember that a positive charge (a lack of electrons) will attract electrons. If by some means such a charge is placed on one end of a conducting wire, it will exert an attraction on the electrons surrounding the atoms in the wire. This lack of electrons is called a difference of electric potential (PD). However, the term Potential Difference is best used to describe the function of a resistor, which, when a current is flowing through it has a difference of potential – voltage - across it.

Batteries are handy sources of power. Consider what takes place when we touch a short length of copper wire to the positive terminal of a battery.

There will be a movement of electrons toward the attracting positive charge (positive = a lack of negative, remember). Equilibrium is reached when the atoms in the wire that are deficient in electrons – therefore positively charged - exert sufficient back pressure on the electrons. This means that only a momentary shift in electron position has occurred, like the tug-of-war rope being pulled tight, resulting in a strain or static charge but no actual flow of electrons.

You can create static charges by combing your hair with a plastic comb, rubbing a balloon on your clothing, or sometimes even walking on certain kinds of man-made carpet. Even wearing insulated shoes can create static charge, especially on hot, dry days.

Right: Lightning is an example of static discharge.

The effects of these charges are interesting, but their uses, as far as the subject matter of this book is concerned, are limited. To make electricity work for us, we need to create the continuous flow of electricity; to create electric current. One way to do this would be to connect the free end of our length of copper wire to the negative terminal of the battery. Because the battery acts like a pump, by chemical means constantly creating an imbalance of charge, electrons will now flow in one direction around the circuit, toward the positive terminal, with replacement electrons flowing into the circuit from the negative battery terminal. With our length of copper wire forming a complete circuit with our battery, we have the two essentials to create a flow of current – a source of electric potential and a circuit to convert the potential into current. It is not a sensible thing to do, however, as we have no control over the resultant current. We have turned the tap full on and a heavy current will flow, limited only by the capacity of the battery. i.e. its internal resistance, to supply electrons at its negative terminal to replace those flowing through the wire into the positive terminal. A small dry battery will rapidly overheat and fail under such uncontrolled conditions. A car battery or wet cell accumulator could burn out the conducting wire.

Whenever a conductor, such as our length of copper wire, is connected directly from positive to negative it is said to have created a short circuit, meaning a circuit with effectively no resistance to the flow of current.

Rather than wasting the power of the current in heating up the battery and the wire, we want it to do something useful so we need to have control over the flow, so we need a way to limit the movement of the electrons. And, of course, we have one in the form of resistance, which is an electrical property of many substances. Resistance comes in several forms. We have already met it in the battery and the wire. It was resistance that caused them to heat up. This is in effect frictional resistance. No conductor of electricity is perfect (unless you count superconductors cooled to a point close to absolute zero!) and there is always *some* resistance and this can be useful, for example in the electric kettle, cooker, fire, toaster or any appliance that uses a resistive element. It is the resistance of the element, due partly to the kind of metal used and partly to the method of construction (cross section and length of the resistive metal wire), that causes the heating effect.

Edison type filament light bulbs work in a similar fashion only in this case the filament wire inside the bulb is very fine and would, in air, normally burn out if a current was passed through it. The glass bulb is evacuated and has no oxygen in it. Without oxygen, the filament cannot burn even though it will become very hot. It can glow white hot, so hot it gives off light.

What if we want to prevent entirely any current from flowing? That's where insulators come in. Most plastics, dry wood, ceramic and rubber are effective insulators and are used to prevent us from getting electric shocks. Plastics of varying kinds form protective 'insulated' coatings around conducting cables.

Fuses are safety devices, designed to fail in the event of excess current flow. There are several types and sizes of glass fuse used in radio, but with vintage valve equipment fuses are usually about an inch in length. They may be placed in series with the HT (high tension) supply that powers a radio, or in series with the mains input to a radio set.

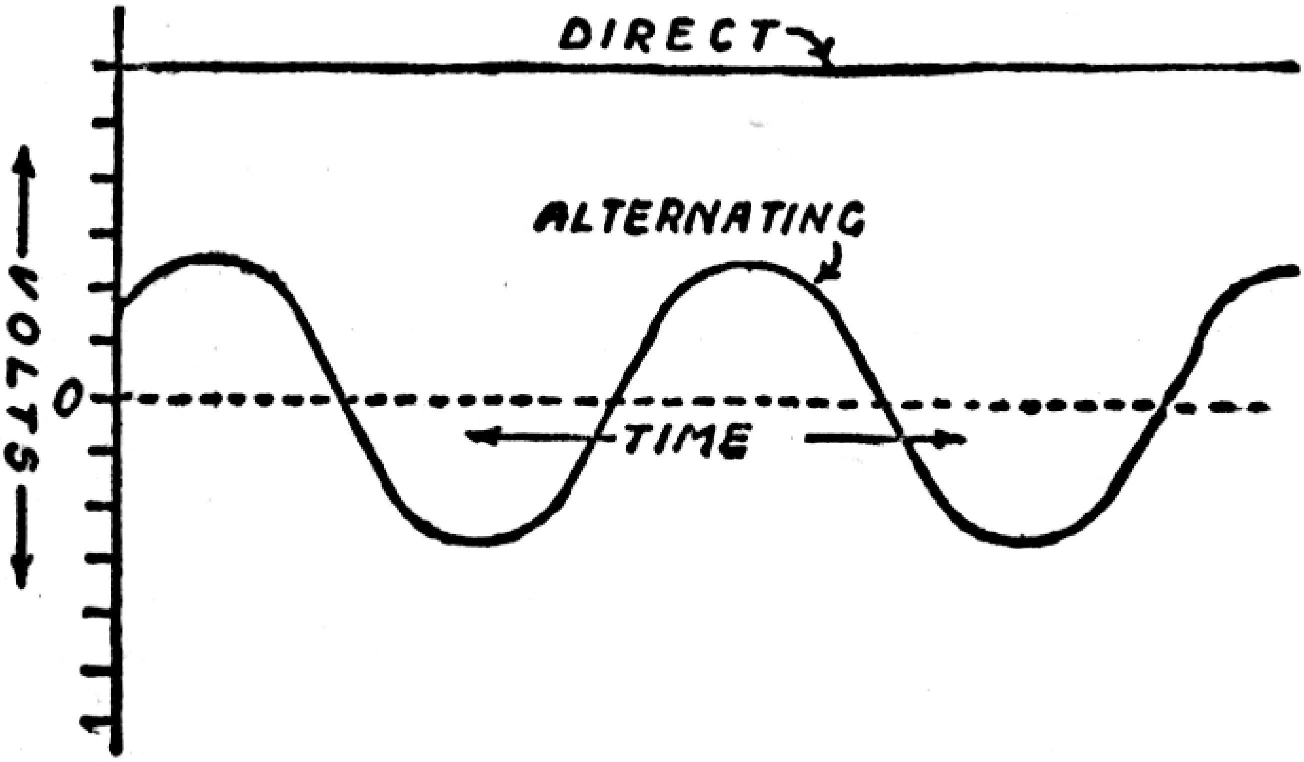


Fig. 6.—Graph illustrating difference between Direct and Alternating Current.

So far, only direct current flow has been described. Direct current (DC) flows in only one direction around a circuit. Which direction? From negative to positive, if you are talking about electron flow. If we arranged a switching system to continuously reverse the polarity of the power, the direction of current flow would continually change, too, and current would flow back and forth around the circuit at the switching rate. In other words, it would alternate. The mains supply is alternating current (AC) for good reason: AC can be stepped up or down in voltage at will, via transformers. Although DC mains were supplied to parts of the UK in years gone by, it is much more efficient to distribute very high voltage AC via the national grid, stepping down where convenient to 240 volts, the nominal supply voltage pressure in the UK. The direction change occurs 50 times a second (50 cycles, nowadays called 50 Hz, after Hertz, the German physicist).

The mains supply is not switched rapidly in polarity, though. In fact it isn't switched at all. The AC generators that create it cycle smoothly through from a peak in power in one direction, falling through zero voltage/current to rise to a similar but opposite peak. I stated 'smoothly' but that's an ideal and the actual wave shape created may fall some way short of that. It is direct current (DC) that valves need. This leaves mains powered radio designers with the need to convert the AC power into DC, of course, because amplifying valves cannot function on high voltage AC supplies.

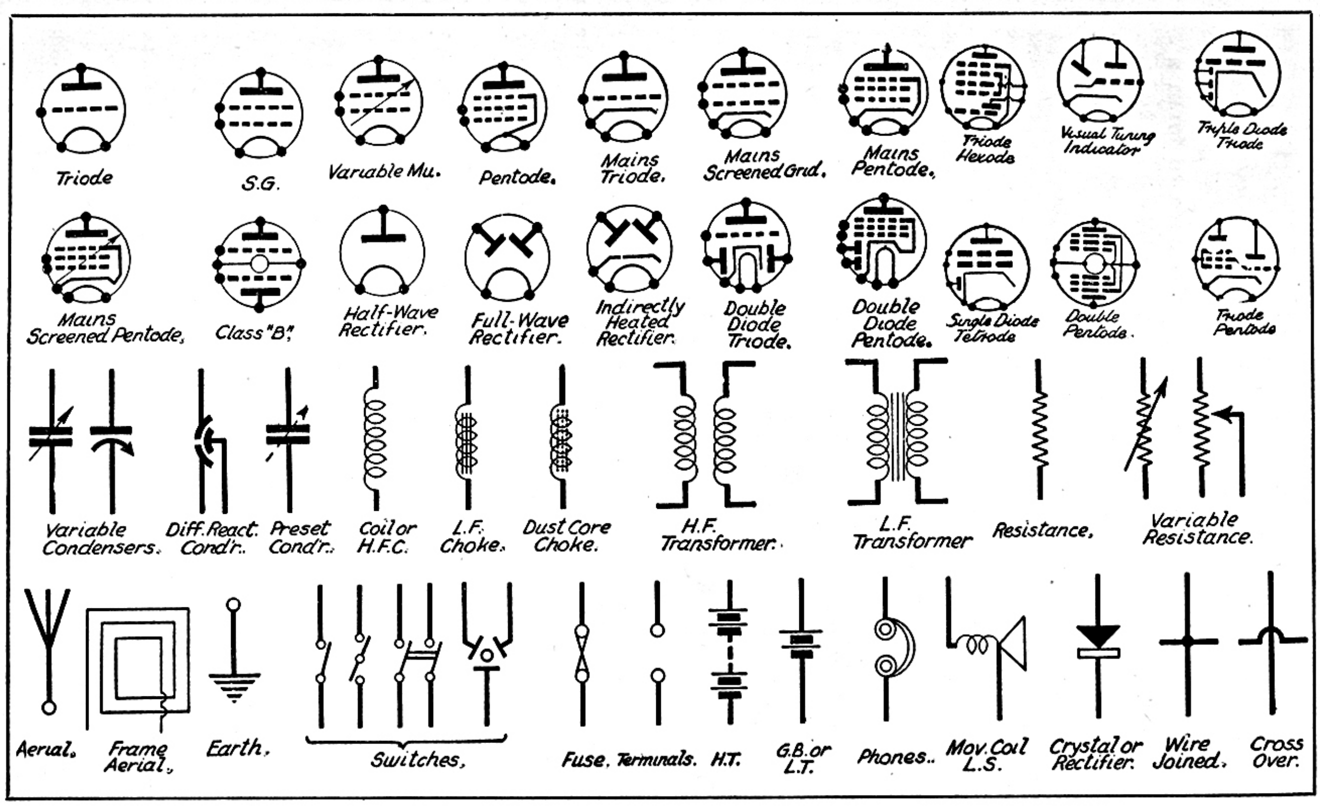
Basic facts: An electric current can only flow when a circuit is complete. Switches are devices that break complete circuits. A broken circuit is said to be 'open-circuit'. There are two forms of electric

current. One is direct (DC), the other is alternating (AC). Valves usually need high DC potentials in order to function.

The last point is significant. Because valves – for the most part – require high or at least relatively high voltage potentials to function, it is essential that the would-be vintage radio restorer works within the safety guidelines given below.

Schematic diagrams and their function

Schematics (or theoretical circuits) are collections of component symbols joined up to make circuits and are also known as circuit diagrams or theoretical diagrams. No surprises there, then. The complex appearance of these is a passing effect; with a little effort the reader soon learns to identify both individual components and the methods by which the may be interconnected. No matter how apparently complex, all theoretical circuitry consists of the same relatively few component symbols.



Component symbols from the early 1930s

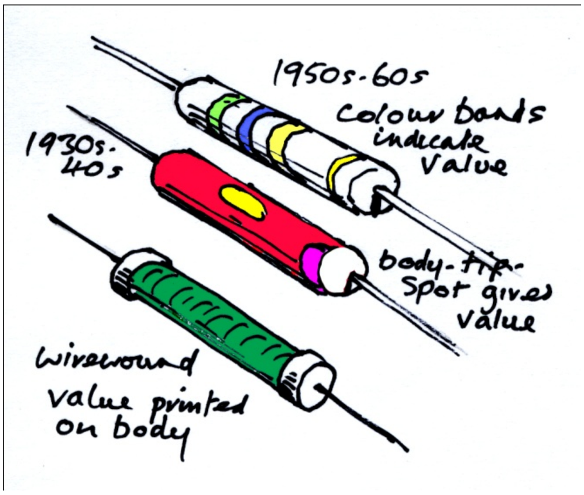
One look at the above chart and you would be forgiven for thinking that there is enormous complication in the subject. Not so. In vintage radio, the symbols are valves, resistors, capacitors and coils. It is how they are arranged, their values and purpose within the circuit that can and does vary from one circuit to another. It is essential that the reader should become familiar with these symbols, remembering the following: vintage symbols do not always translate to modern circuitry. Over the years, a process of standardization has occurred and gradually symbols from all countries have become at least partially integrated into a common acceptance of their meaning. This has meant that certain vintage symbols have had to change, a common one being the symbol for a resistor. In modern schematics a resistor is usually represented as a long, narrow rectangle. The resistor of vintage days is a zigzag (or sawtooth) line. Coils and transformers too may look different: the old way was to represent a winding as exactly that, a winding. Reasonable, you might think but today, many transformer windings are represented by – once again – rectangles.

So it is important to understand the meaning of symbols. But why, you may ask, do we need schematic diagrams? Why not just show the components as they actually are, connected together correctly? That type of drawing is known as a 'point to point wiring diagram' and often appeared in constructor's magazines such as Practical Wireless. These diagrams were certainly helpful, especially to the inexperienced constructor, but once receivers took on greater degrees of complexity, such drawings became impossibly complicated to produce – and probably equally impossible to follow. Think of the theoretical circuit as electronic shorthand. When designing a house, an architect isn't expected to draw every brick. When painting a scene, an artist rarely attempts to draw every discrete blade of grass or ripple of water.

The RESISTOR

The unit of resistance is the OHM. The symbol for ohm is OMEGA, the little horseshoe Greek letter **(Ω)**. The old schematic symbol for the resistor, the symbol used throughout the valve era, is pictured on the right.

If we want to limit the flow of electrons, rather than stop them altogether, then insulating materials cannot be used. Instead we employ materials that allow some current to flow, but limit the amount. Such materials are said to possess resistance to electric current flow. Resistors are made from such materials.

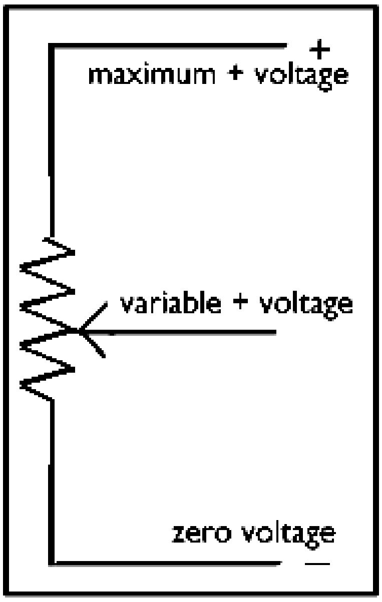


Right: typical appearance of vintage resistors

The most common form of resistor encountered in vintage radio is the carbon type, in rod (stick) form. These types are low-wattage ones, which means they can only handle small currents. The Watt is the unit of electrical power **(P)**. All conventional resistors limit current by converting the electricity into heat, which is dispersed by convection (heat rises) into the surrounding air.

Where heavy current flow is likely, for example in the power supply arrangements of an AC/DC valve radio, carbon resistors would overheat due to the excessive power dissipation needed and wire-wound resistors are used instead. These higher wattage resistors are made as ceramic tubes with resistive wire wrapped around them. They often work at high temperatures, rather in the manner of electric fire elements, though not as hot, of course. Air convection takes the edge off the high temperatures. It may seem wasteful to throw away power in this form, but the resistor is such a simple and reliable device that it is one of the most commonly encountered components in electronics generally and plays an essential part in valve radio.

The sketch shows the typical appearance but as with all electronic components there is variation between makes and types. Carbon composition (stick) resistors from the 1930s use a colour code system known as body, tip, spot. Later carbon composition and high stability resistors use a colour banding system. For more information on the colour codes, see the appendix.



Resistors can be made variable, allowing their value – the amount they resist the flow of current – to be adjusted at will. Variable resistors such as volume and tone controls are actually potentiometers, a term which literally means 'measurement of potential' but in practical terms allows the progressive change of a given value of potential difference.

If we break the simple circuit we made with the wire and the battery and insert a resistor in series, then a current will flow, the strength of which will then depend upon the potential difference as provided by the source of power, and the amount of resistance in the circuit. If we make the resistor a variable one, we can 'tap off' whatever potential - voltage - we like, within the rating of the battery, of course.

We now need to get slightly technical. It's not essential that you grasp the maths involved in what follows, but it can help later on if you have some idea of the processes that are taking place with resistive circuits. You could miss this section out and return to it later, if you prefer.

Potential difference is measured in voltage **(V)** and the relationship between current and voltage is a simple one. For a circuit with a given resistance, **either** doubling the potential difference (the voltage) **or** halving the resistance will double the current flow.

THE RELATIONSHIP BETWEEN CURRENT AND VOLTAGE

V =	1	2	3	4	5
I =	.1	.2	.3	.4	.5
V/I = (Ω)	10 Ω	10 Ω	10 Ω	10 Ω	10 Ω

The symbol (I) is used to represent current. Current is measured in amperes, (usually shortened to amps or simply **A**). We can see that the ratio V over I remains constant. This is because the voltage divided by the current is equal to the resistance as measured in ohms (Ω). In the above chart, the imaginary circuit has a resistance of 10 ohms.

Ohms Law
This is a very neat way to show the relationship between these values. Ohm's Law states that the current through a conductor is directly proportional to the potential difference across it. Our example proves this to be so.

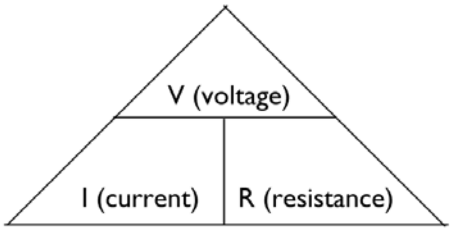
Basic fact: Ohms law only applies to the commonplace resistors made from carbon and from metal alloys.

So far, we have touched on resistance, current and voltage. The useful thing about Ohms law is that it allows us to calculate the value of any one of these *if* we know the other two. We have already shown that you can obtain the value of resistance in a given circuit by dividing the voltage by the current. If we divide the voltage by the resistance, then we obtain the current: if we multiply the current by the resistance we obtain voltage.

The Ohm's Law triangle

This triangle mnemonic can help you to remember the rules of Ohm's law.

Divide or multiply any two to obtain the third. Cover the value you wish to find and work out the remaining visible figures. Although the values are in volts, ohms and amperes, an ampere is a rather large unit for radio and it is easier to substitute milliamps (mA) for A and kilohms (k) for R. You must substitute both, however.



The OHMS LAW triangle

One milliamp is one thousandth of an Amp. Ten mA equals one hundredth of an Amp and one hundred mA equals one tenth of an Amp.

Power

Power is the term used to describe either the rate of production of electrical energy (for example, an electric generator) or the rate of dissipation of electrical energy (for example, a light bulb). The symbol for power is **P**. We use the term watt as the unit of power. It is named after James Watt.

Resistors in series


Resistors in series

When we connect resistors in series by wiring them end to end, their individual values simply add up and the total resistance becomes the sum of the individual values in the circuit. Why bother? Well, if two are in series, it follows that each will take its share of the power dissipation. Say we wire two identical value 1-watt resistors in series, we will have effectively made a 2-watt resistor whose value is the sum of the two individual resistors: a neat way of preventing premature ageing due to excess heating, in fact. Another good reason is to expedite a repair or to carry out tests when the exact value of resistor is not to hand.

Resistors come as so-called preferred values. This prevents the proliferation of values that would give rise to manufacturing problems. The designer chooses the nearest preferred value to the mathematical ideal. Usually, this is near enough as valve circuitry rarely needs exact values, especially with the higher resistance ranges. Another consideration is 'tolerance' which, in simple terms, means the amount a given resistor may deviate from its stated value. Tolerance is stated as a percentage i.e. 10%, 5% etc.

Line Cords are resistive mains leads and will run slightly warm in use. These were fitted to small table radios where the heat from an internal dropper would have been too confined, and certain American-made imports to convert them in as simple a way as possible from 110V to 240V mains. They should never be replaced by standard mains cable or the radio in question will be overrun and its major components could be permanently damaged.

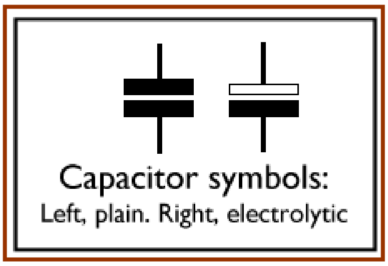
- Basic facts: Resistors limit the flow of current, dissipating the power as heat.
- Resistors cannot drop voltage unless a current is flowing through them.
- The values of two or more resistors wired in series – like railway carriages on a track – add together to make a total, which is the sum of the individual values. Example: one 5 Ω and one 10 Ω wired in series = 15 Ω .

The non-linear resistor

These are components that do not follow ohm's law. A type of non-linear resistor type commonly found in valve radio is the 'thermistor'. These devices, usually rod-shaped in vintage radios, present a high resistance from cold, which drops rapidly as the device warms. They are used in the heater circuit to prevent heavy surges of current at switch-on of a radio (cold heaters offer low resistance) and may also be found doing a similar task where a solid-state HT rectifier diode is powering a set. Indirectly heated valves, which means almost all valves designed to work from mains supplies, take time to warm up. Because of this, immediately power is applied the HT voltage can rise to a high peak due to the lack of power demand from the still cool valves. Protection to components can be provided by the inclusion of a thermistor with its high cold resistance, the action of which can be to drop the available HT potential by limiting current for the first few seconds, allowing the current to increase as it warms and drops in resistive value.

The CAPACITOR

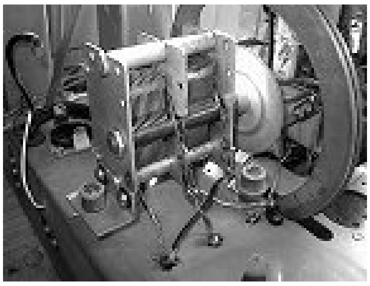
Capacitors (old name, condensers) are made in various sizes and shapes, from a variety of materials. But they all have certain things in common. There is a conducting material used for the plates (or connections, of which there are two*) and there is a non-conducting material, an insulator, which is used to keep the two plates electrically separate. This insulator is known as the dielectric. It can be paper, plastic film, mica, air or even, with electrolytic types, microscopic gas bubbles.



**Except for multiple capacitors, where several capacitors occupy the same can or case*

Capacitors store electricity. They can be charged up and can hold their charge for brief periods. This capacity to store electricity is used in a number of ways.

In valve radio power supplies, where AC mains electricity is converted into high voltage DC, they can be used in parallel with the supply to store power and give it back as needed, thus smoothing out the slight AC ripples left after rectification. An analogy with water can help here. Imagine that the flow of electric current is a flow of water and the capacitor is a container with a tap on the side.



Tuning capacitors use air as a dielectric and have fixed and moving plates known as vanes

The water may spurt into the top of the container, filling it at regular but jerky intervals. Turn the tap on the side, however, and a steady flow of water occurs. The volume of water contained within the tank has smoothed the flow. So, the fluctuating pulses of power (the ripples) going into a smoothing capacitor in a mains radio power supply are levelled. This is why hum occurs when smoothing and reservoir capacitors dry up and lose their capacity, allowing the ripples that should have been removed to remain and be amplified as a 50Hz or 100Hz note.

Capacitors in series with a supply can effectively pass alternating signals such as fluctuating voltages that are the electrical equivalents of speech or music, at the same time blocking any fixed voltage that the alternating signal may be carried on. DC is also blocked. This allows valves to be coupled together with relative simplicity.

***Basic facts:** Capacitors can be charged to hold power temporarily. Capacitors cannot pass fixed voltages. Capacitors can pass alternating voltages.*

Capacitors designed for reservoir and smoothing tasks are often made in combination – two or three separate capacitors in the same container, usually an aluminium tubular can in all but very old receivers.

The value of a capacitor greatly affects its ability to pass or to block alternating signals. Various values of capacitor pass alternating signals at different frequencies. The greater the capacitance, the lower the alternating frequency it can pass. Values in the order of 0.001µF to 0.1µF are often associated with tone control circuits and values in the order of 100pF to 500pF are used in tuned circuits together with an inductance (coil, transformer) to select wanted signals and reject unwanted ones. Typically in valve radio receivers, a 300pF to 500pF (0.0003µF to 0.0005µF) variable capacitor with an air dielectric will be used to allow the tuning to the differing frequencies of broadcast stations.

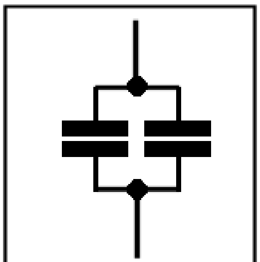
Also found in the majority of vintage radios are preset capacitors. These allow final trimming of tuned circuits which, once set at their optimum need no further adjustment. They are usually adjustable by means of a small screw.

Electrolytic capacitors are used whenever very large values of capacitance are required. These use damp paste electrolytes and are usually polarised. They must be connected correctly or they will pass DC, a problem known as leakage. The use of an electrolyte saves physical size. Without this, large µF values would be physically very large. The technicalities of these types of capacitor need not concern us here. Suffice to say that submicroscopic gas bubbles act as the dielectric.

Capacitors are measured for their amount of capacity by a unit called the **Farad**, named after Michael Faraday. In vintage radio, the Farad is a very large unit and we mostly work in **Microfarads (ųF)** and **Picofarads (pF)**, of which the largest measurement is Microfarad. Most electrolytic capacitors are in microfarad values.

Typical values for electrolytic capacitors used in valve circuitry might be 10µF to 100µF. Waxed paper, metal-cased and pitch-coated plain (non-polarised) capacitors usually range from 1µF to 0.001µF. 0.001µF is equivalent to 100 pF. These ordinary capacitors are found in the audio amplifying stages and as signal bypass devices in automatic volume control systems (AVC). Tiny capacitors, mostly used in the tuned circuits of radio receivers can go down to a few pF.

***Basic fact:** Capacitors in parallel (side by side) add in value. Example: Two one hundred µF capacitors in parallel = 200 µF.*


capacitors in parallel

As well as their value in decimal fractions of a Farad, capacitors have another important value – their voltage rating. This figure determines the safe maximum working voltage that the component can handle without breaking down. Ignore this at your peril. It is best to err on the safe side when replacing these components, and you certainly will be replacing them. Capacitors are often the culprit behind the dead, distorted, low volume or crackly set. The **Volts Working** figure is usually abbreviated to V.W. and applies most often to DC (Direct Current) circuits. Some capacitors designed for special functions may be rated for use in AC (Alternating Current) circuits. The electrolytic capacitors used as power reservoirs in mains receivers also should have a ripple current rating. See power supplies for more on this topic.

***Basic fact:** Electrolytic capacitors have the great advantage of high capacitance in small physical space.*

The types used in valve radio are usually of much higher voltage rating than those used for transistor circuitry. This is because valves are basically voltage driven devices, whereas transistors work in the main as current amplifiers.

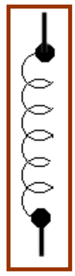
A further measurement to consider where electrolytic capacitors are used for power supply filtering is the ripple current handling capacity of the capacitor. When AC is rectified by diode action into DC, there remains a proportion of AC due to the fluctuations of voltage across the reservoir capacitor as it charges and discharges in time with the pulses of DC supplied from the rectifier diode. This AC waveform tends to be of a sawtooth form due to the switching action of the diode and the reservoir capacitor must be capable of withstanding this spikiness. Capacitors designed for reservoir use will have a maximum ripple rating printed on the can or sleeve.

The most suitable components for replacement purposes are new old stock types, preferably of a similar style and size. These should be checked for function and capacitance before use. Unfortunately though quite predictably, sources for such spares are becoming rare. A time will inevitably arise when the well will run dry and no old stock types will be left. In particular, high voltage electrolytics of the can type used for HT smoothing and reservoir purposes are rare and manufacture has almost ceased, so new equivalents are hard to find, and expensive. Of course, some components are in any case better replaced with alternatives. Imagine fitting brand new waxed paper capacitors in the full knowledge that, being identical to the ones being replaced, they are unreliable in the medium to long term. This is one very good reason never to use salvaged capacitors unless you can be very sure of their quality.

Replacing with modern components can be a little tricky until the restorer becomes familiar with the modern nF values that are now used for capacitor coding.

The INDUCTOR

When a direct current flows through a conductor, there is perhaps only a very small resistance to the flow. (Remember that all conductors show some resistance.) The current flow will remain more or less the same regardless of the shape of the conductor. We could, for example, take a length of copper wire and wrap it around a core of some sort, perhaps a cotton bobbin from a sewing machine, or a pencil. This wire **coil** would still pass much the same current as the straight wire did before we wound it into a coil.



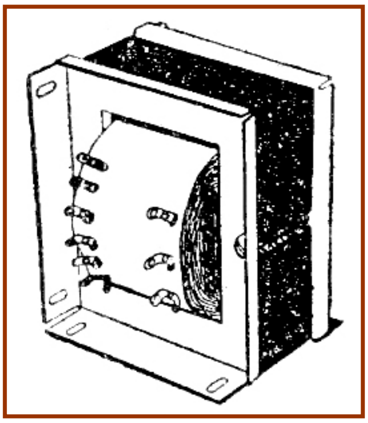
The basic symbol for an air-cored coil is shown on the right.

Coils offer a low resistance to the flow of a direct current. However, it is very different if we change the direct current for an alternating current. Coils are **inductors**: they possess **inductance**. Inductance means that they are capable of (a) creating a magnetic field and (b) are able to store magnetic energy when carrying a current. Whenever current (whether DC or AC) passes through a conductor, a magnetic field develops around it, at right angles to the flow. The DC field remains in place for as long as the current is flowing. But as an alternating current varies, so does the field. For example if the current alternates as AC does, the field collapses and reappears in the opposite polarity at every cycle. This happens with a straight wire, of course but this doesn't usually matter much except for the physical layout of conductors and components within the chassis of a radio, some of which may be affected by the proximity of the changing field.

However in a coil where the windings lie alongside each other, complex interactions takes place resulting in the creation of a magnetic 'brake'. This is the effect we call reactance. It is due to inductive resistance. You may see the term 'back EMF' used when coils such as chokes are described. EMF is an abbreviation for Electro-Motive Force, not a term much used today.

A choke is a coil of wire that has a large inductive reactance to alternating signals, but low resistance to DC. A typical choke is the RF (Radio Frequency, or High Frequency) type, which is a coil wound upon an air-cored former made of an insulating material. The EMF created when RF signals are applied causes a voltage drop across the coil and therefore RF signal amplification.

The **transformer** employs the phenomenon of inductance. If a further winding *not connected electrically* to a given coil is wrapped over it or wound upon a common core, which may be soft-iron for power transformers like the mains transformer pictured here, or air and ferrite cores for radio-frequency transformers (see below), then a current flowing through the first coil will be induced in the second one.



Typical mains transformer

The first, current-carrying coil is called the **primary** winding and the second, induced-current coil is called the **secondary.** There may be several secondary windings over a single primary, to allow for low voltage supplies to valve heaters and high voltage for the valve anodes, or a single secondary with tapping points along the coil. Mains transformers almost always have a tapped primary which allows them to be set for prevailing voltages, perhaps from 200V to 250V.

At radio frequencies, all that may be needed is to place the coils near each other, usually by winding them on an insulating tube. This is how the IF transformers in valve radios function. To tune such coils, fixed or adjustable capacitors or metallic iron dust (ferrite) cores are used to make sharp points of resonance. At the point of resonance of such a circuit, peak current flows for only a minimum input. This makes the circuit, in effect, into a very selective amplifier which may be adjusted (tuned) either by changing the value of the parallel capacitor (changing the setting of the variable tuning capacitor) or by altering the position of the metallic core relative to its coil.

HF transformers are widely used. Usually called tuning coils, they are formed by coils wound to suit radio frequency transmission bands, for example long wave or medium wave. The transformer action is used to couple and amplify the tuned signal. Careful design allows coverage of a complete waveband by a single winding, tuning being achieved by the use of a variable capacitor (tuning capacitor). Such systems are called **band pass** circuits for the obvious reason that they can pass an entire band.

Wound components in power supplies

At the much lower frequencies – and much greater power requirements – of mains power supplies, air is just not adequate as a core material. Here, the use of a soft iron core, built up from thin laminations which are insulated from each other to limit losses due to excess heating of the iron, helps concentrate the magnetic flux.

The **LF Choke** is a single winding on laminated core and is used to help to filter ripple current after rectification of AC mains power as it offers low resistance to DC but a higher resistance to the AC ripple left after rectification from AC to DC by the diode. LF chokes look like output transformers but have only two connection terminals. The field coil in energized loudspeakers generally doubles as a choke.

The **Mains Transformer** only works with AC mains – remember, all transformers only work with alternating currents. Transformer action means that current flowing through the primary coil will induce a current to flow in the secondary coil even though there is no fixed electrical connection between the two. Changing the comparative number of the turns on the windings allows the voltages to be stepped up or down. The difference between the number of primary and secondary turns is called the **turns ratio.** It can also isolate radios from the mains, which tends to make them safer to work on.

The **Audio Output Transformer** is used to convert the voltage changes present at the anode of the sound output valve into a form suitable for the loudspeaker to handle. These often look like a smaller version of a mains transformer. There is a class of mains transformer that is called a heater transformer because they produce only power for the valve heaters: the HT is derived directly from the mains. These look like audio output transformers. *See* glossary: impedance.

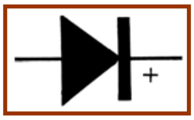
DIODES AND RECTIFIERS

This section looks at the solid-state types of diode.

The solid-state diode has its origins in another very early device, the cat's whisker or crystal diode, as used in crystal radio receivers from the early 1920s. The arrow on the symbol is the anode and the line is the cathode, the latter sometimes being marked positive or input. The symbol is the same for all non thermionic (non valve) solid state diode devices, including the metal oxide rectifiers found in some sets. Current can flow in only one direction through the diode. Electrons flow from the cathode to the anode. This creates the current flow and is a basic property of all diodes.

Remember, current will flow in only one direction. Whenever the anode is positive with respect to the cathode or filament, the diode will conduct and current will flow from the cathode through any complete circuit back to the anode. Therefore in terms of electron flow, the cathode is input. In other words, electrons flow into the diode through the cathode connection. Often, in circuitry the 'plus' symbol is placed at the cathode of a diode.

The symbol for a solid-state diode



This may seem puzzling, but it is easier if you remember that the arrow shape of the anode represents conventional current flow (which is positive) whereas electron flow, being the opposite of positive, is in the opposite direction. This is because the terms positive and negative were a means of describing the flow of electricity around a circuit, before a complete understanding of electron flow emerged.

Tiny, glass encapsulated diodes are called SIGNAL DIODES and are used for the DETECTION (also known as rectification or demodulation) of radio frequency signals. These are found in some radios, especially the early transistor radios where discrete transistors were used rather than microchips. The crystal diodes, as used in crystal sets of the 1920s, worked on exactly similar principles as point-contact solid state diodes and early transistor junctions. The symbol for these types of diode is therefore the same as the one for solid state types and also metal-oxide rectifiers, described below.

Many older valve radios use air cooled metal oxide rectifiers. These have large fins for good heat convection. A variation sometimes found is the contact cooled version where mounting directly to the metal chassis removes the need for cooling fins because the chassis acts as a heat sink. Where these devices are found to have failed, replacement by modern rectifier diodes is possible.

For power supplies in mains radios, diodes are combined with inductors in the form of chokes and/or transformers, and capacitors.

End of section