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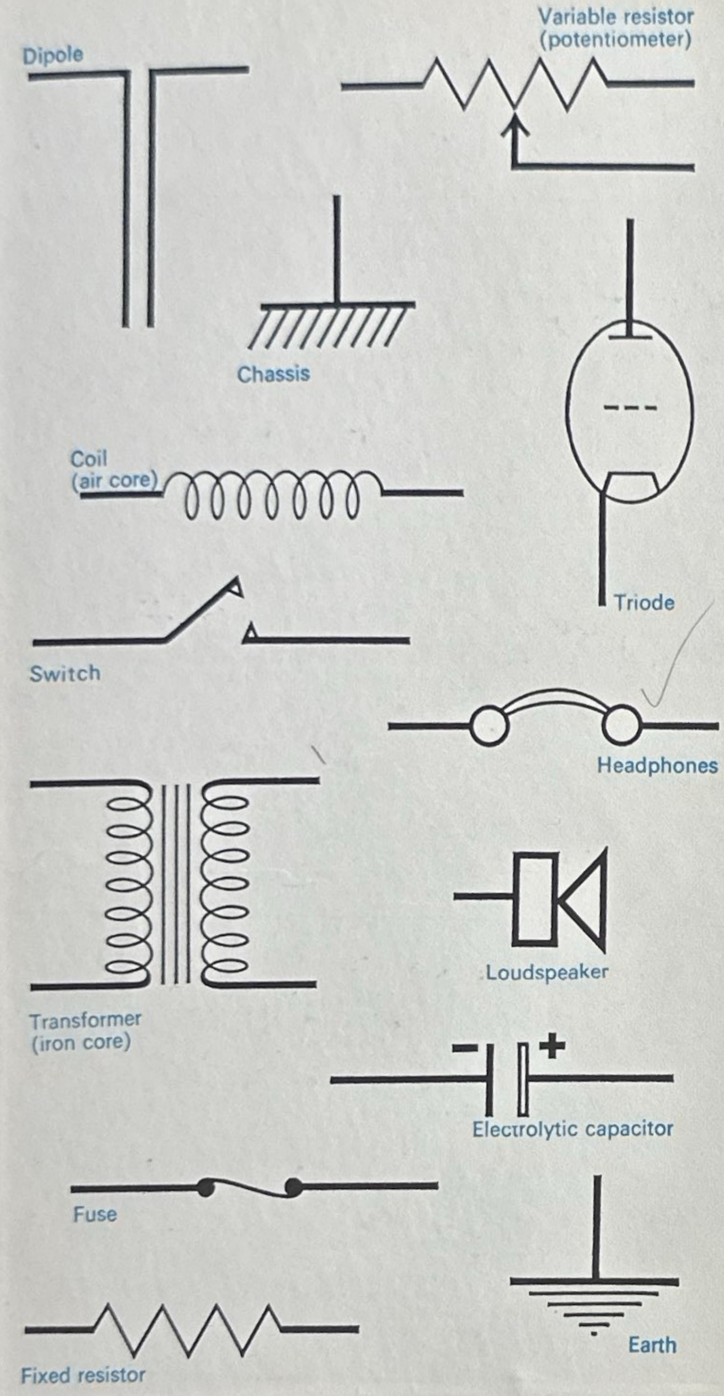
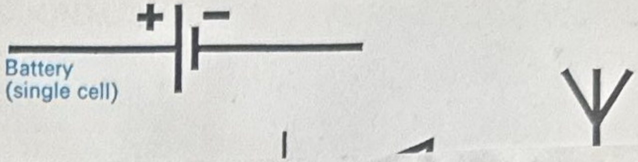
RADIO AND TELEVISION





Thermionic diode

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RADIO and TELEVISION

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Editor's Note

This book is intended for readers who already have a basic knowledge of electricity and are interested in the electronics of radio and television. It describes the main systems and components used in transmission and reception.

Acknowledgements

We gratefully acknowledge the assistance of the following organisations in assembling photographic material for this book: the Rank Organisation; the British Broadcasting Corporation.

Contents

The Development of Radio Communication

In 1873 James Clark Maxwell published his book on Electricity and Magnetism in which he provided the mathematical foundation for the existence of electromagnetic waves. In 1887 Heinrich Hertz detected these radio waves for the first time. He made them by passing a spark across an air gap between two metal spheres. The spark had produced electromagnetic disturbances around the spheres. These disturbances, or waves, produced smaller sparks between two similar spheres a few yards away.

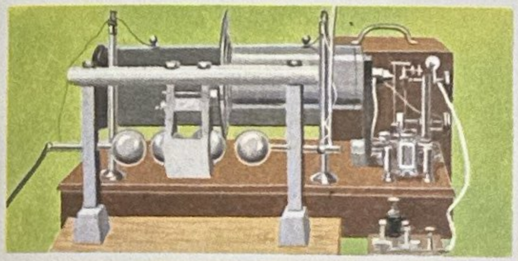
Sir Oliver Lodge transmitted and received the first radio message in 1894, using groups of waves to represent the dots and dashes of the Morse Code; the apparatus used on this occasion was similar to that of Hertz.

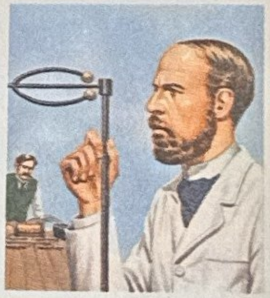
In 1890 Sir Oliver Lodge and Professor Edouard Branly improved the coherer for the detection of waves. The coherer was a small tube, full of metal filings, with a metal plug at each end to connect the wires.

In 1897 Marconi made the first transmission by wireless signals, over a distance of nine miles, using a spark gap transmitter, a tapper or buzzer, and a coherer. In 1901 he performed the first successful Transatlantic communication.

The important components developed for radio were the diode valve, invented by Sir Ambrose Fleming in 1904, the triode amplifier by Lee de Forest in 1907 and the cat whisker by Meisseur in 1910.

Broadcasting really started with the first experimental broadcasts from Chelmsford in 1919, and with the formation of the BBC in 1922.





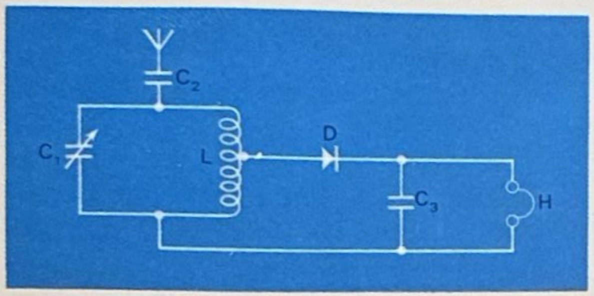
Above: Hertz sent radio waves across a room in 1887. Left: Marconi made the first wireless transmission with this transmitter in 1897.

Radio Receivers

The simplest type of receiver consists of a tuned circuit and detector, feeding audio frequency signals into a pair of headphones.

The purpose of the *tuned circuit* (LC_1) is to enable the aerial circuit to be tuned in *resonance* with the incoming frequency from a transmitting station. It is at resonance that maximum voltage is developed across the circuit. The detector diode D is used to detect the audio frequency modulation present in the R.F. modulated carrier. The resonant frequency of the circuit is found from the equation,

$$\text{Frequency} = \frac{1}{2\pi\sqrt{LC_1}}$$



The circuit of a simple radio receiver.

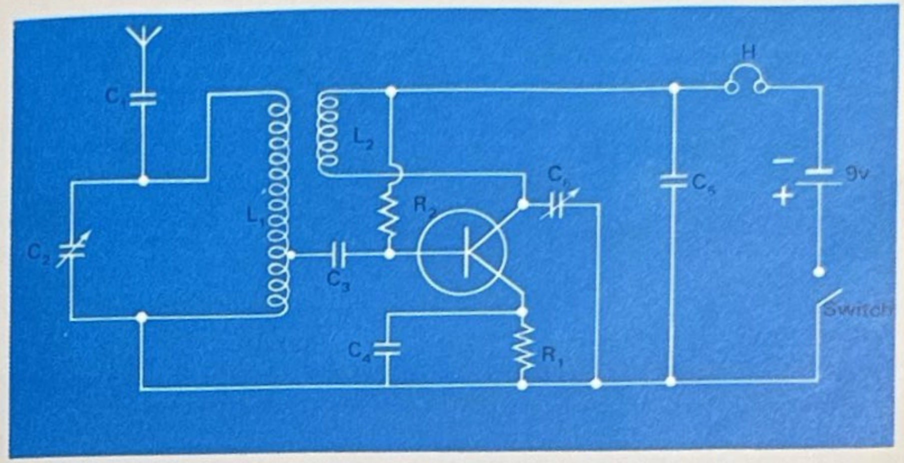
Typical components for this simple receiver are as follows:

- *C_1 – 500pF variable capacitor*
- *C_2 – 220pF mica capacitor*
- *C_3 – 0·001μF mica capacitor*
- *D – GEX34 germanium crystal diode*
- *H – high resistance headphones. Capacitor C_3 across the phones acts as an H.F. filter for the diode.*
- *L – 50 turns of 38 gauge enamelled copper wire, wound on a Ferroxcube B2 aerial rod*

The disadvantages of low signal output and poor selectivity which the simplest type of receiver has may be largely overcome by using a regenerative receiver.

The circuit shows how a transistor is used in an improved design of a receiver.

The principle of operation of this circuit is that by applying some of the amplified signal in the collector circuit back to the

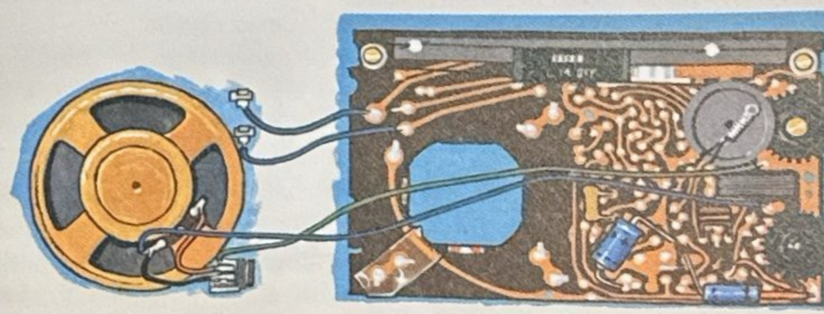


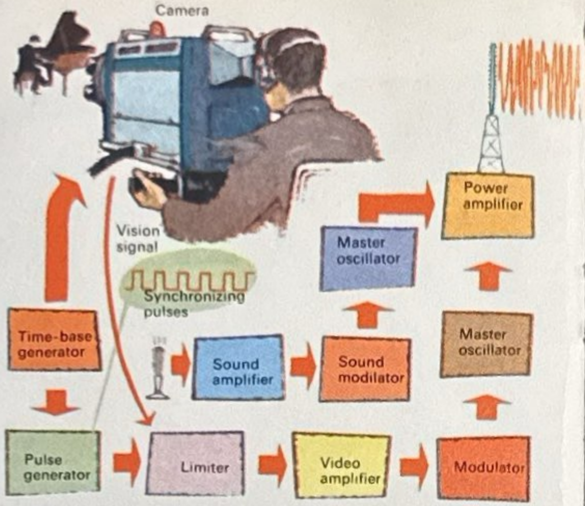
Circuit diagram of a regenerative receiver which uses a transistor.

base again, the signal is much more amplified, which increases the gain of the stage considerably. A limit is reached when too much *feedback* makes the stage unstable, or when it begins to *oscillate*. This feedback signal from collector to base (L_2 to L_1) must be in correct phase, to reinforce the input signal.

The feedback is arranged through inductive coupling of the tuning coil (described in the simple-type receiver) with an additional coil, wound on the same ferrite rod. The degree of regenerative feedback may be controlled by a small variable capacitor (C_6) between the collector and the base.

The underside of a superhet. transistor radio receiver. The loudspeaker on the left has been pulled out to show the connections. The long blue wire is connected to the volume control knob and the green wire to the tuning knob.





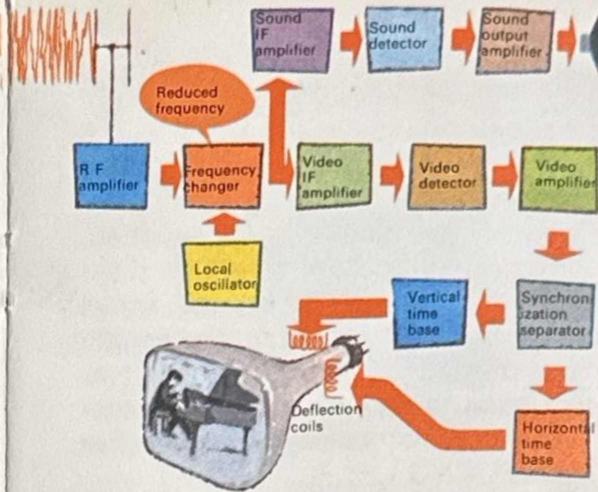
Television transmission. The camera produces a vision signal and these video pulses are mixed with synchronizing pulses from a time base generator. The signal is then modulated and amplified before being transmitted at a very high frequency. The sound signal is transmitted at a slightly higher frequency.

Television

A picture on a television screen is produced by a very small but strong spot of light, scanning the screen from side to side 625 times during every one fiftieth of a second. The number of scanning lines making up the picture governs the detail which can be obtained. These lines trace on the screen a rectangular area known as the *raster*, on which the picture is seen. The picture is really made up of a large number of very small still or stationary pictures, changing rapidly. However, due to the persistence of vision, the human eye does not see it as a series of pictures, but as a continuous moving picture. Although the modern television scanning is performed electronically, it is worth recalling the early mechanical methods adopted by Nipkow, Baird and others.

In 1884, Paul Nipkow invented a scanning disc. It is a plain circular disc, with a number of small square apertures, cut along a single-turn spiral; each aperture being set back from the previous one by its own width. As the disc rotates the scene is analysed, or scanned, into strips of light and shade.

John Logie Baird used the basic Nipkow system by placing the subject to be televised under intense light and scanning it with the rotating disc. The light reflected from the subject passed through the aperture on to a photoelectric cell. (See PHOTOELECTRICITY.) This cell produced current, which varied as the light intensity, for modulating a carrier wave (C.W.). The C.W. signal was then amplified and radiated over an aerial. (See AERIALS.) At the receiving end, another Nipkow



Television receiver. The very high frequency signal is received at the aerial and amplified. The sound and vision signals are separated. The sound signal drives the loudspeaker and the vision signal varies the voltage on the grid of a cathode ray tube.

disc was rotated at the same speed so as to restore the transmitted picture of the subject.

This electro-mechanical method of picture transmission and reception was slow, inaccurate and noisy. Modern television cameras employ electro-optical systems, in which the subject to be televised is focused on to a special screen of very many tiny photo-electric cells within the camera tube. This screen, or *mosaic*, stores the electron image of the subject all the time the light is falling on the camera. (See CAMERA.) Scanning of the stored electron image is performed by an electron beam. The voltages picked off the stored electron image are amplified and used to modulate the carrier wave of the transmitter.

Signals from the cameras are amplified and their amplitude is controlled in a *limiter* to prevent overloading at later stages. A television producer can switch the cameras as required by using the *fader* and *mixer* unit.

At the end of each scanning line and frame, synchronizing pulses are superimposed on the signal currents. These are square-topped pulses of equal amplitude.

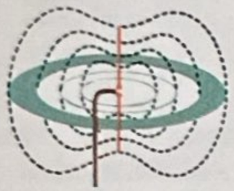
Blanking-out or marking pulses are also fed to the television camera, so that there is no picture distortion during the flyback of the scanning beam. (See FLYBACK.)

Further amplification of the signals takes place in the video amplifier, and these signals are used to modulate the R.F. power amplifier which amplifies carrier-wave (C.W.) signals. The modulated C.W. signals are fed to the aerial via a coaxial cable and are radiated. (See VIDEO WAVEFORM.)

Radio and Television A to Z

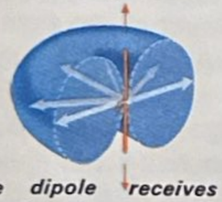
AERIALS In order to transmit or to receive radio signals we need an electrical conductor, which can either radiate or receive energy as electromagnetic waves.

Radiating and receiving aerials are similar in construction. At longer wavelengths, a length of insulated wire is often sufficient. With shorter wavelengths, however, a stronger signal is transmitted or received if the aerial is one half wavelength long. The half wave dipole is divided at its mid point into two parts, and connected at that point to the receiver or the transmitter by a coaxial cable. (See SCREENING.)

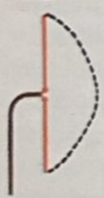


The electrical and magnetic fields around a halfwave dipole.

When the dipole halves of an aerial are a quarter of a wavelength long, the surges of alternating current are in step and the aerial is said to be *tuned* or resonant to the frequency. When this happens, the current flowing in the aerial is at a maximum. Weak signals may often be amplified by placing a reflector behind the dipole. This might be simply a strip of metal as in a television aerial or a large curved metal bowl such as those on the Jodrell Bank and Goonhilly Downs aerials. A television aerial consisting of a transmitting dipole and a reflecting dipole is called an 'H' aerial.

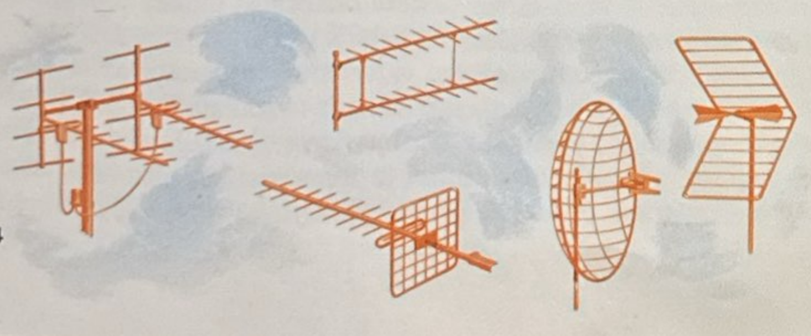


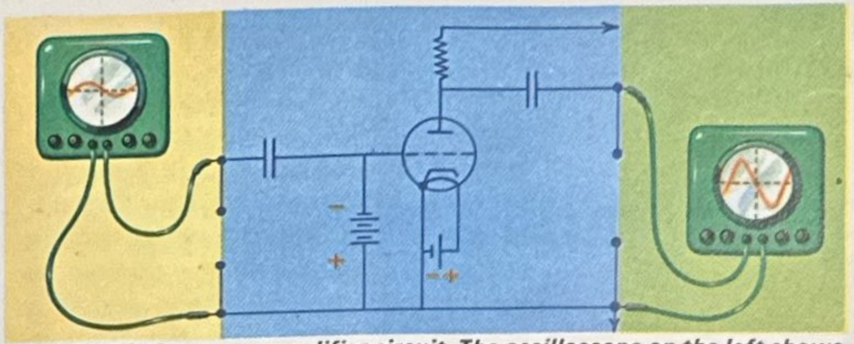
The dipole receives signals from most directions.



The dipole aerial which is half a wavelength long.

Below: five different types of ultra high frequency (U.H.F.) television aerials. The three on the left with several extra rods are variations of the Yagi array.



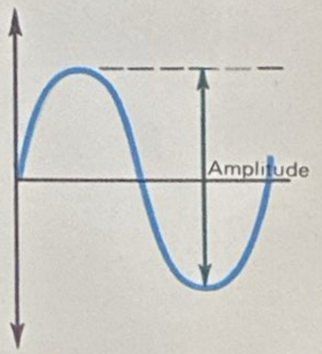


An audio frequency amplifier circuit. The oscilloscope on the left shows the amplitude of the signal before amplification. The one on the right shows how much greater it is afterwards.

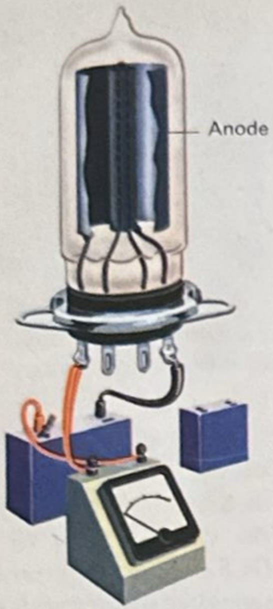
AMPLIFIER A valve or transistor circuit designed to increase the amplitude of an input signal is called an amplifier. In a valve circuit this will be voltage amplification, in a transistor circuit it is more often current amplification. The early stages of a receiver are known as Radio Frequency (R.F.) amplifiers, while the stages from the detector to the loudspeaker are known as Low Frequency amplifiers (L.F.). The term is also used to describe a complete series of circuits built to amplify low frequency signals from a microphone, tape recorder or pick-up.

The amount by which an amplifier increases the input signal is called its *gain*.

AMPLITUDE The measurement of an alternating voltage or current from the upper peak of one wave to the lower peak of the next is called its amplitude. This may be measured in microvolts in the aerial itself and later on, after amplification in the receiver, in millivolts or even volts. In a sound wave sent out by a loudspeaker, the greater the amplitude the greater is the volume and vice versa. The loudness of sound is usually measured in Phons or decibels (dB). (See DECIBELS.)



Right: the amplitude of a signal is measured between the upper peak of one wave and the lower peak of the next wave.



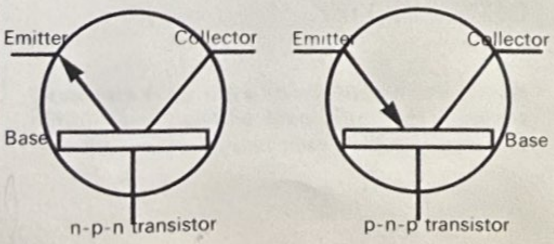
ANODE The metal plate in Fleming's diode now forms the final electrode in most modern thermionic valves. (See DIODE.) When it is made positive with respect to its cathode a current of electrons streams across the vacuum to the anode. This forms an anode current in the conductor connected to the plate and a voltage across a resistor connected in series with it. Modern valves use cylindrical or flat anodes surrounding the other electrodes of the valve. The anode is usually brought out to a pin at the bottom of the valve.

***Left:** A diode valve with the anode cut away to show the filament and cathode inside. The anode is connected to the positive terminal of the battery through the voltmeter.*

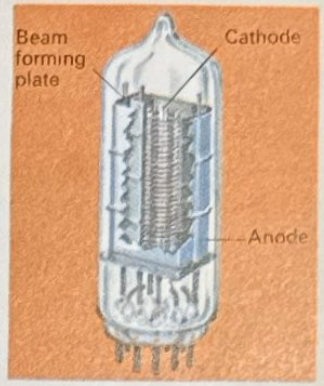
A junction transistor showing the thin semiconductor base layer sandwiched between the collector and emitter layers.

BASE The most common kinds of transistors are made up of thin slices of germanium or silicon in a three layer sandwich. (See SEMICONDUCTOR.) The current passes first through the emitter, then through the base and out through the collector. These three layers form a junction which behaves like Lee de Forest's triode valve. Usually the signal currents enter through the base and cause a much bigger change in the current that passes from emitter to collector.

The symbols used to represent transistors in circuit diagrams.



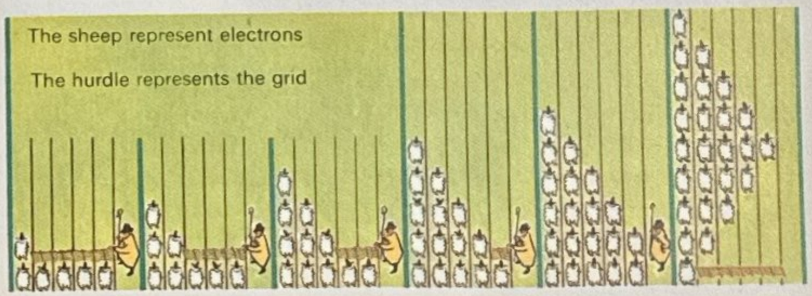
BEAM TETRODE This is a valve containing four electrodes: anode, cathode, control grid and a screen grid. The screen grid reduces the unwanted capacitance between the control grid and the anode; it also assists in attracting electrons from the cathode to the anode. Beam tetrodes are often used in output stages of amplifiers to drive powerful loudspeakers such as those in public address systems.



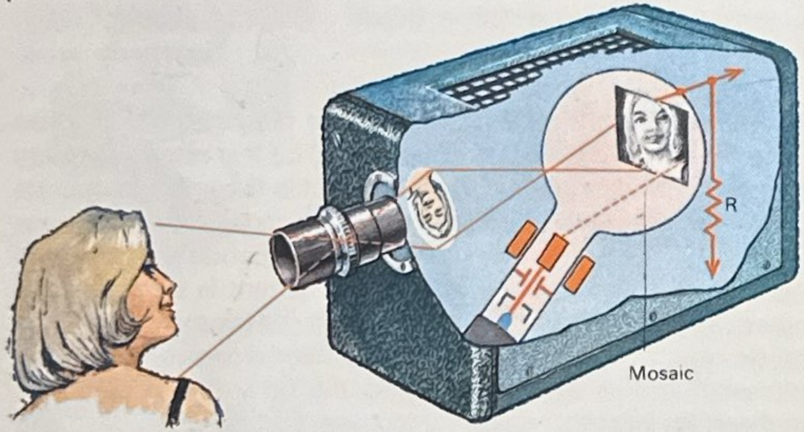
The beam tetrode valve.

BIAS When the grid of a valve is made negative, the electron flow to the anode is reduced. (See TRIODE.) It is often necessary to have a fixed voltage on the grid to enable the valve to operate correctly. In the early days of radio this negative voltage was supplied by a small grid bias battery. If the cathode is made more positive with respect to the anode, the current is also reduced. Modern valve circuits use the current passing through the cathode resistor to give the cathode a fixed positive voltage. In a transistor a bias or opposition to the flow of the electrons already exists between emitter and base, and between base and collector. A signal varying from positive to negative at the base assists the bias or decreases it.

The bias is the grid voltage which controls the flow of electrons to the anode of a valve. Its effect is rather like that of a hurdle restricting the passage of sheep in a narrow lane. A small movement of the hurdle one way allows more sheep to pass, a movement the other reduces the number of sheep passing through. Similarly, a reduction in the negative charge on the grid allows more electrons to pass to the anode, an increase reduces the number.



BRILLIANCE When the electrons from the gun of a cathode ray tube strike the light-emitting screen, they appear as a pin-point of light. (See CATHODE RAY TUBE.) As the electron stream leaves the cathode they pass straight away through the cylindrical grid as they do in an ordinary triode. The purpose of the grid is to control the number of electrons passing through to the screen. If the grid is made negative fewer electrons get through, if positive the stream is increased. A control which can change this voltage will alter the brightness of the spot or picture on the screen.



In the television camera there is a screen of tiny mosaic elements. These become charged when a scene is focused on the signal plate. A scanning electron beam neutralises the charge on each element of the mosaic in turn. This causes a train of current pulses to pass through the resistor R and these are amplified before being transmitted.

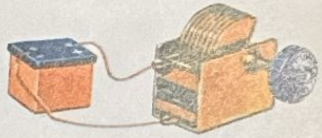
CAMERA In a television camera an image of the scene in the studio is focused by lenses on to a screen covered by rows of small photocells. As light falls on each cell the cell receives an electric charge. (See PHOTOELECTRICITY.) To transmit the image falling on the screen each cell must be scanned in turn by a beam of electrons. As this beam passes over each cell it discharges them in turn, producing a small electric current.

When the current passes through a resistor a varying voltage is produced representing the brightness of pieces of the studio picture. This vision signal, together with the sound and synchronizing signals, is used to vary the amplitude of a carrier wave which is amplified, and transmitted from the aerial.

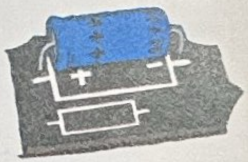
CAPACITOR A capacitor is basically two metal 'plates' separated by an insulated layer. In practice the 'plates' might be a long length of foil rolled like a film, each layer being insulated from the next by waxed paper. Although no direct current will pass through it, it will allow voltage variations to pass. The action is rather like that of a rubber sheet stretched across a water pipe. The sheet prevents any actual flow of water, but because it is elastic, changes in pressure (voltage) on one side are transmitted to the water on the other side. Capacitors can do a variety of jobs, the most common of which are preventing a high voltage from an anode appearing on the following grid, but allowing the alternating voltage to appear there; and smoothing out the ripples in a d.c. supply after it has been rectified from the mains a.c. (See RECTIFICATION and SMOOTHING.)

The *capacitance* of a capacitor is measured in farads; however, since a farad is too large for practical purposes, it is subdivided into microfarads and picofarads. One microfarad (uF) is one millionth of a farad, and one picofarad (pF) is a millionth part of a microfarad.

The rubber sheet transmits the effect of a change in water pressure on one side to the water on the other although no water flows through. Similarly a capacitor transmits the effect of a change in voltage although no direct current passes through it.

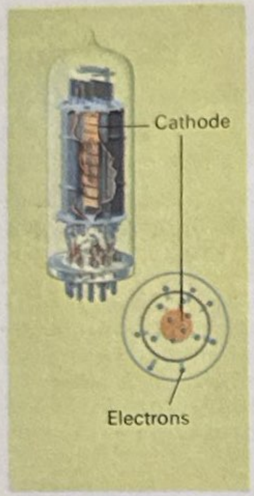


A variable capacitor. By turning the knob the effective area of the plates can be altered.



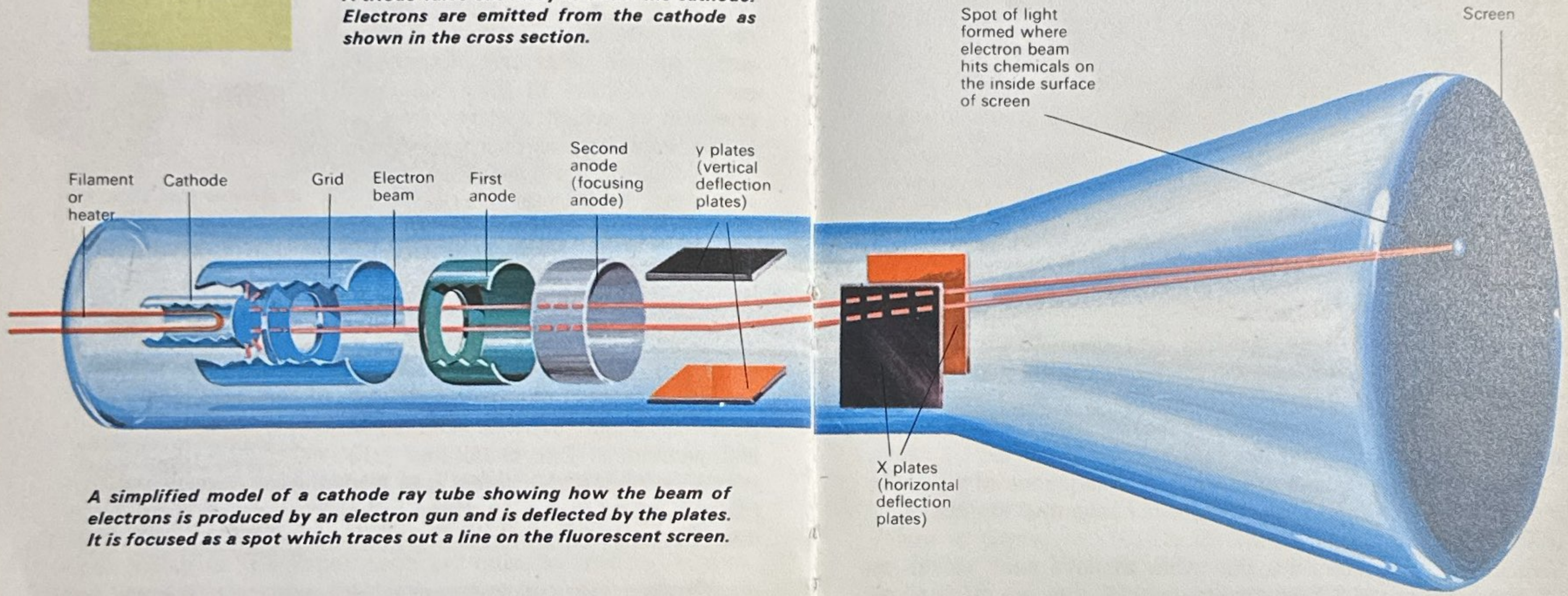
An electrolytic capacitor. In this the insulating layer consists of a thin film of oxide on the plates which has been formed electrolytically.

CARRIER WAVE A radio wave of constant frequency and amplitude is generated in the transmitter. Either the amplitude of this wave, or its frequency, is made to vary with the speech or music sounds produced in the studio. The radio receiver is tuned to receive only this carrier which is of a fixed wavelength for any particular station. (See MODULATION and DETECTION.)



CATHODE In a valve, a heated filament is usually encased in a metal sleeve where the outer surface is coated with barium or strontium oxide. (See DIODE.) As the cathode becomes hot, electrons are emitted from the oxides, forming a cloud around the cathode or being attracted to a positive anode. The number of the electrons emitted depends on the material and its temperature.

A triode valve cut away to show the cathode. Electrons are emitted from the cathode as shown in the cross section.



A simplified model of a cathode ray tube showing how the beam of electrons is produced by an electron gun and is deflected by the plates. It is focused as a spot which traces out a line on the fluorescent screen.

CATHODE RAY TUBE The main display tube in television receivers, oscilloscopes and radar is called a cathode ray tube. Basically, it is a device to change electrical energy into light. This is the reverse of the action of the television camera which changes light and shade from a scene in a studio into electrical impulses. A stream of electrons sent out by the cathode is gradually accelerated by higher and higher positive voltages on successive anodes until it strikes a fluorescent screen.

The brilliance on the tube can be altered by changing the negative voltage on the grid. The thickness of the beam can be altered by changing the positive voltage on another anode. This tends to make the electrons bunch together. This is called the focusing control and is often controlled inside the television set. Before the beam of electrons reaches the screen, it is made to sweep out a single trace (in an oscilloscope) or a complete picture on a television set. (See OSCILLOSCOPE.)

COLLECTOR The third layer of the sandwich in a transistor is the collector. When a signal is fed into the base an amplified signal current appears on the collector. A resistor in the collector circuit sets the current and voltage at the correct values.

End band	Second band	Third band (number of noughts)	Fourth band (tolerance)
0	0	None 10-100 ohms	1%
1	1	1 100-1,000 ohms	2%
2	2	2	3%
3	3	3	4%
4	4	4	Gold 5%
5	5	5	Silver 10%
6	6	6	No fourth band 20%
7	7	7	
8	8	Gold x 0·1 1-10 ohms	
9	9	Silver x 0·01 0·1-1 ohms	

There may also be a fifth colour band, This gives the stability of the resistor.

Chart showing the colour code. Resistors and capacitors are marked with a series of coloured bands which give their value. Each colour represents a figure. The last figure gives the number of noughts. For example, red stands for 2 so three red bands would mean 2200.

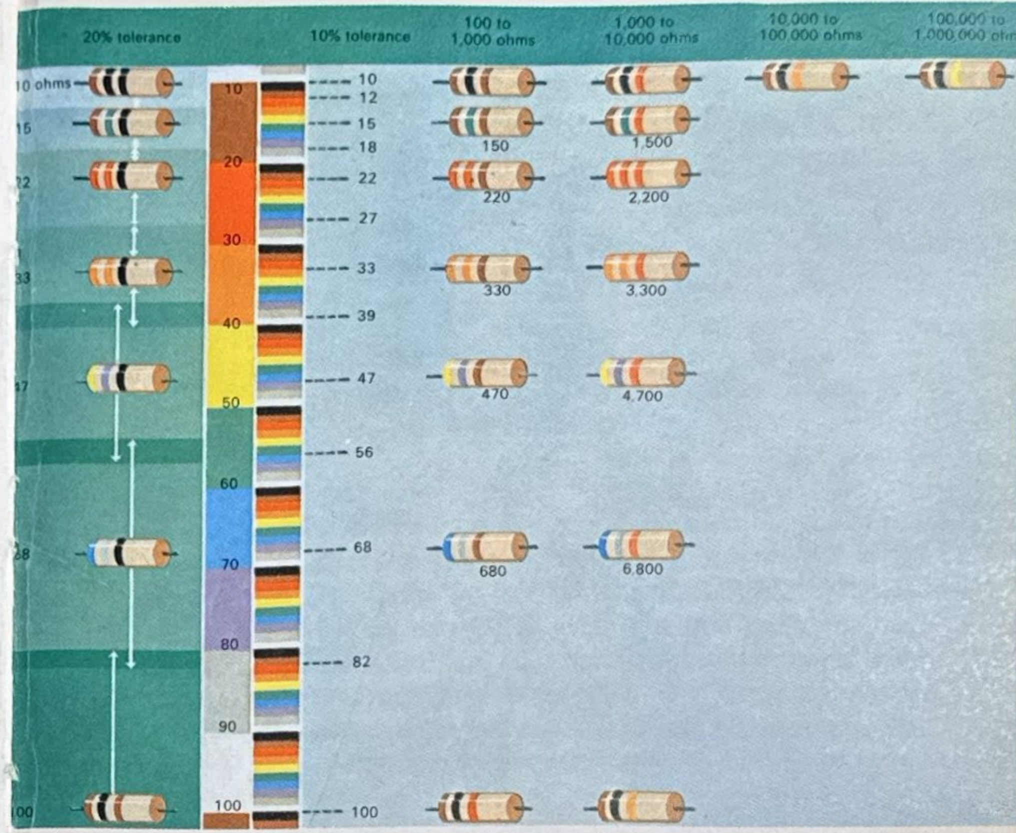
COLOUR CODE Some resistors and capacitors have their values written on them, but more often they are marked with bands or dots of colour in an international code. This enables electrical engineers anywhere in the world to identify their value at a glance.

Each colour represents a number. The sequence of numbers gives the full value of the resistors in ohms, and the accuracy of that particular value.

In practice, resistors are not made to have such values as 20 ohms, 50 ohms, 100 ohms etc. Instead, they are made so as to have an approximately constant percentage change of resistance, above and below a particular resistor. Resistors made in this way have what is known as *preferred* values.

It should be noted that the differences between adjacent values of resistors are planned on a logarithmic scale.

Two other colours may also be found on resistors: silver and



Some of the preferred values of resistors and their tolerances. The tolerance shows how accurate the value of the resistor will be.

gold. The silver band specifies a resistance tolerance of plus or minus 10 per cent, whereas the gold band denotes a tolerance of plus or minus 5 per cent.

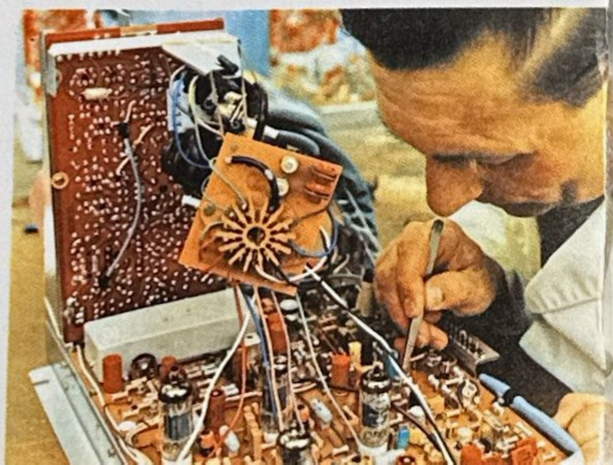
The complete range of preferred values of resistors is:

Values in ohms:	10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82, 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820, 1,000.
Values in kilohms:	1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2, 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82, 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820, 1,000.
Values in Megohms:	1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3., 3.9, 4.7, 5.6, 6.8, 8.2, 10, 12, 15, 18, 22.

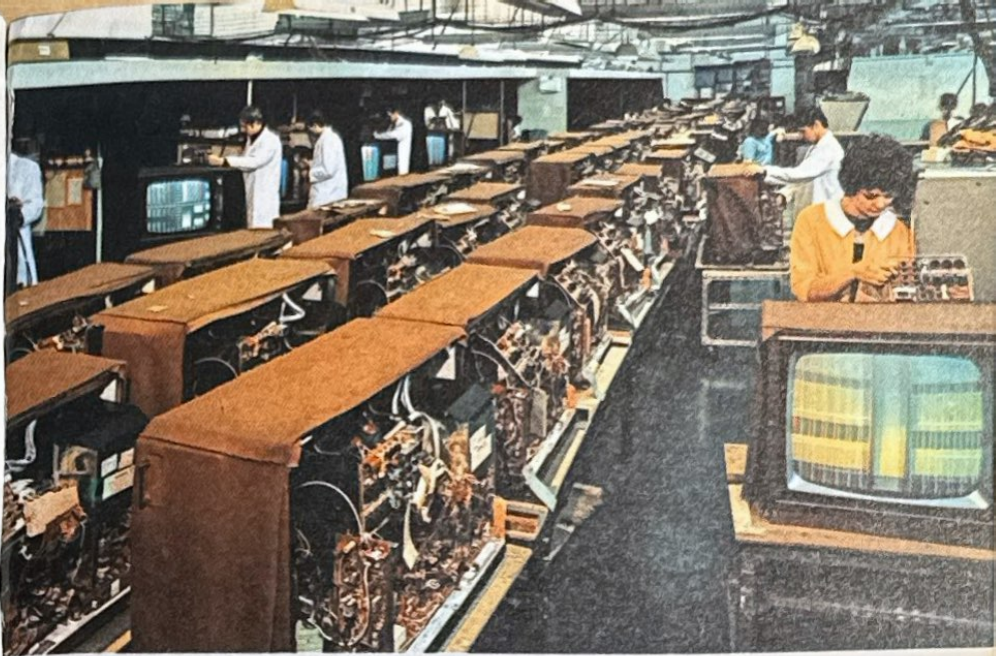
COLOUR TELEVISION In 1666 Sir Isaac Newton showed that when light is passed through a prism, it is split up into several colours. The three principal colours of the spectrum, as it is called, are red, green and blue. If these colours are added together they give white light again. Both these important discoveries have been used in the last few years to bring colour television into our homes.

Light from the studio picture is focused onto the camera by a lens. When the light reaches the camera it is split up into three beams by a system of mirrors. Each beam of light is then passed through a filter to produce three separate beams of red, green and blue light. These three primary colours strike separate light sensitive screens to produce three colour signals.

Added together, these three colours will give the total *intensity of light*, that is the brightness of the picture. Brightness is one of the three characteristics of colour. This is called the *luminance* signal. The other two characteristics are *hue* and *saturation*. *Hue* is the sensation by which the eye is aware of the difference between light of various wavelengths – between red, green, blue, yellow and so on. *Saturation* is a measure of colourfulness – the difference between a colour and white. For example red and pink have the same wavelength, hence, the same hue. Red, however, has a greater saturation, or contrast, than pink. Signals which represent hue and saturation are produced by adding or subtracting the signal that the primary colours red, green and blue give. These are called *chrominance signals*. The luminance signal and the two chrominance signals are then transmitted with the usual sound signals and synchronizing pulses. At the receiver, the three signals are separated



An engineer checking the connections on part of a colour television receiver. He uses tweezers to handle the tiny components which all have to be soldered by hand.



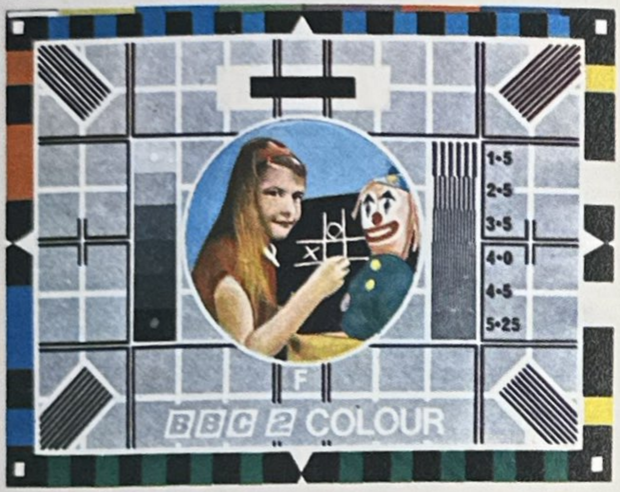
The end of the production line in a factory producing colour television receivers. The sets are being given a final test before being packed and despatched.

into their original three primary colours. Each colour is fed into its own 'gun' in the neck of the cathode ray tube. All three beams are directed at the cathode ray tube screen. Unlike the black and white screen, the phosphor is divided into half a million dots. These phosphor dots are grouped in threes forming small triangles. One emits blue, one red and the third green light.

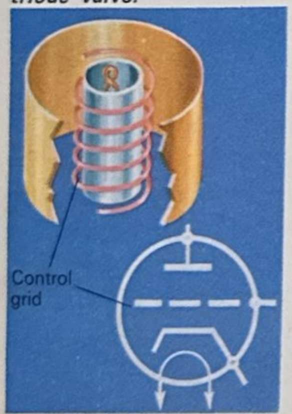
A very short distance behind this phosphor screen is a *shadow mask*. This is a metal screen with holes on it, one for each group of three phosphors. The shadow mask holes and the dots of phosphor on the screen are very accurately in line with the guns. Only the blue beam strikes the blue phosphor; the green beam strikes the green phosphor and the red beam strikes the red phosphor. The phosphorescent screen sends out light of all three colours; so almost any combination can be seen when it is viewed from a distance. To reduce the cost of colour television, the system must use the same transmitters as black and white television. Although ordinary black and white television sets cannot reproduce the pictures in colour they must be able to produce them in black and white. Also, colour television receivers should be able to produce a black and white picture. These conditions are called *compatibility*.

CONTRAST The television receiver contrast control is used to adjust the difference in shades between a black and white picture. This is best done by using a test card which is transmitted at certain times during the day. A six-step contrast wedge shows Black, Dark Grey, Medium Grey, and White shades, and two intermediate colours.

The 625-line colour test card. It is designed to test all the functions of black and white and colour television receivers. The test engineers can adjust the contrast and shape of the picture accurately when this card is transmitted.



A cut-away model and the circuit symbol showing the control grid of a triode valve.



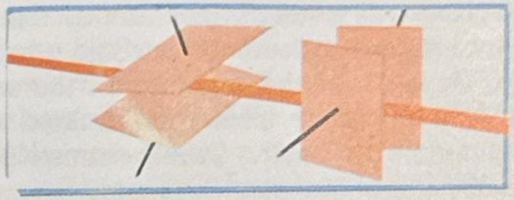
CONTROL GRID If a third electrode is inserted between the cathode and anode of a diode it is called the grid, and the valve becomes a triode. (See TRIODE.) It is usually an open spiral of fine wire surrounding the cathode. When the grid is given a negative charge it repels electrons back to the cathode. If this negative charge is made less, the flow of electrons increases. If an alternating voltage is applied to the grid there is a much larger change in the anode current. In this way the triode acts as an amplifier.

CRYSTAL A slice of quartz will vibrate mechanically, at a definite frequency (like a tuning fork). If the slice is made to vibrate, an alternating voltage develops. The opposite is also true; if an alternating voltage is connected across the opposite faces, the crystal starts to vibrate at its own particular frequency.

Because of this remarkably constant vibration, crystals are used to control the frequency of oscillators in both transmitters and receivers.

DECIBEL The decibel is a logarithmic unit, used in radio and television work, to express *power ratios.*

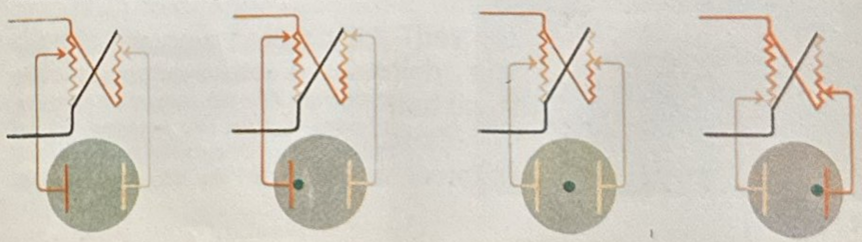
The deflection plates in a cathode ray tube are placed at an angle so that they do not obstruct the beam of electrons as it passes between them.



DEFLECTION In order to produce a straight line on the screen of a cathode ray tube, the electron beam has to be made to travel so fast across the screen that the eye sees only a line or a trace. It is usually moved from the left of the screen to the right. At the end of its journey it is allowed to return to the start to make another line. This process is so fast that all the eye sees is a continuous line across the face of the tube. To do this the beam is made to pass between a pair of plates called the X plates. A steadily increasing voltage to these plates is applied which pulls the spot from left to right. At the end of its journey the voltage drops suddenly to zero and the spot flies back for the start of the next trace.

Because of its shape, this voltage is called a saw-tooth waveform. The electron stream is cut off during the spot's return

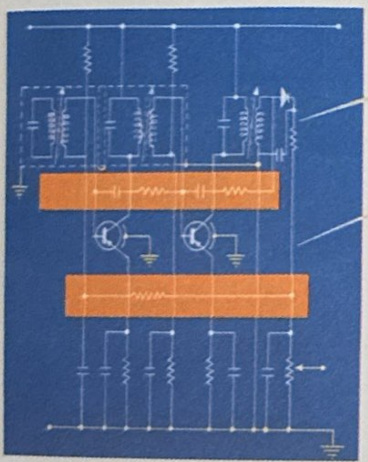
In a cathode ray tube the spot is deflected from one side of the screen to the other by increasing the voltage on one plate and decreasing it on the other. This can be done by using sliding resistors.

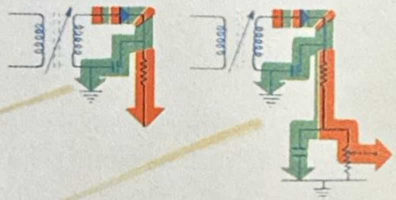


journey (the flyback), so that the return trace is not seen. As well as passing between the X plates the beam has also to pass through another pair of plates at right angles to the X pair. These are called the Y plates. Any positive or negative voltage placed on the Y plates will cause the trace to move up and down at the same time as it travels from left to right. The beam of light can be seen on the screen, following the exact voltage waveform which is fed into the Y plates. If an alternating voltage is placed upon the Y plates, then the spot will trace out an exact replica of that waveform.

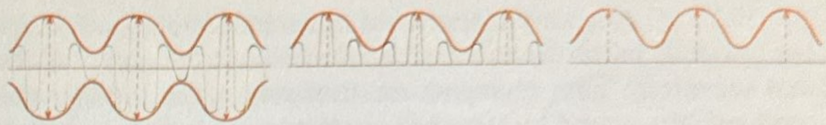
In a television cathode ray tube, the beam has to be pulled downwards a little further after each line or trace has been made, until it reaches the bottom of the tube. It has then to be allowed to fly back to the top to start the whole process over again. When no picture is being transmitted the eye will see a complete rectangle of light. During transmission time, however, the intensity of the spot is changing with the blacks and whites picked up by the camera. The eye therefore sees the complete black and white image of the studio picture. Most television cathode ray tubes do not use plates for deflection, but current carrying coils wrapped around the neck of the tube. Modern television sets use 625 lines (traces) to produce one complete frame or picture and 25 of these are transmitted per second.

DETECTION When the radio signal arrives at the aerial, it is selected by a tuned circuit, amplified, and passed on to the





Left: circuit diagram for the detection stages of a superhet receiver. Above: when the route divides in two the wanted signal takes one path and the other signal is filtered off by the other path.



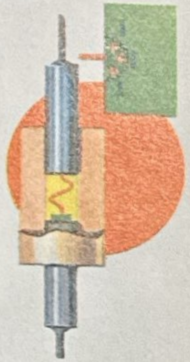
Half the signal is cut off by the diode valve. By the time the signal reaches the next stage all the high frequency part has disappeared.

detector. It still cannot operate a loudspeaker because its average value is zero. When the signal arrives at the detector it consists of the high frequency carrier, which is varying exactly above and below the zero line with the sound or picture from the studio. The diode detector chops off the bottom half of this wave and passes on the top half, which is a replica of the varying voltage produced by the microphone or camera. All that is necessary now is to get rid of the carrier frequency and allow the varying low frequency voltage to be amplified to drive the cone of a loudspeaker, or the grid of the cathode ray tube.

Modern detectors are usually germanium or silicon diodes, but miniature thermionic diodes are still in common use. (See DIODE.)

DIODE The thermionic diode is a two electrode valve containing a cathode and an anode. Modern diodes are usually semiconductors of germanium or silicon. Both types conduct in one direction only; if an alternating voltage is placed across the diode, one half of this voltage is removed when the diode does not conduct.

Diodes are used as detectors, as rectifiers which change alternating current (a.c.) into direct current (d.c.), and as stabilizers to keep voltages constant. In very fast switching circuits and high frequency oscillators, tunnel diodes are now being used. They are semiconductor devices which can operate at frequencies a hundred times greater than current transistors but require only a fraction of the power.



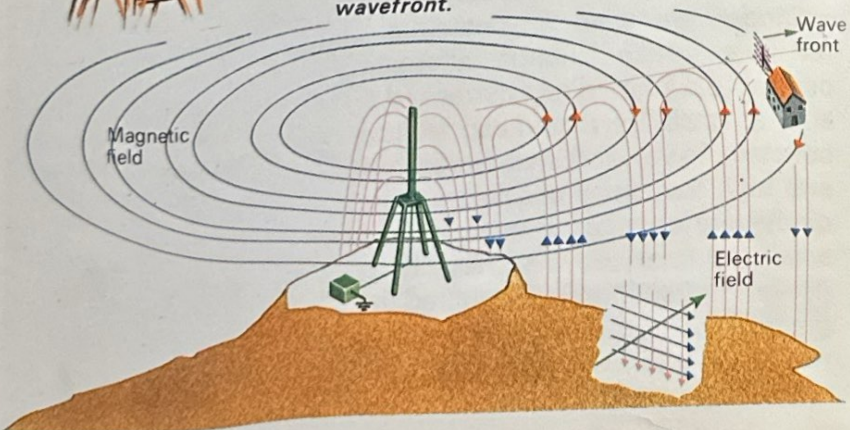
Above: a point contact semiconductor diode. Below: a thermionic diode valve.

DISTORTION Any amplifier should reproduce the signal which is fed into it as faithfully as possible. Sometimes the shape of the signal waveform gets changed, so that when the loudspeaker reproduces the sound, or when the cathode ray tube reproduces the picture, they are not true replicas of the original transmissions. This distortion may be caused by a faulty component in the amplifier circuit, incorrect operating voltages of valves or transistors, or, more rarely, a fault at the transmitter.

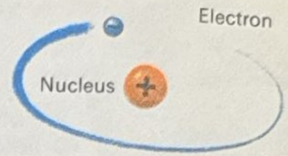
The aerials of a repeater station in a cross-channel television link. It is used to relay microwaves which are very short radio waves.

ELECTROMAGNETIC WAVES When a signal is passed along a wire of an aerial, the energy in the conductor is changed into electromagnetic energy which moves along the aerial as a form of wave motion. These waves will radiate from the aerial out into space at the speed of light. Gamma rays, X-rays, light rays, radio waves and microwaves are all forms of electromagnetic energy of different wavelengths.

Below: electromagnetic waves being radiated from the aerial of a radio transmitter. Electrical and magnetic fields are set up around the aerial and travel outwards as a combined wavefront.

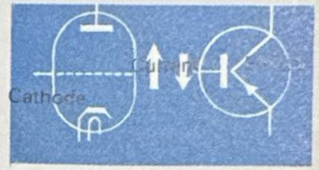


ELECTRON All substances are made up of atoms, the smallest particles of matter. The very small negatively charged particles surrounding the core, or nucleus, of an atom are called electrons. In many substances there are always electrons which are free to move from one atom to the next. These free electrons can all be made to move in one direction, by a battery, for instance. When this happens they produce a direct current (d.c.). When they are made to move rapidly backwards and forwards they produce a see-saw current or alternating current (a.c.).



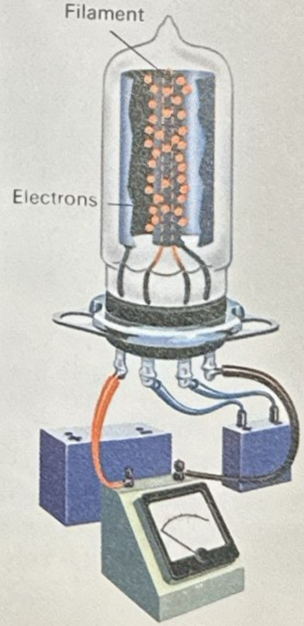
An atom of hydrogen. It has one electron which travels around the nucleus.

EMITTER The equivalent of the valve cathode in a transistor is the emitter. (See TRANSISTORS.) It is always shown as an arrow on the circuit diagram to show that positive charges flow from the emitter to the collector. The electron flow is in the opposite direction.

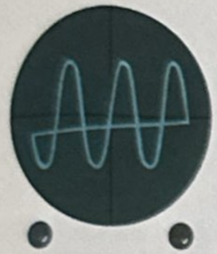


The emitter in a transistor is equivalent to the cathode in a valve as shown in these circuit symbols.

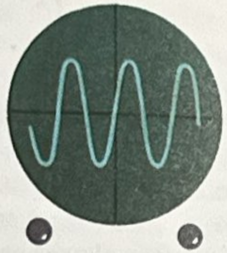
FILAMENT The filament, or heater, is a fine tungsten wire stretched between the base of a valve and a support near the top. It is often set inside the cylindrical cathode but certain rectifiers are directly heated and have no cathode. When a strong electric current is passed through the filament it becomes red hot and this raises the temperature of the surrounding cathode. The chemical coating of the cathode then emits (sends out) free electons. Valves of this type are called thermionic valves.



Right: a model of a thermionic diode valve showing the filament heating the cathode which then emits electrons.



Without flyback suppression the spot would leave a trace on the cathode ray tube (left). So the electron beam is shut off during the return trace (right).



FLYBACK After the spot on the cathode ray tube screen finishes its journey from left to right, it is allowed to return rapidly to start the trace again. This return journey is called a flyback. If this showed on the screen it would distort the picture, so the electron beam is shut off during the return trace; this is called flyback suppression.

FREQUENCY Alternating current passes backwards and forwards in a circuit a constant number of times per second. The number of oscillations each second is called the frequency, and each complete to and fro motion is called a cycle. The mains alternating current oscillates 50 times a second, so its frequency is 50 cycles per second (cps).

The system of units now being used internationally is the MKS system in which the number of cycles per second is called Hertz (Hz). The frequency of the BBC 1 Television Transmitter at Crystal Palace is 45 million (Mega) cycles per second, so this is now written as 45 MHz.

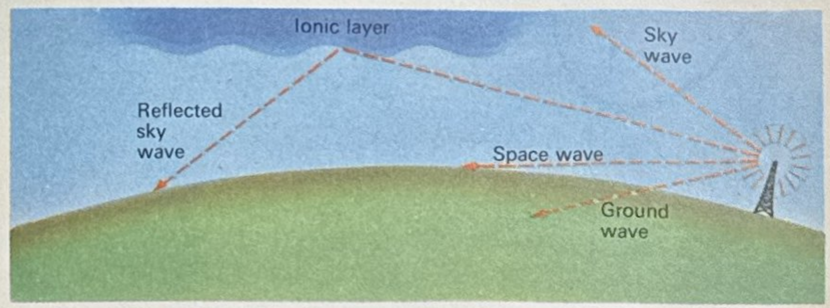
Regular transmissions are made on certain wavelengths. These lie in frequency-bands which have been agreed internationally.

Frequency	Frequency-bands	Wavelength
300,000 MHz		1 millimetre
30,000 MHz	EHF Extremely high frequency	1 centimetre
3,000 MHz	SHF Super high frequency	10 centimetres
300 MHz	UHF Ultra high frequency	1 metre
30,000 KHz	VHF Very high frequency	10 metres
3,000 KHz	HF High frequency	100 metres
300 KHz	MF Medium frequency	1,000 metres
30 KHz	LF Low frequency	10 kilometres
3 KHz	VLF Very low frequency	100 kilometres

FREQUENCY CHANGER The frequency of most transmitted signals is too high to be amplified properly. A very high frequency is reduced by mixing it with another signal higher in frequency than the incoming signal. The effect is to produce a 'difference frequency' which is called the Intermediate Frequency or I.F. The valve or transistor in the early stages of a receiver which oscillates at this higher frequency is called a frequency changer or a local oscillator. The valve or transistor into which both these signals are fed is called the mixer. A receiver which reduces the incoming signal to a lower value is called a *superheterodyne*. (See SUPERHETERODYNE.)

GROUND WAVE Electromagnetic waves produced by transmitting aerials usually spread out in all directions. (See ELECTROMAGNETIC WAVES.) Those which pass along the ground are called ground waves. Sky waves are directed towards the sky to miss the horizon. Most of the energy in the long and medium wavelength transmission is radiated in the ground wave. Because this energy dies away over fairly short distances, long and medium wavelengths are only used for short distances, up to 200 miles from the transmitter.

A radio transmitter emits electromagnetic waves in the form of sky waves, space waves and ground waves.



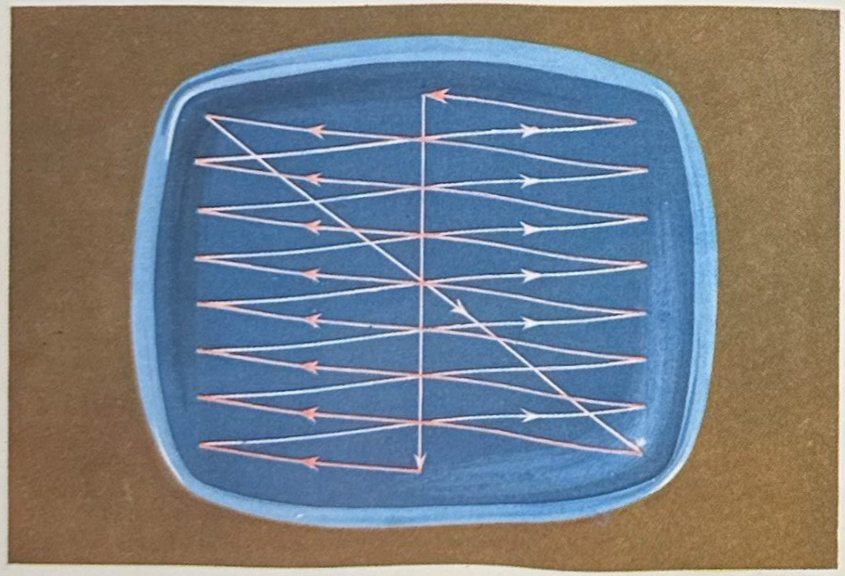
IMPEDANCE Most circuits are made up of resistors, capacitors and inductors. The combined resistance of these components will be very different for d.c. than for a.c. Their combined resistance to a.c. will have to be added together and will be different for various frequencies. This changing resistance, which depends on frequency, is called impedance, and it is measured in ohms.

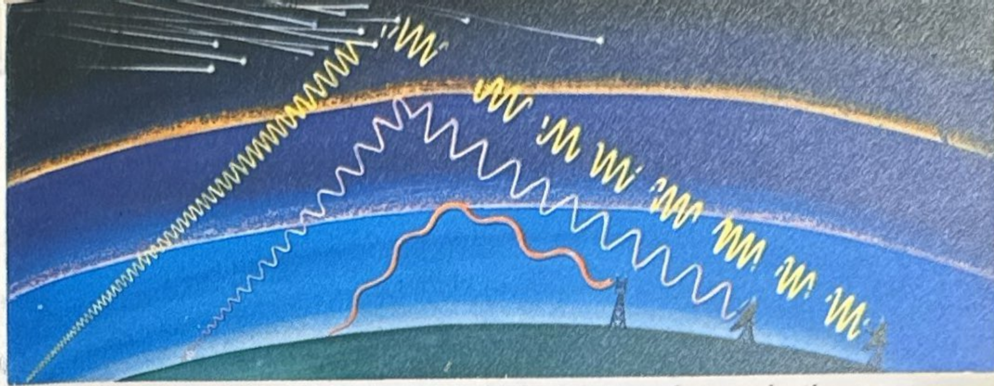
INDUCTORS OR CHOKES Inductors or chokes are used in circuits carrying alternating current. They have a small resistance to d.c. but high resistance to a.c. at different frequencies. Some chokes may have turns of wire on a core similar to those on a transformer. (See TRANSFORMER.) These offer a high resistance to low frequency a.c. Radio frequency chokes with no core and only a few turns of wire offer a high resistance to high frequency alternating currents. Their main use is to prevent a.c. of different frequencies passing into other parts of a circuit.

The *inductance* of an inductor or a choke is measured in units called henries; however, since the *henry* is too large for practical purposes, it is subdivided into millihenries and microhenries. One millihenry (mH) is one thousandth of a henry, and one microhenry (μH) is one millionth part of a henry.

INTERLACED SCANNING In a cathode ray tube, each completely scanned picture is called a frame. If too few frames are shown each second the picture will flicker. More than fifty frames per second gives a steady picture. The travelling spot on the cathode ray tube traces out parallel lines moving down the screen. When it has covered the picture, it returns back to trace out another series of lines in the gaps between the lines of the previous trace. This is called interlaced scanning.

To make a complete picture the spot traces two sets of parallel lines alternately.

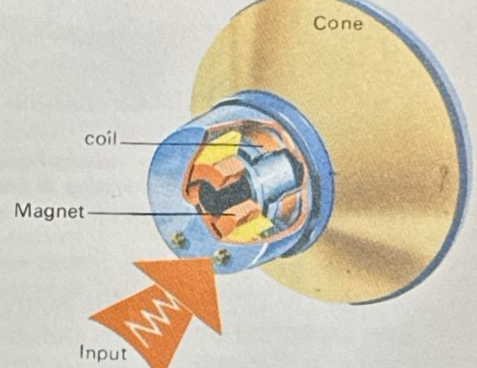




Radio waves are reflected off the ionised layers of gases in the upper atmosphere. Sometimes they are reflected off showers of meteorites too.

IONISATION When atoms of a gas lose or gain electrons, they are called positive or negative ions. The gas is then said to be ionised. When this happens inside special gas-filled valves, the gas becomes a conductor of an electric current. Thirty miles above the earth the gases of the atmosphere become ionised in layers by radiation from both the sun and outer space. These layers act as good reflectors for short wave transmissions from earth.

A moving coil loudspeaker showing the coil and the magnet which causes the cone to vibrate.



LOUDSPEAKER After detection in the receiver we are left with electrical pulses corresponding exactly to the sound waves produced in the studio. These electrical pulsations have to be changed back to sound waves in the listener's room. After amplification by the output valve, this varying electric current causes a coil to move in a narrow gap in a powerful circular magnet. Attached to this coil is a paper or plastic cone which is also made to move backwards and forwards. In this way, the air on both sides of the cone is made to vibrate and reproduce the original sound waves. This type of speaker, commonly used today, is called a moving coil speaker.

A singer's voice is picked up by the microphone which changes the sound waves into electrical pulses. The recording is made in a soundproofed room so that the microphone does not pick up any stray sounds.

MICROPHONE In the studio, the sound waves first have to be changed into electrical pulsations before they are impressed on the carrier wave for transmission. Although there are many types of microphone, each one works on the same basic principle. Each contains a diaphragm which vibrates in sympathy with sound waves striking it. The moving coil microphone is similar in construction to the moving coil speaker. The diaphragm is attached to a small coil of wire set between the poles of a magnet. Each movement of the diaphragm causes the coil to move between the poles of the magnet. Whenever this happens a current is produced if a circuit is connected to the coil. So the oscillations of the diaphragm produce a similar varying current. These small variations of current can then be amplified by valves or transistors.

MODULATION In order to transmit sound or a picture, the sound or light variations have to make the carrier wave change in shape when the waves are impressed upon it. This is called modulation, and two different methods are now common in broadcasting.

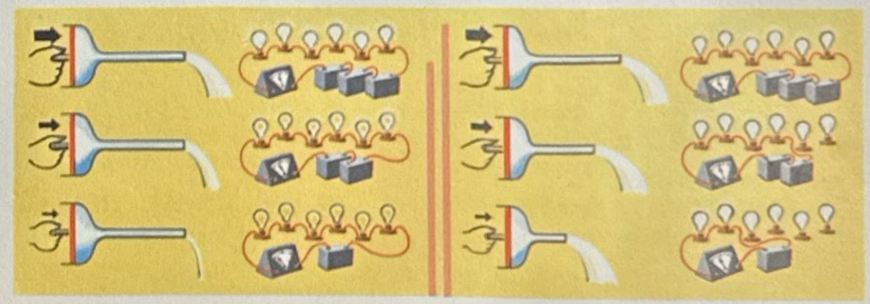
In the first, called amplitude modulation, the amplitude or peak-to-peak level is made to change with light and sound variations. In the second method, the amplitude remains constant and the frequency is made to alter in sympathy with sound signals. Other types of modulation are used in radar and satellite communication; the most common of which is Pulse Code Modulation where the carrier is broken up into pulses of varying lengths.

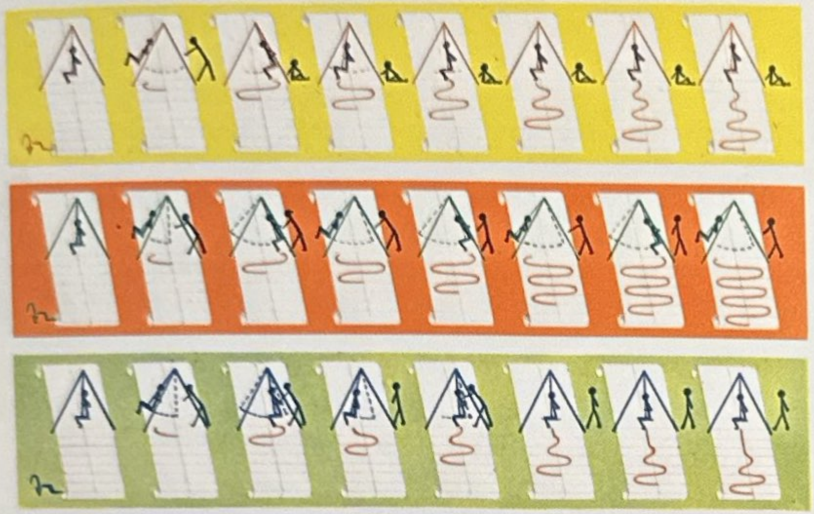
OHM'S LAW When you increase the voltage across the ends of a conductor, the current flowing through it will also be increased. This statement is the basis of most of our calculations in all electronic circuits. It is only true if the temperature remains the same all the time. In alternating circuits using capacitors, chokes and resistors, the calculation will be different for every change of frequency. The formula is often expressed as:

$$\text{I (current)} = \frac{\text{V (ElectroMotive Force or Voltage)}}{\text{R (Resistance)}}$$

Voltage is proportional to current through a constant resistance (say six light bulbs). As the voltage is increased by adding more batteries the current rises as shown by the ammeter and the brightness of the bulbs. This is similar to increasing the pressure in a water pipe so that the flow of water increases.

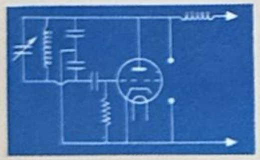
Voltage is proportional to resistance if the current is constant. As the voltage is increased the resistance must be increased to maintain the same current. Similarly, to maintain the same rate of flow in a water pipe, the resistance, or length of the pipe, must be increased as the pressure is increased.



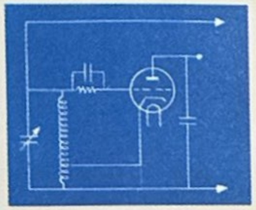


Electrical oscillations are rather like mechanical oscillations. Unless they are given a 'push' at exactly the right moment they will die away.

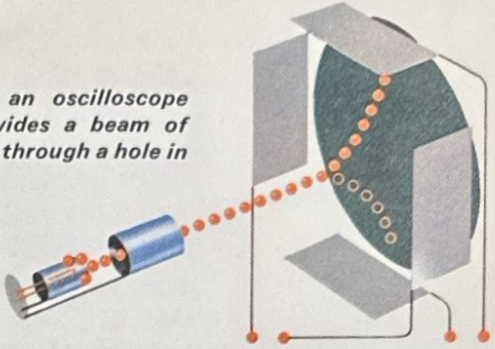
OSCILLATOR A valve or transistor circuit which can produce continuous electrical vibrations is called an oscillator. Like a pendulum, which is a mechanical oscillator, the vibrations would soon die away, unless they can be given energy at exactly the right moment. In a valve, or transistor oscillator, this energy is often obtained by feeding back some of the vibrations from the anode or collector circuit to the grid or base circuit. This 'feedback', as it is called, must be in step with the oscillations in the grid circuit. Oscillators are used in transmitters to produce a single frequency for amplification and transmission. They are also used in receivers to produce a difference frequency with the carrier before it is amplified.



Two standard oscillator circuits. Left: Colpitt's oscillator. Feedback occurs at the junction between the two capacitors. Right: Hartley oscillator. Current oscillations are fed back at the tapping point of the coil.



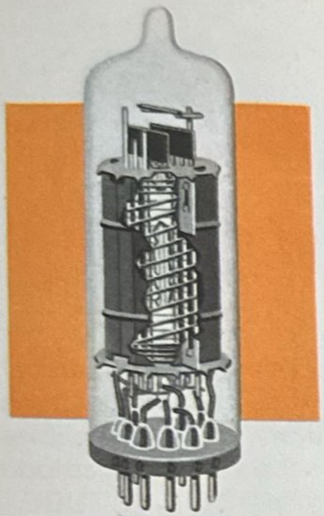
OSCILLOSCOPE A slow or rapid change in most forms of energy can often be converted into electrical energy. For example, changes of light intensity can be converted into



The cathode ray tube of an oscilloscope contains a gun which provides a beam of electrons. These are focused through a hole in the anode and travel onto the fluorescent screen. The spot they produce can be made to travel across the screen by altering the charge on the plates that are around it.

electrical variation. Sound waves can be converted into electrical waves. In order to see these changes, the cathode ray tube converts these changes to light. The instrument which enables us to do this is called a cathode ray oscilloscope. It has a cathode ray tube as its main component. (See CATHODE RAY TUBE.) Distortion in transmitted radio and television waves can also be seen with the help of a cathode ray oscilloscope. This makes it one of the most useful instruments and it is used in all branches of engineering. Another of its uses is in an operating theatre where variations in pulse rates can be converted into electrical pulses by an oscilloscope.

A cathode ray oscilloscope. A beam of electrons produces the signal trace on the screen. Different ranges of signals can be obtained by adjusting the controls. The movement of the trace on the screen can be controlled by adjusting the X- or Y-shift which alters the voltage on the deflection plates.

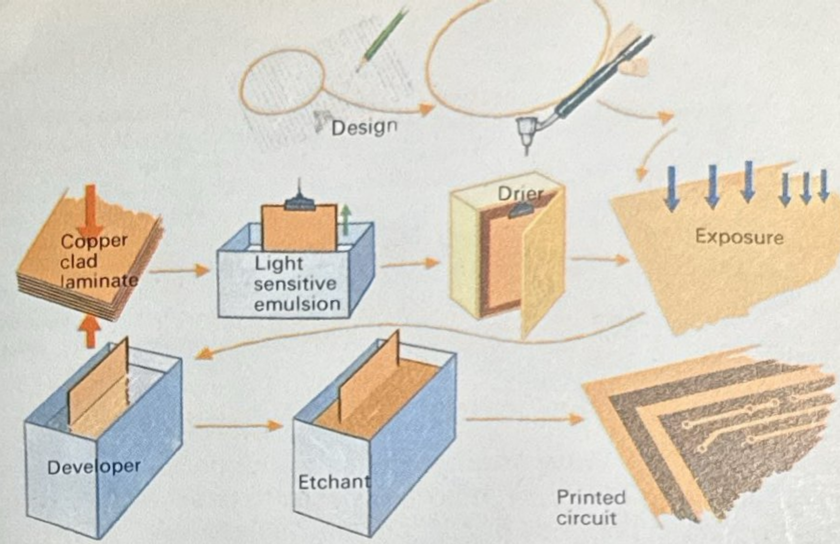


PENTODE The most common valve used in radio today is the five electrode pentode. A central cathode is surrounded by a control grid and an anode. A screen grid is placed after the control grid to prevent the feed back of high frequency currents. A suppressor grid is provided to prevent electrons from the anode being attracted back to the screen grid.

***Left:** a cut-away model of a pentode valve. It shows the five electrodes with the cathode in the centre surrounded by the control grid. A screen grid and then a suppressor grid are placed around this inside the anode.*

PHOTOELECTRICITY All metals throw out electrons when light falls upon them, but some metals do this more readily than others. Copper oxide and lead, in contact, produce an electric current when exposed to light. Selenium is even more sensitive to light and is used in exposure meters for photography. Another type of photo device is called a photoconductive cell. The resistance of this cell decreases with the amount of light falling upon it. If it is connected to a battery the current flowing in the circuit will alter as the light on the cell changes. This cell, sometimes called a light dependent resistor (LDR), is used to control the brilliance of the picture in a television receiver.

A photomultiplier tube. This is another photo-electric device. It passes a current when light falls on it. The amount of current depends on the intensity of the light.

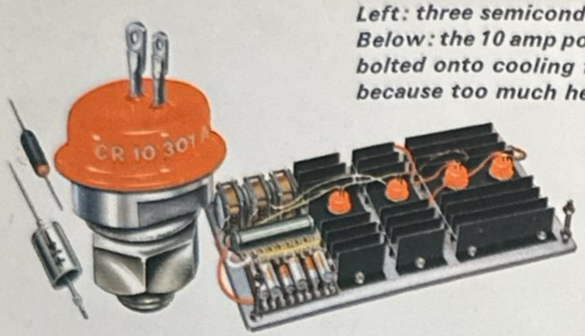


Making a printed circuit from copper clad laminated board and a photographic negative.

PRINTED CIRCUITS The assembly of most of modern radio and television receivers is done using 'printed' wiring, as inter-connections between different circuit components. The basic sheet material is usually a phelolic laminate, such as Paxolin, or it may be glass fibre laminate. Before the printing, one side of this sheet is completely covered by a very thin copper foil, usually 0·002 – 0·005 inches thick.

The manufacture of a typical printed circuit panel involves: overlaying (transferring) the desired circuit connections onto the copper side of the sheet; removing the unwanted copper by chemical means, which leaves only the circuit inter-connections on the panel; drilling holes in the copper wiring, for inserting the leads of different circuit components and for subsequent soldering of those leads to the copper wiring. The components are, of course, mounted on the copper free side of the panel.

For successful soldering, it is important to clean the copper wiring free from grease and dirt. This is best done by using a domestic abrasive cleaner, or fine steel wool and washing the panel off under the tap. Another important point is to keep the tip of the soldering iron clean and hot. The actual soldering of components may be done in two ways: either the components' leads are pushed through the holes, soldered in position and the surplus leads cut off; or the leads are cut short after mounting, bent over onto the copper wiring and then soldered to it.



Left: three semiconductor diode rectifiers. Below: the 10 amp power rectifier is shown bolted onto cooling fins. This is necessary because too much heat is produced by the current surging to and fro in the diode. The heat is conducted away to the metal fins which provide a large surface area for air cooling.

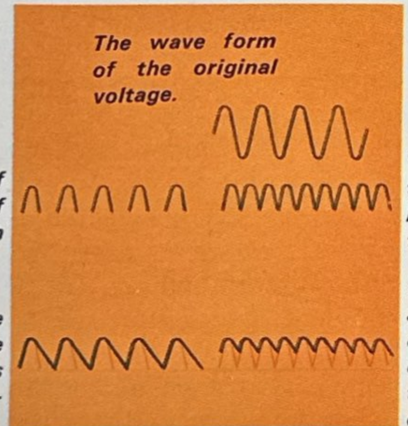
RECTIFICATION Valve anodes and transistor collectors usually require a steady d.c. supply. It is often easier to use the alternating current of the mains, but first this has to be changed to d.c. or *rectified*. The mains voltage is first increased with a transformer for valve and cathode ray tube circuits. (See TRANSFORMER). For transistor circuits it is often stepped down to about 12 volts. The a.c. is then applied to a valve or semiconductor diode which chops off either the top or bottom of the wave. This leaves a series of d.c. pulses which can be 'smoothed out' to d.c. by the addition of a large capacitor. (See SMOOTHING). If one rectifier is used, it produces fifty d.c. pulses per second and this is called half-wave rectification. When two diodes are used there are 100 d.c. pulses per second and this is known as full-wave rectification. Either circuit, with transformer, diodes, and smoothing capacitors is called the power supply.

The wave forms produced after half-wave and full-wave rectification.

Half-wave rectification

The bottom half of the wave is cut off on passing through a diode.

The capacitors have time to discharge between pulses which gives an unsteady voltage.



Full-wave rectification

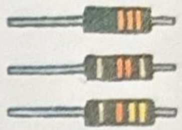
The frequency of the pulses is doubled by passing the signal through two diodes.

The frequent pulses are not fully discharged so that the output is steadier than from a single diode.

RESISTOR All conductors show some resistance to the passage of current through them; some show much more than others. In radio and television circuits it is necessary to have resistors of a fairly accurate value. They are usually made into a cylinder of compressed carbon. Sometimes resistors have to carry fairly heavy currents so these are made of coils of high resistance wire embedded in an insulating material. The value of the resistance is measured in ohms, Kilohms (thousands of ohms) or Megohms (millions of ohms). This is either printed or shown in the international colour code. (See COLOUR CODE).

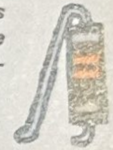
It is often necessary to alter the value of a resistance for volume, brightness or other controls. This is done by moving a slider over a carbon or wire track. The slider is brought out to a spindle which can be rotated by a knob.

Soldering resistors onto a printed circuit board.



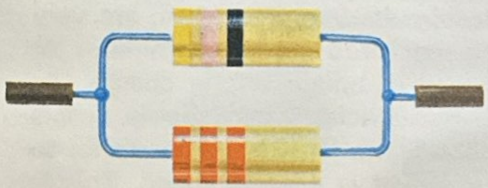
The ends of each resistor are 'tinned'.

The ends are bent over so that the resistor does not move while it is being soldered to the copper on the underside of the board.

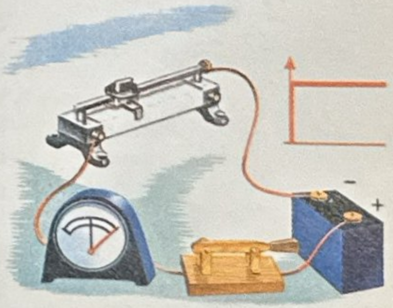


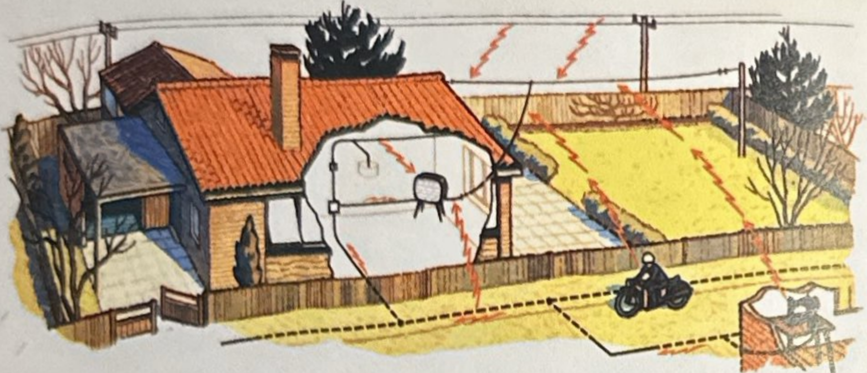
A 2,200 ohm and a 47 ohm resistor connected in series. Their total resistance will be (2,200 + 47) = 2,247 ohms or 2·247 kilohms.

A 2,200 ohm and a 47 ohm resistor connected in parallel. Their total resistance will be ($\frac{1}{2{,}200} + \frac{1}{47}$) = 21·7 milliohms.



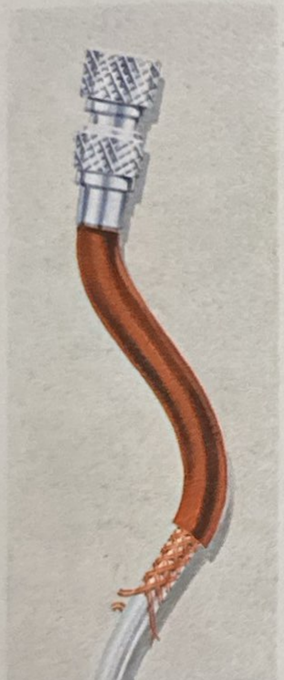
A rheostat. The value of this wire wound resistor can be altered by sliding the contact along the coil.





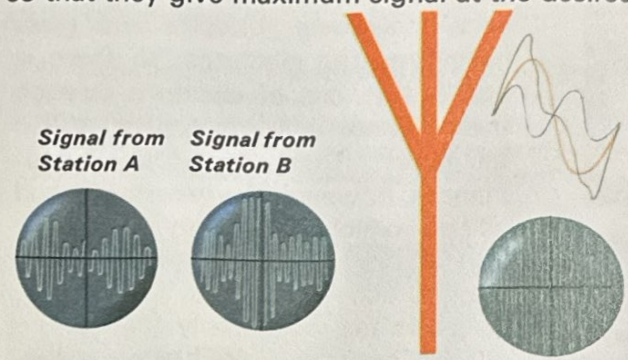
Below: a coaxial plug and cable showing the wire braid screening under the sheath.

Screening is necessary to prevent interference at the television receiver. Stray signals may come from nearby power lines, mains switches and electric motors in household equipment and passing vehicles.



SCREENING In circuits like a modern radio or television receivers, wires carrying many different signals are often placed closely together. Some of these may carry radio frequency, intermediate frequency or low frequency signals, and even the mains electricity wiring. It is often necessary to prevent the signals of one wire being picked up by a nearby conductor. To do this designers have to screen wires by covering the insulating layer around the conductor with a closely woven mesh of copper or aluminium. This braiding is then soldered down to the metal chassis which may be connected to earth. Large components like coils, valves, or complete circuits like oscillators, are very often enclosed in an aluminium or copper can bolted to the chassis. At high frequencies where dipole aerials are used, the lead from the aerial to the receiver is also screened. This is called coaxial cable and its insulating covering may be half an inch thick. The cathode ray tube in an oscilloscope is also covered with a special screen and made of mu-metal. This prevents any mains radiation from deflecting the electric beam.

SELECTIVITY The ability of a receiver to select a signal of one particular frequency from other frequencies close to it is called its selectivity. This will depend mainly on the circuits following the aerial or the radio frequency circuits. These are usually tuned so that they give maximum signal at the desired frequency.

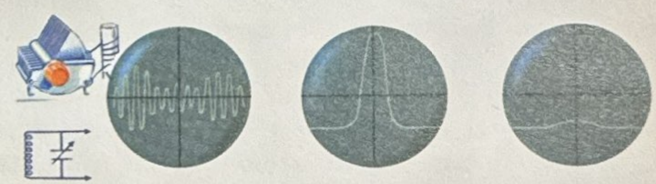


The combined signal arrives at the aerial as a jumble of irregular waves.

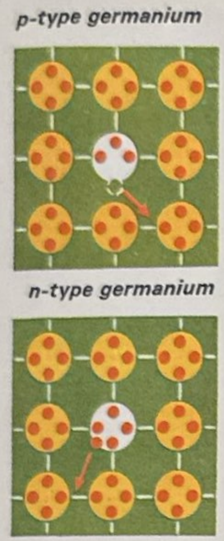
To select signal A (left) a tuned circuit is set to resonate at, or give maximum response (centre) to the frequency of A. The response to other frequencies is much lower (right).

Components of tuning circuit: adjustable capacitor and coil.

Diagram of tuning circuit.



To select signal B (left) the circuit is tuned by adjusting the capacitor. The circuit is now resonating at the frequency of B (centre). Once again the response to other signals is low (right).



Germanium acts as a semi-conductor when it contains certain impurities. One type of impurity has atoms which have an extra electron, in the other type the atoms are short of one electron.

SEMICONDUCTORS When the ends of an electrical conductor such as copper wire are connected to the terminals of a battery, electrons forming an electric current move from the negative terminal of the battery to its positive terminal. Substances which allow this transfer of electrons are called conductors. Most metals are good conductors. Substances like mica, polythene, bakelite and glass have few free electrons, so there is hardly any flow of electrons through them. These substances are called insulators. There are certain substances, however, like germanium and silicon which appear to be neither conductors nor insulators. These substances allow current to pass in one direction far more easily than in the other. These are called semiconductors. Because of this property, small semiconductor diodes now take the place of valve diodes for detection and rectifying the a.c. mains.

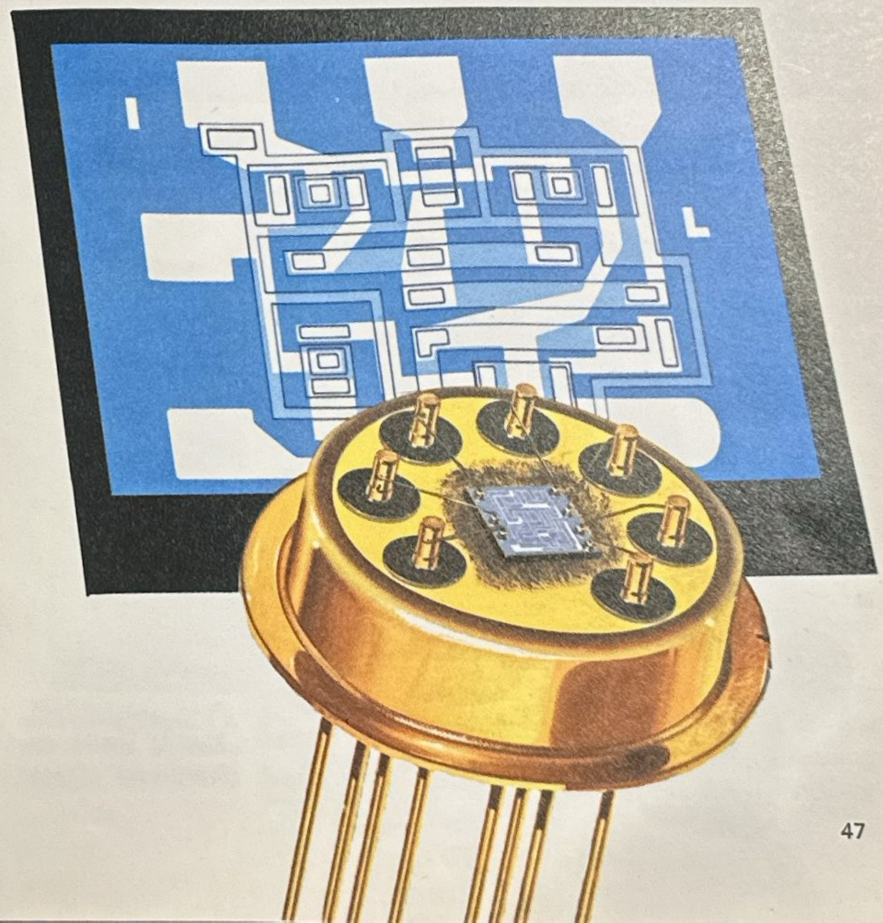
Although by 1930 the crystal detector had given way to the diode valve, the properties of crystals as semiconductors were not forgotten. The rapid development of Radar in the Second World War showed the need for smaller devices which could operate at higher and higher frequencies. Earlier a Russian scientist, Levov, stuck two cat whiskers in a single crystal to make the first 'solid state' sandwich. (See CRYSTAL). In this way, control could be exercised over the flow of current in the device, it could be made to operate as a fast on/off switch, or used as an amplifier. Because of its construction, the Levov transistor was of the type we would now call a *point contact transistor.*

By 1948 Schockley, Bardeen and Brattain, working at the Bell Telephone Laboratories in America, had perfected the *junction transistor,* which was made of a sandwich of either germanium or silicon with a different impurity added to each. At the junction an electrical barrier was produced which could be either

increased or reduced by a positive or negative voltage placed across it.

From this date the 40 years supremacy of the thermionic valve began to fade. The small transistor wasted less energy as heat, now that filaments were no longer needed, and could be used as an amplifier, an oscillator, or a switch. Dozens could be assembled in the space of a few valves. Because of the smaller currents of transistors and the lower voltages needed to operate them, other components in transistor circuits became smaller as well. A natural development of this was the *printed circuit board.* (See PRINTED CIRCUIT.)

An integrated circuit. The components exist only as wafers of chemicals. Making connections to such a tiny contact is one of the problems of using these microcircuits. This one (enlarged 5 times) is soldered to pins on a 'top hat'. To protect it, a cap is fitted, or the whole circuit is set in resin. The pins are then connected to the rest of the equipment.

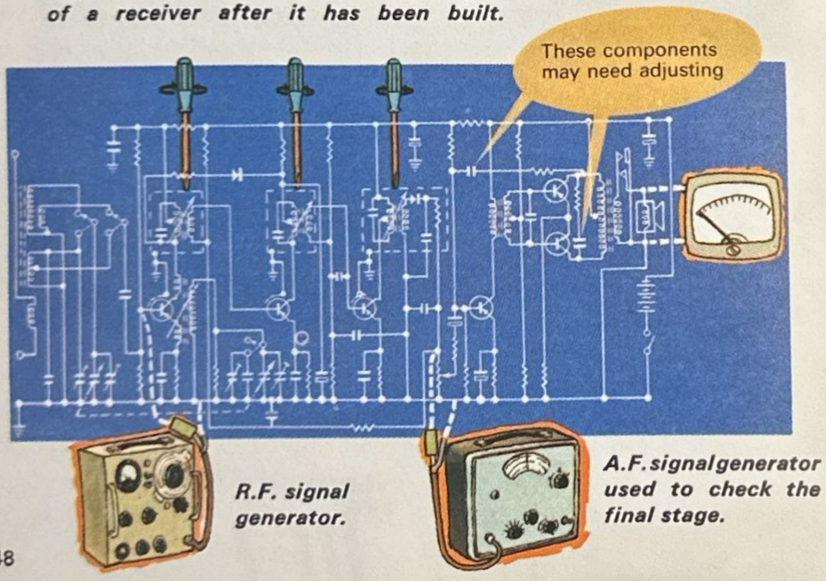


More recently, electronic circuits have suddenly become much more numerous and complex, in large computers and space equipment, for instance. More and more circuits have to be fitted into a limited space. The problem has been solved by the use of integrated circuits. Here the separate components of transistors, diodes, capacitors and resistors are unrecognisable as such, instead they exist in wafers of chemicals only. A modern integrated current amplifier containing, say, several transistors, diodes and resistors, takes up no more space than a single miniature transistor.

SENSITIVITY A receiver with a high sensitivity will be able to receive very small signals, of millionths of a volt (micro-volts), and deliver a high output of sound from the loudspeaker. The movement of electrons in valves and transistors is called noise. It appears as a hiss in the speaker, therefore a receiver must have a high enough sensitivity for the amplified signal to be heard well above the total noise level. The sensitivity is often compared, in decibels (dB), to the noise level of the whole receiver.

SIGNAL GENERATOR When a receiver has been built, the electronic engineer has to tune many of the circuits to exact frequencies, using an oscilloscope (see OSCILLOSCOPE). It is often inconvenient to wait for a transmitted sound or picture to do this. He uses an instrument which is really a small transmitter that can produce electro-magnetic waves over a wide range of frequencies.

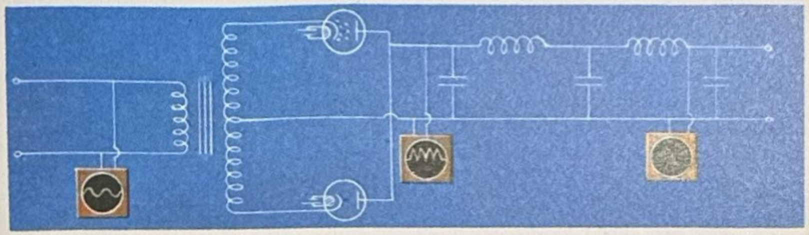
Signal generators are used to test the stages of a receiver after it has been built.



R.F. signal generator.

A.F. signal generator used to check the final stage.

This instrument is called a signal generator. It will not only produce a carrier frequency, but can also generate an amplitude modulated signal. Most signal generators will have some sort of indicator showing the strength of the signal being produced. Signal generators which cover only the lower frequencies including those of sound waves are called Audio Frequency Generators.

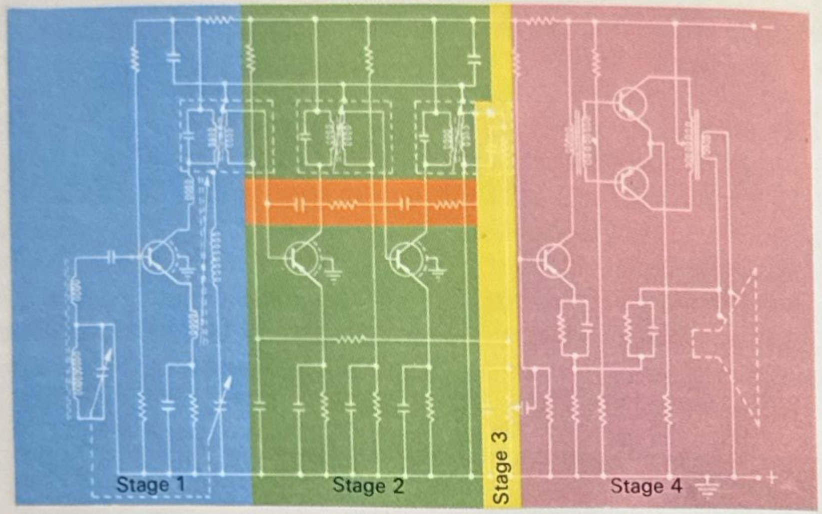


The oscilloscope traces show how this full-wave rectifier first chops off the negative pulses and then smooths the output signal by passing it through several large capacitors.

SMOOTHING After a diode rectifier has chopped off the negative pulses of the alternating current, only positive pulses are left. This pulsating voltage must now be changed to a steady voltage. A smoothing circuit consists mainly of large capacitors which store electricity when the diode passes current. When the diode is not passing current the capacitor will 'fill in the gap' between pulses by giving up its stored charge. The output is now a steady voltage with little or no mains ripple.

SUPERHETERODYNE RECEIVER Most of the present-day receivers for broadcast reception are superhet receivers.

The tuning coils at the input stage provide coupling between the aerial and the grid of the first valve, or the base of the first transistor. The R.F. amplifier increases the amplitude of the received signal and then passes it to a mixer. The R.F. amplifier stage is mainly responsible for providing good selectivity or



The complete superheterodyne receiver. Stage 1 is the oscillator mixer, Stage 2 is the intermediate frequency stage, Stage 3 is the diode detector and Stage 4 is the audio frequency amplifier.

discrimination against unwanted stations, or interfering signals. The oscillator and first detector stage convert the incoming R.F. frequency signal to an intermediate frequency (I.F.) signal. The I.F. stage normally consists of one (or more) circuits of tuned amplification. This section increases the selectivity of the receiver and provides most of its *gain*.

The second detector stage, usually a diode detector, feeds its output to the audio frequency (A.F.) amplifier for driving a loudspeaker.

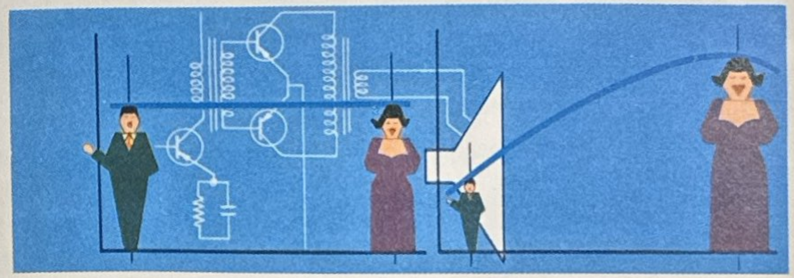
The main characteristics of the superhet receivers are high sensitivity, high selectivity, high gain and good stability.

SYNCHRONIZATION (sin-kron-eye-zay-shun) To synchronise means to make two or more things happen at the same moment in time. In order to obtain a steady picture on the screen of the television receiver, the spot must start at the same time as the scanning beam in the television camera. To do this the transmitter sends out a voltage pulse at the beginning of each line scanned. This synchronizing pulse is received in the television set, and is used to start the spot on the cathode ray tube. There is a synchronizing pulse before the start of each line. At the end of the complete frame another synchronizing pulse is

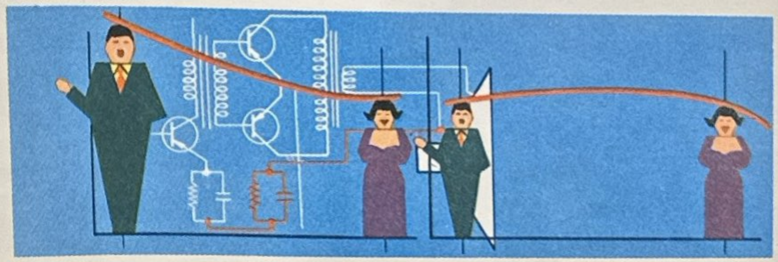
sent to start the spot tracing the next frame. If the synchronizing pulses are too weak the picture will drift up and down the screen.

THERMISTOR The resistance of most conductors increases as the temperature increases. The resistance of a thermistor *falls* with an increase in temperature. If a thermistor is wired into a series of valve filaments its high resistance at the beginning protects the valves from high surges of current when the set is first switched on. So when the temperature rises resistance falls and the valve filaments receive their normal current.

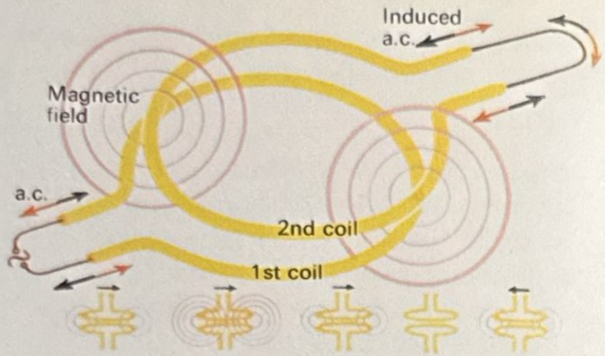
TONE CONTROL Audio-frequency amplifiers are often provided with bass and treble controls for altering the low- and high-frequency characteristics of these amplifiers. These controls enable the listener to compensate for room acoustics, reduce hum, reduce hiss or scratch etc. The tone control is usually inserted in the coupling path between two stages. In general, the high frequency response, or the treble, will be reduced by increasing the capacitance in parallel with the load resistance of the valve or the transistor. The low frequency response, or the bass, may be controlled by varying the coupling circuit capacity.



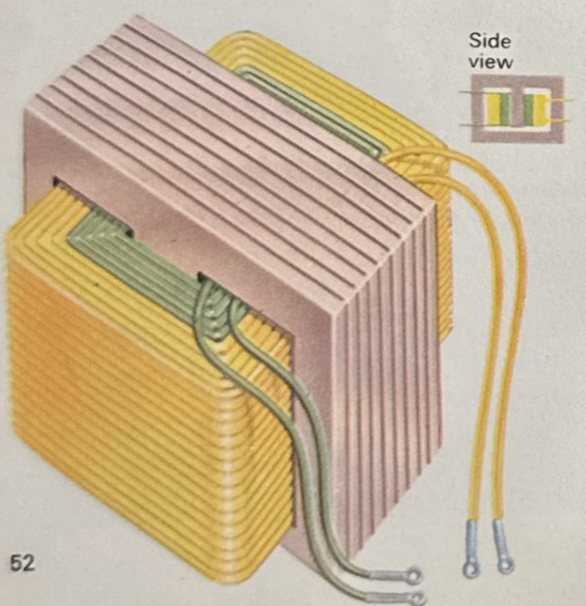
The amplifier increases the volume of the bass and treble equally but the loudspeaker boosts the treble (above). Tone control is provided by a feed-back capacitor (below) which reduces the treble.



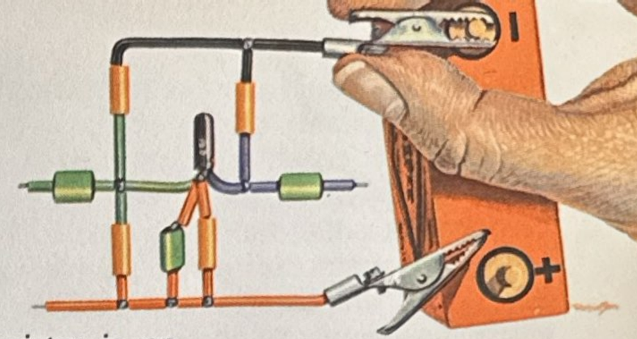
An alternating current flowing in a coil creates a magnetic field which alternately builds up and dies away. If a second coil is placed near the first one, the magnetic field causes an alternating current to flow in it.



TRANSFORMER Very often we need to increase or decrease alternating current at another voltage. To do this we use a transformer. This usually consists of a primary coil wound on a soft iron core. Currents in the primary induce currents in the secondary coil. How much we step up or step down the voltage depends on the number of turns of wire on the secondary coil compared to the number on the primary coil. Transformers for radio frequency circuits usually have iron dust or ferrite cores, or no cores at all. Transformers for mains voltages or for low frequency amplifiers have cores made up of strips of soft iron called laminations, clamped firmly together. Most mains transformers have several secondary coils giving high voltages for anodes (after rectification). There are also windings giving low voltages, for valve filaments.



An iron cored transformer. The secondary coil is wound around the primary. The soft iron former which forms the core concentrates the magnetic field.



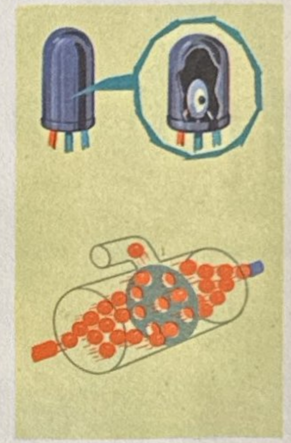
A simple amplifier using a transistor. The three capacitors (green) and four resistors (yellow) are arranged as in a circuit diagram. In practice the arrangement has to be far more compact.

TRANSISTOR The transistor is an amplifier. Compared with a thermionic valve the main difference between a transistor and a valve is that in a valve the electrodes are usually surrounded by a vacuum, whereas in a transistor the parts are in contact with one another in a three tier sandwich.

In a valve, the current carriers (electrons) move across the vacuum from a negative cathode to a positive anode. In a transistor the current carriers can be either negative electrons, or the spaces or 'holes' which electrons can leave or fill. These 'holes' behave just as if they were actual particles with positive charges.

Semiconductors, which have a surplus of electrons and therefore have a negative charge, are called n-type semiconductors. Those with a shortage of electrons, that is, a surplus of 'holes', giving them a positive charge, are called p-type semiconductors. These two types of semiconductors make n-p-n and a p-n-p sandwiches, respectively. (See SEMICONDUCTORS.) Most modern transistors are triodes. Their three parts correspond roughly to the cathode, control grid and anode. Each type of transistor has an emitter (cathode). This injects carriers into the middle part of the

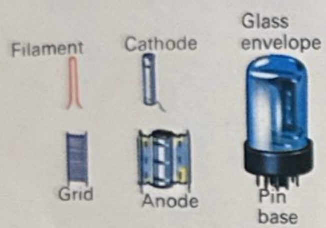
The actual transistor is enclosed in a protective case.



The rate of flow of the electrons between the emitter and the collector is controlled by the charge on the base.

Valves break easily, transsistors are more robust.

sandwich base. The collector attracts the carriers through the base. The majority of carriers reach the collector and therefore increase the collector current. A signal current fed into the transistor between emitter and base will modulate the flow of carriers across the sandwich. The collector current will not only follow the signal current changes but also greatly amplify them. Earlier transistors were nearly all made of germanium. Nowadays silicon has largely taken its place.



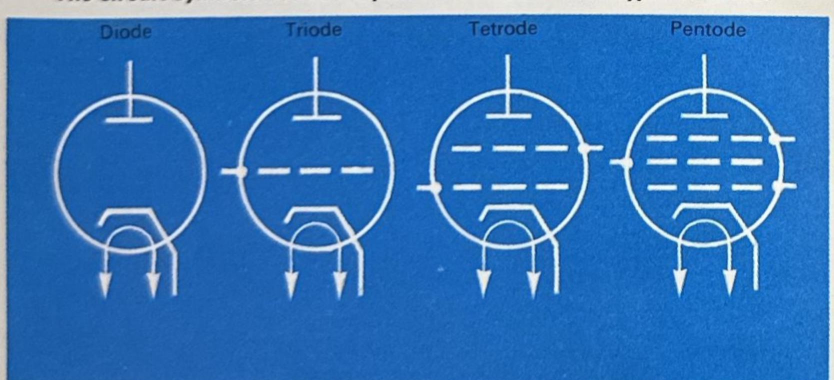
The parts of a triode valve.

TRIODE The cathode and anode, two main parts of a diode valve, are called electrodes. When a control grid is placed between them to control the valve current it is called a three part valve or triode. Other valves have four electrodes (tetrode) and five parts (pentode). Often two or more valves are contained within the same glass bulb, so we have valves called double-diode triodes, triode-pentodes or even triode-hexodes. (See VALVE.)

VALVE A thermionic valve is an electronic device which can be used as a rectifier, an amplifier or an oscillator.

The simplest type is the diode which consists of an evacuated glass envelope containing two electrodes and a heating filament. (See DIODE.) The positive electrode is called the anode and the

The circuit symbols used to represent the four main types of valve.



Making radio valves. The glass cover is fixed to the valve base and then it is evacuated and completely sealed in the machine on the far left.

Measuring the size of the grids with a micrometer gauge.

Assembling the electrodes on a special rig.

Welding the cage of electrodes to the valve base.

negative electrode is the cathode. Sometimes the filament is incorporated in the cathode. Its purpose is to heat the cathode and cause it to emit electrons.

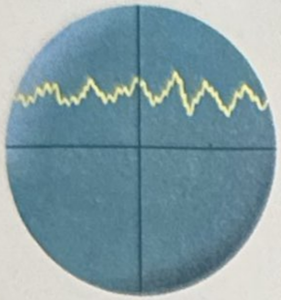
The three other main types of valve are the triode, the tetrode and the pentode. (See TRIODE, BEAM TETRODE and PENTODE.)

Most valves are not very strongly constructed so they are now being extensively replaced by transistors, semiconductors and solid state devices which also take much less space and consume less power.

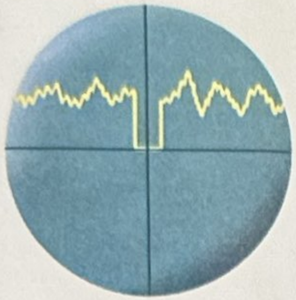
VIDEO WAVEFORM When the television carrier arrives at the receiver it has been modulated at the transmitter with synchronizing pulses, sound frequencies and vision signals. The vision modulation which changes according to the blackness or whiteness of the picture, is called a *video waveform*. After amplification the sound and video signals are separated. The sound signal is detected, amplified and fed to the loudspeaker.

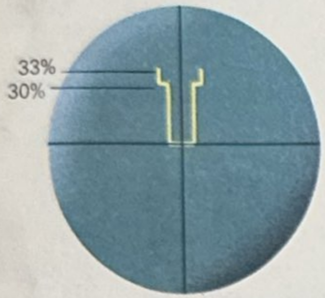
The video waveform is made up of three different signals.

The image signal from the camera in the studio.



The blanking-out pulses that are inserted into the image signal.





The synchronizing pulses introduced during blanking-out pulses. At the 30% line the carrier amplitude level indicates black because the signals are too weak. At the 33% line and higher the televised scene is being transmitted.

The synchronizing and video signals are detected and the former is sent to the time base circuits. The video signals go to the grid of the cathode ray tube where they alter the brightness of thç electron beam as it scans the tube face.

WAVELENGTH All electro-magnetic waves, radio or light waves, can be described either by their frequency or their wavelength. The wavelength is usually the distance measured in metres or centimetres from the crest of one wave to the crest of the next. All electro-magnetic waves travel at the speed of light so there is an exact relationship between frequency and wavelength. As the frequency increases the wavelength gets smaller. For example, the wavelength of BBC 1 transmitter on 45 MegaHertz (MHz) for Crystal Palace is about 7 metres while the BBC 2 transmissions on 570 MHz is nearly half a metre.

Some Important Dates in the History of Broadcasting

1896 Marconi, the inventor of wireless, arrived in London.

1897 The Marconi Company was founded to develop the techniques of wireless telegraphy.

1897 Marconi made the first transmission of wireless signals from Penarth in South Wales to Brean Down in Somerset.

1901 Marconi made the first transatlantic transmissions, to St. John's in Newfoundland from Poldhu in Cornwall, 2,000 miles away.

1906 An American made the first broadcast of music and speech. Previously only morse code signals had been transmitted.

1919 The first broadcast on the continent was made from the Hague, Holland.

1920 The first broadcast in Britain was transmitted from Chelmsford in Essex.

1920 The first broadcasting station in America began regular transmissions from Pittsburgh.

1922 Regular daily broadcasts from London were begun by the British Broadcasting Company.

1924 John Logie Baird produced a working 'television set'.

1926 The first television sets were demonstrated.

1927 The British Broadcasting Corporation (B.B.C.) began operating.

1932 The first experimental television broadcast was made.

1936 The B.B.C. Television Service began regular transmissions from Alexandra Palace.

1939 The National Broadcasting Corporation (N.B.C.) began a regular television broadcasting service in America.

1948 The first 'live' outside broadcast was televised in Britain.

1955 The regular transmission of colour television pictures began in America.

1955 The VHF broadcasting service was started in Britain.

1957 The British colour television system was demonstrated.

1958 Experimental television broadcasts on 625 lines were made.

1960 There was a demonstration of colour television in London transmitted from Paris.

1962 The first broadcast to the world of a message radioed from space. It was the voice of John Glenn, the U.S. astronaut.

1962 The first transatlantic television transmission was made via Telstar.

1967 The colour television service began in Britain.

Units and Symbols

Quantity	Symbol Used in Formulae	Unit	Abbreviation
Quantity	q	Coulomb	–
Current	I	Ampere	A
Voltage	E or V	Volt	V
Time	t	Second	s
Resistance	R	Ohm	Ω
Capacitance	C	Farad	F
Inductance	L	Henry	H
Mutual Inductance	M		
Power	W	Watt	W
Frequency	f	Hertz	Hz
Wavelength	λ	Centimetre	cm

The above list and the following one give some of the units that are used in electronics. The symbols that will be found in formulae and on circuit diagrams are also given.

Multiples of the units that are commonly used in electronics.

Microampere	(μA)	=1 millionth of an ampere
Millampere	(mA)	=1thousandth of an ampere
Microvolt	(μV)	=1 millionth of a volt
Millivolt	(mV)	=1 thousandth of a volt
Kilovolt	(kV)	=1,000 volts
Microfarad	(μF)	=1 millionth of a farad
Micro-microfarad	(μμF)	=1 million-millionth of a farad
Picofarad	(pF)	=1 million-millionth of a farad
Microsecond	(μS)	=1 millionth of a second
Millisecond	(mS)	=1 thousandth of a second
MegaHertz	(MHz)	=1,000,000 Hertz
KiloHertz	(KHz)	=1,000 Hertz
Microwatt	(μW)	=1 millionth of a watt
Kilowatt	(kW)	=1,000 watts
Metre	(m)	=100 centimetres
Kilometre	(km)	=1,000 metres

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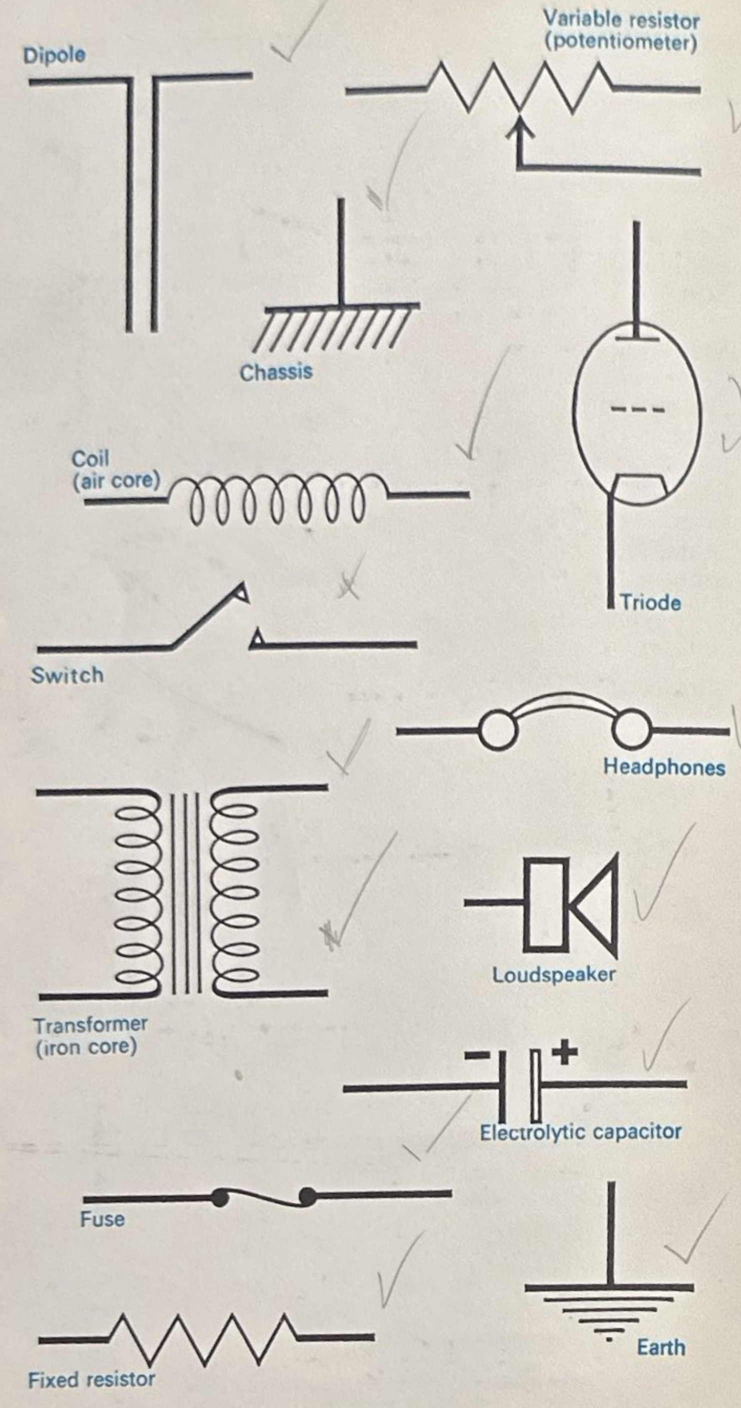
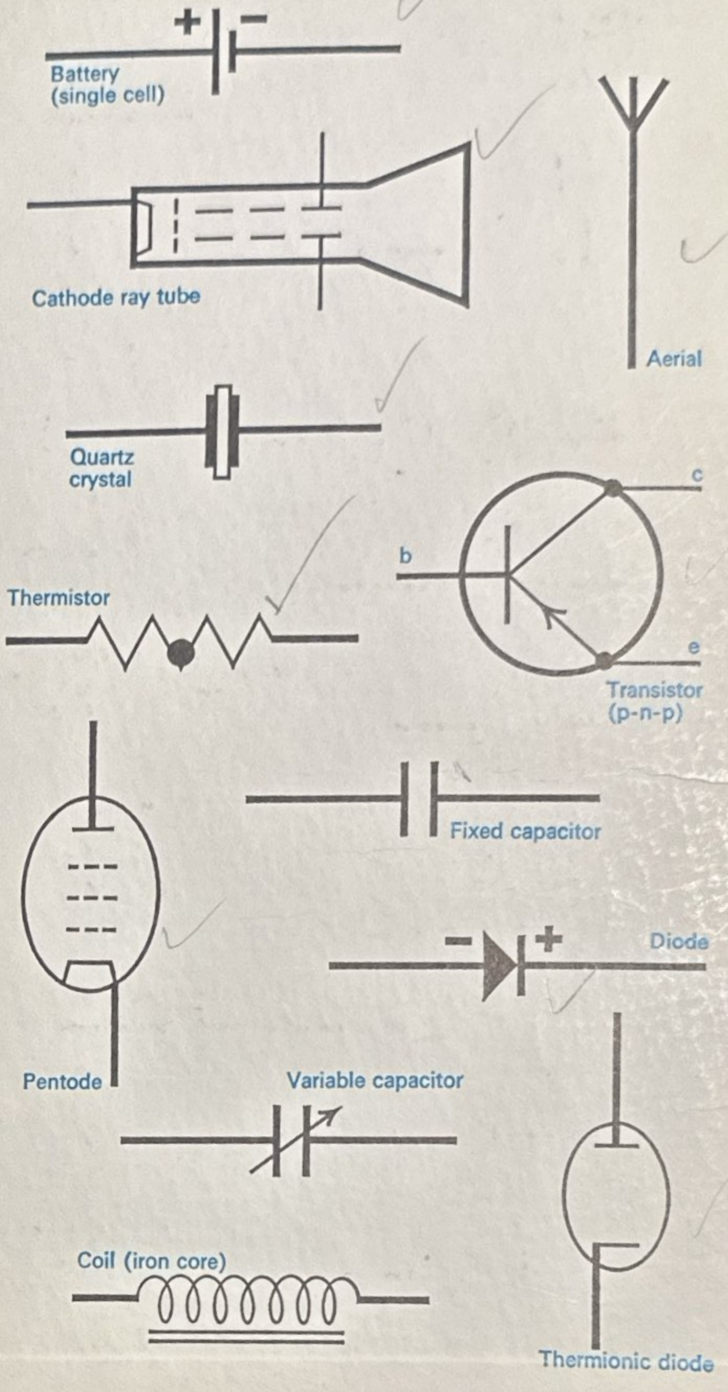

Dipole
Variable resistor (potentiometer)
Chassis
Coil (air core)
Triode
Switch
Headphones
Transformer (iron core)
Loudspeaker
Electrolytic capacitor
Fuse
Earth
Fixed resistor


Battery (single cell)
Cathode ray tube
Aerial
Quartz crystal
Thermistor
c
b
e
Transistor (p-n-p)
Fixed capacitor
Pentode
Diode
Variable capacitor
Coil (iron core)
Thermionic diode

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