# So you want to pass the R.A.E. (Radio Amateurs' Examination)? No. 4

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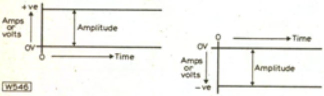
**The passing of the Radio Amateurs' Examination, set by the City and Guilds, requires a certain level of theoretical technical knowledge. Whether one considers that this level is too high or too low is beside the point. The course that follows is intended, with the help of certain external aids, to prepare the reader to pass the examination. It will not teach him all about electronics!**

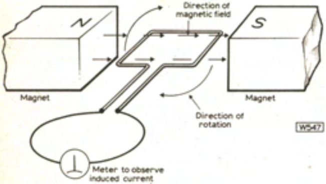
## Alternating current

In the previous sections we have dealt with direct current and we know that D.C. maintains a steady value, either positive or negative in polarity, as shown graphically below. Alternating Current (A.C.) on




the other hand, varies in a special way and to understand this, we return to the magnetics section. You will remember that when a conductor is moving in a magnetic field, the direction of the induced voltage (and the resultant induced current) depends on the direction of movement and the direction of the magnetic field.

Let us imagine two bar magnets, a loop of wire and a current meter, arranged:




The loop is rotated and, using Flemings Left Hand Rule, we look in detail at the induced currents in the loop, as shown in **Fig. 14.** In (a) no current flows because the direction of movement of the conductors forming the loop is parallel to the direction of the magnetic field. In (b) current begins to flow in the direction shown, as the conductor cuts across the field. In (c) maximum current flows as the conductors now cut the field at right angles. In (d) the current is decreasing and at (e) again no current flows. Here the position is similar to (a) except that conductors A and B are transposed. This means that when moving to (f) and beyond, conductors A and B are then cutting the field in the opposite direction. This results in the flow of current being reversed every half revolution. This is shown graphically in **Fig. 15** and it can be seen that in one revolution, the current starts at zero, rises to a positive maximum and falls to zero again, then rises to a negative maximum and again falls to zero, thereafter the pattern is repeated for every revolution of the loop. If the rotation is continuous and at a constant speed then the **peak amplitude** of the voltage (and resultant current) waveform and the **period** are also constant.

## The Sine Wave

The shape of the alternating waveform we have observed is called **sinusoidal** or a **sine wave** because the amplitude of the voltage or current at any point during the cycle is related to the trigonometrical function called the 'sine' of the angle of rotation. Fig. 16 will help you to remember some of the terms used when referring to sine waves. The amplitude at the peak of a sine wave is known as the **peak value.** Because the instantaneous value is continuously varying between the peak value and zero, the value which is equivalent in heating effect to D.C. lies between these values. It is known as the **root mean square** or rms value and it is this rms value which we use when stating the mains supply voltage, transformer ratings, etc. The rms value is 0·707 of the peak value and conversely, the peak value is 1·414 the rms value. For example, the peak value of the 240 volt mains supply is 240 x 1·414=339 volts. The peak value is of particular interest when specifying the maximum voltage rating of components in an A.C. circuit.

In Fig. 16, a 2Hz sine wave is shown, each period or cycle occupying 0·5 second.

As a further example, suppose that the time of one period was 1 ms (1/1,000 second) then there would be 1,000 cycles or periods in 1 second and the frequency would be written as 1,000 Hz or 1 kHz.

$$f\ (\text{frequency}) = \frac{1}{t\ (\text{time of one period})}$$

and

$$t = \frac{1}{f}$$

## Now test yourself:

Q. If the time of one period of an alternating current supply is 0·02 second (or 0·0166666 second if you live in the U.S.A.) what is the frequency?

A. The answer to this one is engraved on the front of your electricity supply meter.

The alternating current supply to your home is generated at the power station in a similar manner to the mechanically rotating coil we have just described. The alternating current passing from an Amateur VHF transmitter to the aerial is generated

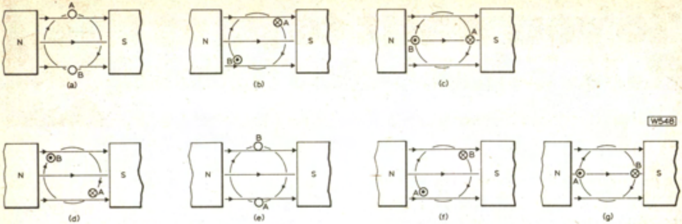
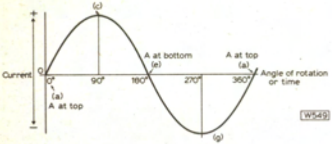



*Fig. 14: (above) and Fig. 15 (below).*




by a valve or transistor oscillator and amplifier. The frequency may be 145MHz (145,000,000 cycles-per-second) but the alternating current is still a sine wave and it has the same properties as its lower frequency compatriot.

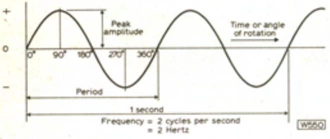



*Fig. 16: 2Hz sine wave, showing peaks.*

## Self Inductance

When a conductor is carrying A.C., the magnetic field produced by the current varies in both amplitude and direction. This variation of the magnetic field around the conductor induces, by self inductance, a voltage (back e.m.f.) in the conductor and this produces a current which opposes the 'main' current producing it (Lenz's Law).

In a straight conductor, the self induced current is smaller than if the conductor is wound into a coil or solenoid. Here the magnetic field lines surrounding each conductor also pass through adjacent conductors and induce currents in these which also oppose the 'main' current. The effect is shown diagramatically in Fig. 17. The self inductance of a coil depends on a number of factors including the number of turns, the diameter of the conductor, the permeability of the material in the core, and the volume and general configuration of the coil. The unit of self inductance or inductance is the Henry (H) and practical coils or inductances may have values from a few micro-henrys ($\mu$H) to several millihenrys (mH) for radio frequency use and up to many tens of Henrys for low frequency purposes.

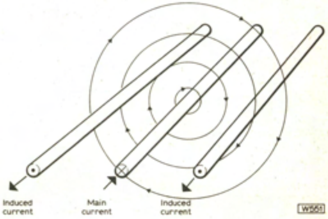
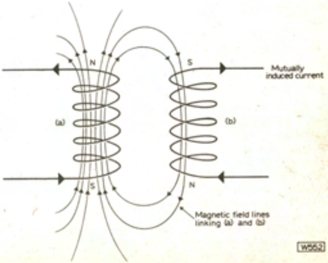



*Fig. 17*

## Mutual Inductance

Mutual inductance is easier to visualise than self inductance and is shown in diagram form in Fig. 18:



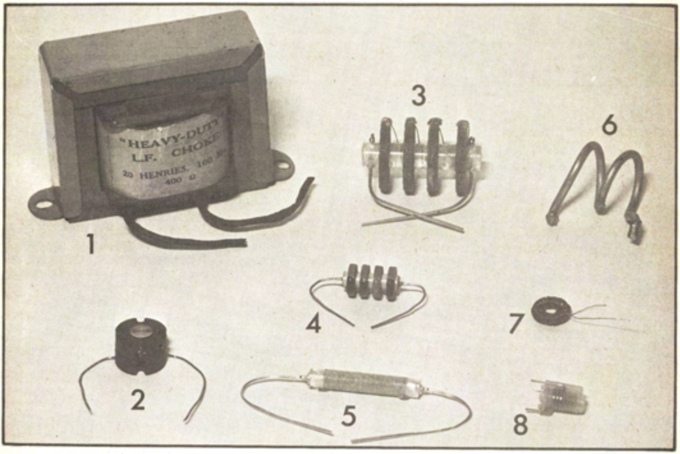
Suppose we pass a current through coil A in the direction shown. The resultant magnetic field lines link it with B and induce a voltage and resultant current in that coil. (Note that the current flowing in coil B is opposite to that in A. See Memory Aid Fig. 7.)

If an alternating current is made to flow in A, then for each change in current direction there will be a change in magnetic field direction and a resultant change in the induced voltage and current in B. In other words, an alternating current in A produces an alternating current in B. The circuits are electrically isolated but magnetically linked or coupled by the 'magnetic circuit'. You will no doubt recognise this as the action of a **transformer.**

all of the primary field lines pass through the secondary winding. The losses in the windings themselves result from power being dissipated as heat due to the ohmic resistance of the copper wire used. With careful design, transformers can be made where these losses are very small indeed, in fact a modern power transformer can have an efficiency as high as 98%.

## Transformer types

Transformers come in many shapes and sizes. The construction may vary between two "hairpins" of heavy gauge wire making a transformer that will couple power out of a VHF or UHF transmitter, to




*1: Heavy duty L.F. choke. 2: Ferrite pot-core inductance. 3: Transmitting H.F. choke. 4: H.F. choke. 5: VHF choke. 6: VHF transmitter tank coil. 7: Ferrite toroid inductance. 8: VHF tuning inductance.*

## The Transformer

A Transformer consists of two (or more) coils or 'windings' magnetically coupled, so that an alternating current in one coil, the **primary**, produces an alternating current in the other, the **secondary.** The method of magnetically coupling the coils depends largely on the frequency of the alternating current with which it will be used.

Providing that the primary and secondary windings have the same number of turns then the secondary current will be almost equal to the primary current and the secondary voltage almost equal to the primary voltage. It will not be exactly equal because of losses in the magnetic circuit and in the resistance of the windings. The losses in the magnetic circuit are mainly due to a loss of induced current because not

the heavy, laminated iron cored, version found in the mains transformer. The primary and secondary windings need not be physically placed side by side. Often they are wound one on top of the other, or adjacent, end to end. The windings may also share a common core material, such as in the mains transformer. This serves to concentrate the linking magnetic field, improving the efficiency of the magnetic circuit. The windings may also form part of a tuned circuit, as in the case of the I.F. transformer, which we will be dealing with later.

## Basic rules

There are some basic rules that apply to transformers, particularly low frequency and power types, which define the relationships between **primary and secondary current, primary and secondary voltage** and the **numbers of turns** in the primary and secondary windings. These are best summarised in some simple equations, but let us first define the quantities involved.

Primary current = Ip
Secondary current = Is
Primary voltage = Vp
Secondary voltage = Vs
No. of primary turns = Np
No. of secondary turns = Ns

In these equations we will ignore the losses which occur since they are relatively small, so that:

$$\frac{\text{V secondary}}{\text{V primary}} = \frac{\text{No. of secondary turns}}{\text{No. of primary turns}}$$

$$\text{or } \frac{Vs}{Vp} = \frac{Ns}{Np}$$

also:

$$\frac{Ip}{Is} = \frac{Vs}{Vp}$$

We may combine these two equations, as follows:

$$\frac{Ip}{Is} = \frac{Ns}{Np} = \frac{Vs}{Vp}$$

Using these equations it is possible, if we know some of the quantities involved i.e. current, voltage, no. of turns, to calculate the others without too much trouble.

### Example 1

A mains transformer has a 250 volt primary winding and a secondary winding that provides 15 volts for use in a low voltage supply unit. How much current can be drawn from the secondary if the primary current is 0·5 amps?

The part of the equation we require is:

$$\frac{Ip}{Is} = \frac{Vs}{Vp}$$

putting in the values that we know:

$$\frac{0{\cdot}5}{Is} = \frac{15}{250}$$

Rearranging we get:

$$Is = \frac{0{\cdot}5}{0{\cdot}06} = 8{\cdot}33 \text{ amps (say 8 amps)}$$

So we have found that we may draw 8 amps from the secondary winding, at 15 volts.

### Example 2

A mains transformer has the following windings:

Primary 240 volts
Secondary (a) 1000 volts
Secondary (b) 12 volts

The primary winding consists of 1,440 turns of wire. Assuming there are no losses, calculate the turns required for the secondary windings (a) and (b).

$$\frac{Ns}{Np} = \frac{Vs}{Vp} \text{ therefore } Ns = Np \times \frac{Vs}{Vp}$$

$$Ns\,(a) = 1440 \times \frac{1000}{240} = 6000 \text{ turns}$$

$$Ns\,(b) = 1440 \times \frac{12}{240} = 72 \text{ turns}$$

# CONSTRUCTION

## Inductances and Chokes

In a practical circuit the actual value of the Inductance and its construction is governed largely by the frequency and the characteristics of the circuit in which it is to be used. A selection of inductors and chokes is shown in the photograph.

Low frequency laminated iron-cored chokes are used for filtering purposes in D.C. power supplies. The winding is carried on a bobbin, through which the core is asembled. In audio frequency circuits, chokes may also be wound and enclosed in a ferrous material 'pot-core'.

Intermediate and low radio frequency coils are usually layer wound on a former or tube, sometimes in several sections to reduce self capacitance. Tuning coils are wound on a former inside which is a threaded core of iron dust material which can be

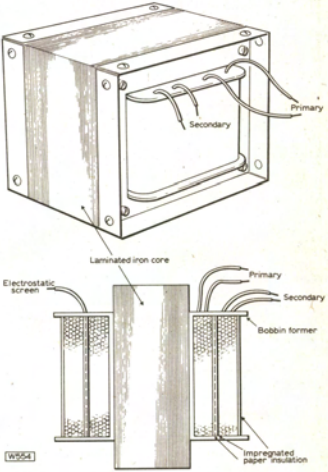



*Fig. 20: Mains transformer-physical construction.*

screwed in and out to adjust the inductance to the exact value required. Coils for HF and VHF are usually made of thicker wire wound on low-loss formers or self supporting with an air 'core'. At UHF inductors may be in the form of strips or lines of flat strip or rod and bear little physical resemblance to a conventional coil.

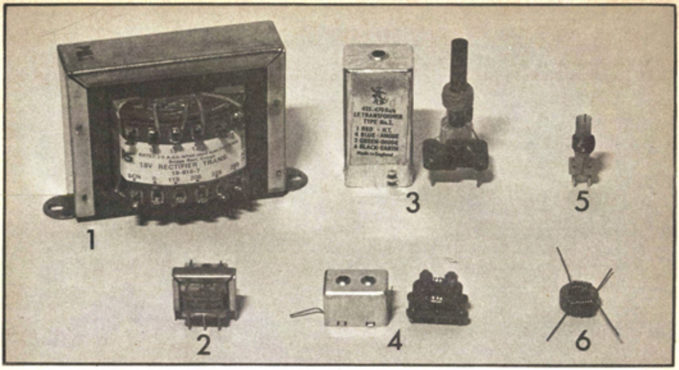



*Fig. 21: Mains transformer (18V rectifier trans.). 2: Transistor driver transformer. 3: I.F. transformer. 4: Miniature I.F. transformer. 5: R.F. transformer coil. 6: Broadband R.F. transformer.*

## Transformers

The mains transformer has windings designed to suit the expected operating conditions. If the transformer has to provide a high value of current (as in our Example No. 1) then the windings are of heavy gauge (diameter) wire, appropriate to the current, so that the overall resistance of the winding is small and the power lost, also small. The mains transformer often has an electrostatic screen between the primary and secondary windings. This is connected to 'earth' and prevents any capacitive leakage or other effects from affecting the secondary windings. The windings themselves consist of enamel covered copper wire wound on a bobbin with layers of insulating material between each winding. The core is made up of thin laminations of special iron to reduce 'eddy current' losses. Eddy currents are produced in the core by induction (remember that iron is also a conductor) and the laminations provide many breaks in the electrical continuity of the core material thus preventing the flow of eddy currents while leaving its magnetic properties largely unaffected.

Transformers for audio frequencies are similar in construction to power transformers but the core material is specially made to operate over a wide frequency range and to cause negligible distortion.

I.F. (Intermediate Frequency) transformers usually consist of two windings which are each tuned to the operating frequency by associated capacitors and adjustable tuning iron dust cores. The magnetic coupling between the windings is critical and is set in manufacture to provide the desired selectivity characteristic.

R.F. (Radio Frequency) transformers vary widely in design and construction and may be wound on a former with or without an adjustable core. R.F. transformers for use over a wide range of frequencies are sometimes wound on a ferrite ring. The secondary winding may be separate from or interwound with the primary. ●

# KINDLY NOTE!

**IC of the month—Nov 1977**

We apologise to our readers, and to Ferranti Ltd., for misquoting the type number of the timer IC on the cover and contents page of the magazine. The number should be ZN1034E, as given in the article.

**Low Distortion Sine/Square Wave Generator, October 1977**

In Fig. 1 the connection from the switch S2a 'Sine' position should go only to VR5, and not to S3 or VR2. The PCB is correct. If the circuit is constructed on other than our PCB, using Fig. 1, the effect of the error will be that the output attenuator will be inoperative on 'Sine'.

Resistors R4 (3·3kΩ) and R5 (680Ω) are shown transposed on the PCB. The circuit diagram is correct.

**Solo Supermind, October 1977**

The case details should be "R.S.Comps. code 509-276, with a front panel size of 250mm x 130mm. If inaccuracies are noted in meter deflection, resistors R1 to R8 (all 2·2kΩ) should be changed to 2kΩ high stability (metal oxide).