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ELECTRONIC CIRCUIT COMPONENTS

1. INTRODUCTION.

1.1 In this paper the term *electronic component* means a device such as a resistor, transformer, diode, etc., that is a component of electronic equipment.

1.2 Each electronic circuit uses a number of components, and it is essential to be able to identify them when manufacturing and servicing equipment. Identification implies recognition of external shapes, component values, lead arrangements, lead numbering schemes and mounting procedures, and the interpretation of relevant data such as operating characteristics.

1.3 This paper introduces some of the common symbols, shapes and lead arrangements of basic components. Information regarding mounting procedures and the interpretation of data are described in relevant course papers.

2. MANUFACTURERS DATA.

2.1 GENERAL. Identification of components can be difficult. They are made in numerous shapes, and with a variety of lead arrangements and markings; sometimes this results in quite different components (such as resistors, capacitors and inductors) looking alike.

In many instances, the only means of positive identification is the literature produced by the manufacturers. The literature either presents data on a range of individual components (capacitors, transistors, etc.), or describes equipment (amplifiers, telephones, etc.) which incorporate the components.

When there is any doubt about the identity of a component, always refer to the associated literature.

2.2 COMPONENT MANUFACTURERS DATA. Component manufacturers produce information related to all their products. This information is presented in several forms, the most appropriate of which depends upon the degree of detail and type of information required.

- DATA CATALOGUE. The data catalogue groups types of components, such as resistors, into one publication. Only commonly required information is supplied, and for this reason it is sometimes termed a 'Short Form Catalogue'.

  To help locate a component in the catalogue and to provide comparisons with similar components, the data catalogue is divided into sub-sections, grouping components by common functions. For instance, a catalogue of resistors may be divided into sections, such as: Fixed Resistors, Potentiometers, Thermistors, etc.

  The index of a semiconductor catalogue often lists the component identification code in an 'Alpha-Numerical' form. The identification code, which is printed on, or moulded into, the semiconductor case, consists of a combination of numbers and letters. Typical examples are 2N3055, BC109, etc. The index first lists, in numerical sequence, those codes that commence with a number. This is followed by an alphabetical listing of those codes that commence with a letter.

  Apart from giving the page on which the device's characteristics are listed, adjacent columns of the index may also indicate the function of the device (rectifier, zener diode, etc.) and the material of which it is made (silicon or germanium).

- DATA HANDBOOK. The data handbook provides more detailed information than does the data catalogue. This detail is necessary when designing equipment, and may be necessary when selecting a substitute replacement component. The information may include typical ratings, with graphs for several characteristics and conditions, possibly including the circuits used to derive the graphs. Comments may be provided regarding some ratings and graphs.

  As this form of publication is bulky, making it expensive to produce and to modify for any additional, superceded or modified devices, this information is commonly supplied in loose leaf form as Specification Sheets.

- APPLICATION NOTES. These are produced by component manufacturers to assist circuit design. They illustrate and describe typical circuits for which devices are most suited.

2.3 EQUIPMENT MANUFACTURERS DATA. Equipment manufacturers publish handbooks and associated material to describe the layout, operation and maintenance procedures for their products.

The equipment layout may illustrate the arrangement of sub-assemblies, and the component layouts within each sub-assembly.

The description of the equipment operation usually refers to related circuits, which are provided as part of the publication, or separately. Quite often, components are listed in a table that includes brief descriptions and also manufacturers' catalogue numbers.

Maintenance procedures are normally limited to selected items, and to techniques that test overall functioning of the equipment.

2.4 USE OF DATA. When replacing a component, try to use an identical replacement, unless otherwise directed. Check the component values and related ratings, materials of which it is made, quality, physical construction, etc. When the component performs a vital function, use a replacement component made by the same manufacturer, since unpublished information could have been a determining factor in the choice of the original component.

A substitute replacement component can be used when an identical replacement cannot be obtained, provided that it fully satisfies all the physical and electrical requirements of the equipment. When using a substitute replacement in a non-critical function, only significant values and ratings need be considered. Ensure that the replacement will operate correctly with the circuit conditions encountered; for example, some components, such as wire wound resistors, are frequency sensitive and may not have the characteristics for correct operation at the frequencies in the circuit. Always check that the circuit is not adversely affected by the substitute component.

The physical mounting of a component may also have to be considered; for example, a variable component, such as a trimmer resistor, should be selected so that it can be readily adjusted when mounted.

3. RESISTORS.

3.1 GENERAL. There are often more resistors in a circuit than any other component. They range widely in appearance, quality, constituent material, resistance value, power dissipation, and in the applied voltage that they can withstand. Resistors can have either a fixed or variable resistance.

3.2 FIXED RESISTORS – SYMBOLS. Fig. 1a shows the fixed resistor symbol most commonly used in the Department. The symbol given in Fig. 1b is often encountered with circuits of European (Continental) origin; it is the preferred symbol of the IEC, which is the international organisation for determining standards.

(a) General (b) I.E.C. Standard

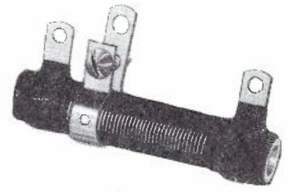
FIG. 1. FIXED RESISTOR SYMBOLS.

3.3 FIXED RESISTORS — SHAPES. Fixed resistors are often cylindrical in shape (Fig. 2a). However, there are numerous other shapes and a few of these are illustrated in Figs. 2b-f. The resistor shown in Fig. 2e is mounted in a heatsink to increase the rate of heat dissipation, thus increasing its power handling capacity.

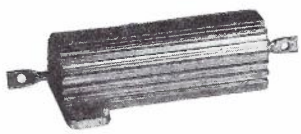
(a) Moulded Cylindrical

(b) Moulded Rectangular

(c) Flat



(d) Tubular (Adjustable)



(e) Horizontal Heatsink

(f) Vertically Mounted

FIG. 2. SOME FIXED RESISTOR SHAPES.

3.4 FIXED RESISTORS — LEADS. The lead style used is determined by the method of mounting and connecting.

- AXIAL LEADS (Figs. 2a, b) allow shaping of the leads to suit a variety of mounting spacings and methods of terminations. They are used when a resistor is mounted between terminals or mounting holes (such as on a printed board). This is the most common type.

- LUGS (Figs. 2c-e) provide connection for flexible leads, and are usually used with resistors dissipating relatively large power. Flexible leads are used when the resistor is mounted some distance from the panel or board. This is usually done to obtain maximum cooling from passing air currents, and to prevent possible damage to the equipment from the dissipated heat.

- SPADE TERMINATIONS. The spade is a flat piece of metal having a shaped slot to allow the spade to slide under a screw terminal.

3.5 FIXED RESISTORS — TYPES. Each type of resistive element and construction has its particular electrical characteristics. These include self-capacitance, inductance and temperature dependent characteristics. Variations in these characteristics can have significant effects on the operation of a circuit, and when a resistor is replaced, the replacement component should have an element of similar material and type of construction.

Resistive elements can be sub-divided into three main types - carbon composition, wirewound and film resistors.

- CARBON COMPOSITION. The resistive element is a mixture of carbon and a variety of binders. In one manufacturing process the resistive materials, insulation and leads are combined into an integrally moulded structure (Fig. 3). In another process the resistive element is coated on the outside of a tube, and an insulating jacket is moulded around the assembly after the leads have been connected.

  Carbon composition resistors are available with resistance values from 1 Ω to 22 MΩ, with power ratings from about 0.1 watt to 5 watt and can be used at frequencies up to several MHz. The colour bands shown in Fig. 3 indicate component values, and are described in Para. 3.6.

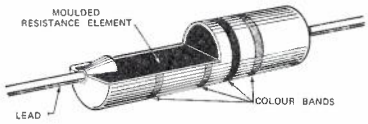


FIG. 3. ONE TYPE OF CARBON COMPOSITION RESISTOR CONSTRUCTION.

- WIREWOUND. The resistive element is a precisely measured length of metal-alloy wire wrapped around a core. The assembly is sealed to protect the element and to keep the turns in position, preventing the adjacent turns contacting.

  A range of metal alloys is used, and the wire is wound in various forms to control or eliminate the inductance and the distributed capacitance. The reactance determines the range of frequencies through which the resistor can be used. Fig. 4 shows the typical construction of wirewound resistors.

  General purpose wirewound resistors are available with resistance values from 0.1 Ω to 1 MΩ, with power ratings from about 1 watt to 1500 watt, and can be used from d.c. to audio frequencies. Precision wire wound resistors are available with resistance values from 0.001 Ω to 60 MΩ with power ratings from 0.04 watt to 250 watt, and can be used at frequencies up to about 1 MHz.

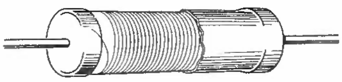


FIG. 4. TYPICAL WIREWOUND RESISTOR CONSTRUCTION.

- FILM RESISTORS. These resistors are available as Metal Oxide, Metal Glaze and Carbon Film types. The resistive material is deposited on a ceramic or berillium core, and a spiral is cut in the film to produce the required resistance (Fig. 5). Metal Oxide and Metal Glaze resistors are often termed Metal Film resistors. Carbon Film resistors are sometimes termed Cracked Carbon Resistors; this term is derived from the manufacturing process.

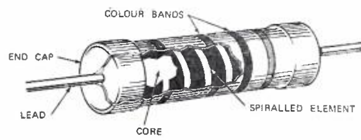
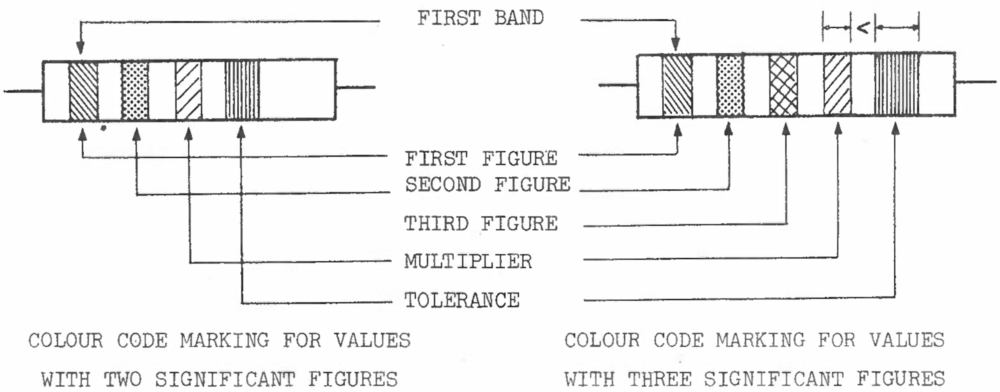


FIG. 5. FILM RESISTOR CONSTRUCTION.

3.6 CODING VALUES ON FIXED RESISTORS. Most wire wound resistors and some special carbon resistors have their nominal resistance value and tolerance printed on the body of the resistor. However general purpose carbon and metal oxide resistors, and some low-value wire sound resistors have coloured bands painted on the resistor body as shown below to indicate the nominal resistance and tolerance. Resistor tolerance is the allowable percentage variation above or below the nominal resistance value due to the variations produced during manufacture. Tolerances available range between ±0.1% and ±20%.

The coloured bands and their significance are shown in Table 1.



COLOUR	FIGURE	MULTIPLIER		TOLERANCE ±%
SILVER	-	10^{-2}	0.01	10
GOLD	-	10^{-1}	0.1	5
BLACK	0	10^{0}	1	-
BROWN	1	10^{1}	10	1
RED	2	10^{2}	100	2
ORANGE	3	10^{3}	1 000	-
YELLOW	4	10^{4}	10 000	-
GREEN	5	10^{5}	100 000	0.5
BLUE	6	10^{6}	1 000 000	0.25
VIOLET	7	10^{7}	10 000 000	0.1
GREY	8	10^{8}	100 000 000	-
WHITE	9	10^{9}	1 000 000 000	-
NONE	-	-	-	20

TABLE 1 IEC STANDARD COLOUR CODE

3.7 PREFERRED RESISTANCE VALUES. Standard resistors are manufactured with values selected so that the highest possible value allowed by the tolerance does not greatly overlap the lowest possible value of the next higher range. For instance, the highest possible value of a 100 ohm resistor marked ±10% is 110 Ω, and the lowest possible value of the next higher value, a 120 Ω ±10% tolerance resistor, is 108 ohms.

These values are termed Standard Preferred Resistance Values, and values from 10 Ω to 91 Ω are given in Table 2.

For values greater than 91 Ω, multiply the given value by a power of 10. For example, 15 Ω, which is available in ±5%, ±10% and ±20% tolerances, is to be understood as 150 Ω, 1.5 kΩ, 15 kΩ, etc. The maximum preferred resistance value is 22 MΩ, although higher value resistances are made for special purposes.

The minimum preferred resistance value is 10 Ω, but values as low as 0.24 Ω are not uncommon. To derive resistance values below 10 Ω from Table 2, divide the given value by a power of 10. For example, 27 Ω, available as ±5% and ±10% tolerances, is to be understood as 2.7 Ω, and 0.27 Ω. (E6,E12,E24 denotes range in Standard Preferred Resistance table)

E24	10	11	12	13	15	16	18	20	22	24	27	30	33	36	39	43	47	51	56	62	68	75	82	91	5%
E12	10		12		15		18		22		27		33		39		47		56		68		82		10%
E 6	10				15				22				33				47				68				20%

TABLE 2. STANDARD PREFERRED RESISTANCE VALUES.

3.8 POWER RATING OF FIXED RESISTORS. The heat dissipated by resistors is proportional to I^2; the actual heat dissipated and the temperature reached by a resistor includes a number of other factors, such as ambient temperature, resistor design, enclosure limitations on flow of heat, grouping of components, etc.

When replacing a resistor, use one that has a power rating at least as high as that of the original component. The connection of resistors in parallel will not achieve a total power rating equal to the sum of their power ratings, so do not use low power rated resistors in parallel to replace one high power rated component. The heat travelling along the component leads and the radiated heat reduce the effective power rating of each resistor. Generally, the larger the physical size of a resistor, the greater is its ability to dissipate heat.

3.9 MAXIMUM OPERATING VOLTAGE. This is mainly determined by the shape and size of the resistor, the materials of which the resistor is made, and the resistance value (as this determines the maximum current through the resistor and therefore the voltage for a given wattage).

3.10 VARIABLE RESISTORS often provide the most convenient, practical means of controlling the operation of a circuit. The variation in resistance is most often obtained by mechanically tapping a portion of the whole resistance. These are termed 'variable resistors'. Resistance variation may also be produced by using materials that respond sensitively to conditions such as temperature, light and pressure. Such components are known by the condition to which they are most sensitive. For example, 'Light Dependent Resistor', etc.

3.11 VARIABLE RESISTORS – SYMBOLS.

- GENERAL SYMBOL. Fig. 6 shows the general symbol used for variable resistors. The upper symbol in each case is the one most commonly used in the Department. The lower symbol is the one preferred by the IEC, and is often encountered with circuits of European (Continental) origin.

(a) General Purpose (b) Trimmer Resistor

FIG. 6. GENERAL SYMBOLS FOR VARIABLE RESISTORS.

- TYPICAL SYMBOLS.

GENERAL PURPOSE VARIABLE RESISTORS. Depending upon the circuit connections, these components are termed 'potentiometers' or 'rheostats'.

A potentiometer taps a proportion off a potential that is applied to the whole resistive element. This normally requires three connections: one to the wiper (moving arm) and the others to each end of the resistive element (track). Fig. 7a shows the symbol for a potentiometer. A fourth terminal is provided when connection to some point on the resistive element is required. This condition is not shown on Fig. 7a.

A rheostat varies the resistance in the circuit and hence the current. When the device is connected as a rheostat there are normally two connections: one to the wiper and the other to one end of the resistive element. Fig. 7b shows the symbol for a rheostat. Note that although the device may have three terminals, only two are usually shown when it is wired as a rheostat.

(a) Potentiometer (b) Rheostat

FIG. 7. VARIABLE RESISTOR SYMBOLS.

TRIMMER RESISTORS. These variable resistors are also referred to as presets and as trimmer pots. They are primarily designed to compensate for variations between individual circuits, usually on a 'set and forget' basis.

Fig. 8 shows typical symbols for a trimmer resistor.

FIG. 8. TYPICAL TRIMMER RESISTOR SYMBOLS.

3.12 VARIABLE RESISTORS – SHAPES.

- GENERAL-PURPOSE VARIABLE RESISTORS.

ROTARY UNITS. Generally, the shaft of a rotary variable resistor has an effective rotation of approximately 280°, although continuous (360°) rotation components are also made. Multi-turn devices, in which full wiper travel is achieved in a number of complete revolutions of the shaft, are also available but are not in common use.

Rotary multi-unit devices having several units controlled by a common shaft are also available. The most common type has two units; one such arrangement is included in Fig. 9. Both wipers may be controlled by a common shaft (ganged) or each wiper may be individually controlled. With this latter type (not shown) the hollow external shaft controls the front wiper, and the central shaft controls the rear wiper.

Fig. 9 also includes a rheostat capable of dissipating up to 25 watt.

SLIDER POTENTIOMETER. Fig. 9 includes a single-unit slider potentiometer. A dual track device has one unit on each side of the slider control. The case is larger than that for a single unit component.

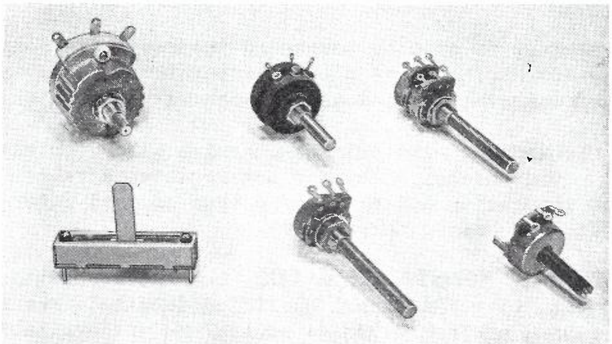


FIG. 9. GENERAL PURPOSE VARIABLE RESISTORS.

- TRIMMER RESISTORS. The devices shown in Fig. 10 represent only a small range of trimmer resistor shapes. Adjustment may be made by knob or screwdriver. On some trimmers the terminals are designated by a symbol marked on, or moulded into, the case.

Sometimes, a trimmer may be mounted on the rear of a rotary potentiometer; do not be misled into believing that this is a multiple-unit device. The trimmer is adjusted by screwdriver either from the rear, or from the front through the hollow shaft.

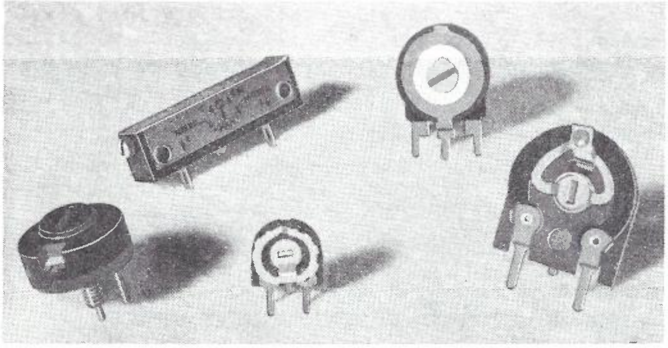


FIG. 10. VARIOUS TRIMMER RESISTORS.

3.13 VARIABLE RESISTORS – RESISTIVE ELEMENTS. The quality (grade) of a component largely depends upon the type of resistive element and upon the method used to form it.

Elements can generally be classified as Carbon Composition, Metal-Based, and Wirewound.

- CARBON COMPOSITION ELEMENTS. Cheaper components, such as those used in many T.V. sets and radios, generally have carbon film elements. These are formed by applying a carbon film to an insulating material such as plastic. The better quality carbon composition components, such as those used in equipment purchased by the Department, have the element formed by screening a carbon compound on to a ceramic base (carbon ceramic), or by moulding the element at the same time as the other parts of the component (moulded carbon).

- METAL-BASED ELEMENTS. Metal film and metal glaze elements provide greater stability, closer tolerance, higher power rating for a given size, and longer life than can be obtained with carbon elements.

  The metal film element is made by depositing a metal alloy film on to a substrate. This type can be made physically very small.

  The metal glaze element is made by screening the resistive composition on to a ceramic substrate and firing it at a high temperature. This type is very stable under extreme environmental conditions, and can withstand high overloads.

- WIREWOUND. Resistance wire (nickel-chromium alloy for high resistance values, and copper-nickel alloy for low resistance values) is wound on to a flat card made of insulating material. The type of card material used depends upon the anticipated operating temperature.

3.14 VARIABLE RESISTORS – RESISTANCE VALUE. The rated resistance is the value of the whole element, with additional qualifications made regarding tappings, when provided. Resistances of from 0.5 Ω to several MΩ are available. The resistance value is normally printed on, or stamped into, the case.

3.15 VARIABLE RESISTORS – POWER RATING. The power rating is normally marked on the component and is also provided in the manufacturers data. Carbon elements can often dissipate up to 2 watt and possibly 5 watt; wire wound elements dissipate more heat, and units are made that can dissipate 1000 watt. Generally, the larger the component the greater is its heat dissipation capability.

3.16 VARIABLE RESISTORS – TAPER. The percentage of resistance tapped for a particular position of the wiper on the track depends upon the nature of the resistive element, which is designated as its 'taper'. For instance, the resistance tapped on a linear taper element (taper A) is directly related to the position of the wiper. (For practical purposes, Taper A is considered linear). When the wiper is halfway along the element it taps half of the total element resistance. Fig. 11 gives three commonly available tapers, and shows the percentage resistance tapped when the wiper is half way along the element. Note that Tapers C and F are non-linear. Because of their characteristics, Taper C is termed logarithmic and Taper F is termed antilogarithmic.

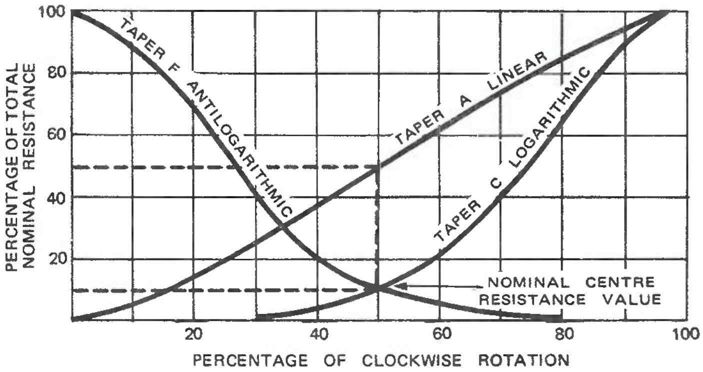
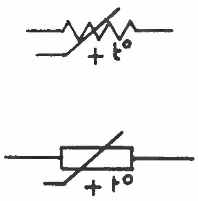


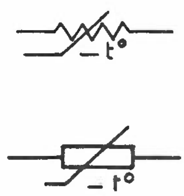
FIG. 11. THREE RESISTANCE TAPERS.

3.17 SWITCH PROVISION. A switch may be mounted on the rear of a rotary general purpose potentiometer. The switch is mechanically linked to the shaft and may be operated by either rotating the shaft or by pulling and pushing it.

3.18 TEMPERATURE SENSITIVE RESISTOR (THERMISTOR). The resistance of these components varies markedly with changes in temperature. The resistance may increase with an increase in temperature (positive temperature coefficient), or decrease with an increase in temperature (negative temperature coefficient). The temperature of the device may be influenced by the surrounding atmosphere, the passage of current, or by an adjacent heated resistance element.

3.19 THERMISTORS – SYMBOLS. Fig. 12 shows typical symbols for thermistors. The symbol for a positive temperature coefficient thermistor is shown in Fig. 12a. Fig. 12b shows the symbol for a negative temperature coefficient thermistor.





(a) Positive temperature coefficient (b) Negative temperature coefficient

FIG. 12. SYMBOL: THERMISTORS.

3.20 THERMISTORS – SHAPES.

Fig. 13 shows typical thermistor constructions, although many other styles are in common use.

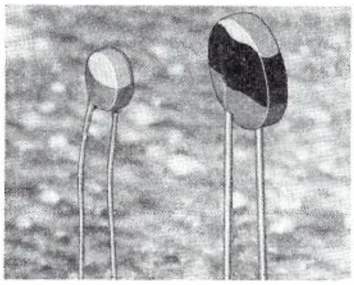


FIG. 13. TYPICAL THERMISTORS.

3.21 CODING THERMISTORS. Methods of coding thermistors include printed codes, coloured bands or dots, and coloured leads. Sometimes the international colour code for resistors is used for coding thermistors; the colours often indicate the resistance of the device at a specified temperature, usually 20°C or 25°C. For device identification, reference should be made to the manufacturers literature.

3.22 VARISTORS. These devices are also called voltage dependent resistors (VDR). They are made of a semiconductor compound formed into rods and discs, and are also included in Section 7 of this Paper. The sides of the units are sprayed with a metal to allow the leads to be connected. The resistance of a varistor decreases with an increase in applied potential.

3.23 VARISTOR SYMBOL. Fig. 14 shows a typical varistor symbol, although others are used.

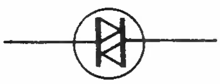


FIG. 14. TYPICAL VARISTOR SYMBOL.

3.24 VARISTOR SHAPES. Fig. 15 shows a typical varistor. There are several other types of construction used.

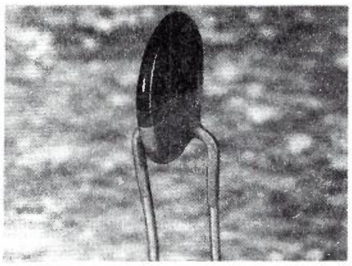


FIG. 15. TYPICAL VARISTOR.

3.25 CODING VARISTORS. Various methods of coding are used for varistors. Reference to manufacturers literature is essential in all cases of device identification. Sometimes colours indicate the voltage rating for selected current value.

3.26 LIGHT DEPENDENT RESISTOR (LDR). These devices are photo-conductive cells, with their resistance decreasing for increased illumination. Different materials are used, each having individual characteristics. Consequently an LDR must be replaced with an identical type.

3.27 LDR SYMBOL. Fig. 16 shows one typical LDR symbol. Other symbols are used.

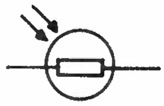


FIG. 16. TYPICAL LDR SYMBOL.

3.28 LDR – SHAPE. Fig. 17 shows a common LDR.

FIG. 17. TYPICAL LIGHT DEPENDENT RESISTOR (LDR).

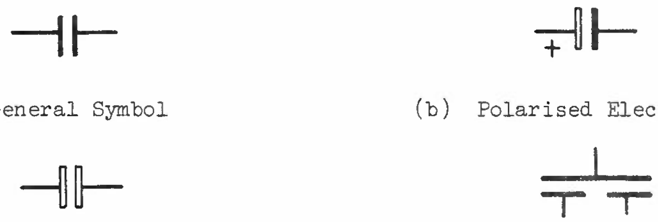
3.29 CODING LDR's. These devices usually have the type number printed on the outside of the case.

4. CAPACITORS.

4.1 GENERAL. A capacitor consists of two conductive surfaces separated by an insulating material termed the dielectric. Capacitors are classified as fixed or variable, with a further classification made according to the type of dielectric material.

The large range of capacitors results from differences in the various ratings and applications required, and from the variety of materials and constructions used.

4.2 FIXED CAPACITOR SYMBOLS. Fig. 18 shows some symbols for fixed capacitors.



(a) General Symbol

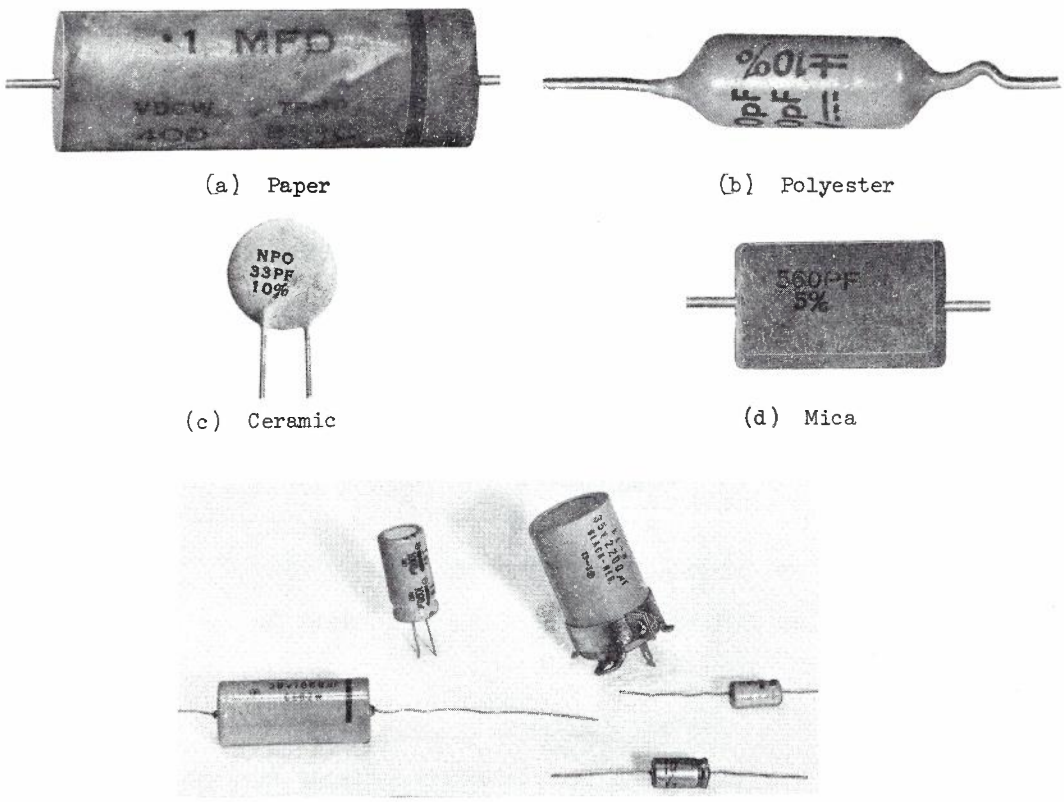
(b) Polarised Electrolytic

(c) Non-polarised Electrolytic

(d) Three-plate Type

FIG. 18. TYPICAL FIXED CAPACITOR SYMBOLS.

4.3 FIXED CAPACITORS – SHAPES. Fig. 19 gives examples of typical capacitor shapes. The capacitors are designated according to types of dielectric materials, as this often determines the external appearance.



(a) Paper

(b) Polyester

(c) Ceramic

(d) Mica

(e) Aluminium Electrolytic

FIG. 19. SOME FIXED CAPACITOR SHAPES.

4.4 FIXED CAPACITORS – LEAD STYLES. As shown in Fig. 19, capacitors are made with various lead styles.

The kinked lead of the polyester capacitor in Fig. 19b allows the component to be mounted vertically on a printed board with the body clear of the board surface.

4.5 FIXED CAPACITORS – LEAD IDENTIFICATION.

- NON-POLARISED CAPACITOR. In general, there is no need to identify the leads of non-polarised capacitors.
- POLARISED CAPACITOR. The anode (positive) lead is usually indicated by a mark on the body. A (+) sign is typical, although coloured spots may be used. Sometimes, a coloured spot is used to indicate the cathode (negative) lead.

Tubular electrolytics with pigtail leads at each end have a slight deformation of the body at the anode lead end. The anode lead is normally fed through an insulator, and the cathode lead is soldered to the metal case of the body. Examples are shown in Fig. 19 e.

4.6 FIXED CAPACITORS — TYPES. Capacitors may be made by interleaving the conductive surfaces with the dielectric (foil type) or by chemically depositing the metal as a film on the dielectric (metallised-type).

Sometimes the dielectric is formed on the conducting area. For example, the dielectric for polarised electrolytic capacitors is formed by depositing an insulating oxide film on the metallic electrode (oxide-film type).

4.7 FIXED CAPACITORS — DIELECTRIC. Apart from the oxide film dielectric, typical dielectric materials include:

- kraft paper impregnated with liquid wax or resin,
- mica,
- plastic, such as polyester, polystyrene, terylene, etc.,
- ceramic,
- glass,
- vitreous-enamel,
- semiconductor material. The junction of the p- and n- type semiconductor materials is the dielectric of semiconductor capacitors.

4.8 FIXED CAPACITORS — CODING. The ratings indicated on the capacitor may include:

- capacitance,
- capacitance tolerance,
- maximum potential the dielectric can withstand,
- temperature coefficient. This is normally only given on ceramic capacitors intended for coupling and trimming.

Significant specifications not usually given on the external markings include:

- type of dielectric material,
- component quality, which is most significant for electrolytic capacitors.

Ratings are either printed or indicated by a colour code on the component body.

- PRINTED RATINGS. The capacitance value is normally marked in µF, nF or pF. When there is insufficient space an abbreviated form is used; for example, '473' may be used for 47000 pF. The last figure indicates the number of zeros in the rating.

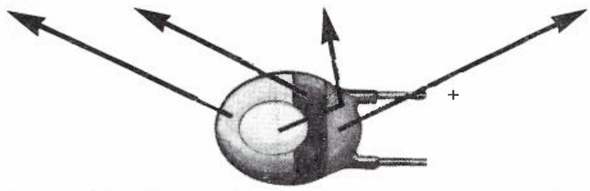
  The capacitance tolerance may be given as a figure, for example ±10%, or as a symbol, for example 'K'.

- COLOUR CODED RATINGS. Many components manufactured outside Australia are colour coded, but as there is little agreement on coding, several styles may be encountered.

  Apart from resin-dipped tantalum capacitors, and some ceramic and polycarbonate capacitors, very few capacitors made in Australia are colour coded.

Table 3 shows one method of colour coding resin dipped tantalum capacitors manufactured in Australia after May 1968. There are other methods of coding this type of capacitor, and whenever a colour coded capacitor is encountered, the relevant manufacturers literature must be consulted.

CAPACITANCE IN µF				D.C. WORKING VOLTAGE	
COLOUR	1st RING	2nd RING	POLARITY and MULTIPLIER	COLOUR	VOLTS
BLACK	–	0	x1	WHITE	3
BROWN	1	1	x10	YELLOW	6.3
RED	2	2		BLACK	10
ORANGE	3	3		GREEN	16
YELLOW	4	4		BLUE	20
GREEN	5	5		GREY	25
BLUE	6	6		PINK	35
VIOLET	7	7			
GREY	8	8	x0.01		
WHITE	9	9	x0.1		



THE COLOURED SPOT SERVES AS BOTH MULTIPLIER AND ANODE INDICATOR.

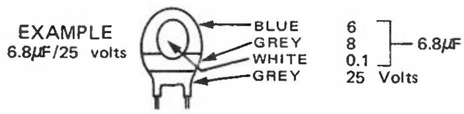


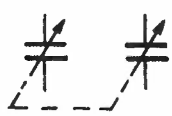
TABLE 3. ONE METHOD OF CODING RESIN DIPPED TANTALUM CAPACITORS MANUFACTURED IN AUSTRALIA AFTER MAY 1968.

4.9 **VARIABLE CAPACITORS.** Variation in capacitance is obtained by altering the relative positions of the conductive surfaces.

4.10 **VARIABLE CAPACITORS – SYMBOLS.** Fig. 20 shows some symbols used for variable capacitors.

(a) Standard Symbol

(b) Showing Moving Plates (Vanes)



(c) Mechanically Linked Units

(d) Trimmer Capacitor

FIG. 20. TYPICAL VARIABLE CAPACITOR SYMBOLS.

4.11 VARIABLE CAPACITORS – TYPES.

- GENERAL PURPOSE. Each conductive surface consists of a number of parallel metal vanes, as shown in Fig. 21. One set of vanes is rotated by a shaft, and the other is fixed. The component in Fig. 21 is a two-gang device. Components with one to five gangs are not uncommon.

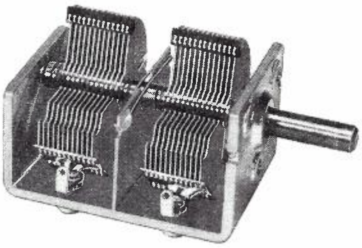
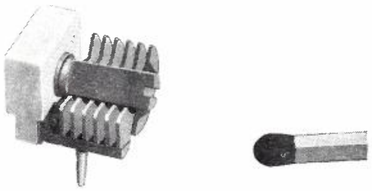


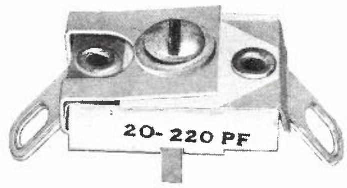
FIG. 21. GENERAL PURPOSE TWO-GANG VARIABLE CAPACITOR.

- TRIMMER CAPACITOR. As the name suggests, these variable capacitors are used for 'trimming' a circuit, which is the fine control of capacitance in a circuit. This adjustment is often made on a 'set and forget' basis.

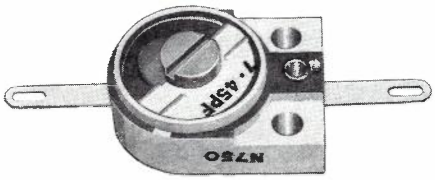
Fig. 22 shows four basic methods of capacitance variation.



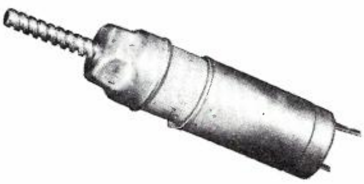
(a) Air-spaced Rotary



(b) Compression



(c) Ceramic Rotary



(d) Tubular

FIG. 22. TRIMMER CAPACITOR TYPES.

4.12 VARIABLE CAPACITORS – DIELECTRIC.

- GENERAL PURPOSE. The dielectric for this type of capacitor is normally air, although some miniature types also include mica between the vanes.

- TRIMMER CAPACITORS. The dielectric materials for trimmers include:

  air, as snown in Fig. 22a,
  mica, as in the trimmer in Fig. 22b,
  ceramic, as in Fig. 22c and possibly Fig. 22d,
  plastic. The component in Fig. 22d may have a plastic dielectric.

4.13 VARIABLE CAPACITORS – RATINGS. Variable capacitors are described by several ratings, the most significant of which are:

Minimum Capacitance. This occurs when the adjacent areas of the conductive surfaces is least, or the surfaces are furthest apart, depending upon the means of capacitance variation.

Maximum Capacitance. This occurs when the conditions are opposite to that for minimum capacitance.

Capacitance Swing. This is the difference between the minimum and maximum capacitance ratings.

Capacitance Law. This describes the variation in capacitance for a given variation in relative position of the conductive surfaces. The law may be linear or non-linear.

5. INDUCTORS AND TRANSFORMERS.

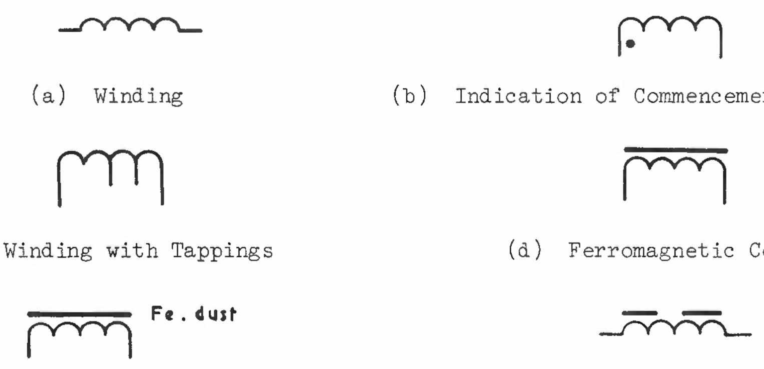
5.1 GENERAL. Because of the number of significant design factors, which includes inductance, frequency range, function, materials, fabrication techniques, etc., and because of the range of variations possible with each factor, these components are often individually designed for a particular circuit. Identification is normally only possible with the relevant manufacturers literature. Classification in the data may be by application (audio output, power supply etc.), operating frequency (voice frequency, carrier frequency etc.), power range, or by method of construction.

The Paper "Transformers and Inductors" describes methods of construction and also the various materials used.

5.2 SYMBOLS. Fig. 23 shows general symbols for windings and cores. The symbols for inductors and transformers are normally adaptions of these, as is shown in Figs. 24 and 25.

The symbol shown in Fig. 23d is used when the core is constructed of ferromagnetic material. When a different material is used the appropriate designation is shown alongside the symbol; Fig. 23e shows the symbol when the core material is ferromagnetic dust. Types of core materials are described in para. 5.6.

The symbol for an air gap in the core is shown in Fig. 23f.



(a) Winding

(b) Indication of Commencement of Winding

(c) Winding with Tappings

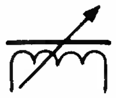
(d) Ferromagnetic Core

(e) Ferromagnetic Dust Core

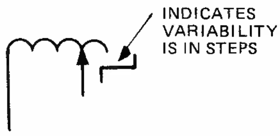
(f) Air Gap in Ferromagnetic Core

FIG. 23. GENERAL WINDING AND CORE SYMBOLS.

5.3 INDUCTOR SYMBOLS. Examples of practical inductor symbols are shown in Fig. 24.



(a) Inductor with Variable Inductance

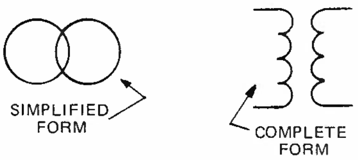


(b) Inductor with Moveable Contact

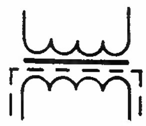
(c) Saturable Inductor

FIG. 24. TYPICAL INDUCTOR SYMBOLS.

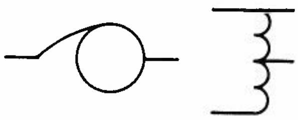
5.4 TRANSFORMER SYMBOLS. Fig. 25 shows typical transformer symbols.



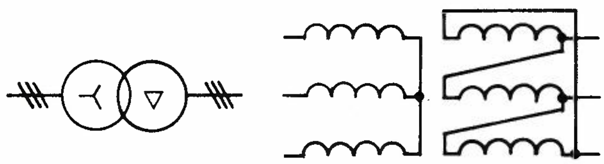
(a) General Symbol



(b) Screen Between Windings



(c) Auto. Transformer



(d) 3-Phase Connection: Star-Delta

FIG. 25. TYPICAL TRANSFORMER SYMBOLS.

5.5 INDUCTOR AND TRANSFORMER SHAPES. Fig. 26 shows a range of inductors and transformers. Inductors can often be distinguished by the number of terminals. As they have one winding, there are usually two terminals, although this is not always the case. A transformer has at least three terminals, and usually more.

The terminals or leads of the components can be seen in Fig. 26, allowing possible identification of each device.

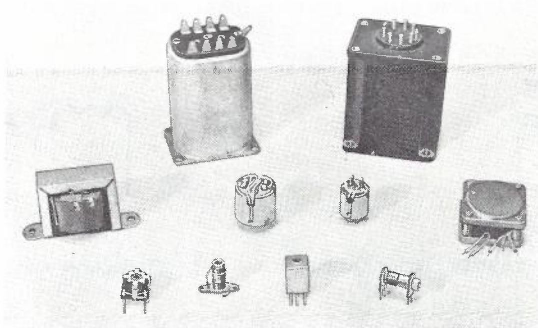


FIG. 26. TYPICAL INDUCTORS AND TRANSFORMERS.

5.6 CORE MATERIALS. Each type of core material has its particular magnetic, electrical and mechanical characteristics.

- SOFT IRON is now generally superceded by improved core materials. Cores made with this material are relatively large and heavy, and are often mechanically weak.
- SILICON IRON AND STEEL. The inclusion of silicon in the iron or steel improves the mechanical, electrical, and magnetic properties of the metal.
- GRAIN ORIENTED STEEL. This is a silicon steel specially manufactured to align most of the crystals so that they are parallel in all directions.
- NICKEL-IRON ALLOYS. Known under the general name of "permalloys". Molybdenum is often part of the alloy.
- POWDER AND CERAMIC CORES. Magnetic metals are reduced to fine particles, coated with an insulating substance, and embedded in a resin. Silicon steel and nickel-iron alloys are often used in this manner.

In recent years, ferromagnetic ceramics called 'ferrites' have become increasingly important. These are usually composed of ferric oxide in combination with manganese, nickel, and zinc, used either singly or in combination.

- AIR. This term can also refer to cores of non-magnetic material, such as plastics.

5.7 CORE TYPES. The main types of core constructions are:

Laminated cores. These are formed by layering thin steel sheets.

Moulded cores. Powder and ceramic cores are moulded into shapes, such as rods, bobbins, etc.

Formers. These are often cylindrical in shape, usually made of plastic or paper. The coil is wound around the former.

5.8 WINDING TECHNIQUES. There are numerous forms that windings can take, and in the case of transformers, there are several methods of placing the windings relative to each other. Each technique has its electrical and magnetic characteristics.

5.9 CODING INDUCTORS AND TRANSFORMERS. The small inductors that are similar in shape to resistors are often colour-coded. However, there is no standard method of colour coding, and the relative manufacturers literature must be consulted for component identification.

Other inductors and transformers are usually designated by a code. This code may be printed on a label inserted into the construction, stamped into the terminal strip, or printed on an exposed side of the core or winding. The code is interpreted in the manufacturers literature.

6. REED RELAYS.

6.1 GENERAL. Reed relays use hermetically sealed reed switches. The reeds are thin, flat blades that serve as conductors, contacts, springs and magnetic armatures. They are placed within the magnetic field of a coil.

A relay may have several coil windings and a number of reed switches. Permanent magnets are used when magnetic biassing of the reed is required, and the contacts may be mercury-wetted for improved switching characteristics.

6.2 SYMBOLS. The symbol for 3000 type relays is often used for reed relays, unless a circuit includes both types of relays. In this case, the symbol in Fig. 27 is normally used, although other symbols may be encountered.

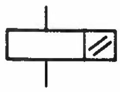
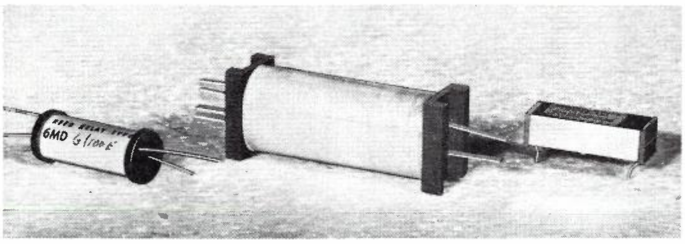


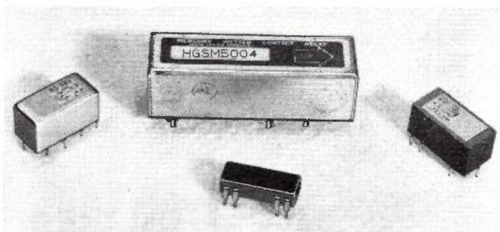
FIG. 27. TYPICAL REED RELAY SYMBOL.

6.3 SHAPES. Fig. 28a shows typical reed relays that consist of a coil and glass insert.

The relays shown in Fig. 28b are fully enclosed units.



(a) Coil and Glass Insert



(b) Fully Enclosed

FIG. 28. TYPICAL REED RELAYS.

6.4 IDENTIFICATION OF TERMINALS. The terminals are often numbered on the relay, and the manufacturers literature should be consulted to assist in identifying them. Many fully enclosed types have the device symbol and the terminal connections printed on the outside.

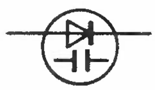
7. SEMICONDUCTOR DIODES.

7.1 GENERAL. Diodes have numerous applications in electronic circuits, including rectification, switching, voltage regulation and current regulation, voltage reference, light generation, light detection, capacitance variation, etc.

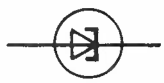
★**7.2 SYMBOLS.** Fig. 29a shows the basic diode symbol. The circuit, which represents the housing, is not always included in the symbol. The words 'cathode' and 'anode' are not part of the symbol; they simply indicate the respective leads. (The diode conducts when the cathode is at negative potential with respect to the anode).

Symbols for other diode devices are based on the basic symbol. Examples are given in Figs. 29b-h.

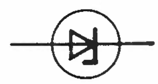
(a) Basic Diode Symbols



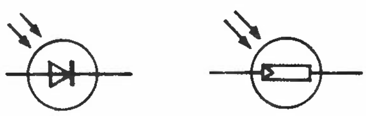
(b) Capacitance Device (Varactor)



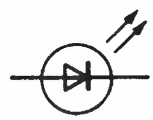
(c) Tunnel Diode



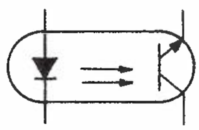
(d) Volage-reference or Voltage-regulator diode (zener)



(e) Light-sensitive diode (asymetic conductivity)



(f) Light-emitting diode (LED)



(g) Opto-isolator

(h) Bi-directional diode (varistor)

FIG. 29. TYPICAL DIODE DEVICE SYMBOLS.

7.3 SHAPES. Several different semiconductor devices have identical external appearances. For example, the same type of component housing may be used for diodes, bipolar transistors and unijunction transistors.

The terms 'case' and 'package' are also used to describe the 'housing'. All of these terms are used in this paper.

A diode can often be identified by having two leads instead of three or more, which is common with most other semiconductor devices. Identification of individual components is only possible by referring to the manufacturers literature.

The different style housings are identified by codes. A common system of coding is that of the Joint Electron Device Engineering Council (JEDEC). It consists of letters, usually DO or TO, followed by a number. Typical examples for diodes are DO 7, DO 35, etc. For transistors, typical codes are TO 1, TO 3, TO 5, TO 66, TO 92, etc., and for integrated circuits typical codes are TO 74, TO 80, TO 100, etc. Examples of typical shapes are given in the relevant sections.

Fig. 30 shows a range of typical housings used for diodes.

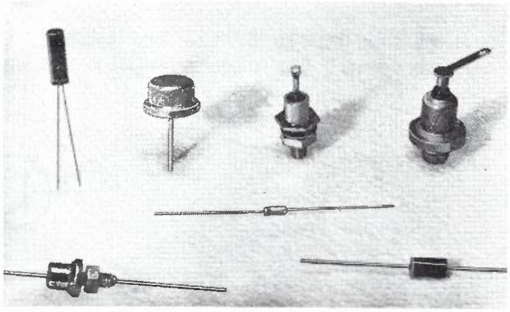


FIG. 30. COMMON DIODE SHAPES.

7.4 LEAD IDENTIFICATION. The cathode lead may be identified by a band, as shown in Fig. 31a, or by a dot, as in Fig. 31b.

Sometimes, both leads are identified by the component symbol printed on the housing (Fig. 31c).

An encapsulated bridge (Fig. 31d) contains either two or four diodes. The leads may be designated by written symbols as shown, or by dots, in which case the leads must be identified with the relevant literature.

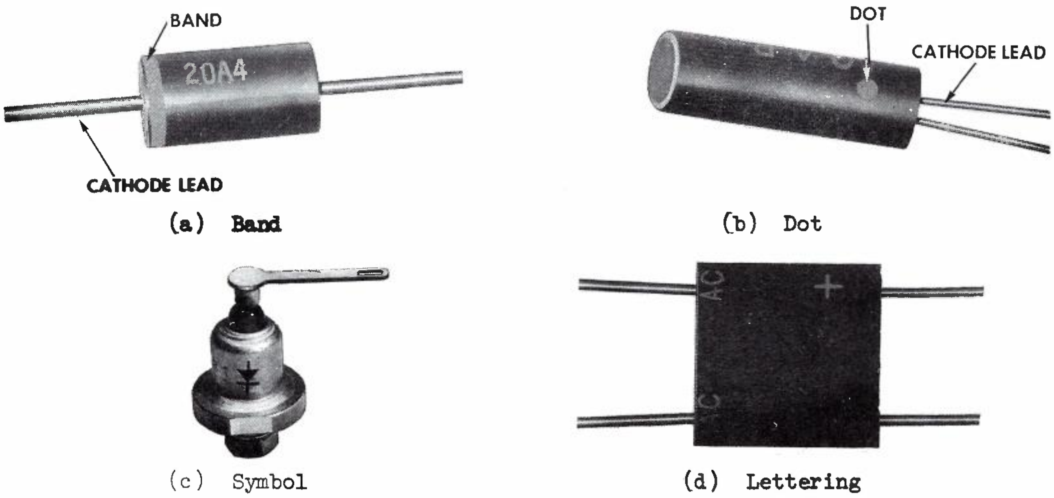


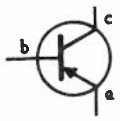
FIG. 31. DIODE LEAD IDENTIFICATION.

8. BIPOLAR TRANSISTORS.

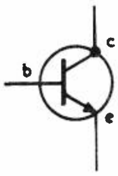
8.1 **GENERAL.** The bipolar transistor is the most common semiconductor amplifying device. With progress in technology, this device has found increasing applications, and with the development of miniature components is being used in sub-assemblies such as integrated circuits (see Section 12) and Darlington pairs.

8.2 **SYMBOLS.** Fig. 32 shows the symbol for each of the two transistor constructions, PNP and NPN. The letters, 'b', 'c' and 'e' on the symbols identify the base, collector and emitter element leads respectively, but are not part of the symbol.

The dot in the collector lead at the circle of the NPN symbol, is used when that lead is electrically connected to the case. The circle represents the housing.



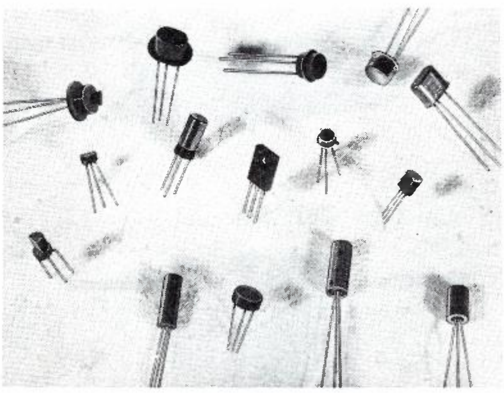
(a) PNP



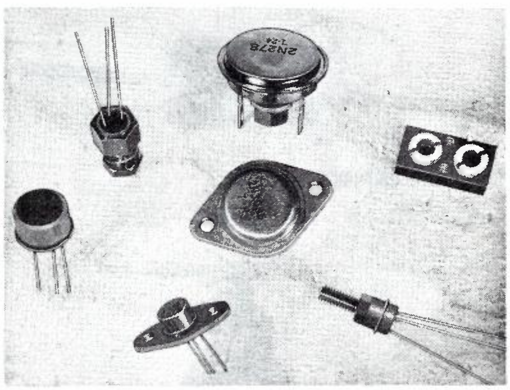
(b) NPN

FIG. 32. BIPOLAR TRANSISTOR SYMBOLS.

8.3 **SHAPES.** As noted in Para. 7.3, several types of semiconductors are housed in identical cases. Fig. 33a shows a range of housing for small and medium power semiconductors (in this instance, bipolar transistors). Fig. 33b shows devices capable of dissipating large power.



(a) Small and Medium Power



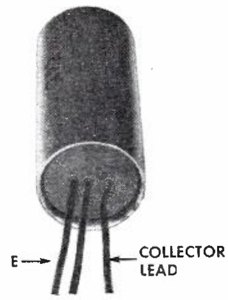
(b) Large Power

FIG. 33. TYPICAL TRANSISTOR HOUSINGS.

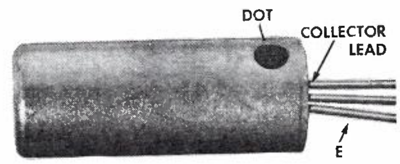
8.4 LEAD IDENTIFICATION. It is quite common for one lead only to be identified on a device. This may be the collector lead or the emitter lead. The other leads are identified by reference to that lead. To determine which lead is identified, and the relative positions of the other leads, refer to the relevant literature.

The base lead is often the centre lead, or the first lead in a clockwise direction from the emitter lead when viewed from the bottom, but this is not always so.

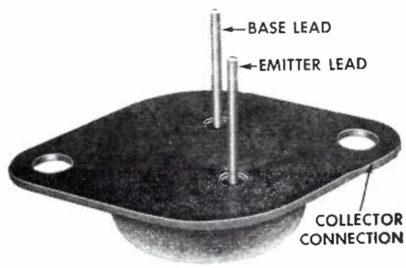
- COLLECTOR LEAD IDENTIFICATION. Fig. 34 shows a few methods of identifying the collector lead. It may be offset from the other leads (Fig. 34a), identified by a dot (Fig. 34b), or connected to the case (Fig. 34c).



(a) Collector lead offset



(b) Dot adjacent to collector lead



(c) Collector connected to case

FIG. 34. SOME METHODS OF COLLECTOR LEAD IDENTIFICATION.

- EMITTER LEAD IDENTIFICATION. Fig. 35 shows one method of identifying the emitter lead. A protrusion is placed at the bottom of the case adjacent to the emitter le

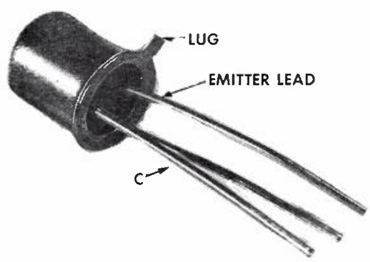


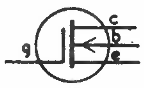
FIG. 35. TYPICAL EMITTER LEAD IDENTIFICATION.

9. FIELD – EFFECT TRANSISTORS.

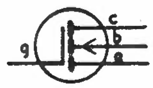
9.1 GENERAL. There are two main types of field-effect transistor (FET), the insulated-gate FET (termed IGFET or MOSFET), and the junction FET (termed JFET and sometimes JUGFET).

9.2 SYMBOLS. Fig. 36 shows the symbols of some n-channel devices. For p-channel devices the direction of the arrows is reversed to that shown.

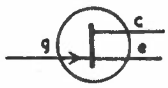
The leads are identified as follows:
- e = emitter or source
- c = collector or drain
- g = gate
- b = substrate



(a) Four terminal, single gate Depletion/Enhancement IGFET



(b) Four terminal, single gate Enhancement IGFET



(c) JFET

FIG. 36. TYPICAL N-CHANNEL FET SYMBOLS.

9.3 SHAPES. Some of the cases used for small and medium power bipolar transistors, as shown in Fig. 33a, are also used for FET's.

9.4 LEAD IDENTIFICATION. The leads can only be identified by referring to the manufacturers literature.

10. THYRISTORS.

10.1 GENERAL. The term 'thyristor' covers a range of semiconductor devices that have two electrical states, off and on.

10.2 SYMBOLS. Fig. 37 shows symbols for two types of thyristors. The symbol shown in Fig. 37a is for a reverse blocking, triode thyristor, p-gate, which is also known as a silicon controlled rectifier (SCR). Fig. 37b is the symbol of a bidirectional triode thyristor, commonly known as a triac.

There are several other types of thyristors.

(a) Reverse Blocking Triode Thyristor, p-gate (SCR)

(b) Bidirectional Triode Thyristor (Triac)

FIG. 37. TYPICAL THYRISTOR SYMBOLS.

10.3 SHAPES. Fig. 38 shows some of the semiconductor housings most commonly used for thyristors. These cases may also be used for other devices, such as transistors.

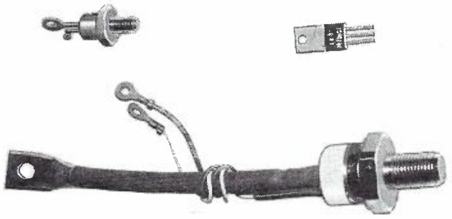


FIG. 38. TYPICAL THYRISTOR CASES.

10.4 THYRISTOR LEAD IDENTIFICATION. The leads may be identified by the symbol printed on the case, otherwise the manufacturers data must be consulted.

With the stud-mounted, p-gate thyristor, shown in Fig. 39, the anode lead is normally connected to the mounting stud. **The cathode lead is the larger** of the two leads.

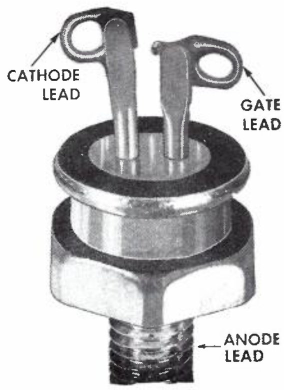
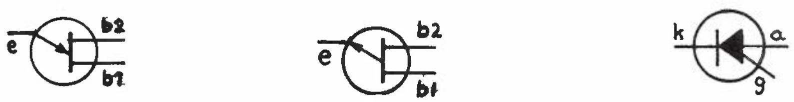


FIG. 39. **STUD CONSTRUCTED P-GATE THYRISTOR LEAD IDENTIFICATION.**

11. UNIJUNCTION TRANSISTORS.

★11.1 SYMBOLS. Fig. 40a shows the symbol for a unijunction transistor (UJT) with an n-type base; Fig. 40b shows the symbol for a unijunction transistor with a p-type base. Fig. 40c shows the symbol for a programmable unijunction transistor (PUT) of different construction being a pnpn device.



(a) n-type base (b) p-type base (c) pnpn device

FIG. 40. UNIJUNCTION TRANSISTOR SYMBOLS.

11.2 CASES. Some of the cases used for small-power transistors (Fig. 33a) are also used for unijunction transistors.

11.3 LEAD IDENTIFICATION. To identify the leads, refer to the manufacturers data.

12. INTEGRATED CIRCUITS.

12.1 GENERAL. An integrated circuit (I.C.) is a circuit module consisting of components and wiring encapsulated as a single unit. The individual elements cannot be isolated, either electrically or mechanically.

12.2 SYMBOLS. These are presented in two general forms:

A stylised representation of the shape of the device. The symbol of its function may be placed within the outline.

A symbol of its function, such as, amplifier, logic element, etc. Some devices have several functions and the respective symbols may be located in various parts of the circuit.

The numbers outside the perimeter of the symbol indicate the lead numbers.

12.3 SHAPES.

- TO 5 STYLES. Although generally known by the designation TO 5, the term only indicates shapes similar to that package. Actual case numbers (JEDEC scheme) include TO 76, TO 97, TO 100, etc. Fig. 41 show two typical shapes. This style of package is made with 8, 10, 12 or 14 leads.

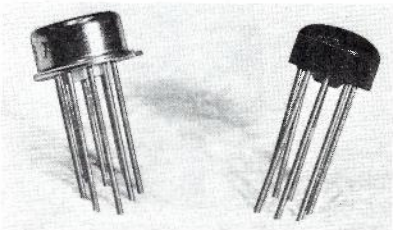


FIG. 41. TO 5 STYLE INTEGRATED CIRCUITS.

- DUAL-IN-LINE. Fig. 42 illustrates the Dual-In-Line package. These normally have 14 or 16 leads, although packages are made with from 8 leads to 36 leads.

Some Dual-In-Line packages have a mounting bar to allow an external heat sink to be mounted; some have a heat sink moulded into the case.

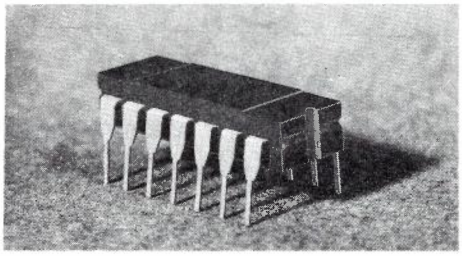


FIG. 42. DUAL-IN-LINE PACKAGE.

- FLATPACK. Fig. 43 shows a typical flatpack package. These are normally made with 10 or 14 leads, although packages with more leads are not uncommon.

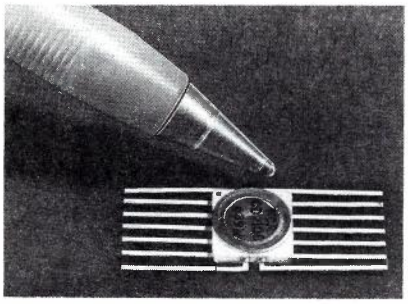


FIG. 43. TYPICAL FLATPACK PACKAGE.

- OTHER STYLES. There are several styles other than the preceding types, but they are not as common. Fig. 44 shows one of these packages. It is similar to the TO 3 package used for transistors, and commonly has nine leads.

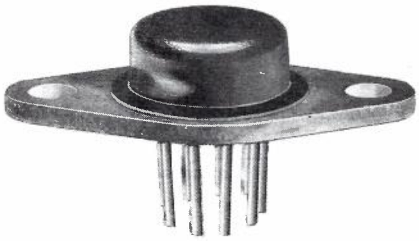


FIG. 44. TO 3 STYLE PACKAGE.

12.4 LEAD IDENTIFICATION.

- TO 5 STYLES. A projection at the bottom of the package, or a flat surface on the perimeter, indicates either the first lead, the last lead, or may be placed between those leads. Refer to the manufacturers literature to determine which lead is indicated. Fig. 45 shows the lead arrangement for a TO 100 package. The projection indicates the last lead in this example.

In all instances, the leads number in a clockwise direction when viewed from the bottom.

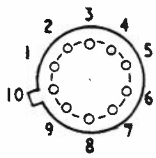


FIG. 45. LEAD ARRANGEMENT: TO 100 PACKAGE (BOTTOM VIEW).

- DUAL-IN-LINE. The method of numbering leads on a Dual-In-Line package is shown in Fig. 46. An indent is moulded into that end of the package corresponding to the first and last leads. The first lead is also often indicated by a mark adjacent to it.

The leads number in an anti-clockwise direction when viewed from the top.

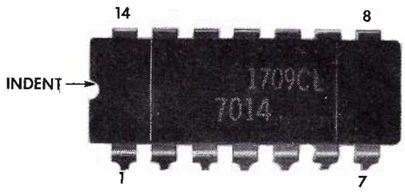


FIG. 46. LEAD ARRANGEMENT: DUAL-IN-LINE PACKAGE (TOP VIEW).

- FLAT PACK. Fig. 47 illustrates the method of numbering leads on a flat pack package. A mark on the case is often placed adjacent to lead 1 or between the first and last leads. The leads number in an anticlockwise direction when viewed from the top.

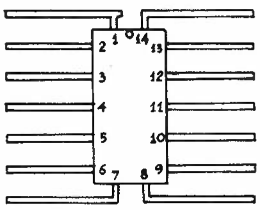


FIG. 47. LEAD ARRANGEMENT: FLAT PACK PACKAGE (TOP VIEW).

- TO 3 STYLE. Fig. 48 shows the method of numbering the leads of TO 3 style packages. Lead 1 is the first lead in a clockwise direction from the gap in the leads. The leads number in a clockwise direction when viewed from the bottom.

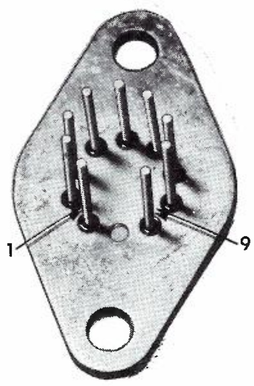


FIG. 48. LEAD ARRANGEMENT: TO 3 STYLES (BOTTOM VIEW).

13. ELECTRON TUBES.

13.1 GENERAL. These are also termed 'valves'. Semiconductor devices are now very often used for functions previously performed by electron tubes.

13.2 SYMBOL. The symbol for electron tubes consists of a solid line enclosing a number of symbols. The solid line represents the envelope, and its shape is often determined by the shape or function of the tube.

Fig. 49a shows the outline used for most tubes. Each element used in electron tubes has its individual symbol. The basic elements are cathode, grid, and anode. The wording shown in Fig. 49a is not part of the symbol.

Some envelopes contain the elements of two tubes, and this may be represented by the symbol shown in Fig. 49b. The two tubes may also be shown detached, with the envelope represented by two semicircles; this allows the symbols for the two tubes to be separated from each other to suit the functional layout of the circuit.

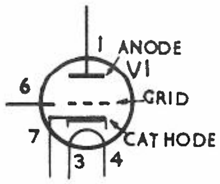
Fig. 49c shows the outline used for a cathode ray tube.

Fig. 49d shows a symbol for a gas filled, cold cathode tube. The dot indicates that the tube is gas filled.

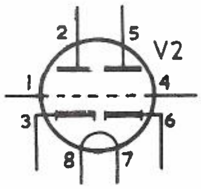
Other types of elements are used, and their symbols are described in Engineering Instruction, DRAFTING, Symbols, S 0390.

The numbers drawn outside the solid line indicate the pin number to which the relative element is connected.

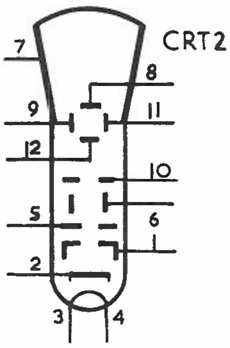
The symbols given in Fig. 49 are for explanatory purposes only. To determine the type and number of elements and the associated pin numbers for a particular tube, refer to the manufacturers literature.



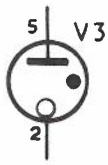
(a) Triode



(b) Twin Triode



(c) Cathode Ray Tube



(d) Gas Filled, Cold Cathode Tube

FIG. 49. TYPICAL TUBE SYMBOLS.

13.3 SHAPES. Fig. 50 shows a few typical electron tubes.

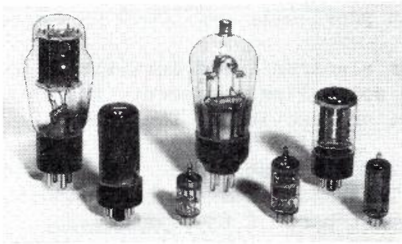


FIG. 50. TYPICAL ELECTRON TUBES.

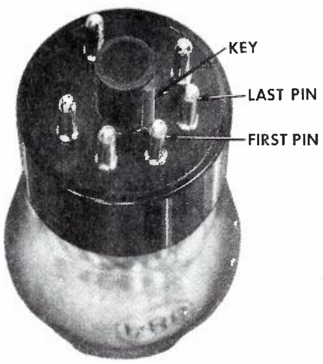
13.4 DEVICE IDENTIFICATION. Electron tubes have a code printed on the glass envelope, or with earlier devices, on the circumference of the base. Although the code may provide some information, the manufacturers literature must be referred to for detailed information regarding functions, operating characteristics, pin connections, etc.

13.5 PIN IDENTIFICATION. Most tubes are connected into the equipment by insertion in a socket. When viewing the pins from the bottom, or the terminal side of the socket, the pins number in a clockwise direction.

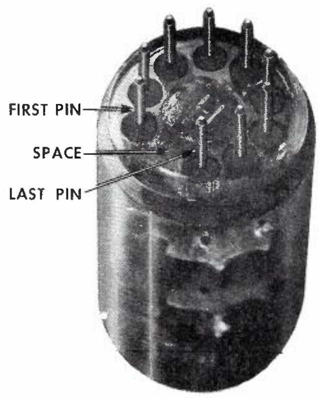
With early style electron tubes, when viewed from the bottom, pin number 1 is often the first pin in a clockwise direction from the key in the centre spigot of the base, as shown in Fig. 51a.

With later style electron tubes, pin number 1, when viewed from the bottom, is the first pin in a clockwise direction from the gap in the pins, as shown in Fig. 51b.

The manufacturers literature gives the electrode connected to the respective pins.



(a) Early Style



(b) Later Style

FIG. 51. NUMBERING OF ELECTRON TUBE PINS.

14. HEAT SINKS.

14.1 GENERAL. These are also termed 'heat exchangers' and 'heat dissipators'. The heat sink improves the dissipation of the heat generated by the semiconductor. It increases the effective surface area of the semiconductor in contact with the atmosphere, mounting frame, chassis, etc.

14.2 SHAPES. Fig. 52 shows a range of heat sinks.

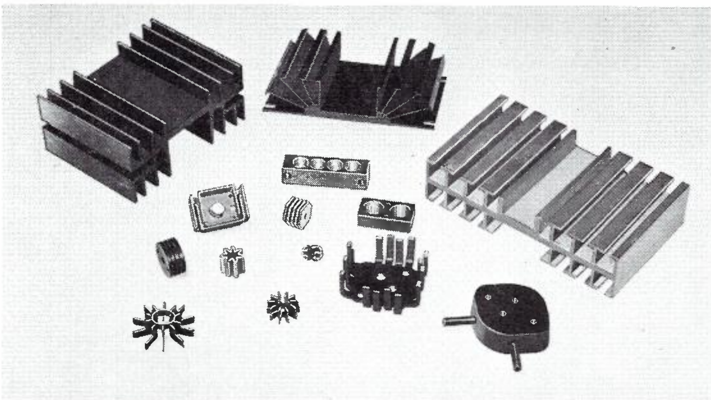


FIG. 52. A RANGE OF TYPICAL HEAT SINKS.

14.3 APPLICATION. The heat sink is either clipped over the semiconductor, or the semiconductor is mounted on the heat sink. Sometimes the heatsink and semiconductor are manufactured as a single unit.

The efficiency of heat sinks is increased by the use of one or more of the following features:

Increasing the size and number of fins.

Increasing the effective surface area by including a large number of small ripples on the surfaces.

Offsetting the fins so that they do not radiate on to one another.

Blackening the surfaces.

Passing water through pipes in the heat sink.

Using silicon grease between the semiconductor and the heat sink to improve the thermal contact.

Using forced air cooling.

NOTES

15. TEST QUESTIONS.

1. *Give a typical instance when you would need to refer to manufacturers data.*

2. *What type of information is supplied in a Data Catalogue?*

3. *What resistance values and tolerances indicated by the coloured bands:*

Red	*Red*	*Yellow*	*Silver*
Yellow	*Violet*	*Gold*	*No Colour*
Green	*Blue*	*Brown*	*Gold*

4. *What coloured bands indicate the following values:*

680 Ω	*±20%*
39 Ω	*± 5%*
0.15 Ω	*±10%*

5. *Give the symbols for:*

   a potentiometer,
   a rheostat.

6. *Explain the term 'taper' when used with respect to variable resistors.*

7. *What are the effects on the resistance of a varistor when the applied potential is increased?*

8. *Show a typical symbol for an LDR.*

9. *What ratings are commonly indicated on a polarised capacitor?*

10. *Draw the symbol for a trimmer capacitor.*

11. *List five dielectric materials used in fixed capacitors.*

12. *Show the symbols for:*

    an inductor with a ferromagnetic dust core,
    a transformer with a screen between the windings,
    a saturable inductor.

13. *What methods are used to indicate code numbers on:*

    inductors and transformers?
    transistors?
    electron tubes?

14. *Show a symbol for a reed relay.*

15. *Draw the symbols for the following semiconductor components, indicating the respective elements:*

    diode,
    bipolar transistor - NPN and PNP,
    unijunction transistor with p-base,
    reverse-blocking triode thyristor with p-gate control,
    JFET with n-channel
    p-channel.

16. *Describe three methods used to identify the cathode lead of a semiconductor diode.*

TEST QUESTIONS (CONTD.)

17. (a) *What physical features are commonly used to indicate the collector lead or the emitter lead of a bipolar transistor?*

    (b) *How may the other leads be identified?*

18. *Briefly explain the JEDEC scheme of numbering housings for semiconductor devices.*

19. *Draw the method of numbering the leads of:*

    a 14 lead dual-in-line integrated circuit
    an 8 pin base of an early style electron tube
    a 7 pin base of a modern electron tube.

20. *Draw the symbol for a twin triode electron tube. Label each of the elements but do not show any pin numbers.*

21. *What is the purpose of a heat sink?*

22. *What methods are used to increase the efficiency of heat sinks?*

END OF PAPER.