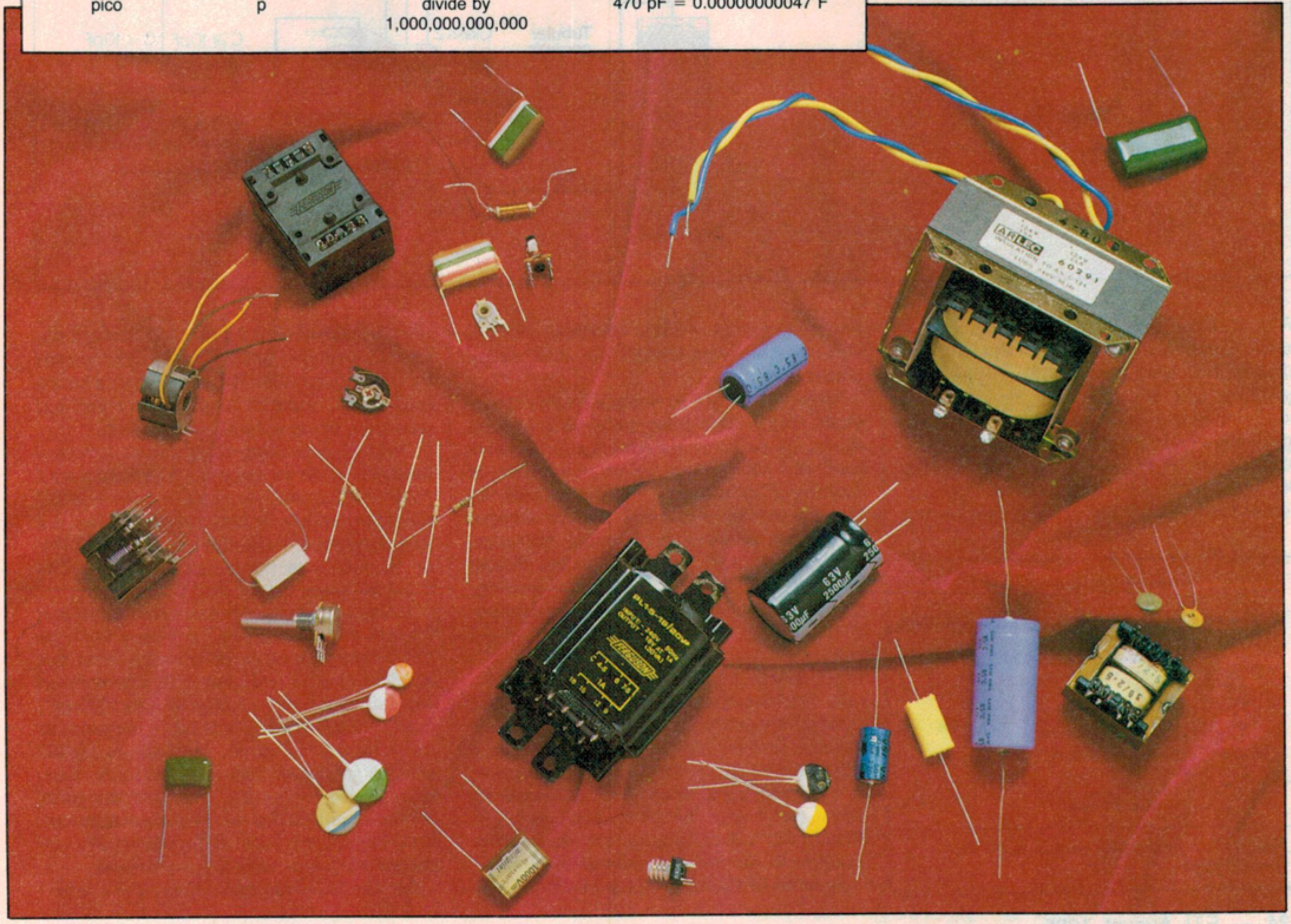
KNOW YOUR PASSIVE COMPONENTS

Peter Phillips

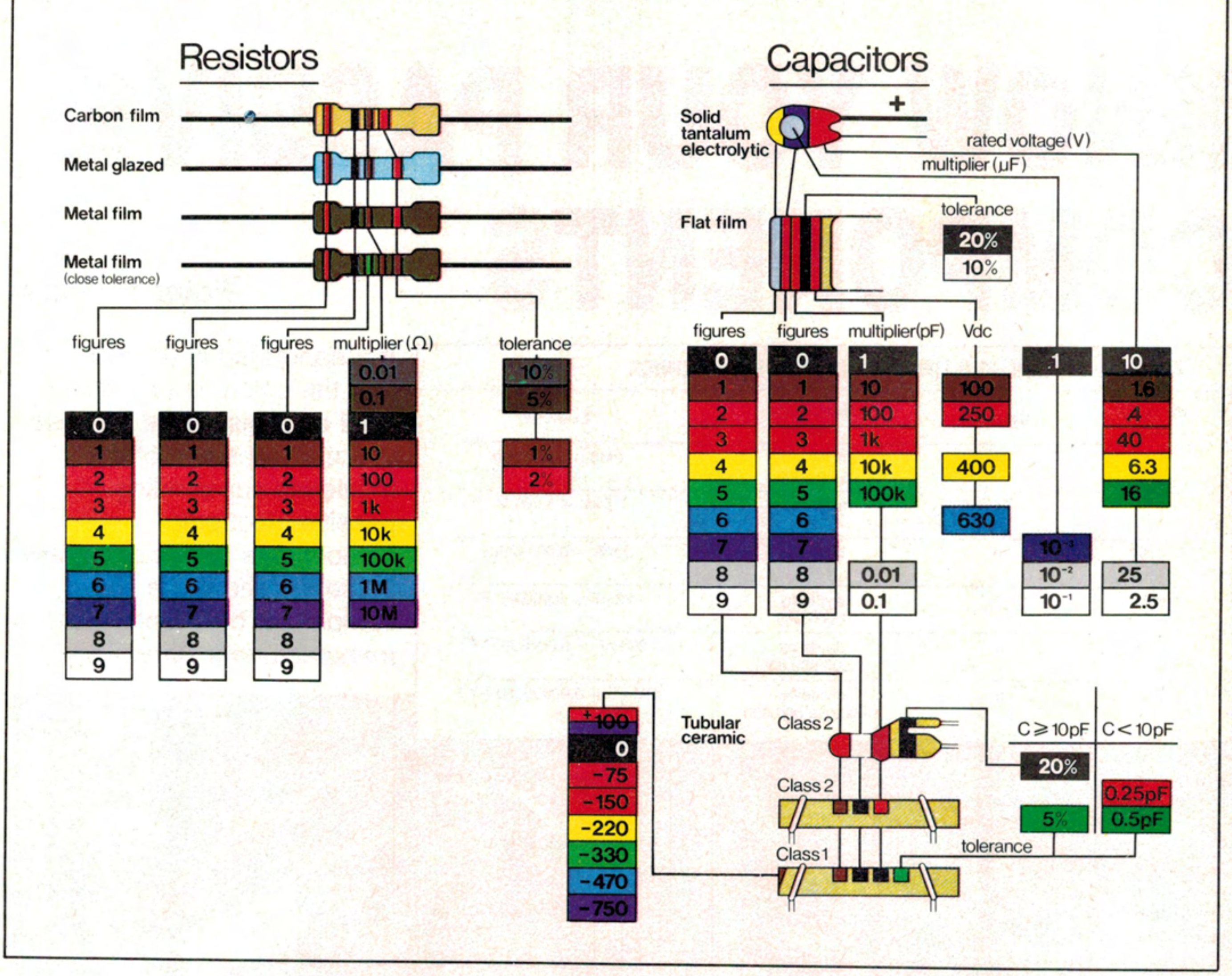
If a nanofarad is unknown and the colour code unclear, read on. This article will help you unravel some of the mysteries surrounding passive electronic components and tell you how to identify the value of a component by decoding the manufacturer's symbology!

TABLE 1. TYPICAL MULTIPLIERS USED IN ELECTRONICS

Multiplier name	Symbol	Multiplier's value	Example
Mega	M	multiply by 1,000,000	2M2 = 2,200,000
kilo	k	multiply by 1,000	5 kV = 5,000 V
milli	m	divide by 1,000	3 mA = 0.003 amps
micro	µ	divide by 1,000,000	22 µF = 0.000022 F
nano	n	divide by 1,000,000,000	330 nF = 0.00000033 F
pico	p	divide by 1,000,000,000,000	470 pF = 0.00000000047 F



COLOUR CODES



WHAT THE HECK is a passive component? If you're a newcomer to the world of electronics, you're probably asking that question right now. The brief answer is it's a component (obviously!) that doesn't require any external source of power in order to do its job. A resistor, a coil, even a piece of wire are all examples of passive components. And they're numerous — in a typical circuit there could well be as many as 90% passive components to 10% active components.

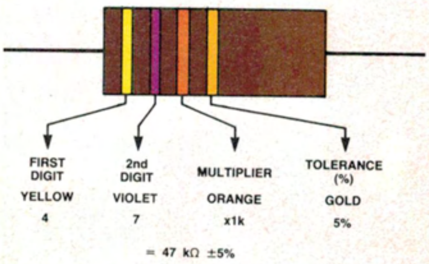


Figure 1. Reading the colour code for resistor value.

In fact there are so many passive components that in this issue we'll stick to such things as coils, transformers and how to read the component values, and then in Starting Electronics 7 we'll continue by looking at the remaining passive components such as meter movements, batteries, cabling, indicator lamps and so on. Future parts of the series will examine cabling, plugs and sockets, as well as active components.

The multiplier

In Starting Electronics 4, resistors and capacitors were discussed with the promise of some further explanation about reading the codes to component values. Resistors, as you will remember, are measured in ohms (after the German physicist, GS Ohm) with values ranging anywhere from fractions of an ohm, to millions of ohms.

Because of the wide range of values, not only for ohms but for most electrical quantities, a shorthand form is used to express the various values. This is achieved by including multipliers, some of which will be familiar now that we have been 'metricated'.

Table 1 lists some of the more common multipliers. As an example, a resistor with a value of 2.2 million ohms becomes a 2.2 megohm resistor or, as is standard now, a 2 meg 2 resistor, written as 2M2 Ω. The 'M' or 'k' resplaces the decimal point, the Ω (omega) being the symbol for ohms.

Using a multiplier makes sense when you try and ask for a capacitor with a value of 330 thousandths of millionths of a farad. It's much easier to ask for a 330 nanofarad capacitor, and even easier to write 330 nF, rather than 0.00000033 farads. One point to watch is the difference between m (milli) and M (mega or meg). In general, kilo, meg, micro, nano and pico are the most common multipliers to the measurements for components, with milli occasionally occurring for inductance measurements.

So, there's some more 'jargon' for you.

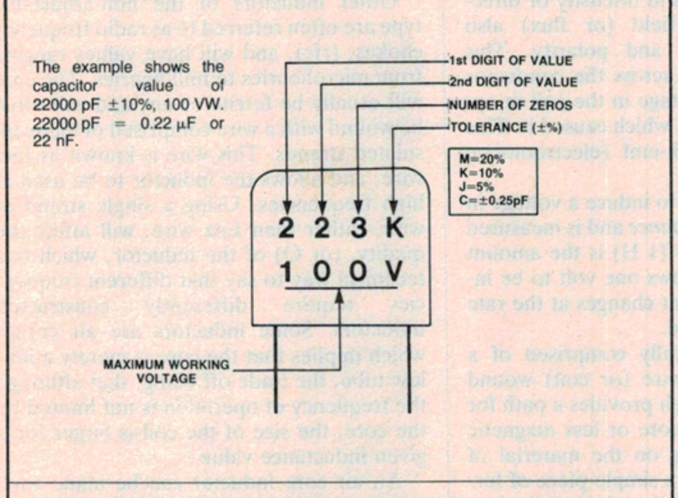


Figure 2. Reading a capacitor's value — 'IEC' standard.

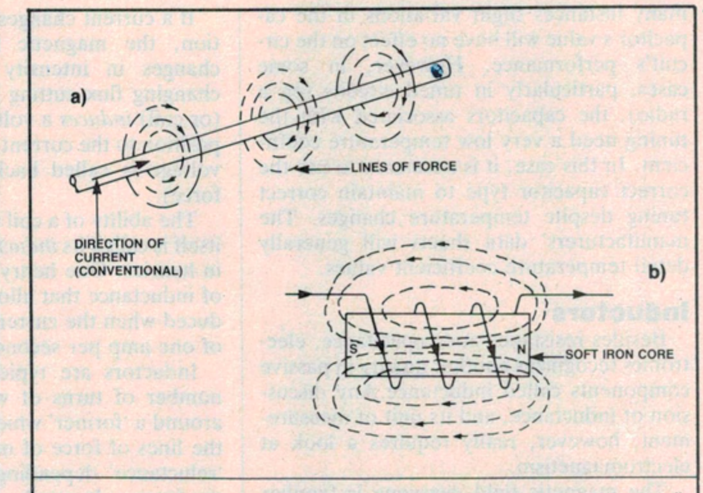


Figure 3a) Lines of force around a conductor, and **b)** combined in a coil wound around an iron former.

Reading the value of a resistor

To indicate the value of a resistor, manufacturers mark those with a wattage of 1 watt or less, with a colour code. This convention associates a particular numerical value, multiplier or tolerance with a particular colour and the total value of the resistor is marked by the order of its colour bands. The colours and their values are shown in the chart opposite.

A rather crude mnemonic I grew up with to remember the numerical order of the colours is: Bad Boys Rape Our Young Girls, But Violet Gives Willingly. Not recommended behavior, but at least it helps me remember the order of the colours. (Gerry Hui knows a polite version but you need to know Chinese.)

Figure 1 shows how this colour code is applied to resistors. The order of the bands is read as digit 1, digit 2, number of zeros or multiplier, and tolerance. For example, a resistor with the colours orange, blue, red and gold starting from the band closest to the end of the component reads 3, 6, x 100, 5%. In other words, 3600 ohms (or 3k6) at 5% tolerance.

Notice that the tolerance band is read last. Five per cent (gold band) is a common tolerance. Another useful point is to note the colour of the body of the resistor. The colour usually denotes the type of construction, with beige being a carbon film, light blue being a metal glazed type and olive green being a metal film type.

Reading the value of a capacitor

The colour code is often, though not always, applied to capacitors. It would be a brave person who would assert that he can identify the value of all capacitors by using the many and varied codes that have been adopted over the years.

In the case of a flat film capacitor, for example, the bands are read as for a resistor, but the resulting figure is the number of picofarads. If you want this value in microfarads, you must then divide by 1 million, or by 1000 if you want the value in nanofarads. Two further bands give the tolerance and the working voltage of the capacitor. The colour coding arrangement varies between capacitor types, with tantalum capacitors having a dot to represent the multiplier and the value comes out in microfarads.

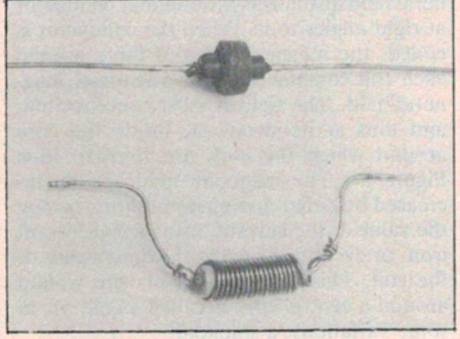
Other standards include the 'IEC' standard, whereby a number is printed on the body of the capacitor. In this case, the first two numbers are the first two digits of the value, the third number is the number of zeros, with a letter (M, K, J or C) representing the tolerance. Again the value will be in picofarads, so further division may be necessary. Figure 2 gives an example.

Sometimes the actual value is printed on the capacitor, which makes life much easier. To help you wade through all these codes look at the colour code chart on page 124. Many parts distributors offer wall charts, or even data sections within their catalogues detailing this type of information. It's indispensible, and the wall charts are often very colourful for adorning the workshop door!

A very useful project would be to build a capacitance meter, as it can save a lot of time and hassle identifying the value of a capacitor.

When using capacitors beware that you take note of the voltage rating marked on the case. This indicates the maximum voltage that the capacitor can safely operate at.

One last word about capacitors is to mention the temperature coefficient. This is simply a way of describing how the value of the component varies with temperature. In



Fixed inductors.

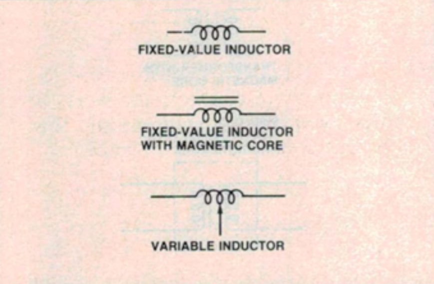
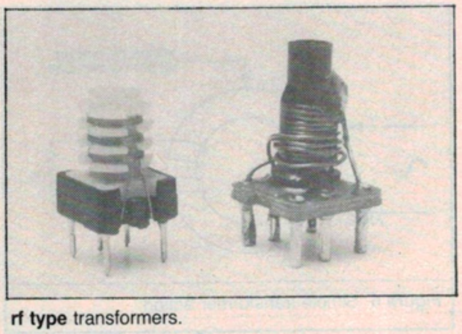


Figure 4. Inductor circuit symbols.



rf type transformers.

▶

many instances slight variations in the capacitor's value will have no effect on the circuit's performance. However, in some cases, particularly in tuned circuits (eg a radio), the capacitors associated with the tuning need a very low temperature coefficient. In this case, it is necessary to use the correct capacitor type to maintain correct tuning despite temperature changes. The manufacturers' data sheets will generally detail temperature coefficient values.

Inductors

Besides resistance and capacitance, electronics recognizes another quality in passive components called inductance. Any discussion of inductance, and its unit of measurement, however, really requires a look at electromagnetism.

The magnetic field everyone is familiar with is the one of radiating lines of force from a magnet's poles. However, when a current flows through a conductor, a magnetic field also forms around that conductor at right angles to it. When the conductor is coiled, the magnetic lines of force around each coil combine to form a stronger magnetic field. The field is most concentrated, and thus at its strongest, inside the core around which the coils are formed. (See Figure 3.) The magnetic field can be increased by either adding more turns, raising the value of the current, using a core of soft iron, or even by changing the dimensions of the coil. This arrangement of wire wound around a central core is called a coil, or, in some variations, a solenoid.

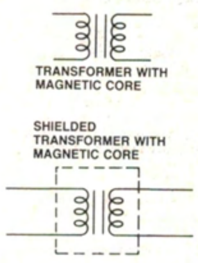


Figure 5. Transformer circuit symbols.

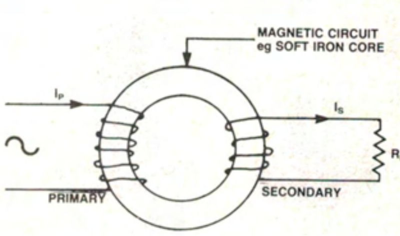


Figure 6. Simple transformer action.

If a current changes in intensity or direction, the magnetic field (or flux) also changes in intensity and polarity. This changing flux cutting across the conductor (or coil) *induces* a voltage in the coil in opposition to the current which caused it. This voltage is called back-emf (electromotive force).

The ability of a coil to induce a voltage in itself is called its *inductance* and is measured in henries. One henry (1 H) is the amount of inductance that allows one volt to be induced when the current changes at the rate of one amp per second.

Inductors are typically comprised of a number of turns of wire (or coil) wound around a 'former' which provides a path for the lines of force of more or less magnetic 'reluctance' depending on the material of the former. It may be a simple piece of ferrite rod, a set of stacked, soft steel laminations, a specially shaped ferrite core, a hollow fibre tube, etc, etc. The properties of the core are carefully designed and the important thing to know is that where a circuit calls for a specific core, in the case where you have to wind the coil, using a different core will often upset the performance greatly.

Basically inductors can be grouped into two types: fixed value inductors and adjustable inductors. A fixed value inductor is one with no facility to either adjust the number of turns or the core position. An example is the sort of large inductor that has a value of many henries (often called a 'choke'), and is wound on a core like a transformer, the core being comprised of a stack of soft iron laminations. This type of inductor would be used in a power supply, or some application where power is a consideration. Generally, this type of core would dictate that it only be used for low frequency applications, in the vicinity of say 50 Hz.

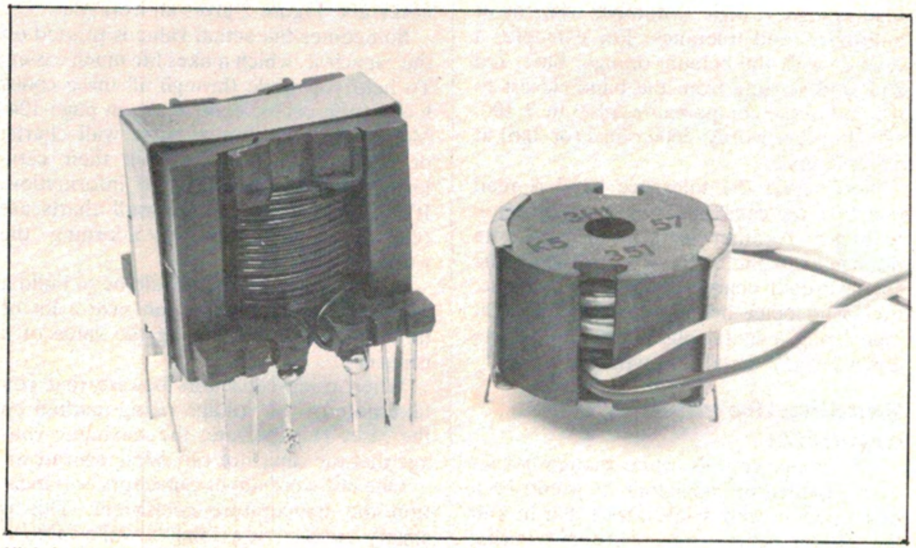
Other inductors of the non-adjustable type are often referred to as radio frequency chokes, (rfc), and will have values ranging from microhenries to millihenries. The core will usually be ferrite or air, and will often be wound with a wire comprised of many insulated strands. This wire is known as Litz wire, and allows the inductor to be used at high frequencies. Using a single strand of wire, rather than Litz wire, will affect the quality, (or Q) of the inductor, which is a technical way to say that different frequencies require differently constructed inductors. Some inductors are air cored, which implies that the core is merely a hollow tube, the trade off being, that although the frequency of operation is not limited by the core, the size of the coil is larger for a given inductance value.

An air core inductor can be made variable by inserting a piece of ferrite (a 'slug') within the hollow core either by a screw thread, or by some other appropriate means. As the slug is screwed further towards the centre of the coil, inductance increases.

Usually, tuning the inductor is done by means of a threaded ferrite slug, the screwdriver being a non-metallic device designed to fit the slug. It is possible to buy a set of tuning tools, and if you are constructing a project which has tunable inductors, then these become essential, because using a metal screw driver will affect the value of the inductor considerably. A cheap alternative to the tuning tool is a ground down knitting needle, the plastic type, not aluminium.

Transformers

Inductors are the least common of the three components treated so far, particularly the 'choke' types, due to their size, with the rfc types (fixed and variable vari-



High frequency power transformers.

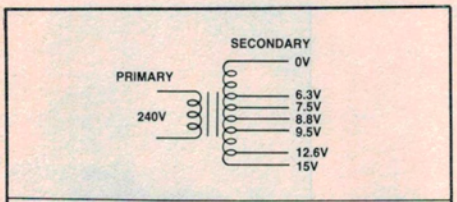
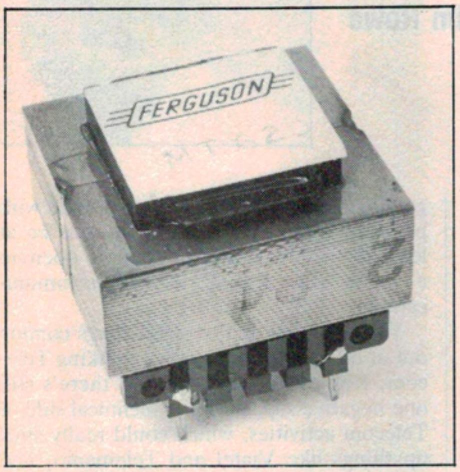
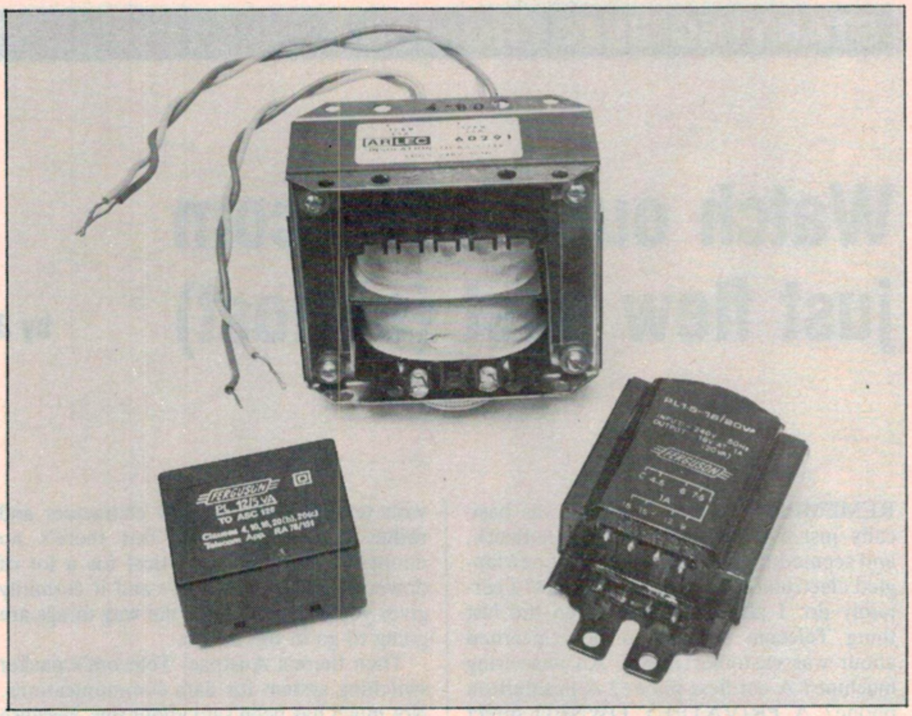


Figure 7. Typical multipurpose power transformer with 21 possible voltages available from the secondary.





Above. Various power transformers.

Left. Close up view of pc mounting transformer.

eties) being encountered occasionally. One sort of inductor commonly used, however, is the transformer, which operates on a further principle of electromagnetism: mutual inductance.

Changing the current in a coil, we have said, has the effect of inducing a voltage in it as the magnetic flux cuts across the coil, but it will also induce a voltage in any adjacent coil it can intersect. This effect is referred to as mutual inductance and the coils are described as 'mutually coupled'. This mutual coupling is the basis of transformer action where a *primary* coil conducting an alternating current will induce a voltage (and current if the coil is connected to a circuit) in the adjacent or *secondary* coil (see Figure 6). The relationship between the primary and secondary voltages is proportional to the number of turns on each winding; currents are inversely proportional.

Transformers are generally either of the power type, or radio frequency type, although another range of transformers could be classed as high frequency power types. By far the most common is the power transformer. The task of the power transformer is usually to convert the 240 volts ac to another, more suitable, ac voltage. Alternating current (ac), is the type of supply available from the mains.

A transformer will not work with dc (direct current), and will probably burn out if dc is connected to it. Normally, you will need to know how much current and voltage a transformer needs to supply.

Power transformers are often given a VA (volt X amps) rating, which represents, to an extent, the power the thing can deliver. A 10 VA transformer, will deliver around 10 V at 1 amp, or 1 V at 10 amps. However, this doesn't mean that you can get a '240 V to 10 V, 10 VA' transformer, and tap off the winding to get 1 V at 10 amps, as the wire size will probably not allow it. The VA rating is more a core rating than anything else, and will be an indication of the physical size of the device.

A power transformer can be a simple two winding object, comprised of the primary winding, often wound nearest to the core, and a single secondary winding, or it may have many secondary windings, each isolated from the other. Furthermore, either or both windings may have tappings, or extra connections, to the windings, allowing a range of input and output voltages to be used.

Many electronic projects will require a transformer which may well be the single most expensive item in the parts list. Many constuctors, working to a budget attempt to get transformers by ratting old TV sets, radios, or buying 'bargains' from parts suppliers. This often requires some adaptation of the transformer, by either combining windings to obtain the required secondary voltage, or by actually adding a tapping to an existing winding to get a lower secondary voltage than is otherwise available.

The main points to keep in mind are that the transformer should be large enough to supply the required power without getting too hot during operation, and that the secondary winding can supply the current required, even though the apparent VA rating is not being exceeded. It is not our purpose here to describe how to modify a transformer, but merely to let you know that this is a possible option, and best done with reference to suitable text books. After all, a power transformer is usually connected to the mains, and can become a very lethal and destructive object if not connected properly.

Generally speaking, most projects only require a transformer with a secondary current of something less than 1 A. General purpose transformers with a 1 A secondary, and a number of tappings along the secondary are good value, as mass production makes them cheap, and a wide range of secondary voltages are possible, perhaps more than you first think. For example, a transformer with a secondary which has six tappings as shown in Figure 7 allows you 21 possible voltages. Other transformers include low profile types, pc board mounting types, and a wide range of other types and styles.

As a final point, pay considerable attention to the connection of the 240 V supply, to make sure exposed terminations are all nicely insulated and safe, and, unless the metal core is not exposed, ensure the core of the transformer is earthed. Keep the 240 V leads as short as possible and well anchored. The earth lead should always be the longest.

Other types of transformers include speaker transformers, (not so common these days), special high frequency power transformers, usually characterized by a ferrite core, impedance matching transformers for use in radio frequency applications, signal transformers, either audio or rf, and various other special types. The main thing to know is that different tasks require differently constructed transformers, which means that the core material, and the manner in which the windings are wound are all part of the design, and it is necessary to use the right transformer for a specific task. ●