



SCHEMATIC READING and COMPONENT FAMILIARIZATION

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PREFACE

In order to make a study of almost any subject, it is necessary to first understand the language. In the field of electronics the symbols used in schematic diagrams are an important part of the language. Just as a road map can be studied to determine the types of roads, and the cities, rivers, and lakes across the country, a schematic can be studied to determine the pathways through an electronic device, and to see what it is made of. The road map uses symbols to represent the different items, and symbols are also used to represent the various components in an electronic schematic.

In this book, the symbols used to represent some of the different electronic components will be given. Enough of an understanding of the construction and operation of the component will be given so that the reason for choosing this symbol to represent it will be apparent. Just memorizing the symbols is of little benefit unless you can see why a particular symbol is used, and know a little about how its represented component operates.

Throughout this book, the electronic concepts needed to understand the operation of the particular component being discussed will be given. This description will be kept as simple as possible. It is not the intent to make this book a complete course in electronics. When completed, however, the details given in this book will provide you with a good fundamental understanding of the operation of electronic components.

SCHEMATIC READING and COMPONENT FAMILIARIZATION

EDUCATION AND TRAINING

Compiled and Edited by Roger Loop

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GETTING STARTED

The understanding of schematic diagrams is probably the most important single item for anyone connected with the science of electronics. Nobody who has even the slightest interest in the subject can escape the schematic diagram. From the casual hobbyist to the advanced engineer - if it is electronics, there is a schematic diagram somewhere. Since schematic diagrams are so important to electronics, it follows then that obtaining a sound understanding of schematics* is the only logical place to start.

Schematics can tell much about the components used in the equipment and their electrical connections, but it cannot tell anything about the physical construction of the equipment.

WHY SCHEMATICS?

Why is the schematic such an important item in electronics? To the novice, the schematic may seem to be only a way to confuse the subject. After all, the symbols used to represent the components do seem unfamiliar at first. Couldn't the schematic just be dispensed with and thereby eliminate a lot of confusion? The answer is no! Through the years, experience has proven that nothing can show as much information in such a small space as the schematic. In fact, the schematic is universally understood. Even if you cannot understand a word of the language a manual is printed in, the symbols will be so close to those given in this book that you will be able to understand the schematic.

A schematic shows all of the electrical connections and circuit components in a piece of electronic equipment. It also tells you the electrical value or the type used for each component in the unit. Just to list the components and to explain the connections in words would take many pages. In fact, for a typical Tektronix instrument the explanation would probably fill more pages than this book contains. A typical schematic is shown in Fig. 1-1.

*The word schematic is an adjective; however, it is commonly used in both the singular and plural form as a noun.

DIAGRAMS AND CIRCUIT BOARD ILLUSTRATIONS

Symbols and Reference Designators

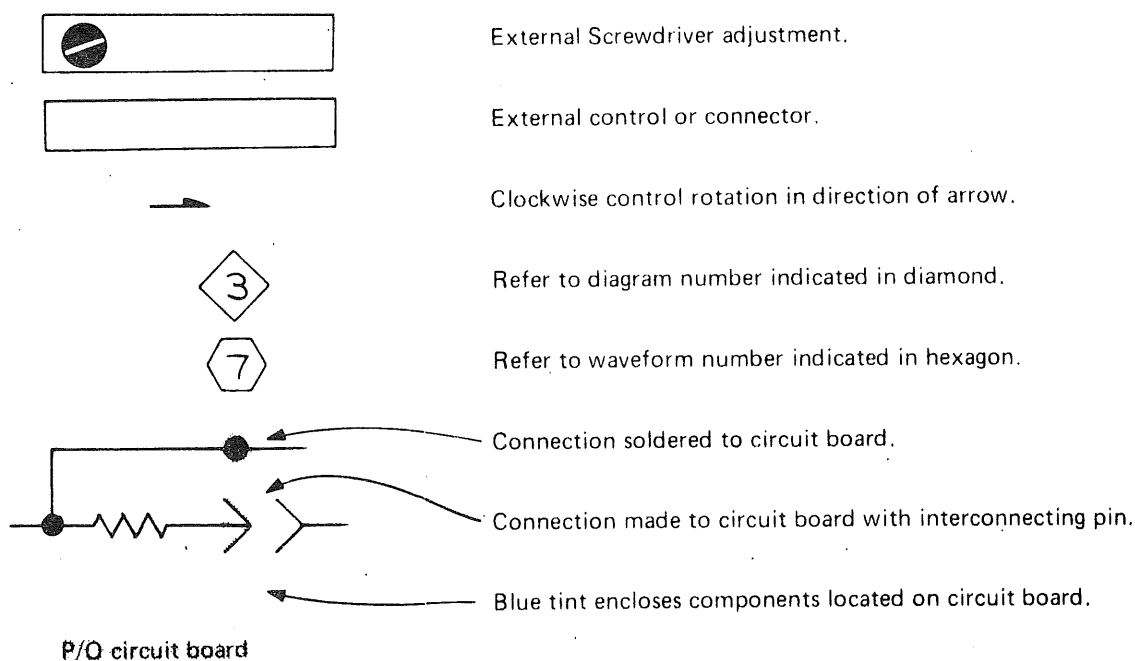
Electrical components shown on the diagrams are in the following units unless noted otherwise:

Capacitors =	Values one or greater are in picofarads (pF). Values less than one are in microfarads (μ F).
Resistors =	Ohms (Ω)

Symbols used on the diagrams are based on USA Standard Y32.2-1967.

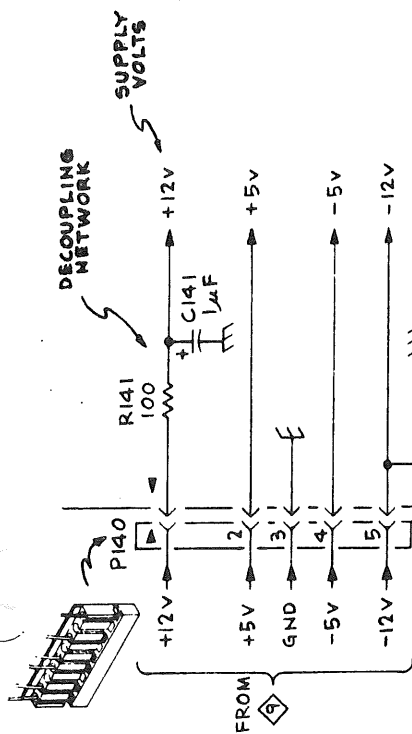
Logic symbology is based on MIL-STD-806B in terms of positive logic. Logic symbols depict the logic function performed and may differ from the manufacturer's data.

The following special symbols are used on the diagrams:



The following prefix letters are used as reference designators to identify components or assemblies on the diagrams.

A	Assembly, separable or repairable (circuit board, etc.)	LR	Inductor/resistor combination
AT	Attenuator, fixed or variable	M	Meter
B	Motor	Q	Transistor or silicon-controlled rectifier
BT	Battery	P	Connector, movable portion
C	Capacitor, fixed or variable	R	Resistor, fixed or variable
CR	Diode, signal or rectifier	RT	Thermistor
DL	Delay line	S	Switch
DS	Indicating device (lamp)	T	Transformer
F	Fuse	TP	Test point
FL	Filter	U	Assembly, inseparable or non-repairable (integrated circuit, etc.)
H	Heat dissipating device (heat sink, heat radiator, etc.)	V	Electron tube
HR	Heater	VR	Voltage regulator (zener diode, etc.)
J	Connector, stationary portion	Y	Crystal
K	Relay		
L	Inductor, fixed or variable		



TEST INFORMATION

WAVEFORMS

WAVEFORMS AND VOLTAGES
OBTAINED UNDER CONDITIONS
ON FORM OUT-4-APR-68

TYPICAL
SCHEMATIC
DIAGRAM

ALL COMPONENTS
INSIDE BLUE OUT-
LINE ARE LOCATED
ON CIRCUIT BOARD

OVERLAY
REGISTRATION

ETCHED CIRCUIT
BOARD OUTLINE

FRONT
PANEL

CH 1
INPUT

COMMON
COMMON

VARIABLE
CAPACITOR
(2-8)

MODIFIED VALUE
SEE PARTS LIST

SCREWDRIVER
ADJUST

DC
BAL

FRONT PANEL
CONTROL, IN BOX

ZENER
DIODE

+12V

VR111 5V

C111 330

Q110A 1/2 FET

R111 1.74k

Q104

R104 1.8k

C106 1 μ F

R106 100

C104

R102 100

C101 2-8

R101 1M

Q104

R104 1.8k

C106 1 μ F

R106 100

C104

R102 100

C101 2-8

R101 1M

Q104

R104 1.8k

C106 1 μ F

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R102 100

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R106 100

C104

R102 100

C101 2-8

R101 1M

Q104

R104 1.8k

C106 1 μ F

R106 100

C104

R102 100

SYMBOL VARIATION

The symbols used by different companies differ. The symbols for each component will be discussed in the following chapters.

Organizations such as the Institute of Electrical and Electronic Engineers (IEEE) have adopted standard symbols which they hope the industry will use. Likewise, there are standards adopted by the American Standards Association and the military services which fortunately, are identical. Recently, the Electronic Industries Association (EIA) has been instrumental in coordinating the efforts of various groups aimed at standardization of symbols.

The symbols used throughout the world are fairly standard. Once the symbols given in this book are mastered, you should have no problem understanding a schematic from anywhere - except of course, foreign terms will be used on it. The differences between two U.S. schematics may be greater than between a U.S. and a foreign schematic.

Fortunately, the differences in the symbol used by various companies to depict a component are not so great as in previous years. Differences still exist, however. In general, the weight of a line or minor differences do not change the meaning of a symbol. In fact, the symbol can be completely reversed; that is, two symbols can be the mirror image of each other and still have the same meaning.

Most of the differences in the symbols chosen stem from differences in the type of drafting and the method of laying out the circuit; they have no effect on the meaning. Schematics may be hand sketched, drawn with ink and a symbol guide, produced using preprinted symbols, or even prepared by a machine having a keyboard similar to that of a type-setting machine. Therefore, minor differences are inevitable. See Fig. 1-2

GRAPHIC SYMBOLS FOR ELECTRONICS DIAGRAMS

COMPILED BY THE EDITORS OF

Electronics

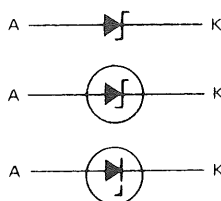
SEMICONDUCTORS

DIODES

rectifier (junction) diode



zener (unidirectional breakdown) diode



bidirectional breakdown diode



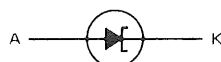
constant-current (field-effect) diode



tunnel diode



tunnel rectifier (backward diode)



Schottky (hot-carrier) diode



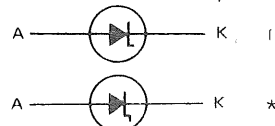
p-i-n diode



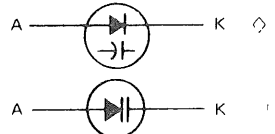
Gunn diode, also Impatt diode



step-recovery
(snap, charge-storage) diode

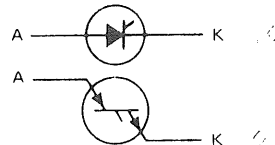


varactor (variable-capacitance) diode



THYRISTORS

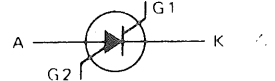
four-layer (pnpn, Shockley) diode



silicon-controlled rectifier (SCR)



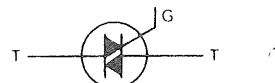
silicon-controlled switch (SCS)



diac (bidirectional switch)

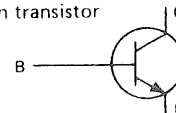


triac (gated bidirectional switch)

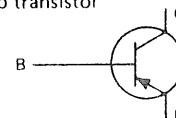


TRANSISTORS

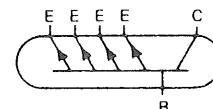
npn transistor



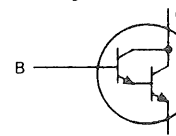
pnp transistor



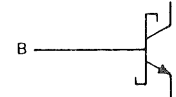
multiple-emitter npn transistor



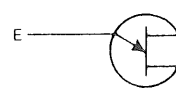
nnp Darlington transistor



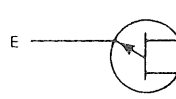
nnp Schottky transistor



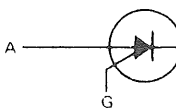
unijunction transistor (UJT) with n-type base



unijunction transistor (UJT) with p type base

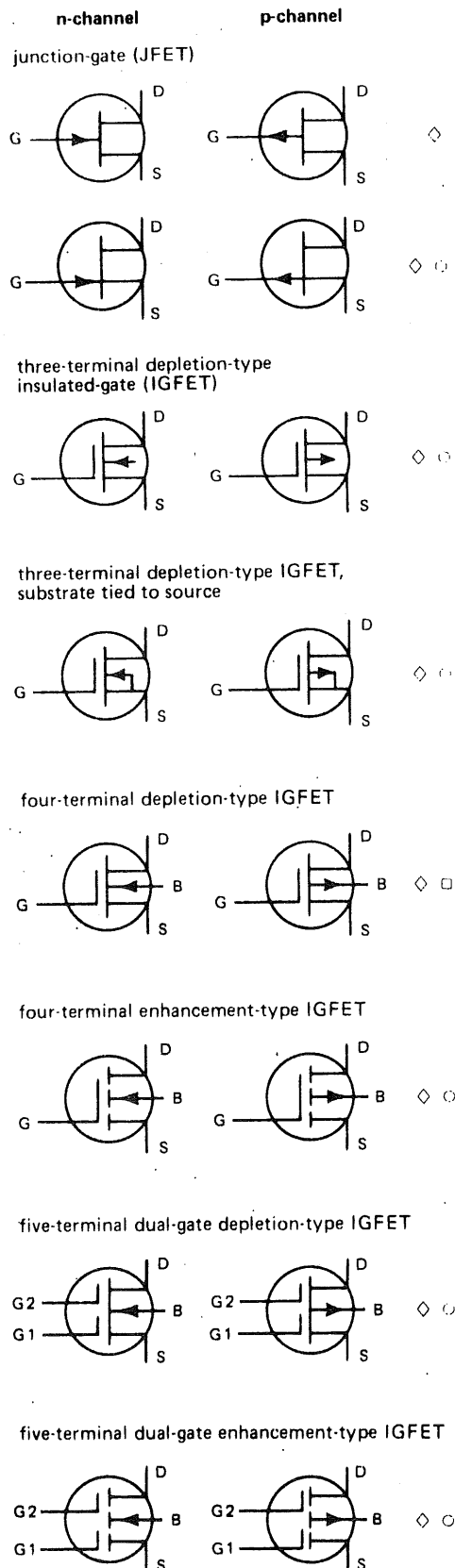


programmable unijunction transistor (PUT),
also SCR with n-type gate



IEEE/ANSI approval

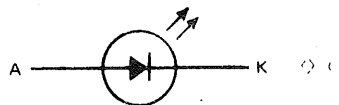
FIELD-EFFECT TRANSISTORS (FETs)



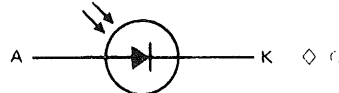
OPTOELECTRONIC DEVICES

DIODES

light-emitting diode (LED)



photodiode



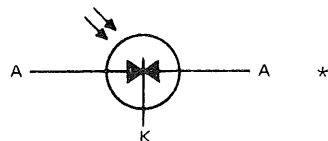
npn bidirectional photodiode (photo-duo-diode)



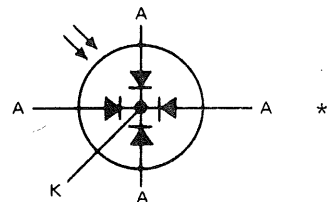
pnv bidirectional photodiode (photo-duo-diode)



pnv two-segment photodiode, with common cathode

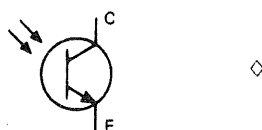


pnv four-quadrant photodiode, with common cathode

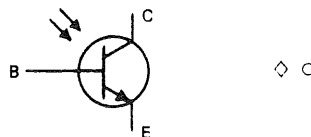


TRANSISTORS

npn phototransistor, no base connection

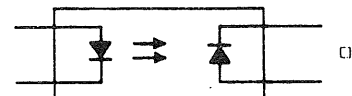
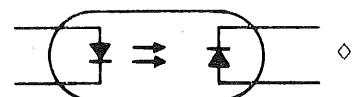


npn phototransistor, with base connection

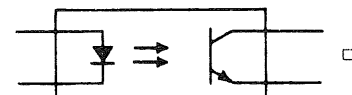


OPTICALLY COUPLED ISOLATOR

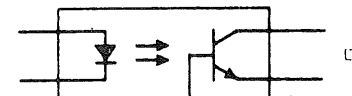
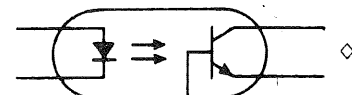
with photodiode output



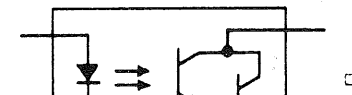
with phototransistor output, no base connection



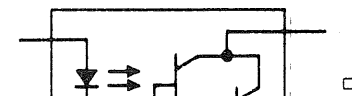
with phototransistor output, and base connection



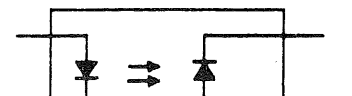
with photo-Darlington output, no



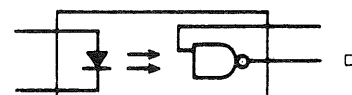
with photo-Darlington output, and base



with photodiode and amplifier-transistor output

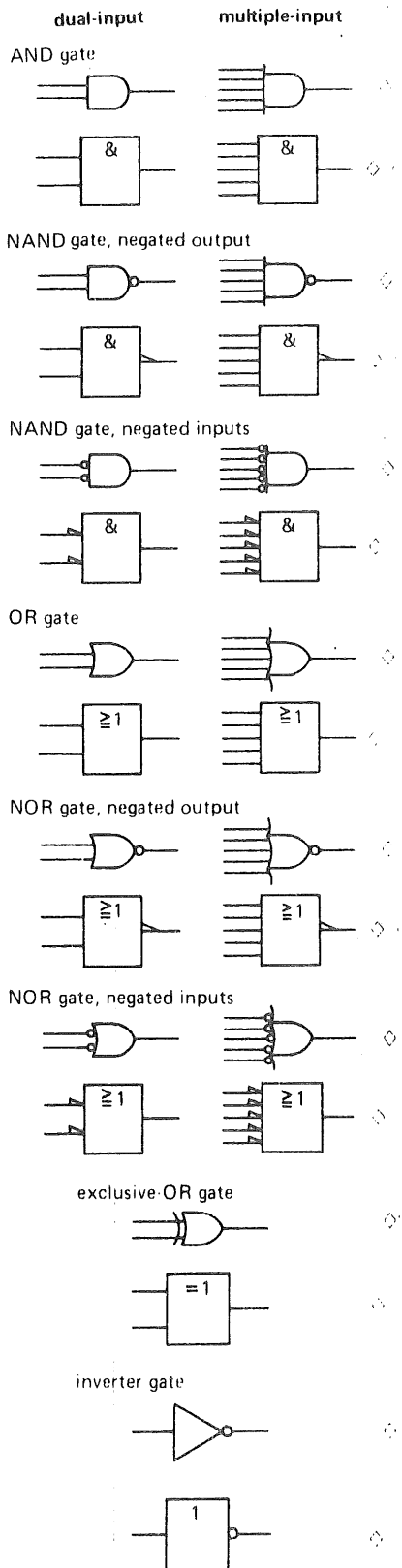


with NAND-gate-photodetector output



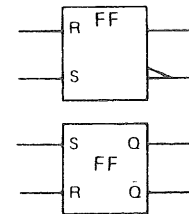
TWO-STATE LOGIC DEVICES

GATES

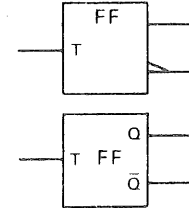


FLIP-FLOPS

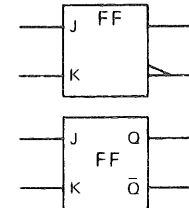
R-S (set-reset) flip-flop



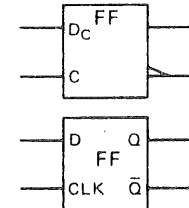
toggle flip-flop



J-K flip-flop

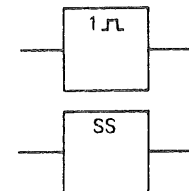


D-type flip-flop



MONOSTABLE MULTIVIBRATOR

monostable
(single-shot, one-shot)



SCHMITT TRIGGER

general

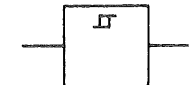


Fig. 1-2 (Cont.)

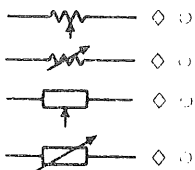
FUNDAMENTAL CIRCUIT COMPONENTS

RESISTORS

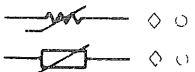
fixed-value resistor



variable resistor



voltage-sensitive resistor (varistor)

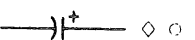


CAPACITORS

fixed-value capacitor



electrolytic capacitor



variable capacitor



INDUCTORS

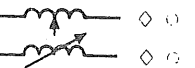
fixed-value inductor



fixed-value inductor with magnetic core

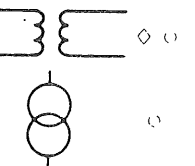


variable inductor

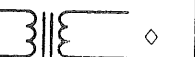


TRANSFORMERS

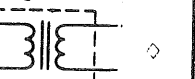
transformer



transformer with magnetic core

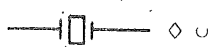


shielded transformer with magnetic core



CRYSTALS

piezoelectric crystal

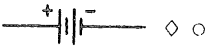


BATTERIES

single-cell battery



multiple-cell battery



SOURCES

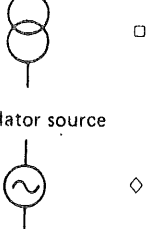
constant-voltage source



constant-current source



ac oscillator source



LAMPS

incandescent lamp



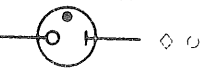
signal lamp



flashing signal lamp



neon lamp, dc type



neon lamp, ac type



fluorescent lamp, two-terminal

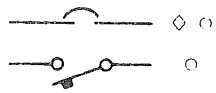


CIRCUIT PROTECTORS

fuse



circuit breaker



AUDIO DEVICES

loudspeaker

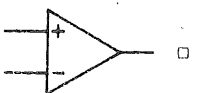


AMPLIFIERS

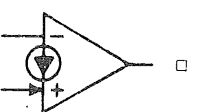
single-ended amplifier



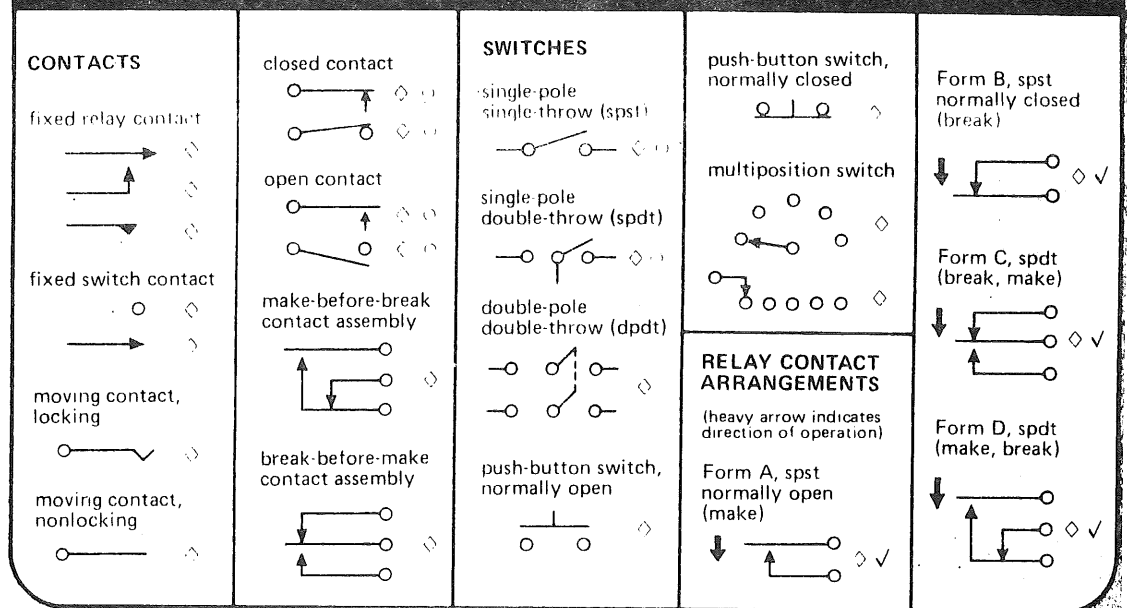
differential amplifier (or comparator)



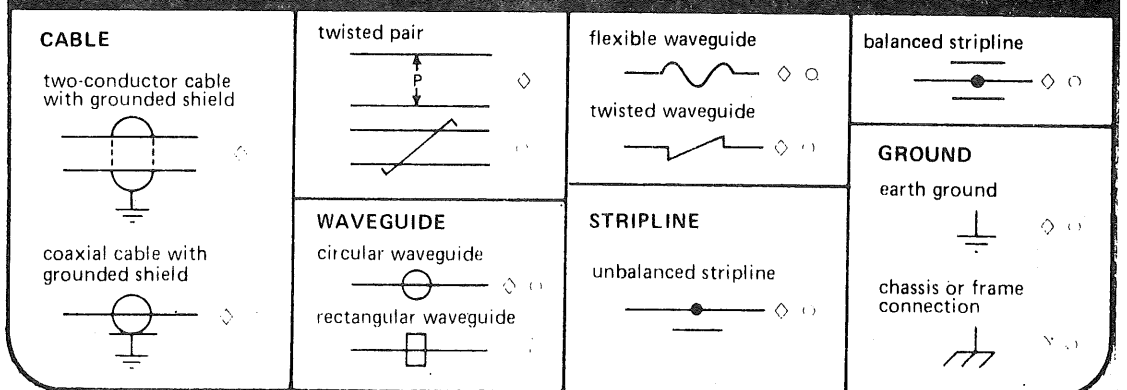
Norton (current) amplifier



CONTACTS, SWITCHES, AND RELAYS



TRANSMISSION PATH



MICROWAVE CIRCUITS

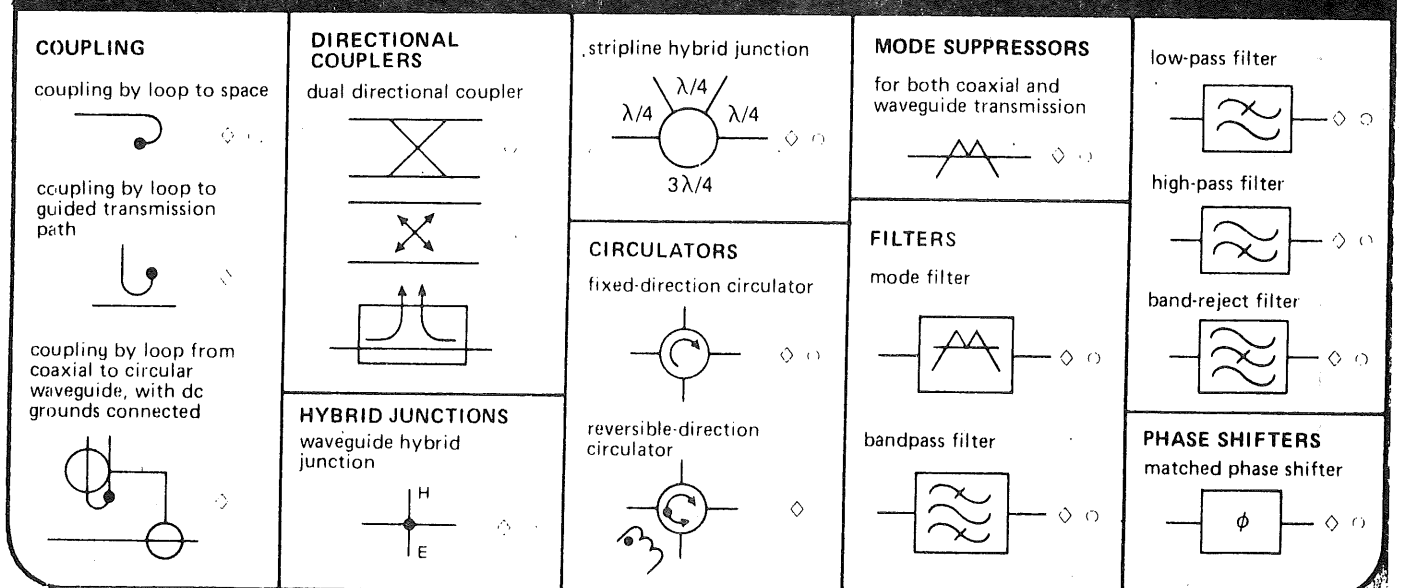


Fig. 1-2 (Cont.)

ELECTRONICS

WHAT IS IT ?

Before describing the various components and symbols used in electronics, a few fundamental concepts must be understood. Before discussing any of the electronic components, let's take a look at electronics and see what it is all about.

THE ELECTRON

All matter is made up of atoms. The atom is the smallest particle which retains all the characteristics of the 100+ known elements that are combined to form all material. The atom, in turn, is made up of smaller particles, called electrons and protons (plus some other particles not important to our discussion). The proton has a minute positive charge and is located in the center of the atom (called the nucleus) along with other particles.

The electrons, having a negative charge, then orbit around this nucleus. Thus, the nucleus could be likened to the sun and the electrons to the planets orbiting around it. However, unlike the planets, each of which has a separate orbit, more than one electron will normally follow the same orbit in the atom. For example, Fig. 2-1 compares the helium atom with a copper atom. Since protons have a positive charge, they are represented by the + sign in the center, while the electrons having a negative charge are shown orbiting around the nucleus. Notice helium has two protons and two electrons in the same

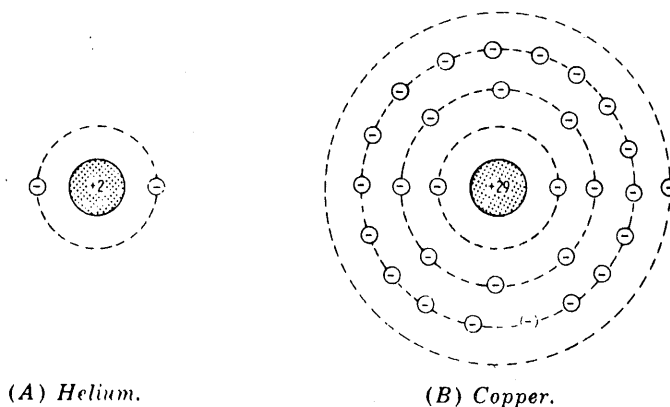


Fig. 2-1. Comparison of helium and copper atoms.

orbit (called a shell). Copper has 29 protons in the nucleus and 29 orbiting electrons arranged in 4 orbits or shells.

Since like electrical charges repel each other and unlike electrical charges attract, electrons in Fig. 2-1 would be attracted to the protons in the nucleus, but the centrifugal force of the orbiting electrons is sufficient enough to counteract the effect of the opposing charges. Thus, each electron stays in place orbiting the nucleus. In an atom such as copper (Fig. 2-1B), where there is a single electron in the outer shell, it is possible to cause the electron to move from its outer orbit to the outer orbit of an adjacent atom. The electron formerly at this point is then "bumped" to the next adjacent atom and so on. This is shown in simplified form in Fig. 2-2. As the electron enters at the left, another electron moves to the center atom, and then another electron moves to the right atom. Thus, in effect we have a flow of electrons through the material. An electric current is nothing but a flow of electrons. This flow is at the speed of light in free space, and just slightly slower in other materials; so, for all practical purposes, the flow is instantaneous.

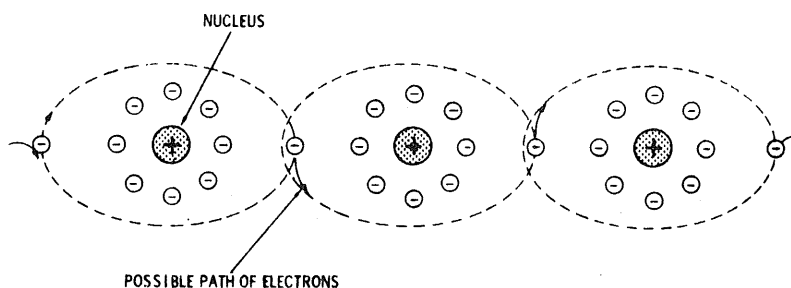


Fig. 2-2. Electron flow.

The construction of some atoms is such that electrons will not flow as readily from one atom to the next. When electrons flow readily as in our example, the material is called a *conductor*. When electrons will not flow, the material is called an *insulator*. Some materials can be treated so that electrons will flow in one direction but not in the other; they are called *semiconductors*.

The flow of electrons can be controlled in several ways. For example, when an electric switch is opened the flow of electrons through the wire is stopped. Electrons can be caused to do much more than flow through a wire, however. By proper manipulation of the flow of this tiny electron, the entire field of electricity and electronics is made

possible. It is difficult to say where electricity ends and electronics begins, but electronics is normally considered to encompass the entire field of controlling the flow of electrons through the use of tubes and semiconductor devices, such as transistors. Thus, radio, television, radar, and most of our modern conveniences are made possible through controlling the flow of this tiny negative charge in an atom.

ALTERNATING AND DIRECT CURRENT

The rate at which electrons flow is defined as current. Thus, if relatively few electrons flow, we have a small current; if more flow we have a larger current, etc. Before any electrons can flow, however, there must be some force to cause it. This force is called *electromotive force* (abbreviated emf), or *voltage*. This force, which can be likened to pressure, can be produced in many ways. Through chemical action, a battery produces voltage; through mechanical action, an alternator produces voltage.

Recall that an electron has a negative charge. Thus, if a material can be made to have more than the normal amount of electrons, it is said to have a negative voltage. Likewise, if a material can be made to have less than the normal amount of electrons, it can be said to have a positive voltage. This is what happens in the flashlight cell shown in Fig. 2-3. Through chemical reaction, an excess of electrons is created at the outside covering (bottom) of the cell. Likewise a deficiency of electrons is created at the center terminal (top). If a wire is connected between these two points, electrons will flow through the wire from the negative to the positive terminal. Recall that like charges repel; therefore, the concentration of electrons at the bottom of the

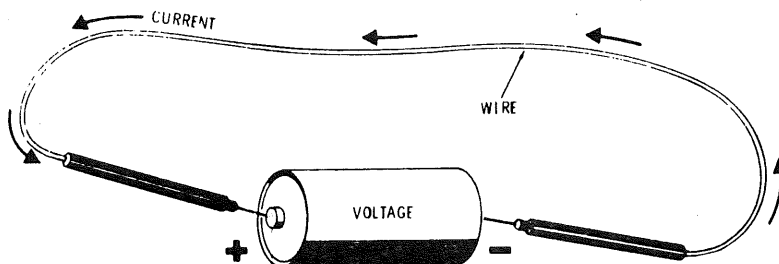


Fig. 2-3. Voltages and current.

repel; therefore, the concentration of electrons at the bottom of the battery will repel those electrons adjacent to it in the wire, and the chain reaction is started. Since the positive post at the top has a deficiency of electrons, they are attracted to this point because unlike charges attract. This flow of electrons (current) will continue until two points equalize.

A circuit like Fig. 2-3 can serve no useful purpose; it will only discharge the battery. However, if instead of a wire other devices are connected between these two points, the electrons can be made to do work while moving from one point to another. For example, if a light bulb is connected instead of the wire, the electrons will heat the wire in the bulb and produce light as they race toward the positive terminal.

The current produced in Fig. 2-3 is said to be direct current because it flows in only one direction through the wire. Such a current is diagrammed as shown in Fig. 2-4A. The instant the wire is touched to the two terminals, current starts flowing; this is represented by the line rising up and then extending in a straight line to the right. The vertical axis - the distance from the center (zero point) to the top - represents the *amount* of current, and the horizontal axis represents *time*.

Now suppose we took the two probes on the ends of the wire in Fig. 2-3 and reversed them so they were connected to opposite terminals of the battery. The electrons would now flow in the opposite direction through the wire. If we continued to reverse the leads, you can see that current through the wire would first flow in one direction and then in the other. Of course, this method of changing the direction of electron flow (current) is not practical, but in mechanical devices such as the ordinary alternator in a car, this is what happens. At a given terminal the voltage (potential) will first be negative and then

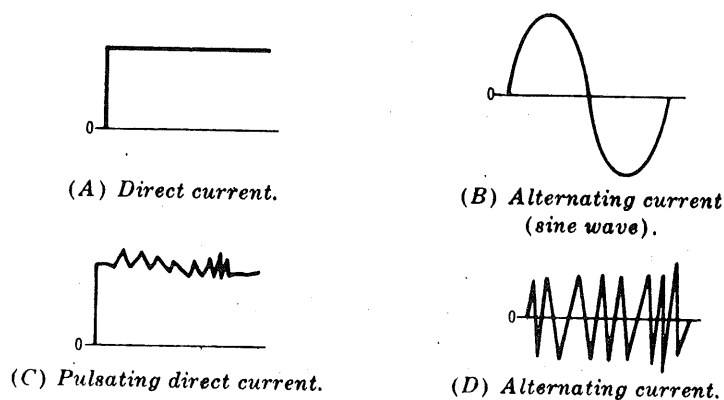


Fig. 2-4. Types of current waveforms.

positive. Thus, when it is positive, electrons will flow toward the terminal, and when it is negative, electrons will flow away from the terminal and toward the opposite terminal. This is alternating current and is diagrammed as shown in Fig. 2-4B. Here, the current builds up to a peak, then decreases and flows in the opposite direction to a similar peak and back to zero. The waveform shown in Fig. 2-4B is a special type of ac and is called a *sine wave*. The power supplied by the power companies is of this type.

Most of the currents encountered in electronic equipment do not follow either of the patterns shown in Fig. 2-4A and B. Instead, they will usually be more like the ones in Fig. 2-4C or D. Notice that the waveform in Fig. 2-4C is dc because it extends in only one direction from the zero line. Notice it is not steady; hence it is called a *pulsating dc*. The waveform in Fig. 2-4D is ac, since it extends both above and below the zero line, but it also varies and does not follow the sine-wave pattern.

While the waveforms in Fig. 2-4 have been described as current waveforms, they also represent the voltage present at a given point. When used to represent voltage, that portion above the zero line represents a positive voltage, while the portion below the line is a negative voltage. Thus, in Fig. 2-4A, a steady positive voltage is represented, while in Fig. 2-4C, the voltage is still positive but it varies. In Fig. 2-4B, the voltage first goes positive and then decreases in value to zero and on to a negative value and back to zero. The same is true of Fig. 2-4D, except here the changes follow a different pattern. The shape of the waveform will be the same whether it represents voltage or the resulting current.

The important points to remember about the electron flow concept can be summarized as follows:

1. Electrons are negatively charged particles.
2. Protons are positively charged particles.
3. Like charges repel and unlike charges attract.
4. When a path is provided, electrons will move from an area having an excess of electrons to one having a deficiency of electrons.
5. When electrons flow in only one direction, direct current (dc) is present.
6. When electrons flow in one direction and then in the opposite direction, alternating current (ac) is present.

7. Electronics is the science of controlling the flow of electrons in such a manner as to produce a desired result, usually with circuitry utilizing vacuum tubes or semiconductor devices.

Now, with the above concepts in mind, the various components used in electronics can be discussed. The effect each will have on the flow of electrons through it and the symbols used to represent each device on schematic diagrams will be given.

THE WORKHORSE COMPONENTS

USED IN EVERY CIRCUIT

There are components that are used in almost every electronic circuit. These items - resistors, capacitors, coils, and transformers - are the subject of this chapter.

RESISTORS

The resistor is probably the most common of electronic components. Several such units are found in almost every piece of electronic equipment. The function of a resistor is to "resist" or oppose the flow of electrons. In other words, it introduces what might be called "electrical friction" into the circuit. All materials offer a certain amount of resistance to electron flow - even a short piece of wire has resistance. However, with the resistor a large amount of resistance can be produced in a small compact unit.

The unit of measure for resistance is the *ohm*. As resistance is introduced in a circuit, the current is reduced. Thus, by the proper selection of resistance value, the amount of current through the circuit is controlled. Also, the voltage is dependent on the current and resistance. As current flows through a resistor, a voltage is developed across the resistor. That is, if you measure the voltage at the point where electrons enter a resistor and the voltage where the electrons exit, you will find the voltage is lower at the exit point by an amount proportional to the amount of current flowing through the resistor.

Resistors are also rated by the amount of current that can flow through them without damage. This rating is the *wattage*. Resistors are available in $\frac{1}{4}$ -, $\frac{1}{2}$ -, 1-, 2-, 5-, (and greater) watt sizes. In general, the larger the physical size, the higher the wattage.

The Greek letter *omega* (Ω) is usually used as an abbreviation for the word "ohm." Also, the letter k is used for 1000. Thus, a 1000 Ω or 1k resistor are both the same - one thousand ohms. The letter M, and the abbreviations *meg* or *megohm*, are used for one million ohms.

FIXED RESISTORS

The most common type of resistor is the so-called fixed resistor. By "fixed", we mean that the unit is constructed in such a way that its ohmic value cannot be altered without damaging the unit. Fig. 3-1 shows such resistors. They are made of carbon composition and are usually called *carbon resistors*. Another type of resistor, the *wirewound* resistor, is made by winding a high-resistance wire over a ceramic (or other insulating material) form. These latter resistors are usually higher wattage units.

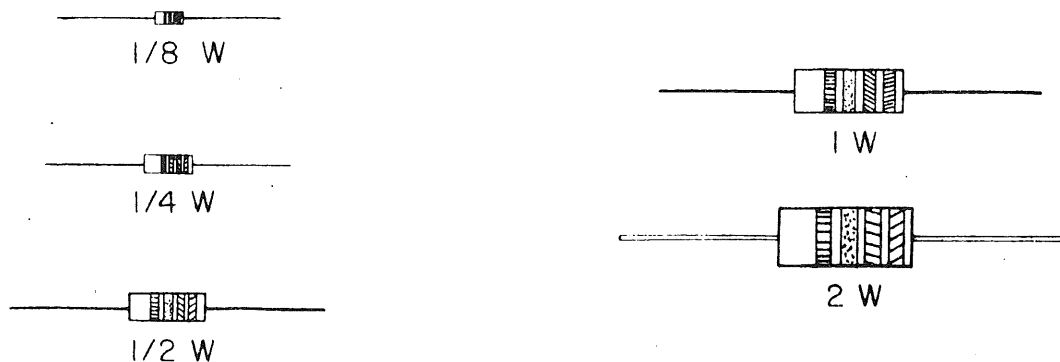


Fig. 3-1

The symbol for a fixed resistor is given at A in Fig. 3-2. The symbol conveys the concept of the unit; the zig-zag line depicts a difficult or resistance path. Connections can be made at various points on a wirewound resistor. If this is done, the symbol at B in Fig. 3-2 will be used. As many connections as there are taps will be shown on the symbol.

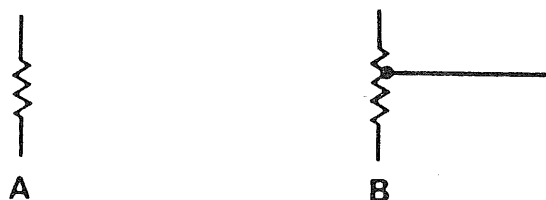
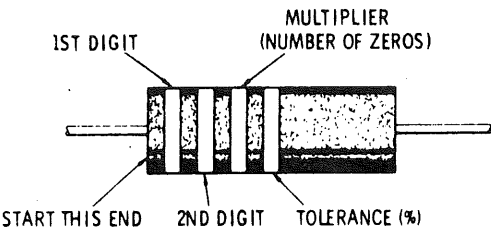


Fig. 3-2. Fixed resistor symbols.

Some means of indicating the value of the resistor must be provided. On wirewound resistors the value is usually stamped on the unit. The value of carbon resistors, however, is usually indicated by colored bands around the unit. Such bands are shown on the resistors in Fig. 3-1. The meaning of these bands is given in Fig. 3-3. Starting at the band nearest the end, the first band indicates the first digit in the number. The second band indicates the second digit. The third band is the multiplier. The first two digits are multiplied by the third to obtain the value in ohms. A fourth band indicates tolerance - how close the actual value of the resistor is to the indicated value. A gold band indicates 5% tolerance; silver indicates 10% tolerance; no band indicates 20% tolerance. As an example of the use of the color code, suppose a resistor has a green, blue, yellow, and silver band. This means the resistor is a $560,000\Omega$ (560k) unit and that it will be within 10% of this value.



Color	Digits	Multiplier	Tolerance
Black	0	1	20%
Brown	1	10	$\pm 1\%$
Red	2	100	$\pm 2\%$
Orange	3	1000	$\pm 3\%$
Yellow	4	10,000	GMV*
Green	5	100,000	$\pm 5\%$
Blue	6	1,000,000	$\pm 6\%$
Violet	7	10,000,000	$\pm 12\frac{1}{2}\%$
Gray	8	.01	$\pm 30\%$
White	9	.1	$\pm 10\%$
Gold	—	.1	$\pm 5\%$
Silver	—	.01	$\pm 10\%$
No Color	—	—	$\pm 20\%$

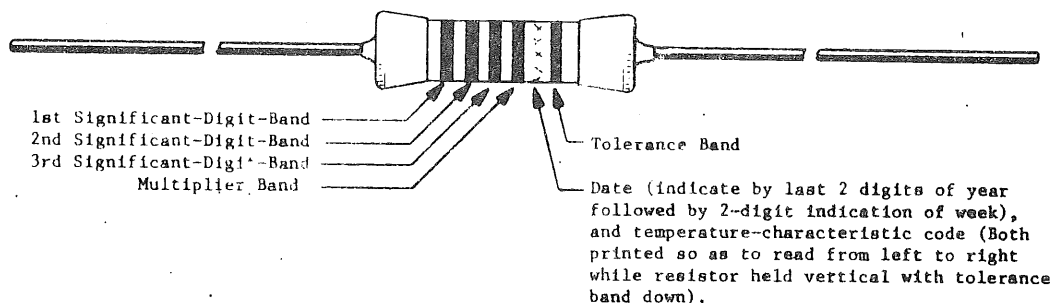
*Guaranteed Minimum Value—That is, $-0\% + 100\%$ tolerance

Fig. 3-3

For five banded resistors, as in Fig. 3-4, write the corresponding numbers for the first three colors and multiply that by the fourth color. The fifth color is the tolerance.

RESISTOR, FIXED (CONT)

METAL FILM



COLOR BAND INFORMATION

COLOR	1ST SIG. FIG.	2ND SIG. FIG.	3RD SIG. FIG.	MULTIPLIER	DATE-TC CODE	± % TOLERANCE	
Black	0	0	0	1	Date code is the last 2 digits of year followed by 2 digits for week using 0X for week if X is 9 or less. Additional 2 symbols denote the TC.	-	
Brown	1	1	1	10		1.	F
Red	2	2	2	100		2.	G
Orange	3	3	3	1,000		-	
Yellow	4	4	4	10,000		-	
Green	5	5	5	100,000		.5	D
Blue	6	6	6	1,000,000		.25	C
Violet	7	7	7	10,000,000		.1	B
Grey	8	8	8	100,000,000		.05	A
White	9	9	9	1,000,000,000		-	
Gold				.1		5.	J
Silver				.01		10.	K
No Color						-	

TEMPERATURE CHARACTERISTIC CODE

Temperature Characteristic Code	Temperature Coefficient (P/M/°C)	Temperature Range (°C)
T-0 D	0 to ±150	-55 to +165
T-1 D	0 to ±100	-55 to +165
T-2 C	0 to ±50	-55 to +175
T-9 E	0 to ±25	-55 to +175
T-E	0 to +100 -500	-55 to +165
T-R	0 to +100 -250	-55 to +165

4 digit resistance values are marked by numbers and multiplier. Tolerance, TC and date code. Ex: 60.82 k .5% T-2 7226.

Mil marking: RN55, T/C: C, Resistance value: 1003, Tol.: F

.125 Watt, T-2, 100 k, ±1%

WATT	RN	PART NUMBER
.125	55	321-0000-00
.25	60	322-0000-00
.5	65	324-0000-00
1.	75	325-0000-00

PART NUMBER SUFFIX			
-00	1.% T-0	-04	.1% T-2
-01	.5% T-0	-05	.25% T-5
-02	.5% T-2	-06	.25% T-9
-03	.25% T-2	-07	.1% T-9
		-08	1.% T-2
		-09	1.% T-9

PART NUMBER EXPLANATION

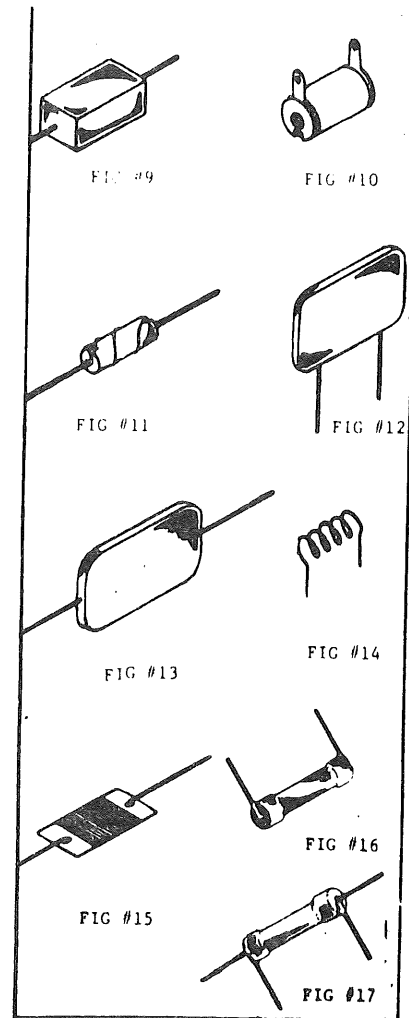
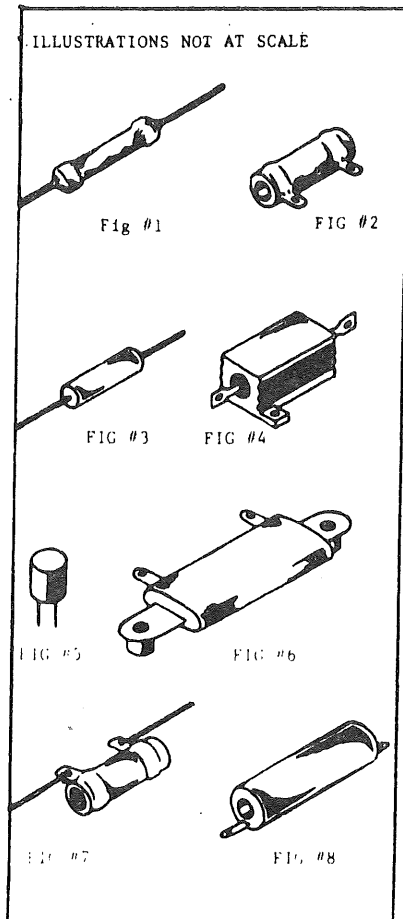
321 .125 Watt 323 .5 Watt
322 .25 Watt 324 1. Watt

Pre-arranged numbers -0001- through -0600- are Mil-Bell resistance values from 10 ohms to 17.4 megohms. Pre-arranged numbers -1001- to -1599- are resistance values from 10.1 ohms to 14.2 megohms. Numbers from -0601- to -0999- are special cases. The -00 through -09 suffix applies to all numbers. The numbers from -0601- to -0999- may not have a description consistent with the -00 part of the number.

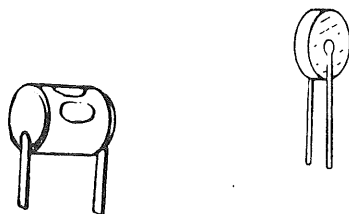
Fig. 3-4

RESISTOR, FIXED (CONT)

WIREWOUND



PELLET



THERMAL

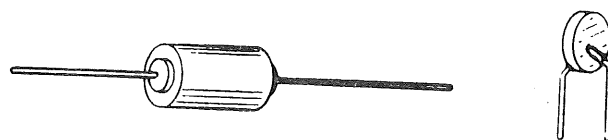


Fig. 3-5

VARIABLE RESISTORS

It is often desirable to have a means of varying the value of a resistor. For example, the volume control of a radio or television set is a variable resistor. Other variable resistors are used in lighting and power circuits. Fig. 3-6 shows some of the many types in use. Most consist of a circular resistance element (either wire or carbon) with connections to one or both ends. A movable arm is placed in contact with the resistance and mechanically attached to the shaft, which protrudes from the unit. Moving this shaft changes the position of the movable arm on the resistance element. By connecting one of the terminals to this movable arm, a point is obtained which can be adjusted to any desired value of resistance between the two ends.

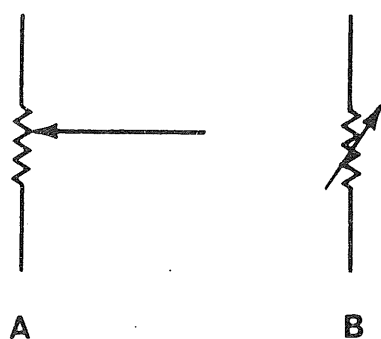


Fig. 3-6 Variable resistor symbols

When terminals are attached to both ends of the resistance element, the resistor is called a *potentiometer*; when a terminal is attached to only one end, it is called a *rheostat*. The most common symbols for potentiometers and rheostats are given at A and B in Fig. 3-6. Notice that it is the normal resistor symbol, with the arrow denoting the sliding contact.

SPECIAL RESISTORS

By using special formulas in the composition of resistors, they can be made to change their resistance when the temperature, voltage, current, light, or some other quantity varies. Most of these units are actually semiconductors, but since their function is that of resistance, they are included in Fig. 3-7. The symbols in Fig. 3-7 all signify temperature-dependent, or temperature-compensating resistors. Such resistors may be made to decrease or increase their resistance as the temperature rises.



Fig. 3-7 Temperature-compensating resistor symbols.

The same symbols in Fig. 3-7 can be used for other special resistors. For example if a "V" is used in place of the "T" on these symbols, the unit is voltage sensitive. An "I" signifies current sensitive, and "L" or " λ " (Greek letter *lambda*) denote light-sensitive units.

RESISTOR, VARIABLE (CONT)

TRIMMER (MULTITURN)

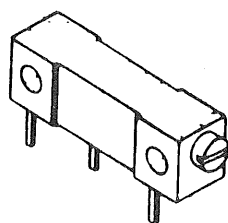


FIG. 1

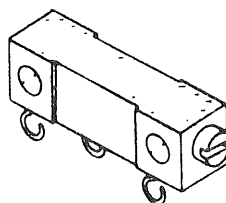


FIG. 2

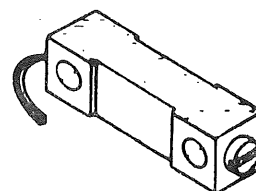


FIG. 3

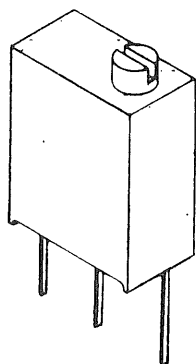


FIG. 4

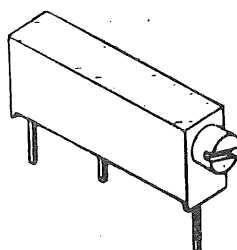


FIG. 5

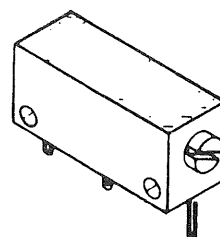
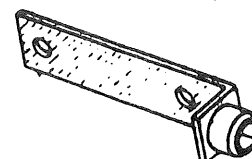


FIG. 6



MOUNTING BRACKET
407-1658-00

Fig. 3-8

RESISTOR, VARIABLE (CONT)

TRIMMER

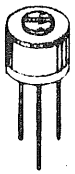


FIG 1

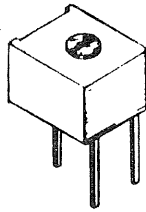


FIG 2

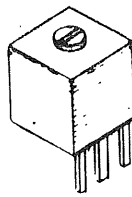


FIG 3

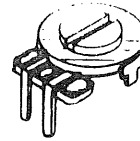


FIG 4

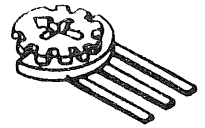


FIG 5

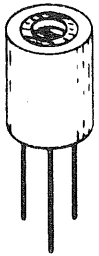


FIG 6

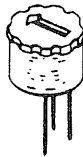


FIG 7



FIG 8

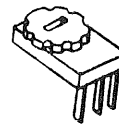


FIG 9

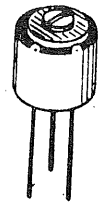


FIG 10

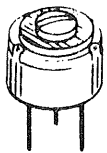


FIG 11

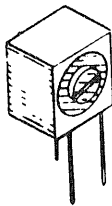


FIG 12

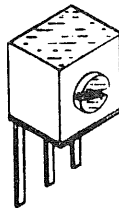


FIG 13

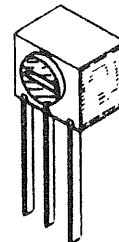


FIG 14

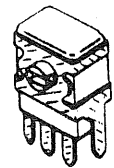


FIG 15

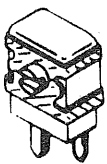


FIG 15A



FIG 16

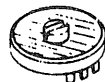


FIG 17



FIG 18

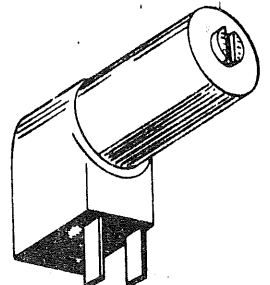


FIG 19

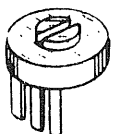


FIG 20



FIG 21



FIG 22

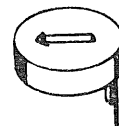


FIG 22A

RESISTOR, VARIABLE (CONT)

SINGLE ELEMENT PANEL MOUNT

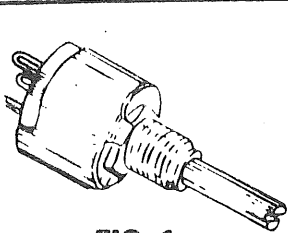


FIG. 1

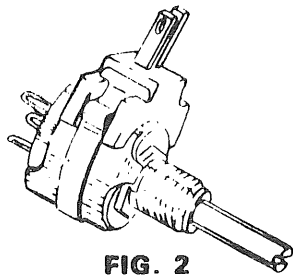


FIG. 2

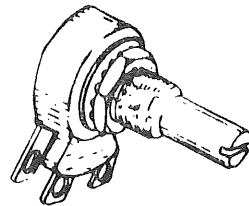


FIG. 3

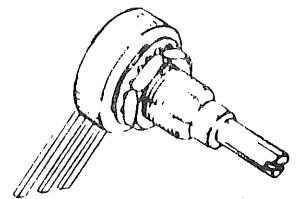


FIG. 4

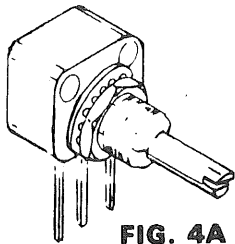


FIG. 4A

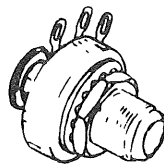


FIG. 5

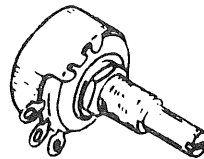


FIG. 6

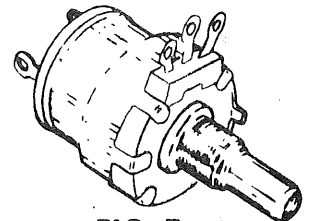


FIG. 7

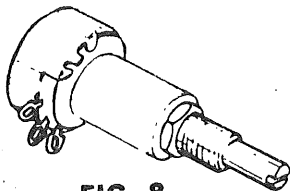


FIG. 8

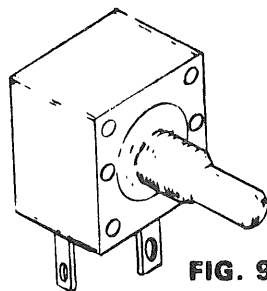


FIG. 9

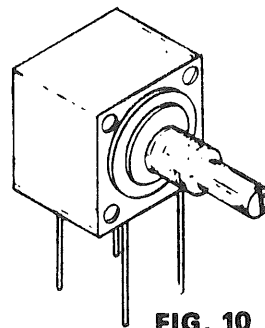


FIG. 10

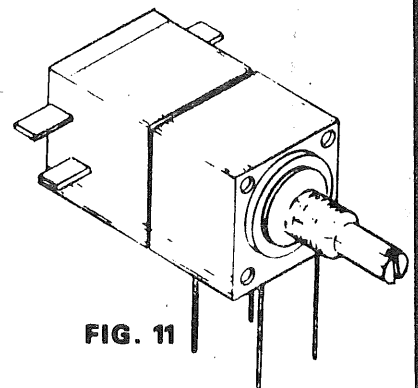


FIG. 11

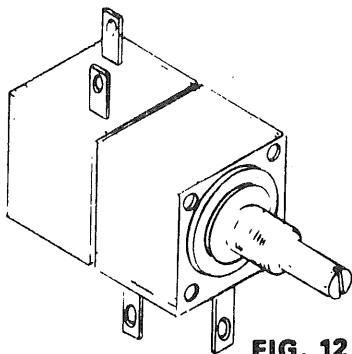


FIG. 12

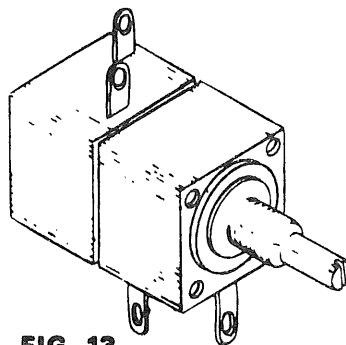


FIG. 13

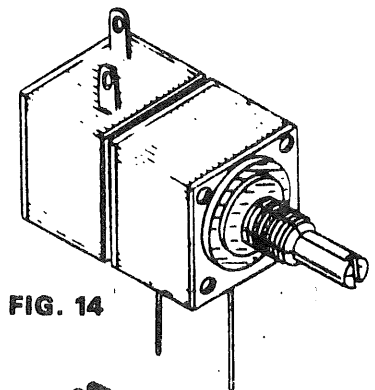


FIG. 14

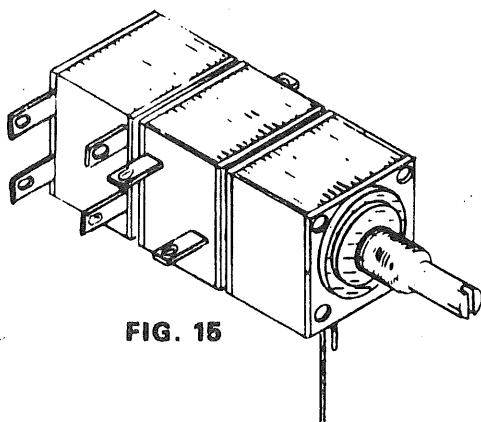


FIG. 15

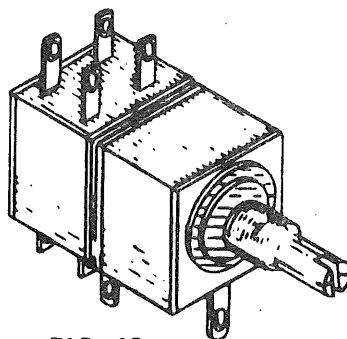


FIG. 16

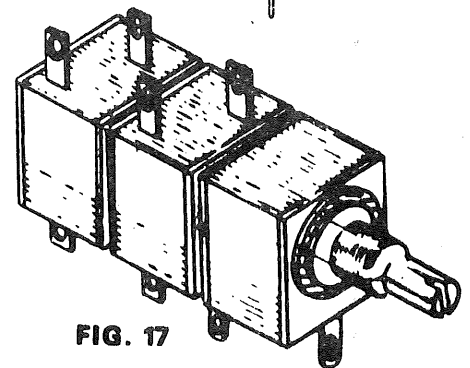


FIG. 17

CAPACITORS

The capacitor (formerly called condenser) is probably the second most common component (after the resistor) found in electronic circuits. Several capacitors will be found in almost every item of electronic equipment.

FIXED CAPACITOR

The basic capacitor consists of two plates separated by an insulator, as shown in Fig. 4-1. Here the two flat, metal plates are separated by air for the insulator. In a practical capacitor, the plates may be made of two pieces of metal foil separated by a paper insulator and rolled up in a cylindrical shape. At other times, ceramic, mica, or several other materials can be used as the insulating material called the *dielectric*. Actually a certain amount of capacitance will exist between any component (even a length of wire) and other parts of the circuit or chassis. Usually this capacitance can be disregarded, however.

A capacitor has the ability to store and release electrons as dictated by the related circuitry. This storage and release of electrons is called the *charge* and *discharge* of the capacitor. Also, while electrons will not flow through the insulating material, when a large quantity of electrons are stored on one plate, making it more negative, they will repel electrons on the other plate, causing an electron flow away from this plate. Thus, while there is no current *through the dielectric*, when an ac signal is connected to one plate, causing a build-up and depletion of electrons on this plate, a similar effect occurs on the opposite plate.

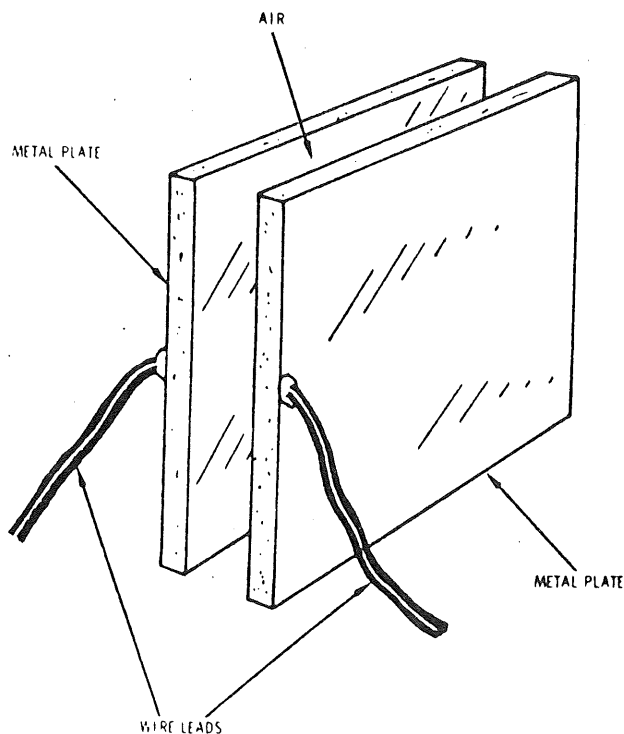


Fig. 4-1 An elementary capacitor

If dc is connected to one plate of the capacitor, it acts as an open circuit. Since the amount of electrons does not vary on the plate connected to dc, there is no movement of electrons to or from the second plate.

The property by which a capacitor transfers the ac signal from one plate to the other is called *coupling*. The property of acting as an open circuit to dc is called *blocking*.

The unit of measurement for this property of a capacitor (called *capacitance*) is the *farad*. Since the farad is a rather large unit, most capacitors are rated in *microfarads*, equal to one millionth of a farad, or *picofarads*, equal to one millionth of a microfarad. The term microfarad is abbreviated mfd or μF . (The symbol μ is the Greek letter Mu and is used in electronics to mean one millionth.) Picofarad is abbreviated pF. Formerly, the term micromicrofarad ($\mu\mu\text{f}$, mmf, or mmfd) was used for picofarad and it may still be encountered.

The symbols for capacitors are shown at A and B in Fig. 4-2. The symbols are representative of the basic capacitor - two plates separated by an insulator.

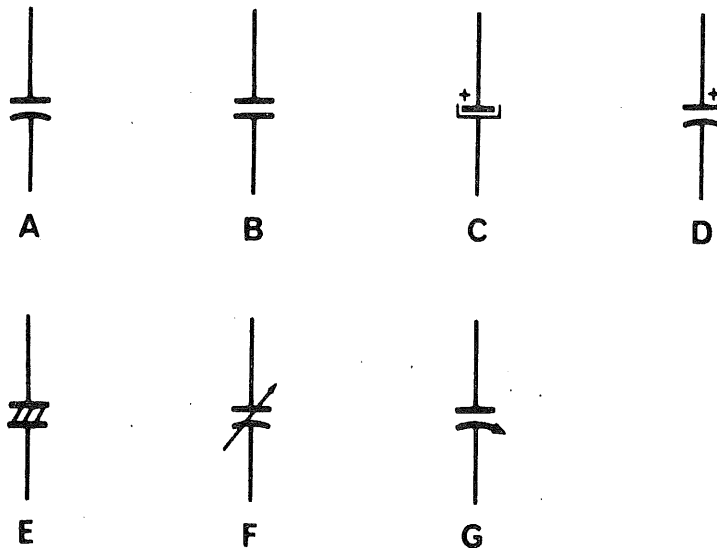


Fig. 4-2 Capacitor symbols

ELECTROLYTIC CAPACITORS

Another type of capacitor utilizes a moist substance, called *electrolyte*, as one plate. This substance, when placed in contact with a material such as aluminum, causes an oxide coating to form on the surface of the metal. This coating becomes the insulation, or dielectric, between the electrolyte and the metal plate. Such capacitors may be made in high capacitance values; however, they must usually be connected to the correct polarity voltage. The positive terminal must be connected to a more positive point than the negative terminal. The symbols for electrolytic capacitors are given at C, D, and E in Fig. 4-2. Notice the + sign which designates the positive terminal on the symbols at C and D. The symbol at E is usually encountered on foreign schematics.

VARIABLE CAPACITORS

There is need for capacitors whose values can be varied. The most common example is the tuning capacitor in radios. As the value of the capacitor is varied, the different stations are "tuned in." Other variable capacitors are used in many applications where, in conjunction with other components, they tune the circuit to a specific frequency. The symbols for variable capacitors are given at E and F in Fig. 4-2. The arrow either placed across the symbol or added to one of the plates signifies that the capacitance value can be varied.

CAPACITOR MARKINGS

Like resistors, capacitors are often color coded to indicate their value. Many different methods of indicating this code are employed, depending on the type of capacitor. Other capacitors have the value stamped on them. In addition to the capacitance value, the working voltage is exceeded, electrons will try to jump across the dielectric and arcing between the two plates occurs, ruining the capacitor. Therefore, the maximum voltage that should be placed across the two plates is indicated.

Some disc capacitors (discaps) values are denoted by K, indicating that a multiplication of 1,000 has to be made. This means they would be read in thousands of μf , e.g., 5K would be read 5000 μf . Others are stamped with only a number, and are read in μf . In most cases, remember that any number greater than one is read in μf . Other capacitors such as trimmers and electrolytics have their values stamped on them. Read them in μf unless stamped otherwise.

CERAMIC DISC CAPACITORS

Often called "discaps" (that is the trademark of one manufacturer), ceramic disc capacitors are available in two categories: temperature compensating or class I, and "high-K" or class II. T_c types usually carry the capacitance in pF's directly. Tolerance may be shown in percent or by letter:

M	= $\pm 20\%$
K	= $\pm 10\%$
J	= $\pm 5\%$
G	= $\pm 2\%$
F	= $\pm 1\%$
P	= $\pm 10\%$
R	= $\pm 15\%$
S	= $\pm 22\%$

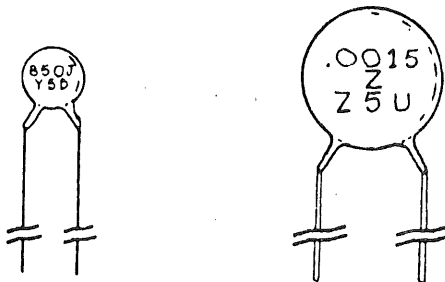


Fig. 4-3

Temperature coefficient is indicated by P100, which means $+100 \text{ P/M}/^\circ\text{C}$, or N750 for $-750 \text{ P/M}/^\circ\text{C}$, N 030 for $-30 \text{ P/M}/^\circ\text{C}$, etc. All these T_c 's have a tolerance, too. NPO is usually $\pm 30 \text{ P/M}/^\circ\text{C}$, with looser tolerance on larger T_c 's. T_c tolerance is also looser on very low capacitance parts.

"High-K" types list capacitance the same way (or in μf), and in addition sometimes use a multiplier scheme as follows: 102 for 1000 pF, 473 for 47,000 pF, etc. Capacitance tolerance is shown as above, with the addition of P for GMV ("guaranteed minimum value" or -0, +100%), and Z for -20, +80%. The temperature coefficient of these units is usually not linear, so only the maximum capacitance change due to temperature from the 25°C value is given. This is called the "temperature characteristic", a typical case being "Z5U". This table explains the meaning of the more common temperature characteristic designation.

Temperature range over which characteristic is effective:	Z5:	+10°C to +85°C	
	Y5:	-30°C to +85°C	
	X5:	-55°C to +85°C	
	W5:	-55°C to +125°C	
	V5:	-55°C to +150°C	
Limits of capacitance change from the room temperature value:	D:	±3.3%	T: +22%, -33%
	E:	±4.7%	U: +22%, -56%
	F:	±7.5%	V: +22%, -82%
	S:	±22%	W: +22%, -90%
	P:	±10%	Z: +20%, -80%
	R:	±15%	

Thus "Z5U" means that temperature can cause the capacitance to increase a maximum of 22%, or decrease a maximum of 56% from the room temperature value, within the limits of +10°C and +85°C.

Whether voltage rating appears on a disc depends on the manufacturer's practice. Most do not include it on their "standard" voltage rating, which is 1000V for Sprague and RMC, and 500V for Erie. Other voltage ratings, however, are printed on the capacitor.

High-voltage ceramic discs and plates used at Tektronix are of class II dielectric material, and carry labels similar to the class II discs.

Some disc caps are too small for the above coding and therefore use a three dot color code.

- ① 1st significant figure
- ② 2nd significant figure
- (M) multiplier

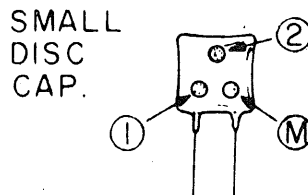


Fig. 4-4

Refer to figure 4-5 for Capacitor Color Code.

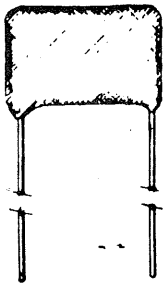
CAPACITOR COLOR CODE

COLOR	FIGURES	MULTIPLIER	TOLERANCE		VOLTAGE RATING *
			10pF or Less	Over 10pF	
Black	0	1	$\pm 2.0\text{pF}$	$\pm 20\%$	4 VDC
Brown	1	10	$\pm 0.1\text{pF}$	$\pm 1\%$	6 VDC
Red	2	100		$\pm 2\%$	10 VDC
Orange	3	1,000		$\pm 3\%$	15 VDC
Yellow	4	10,000		+100% - 0%	20 VDC
Green	5	100,000	$\pm 0.5\text{pF}$	$\pm 5\%$	25 VDC
Blue	6	1,000,000			35 VDC
Violet	7				50 VDC
Gray	8	.01	0.25pF	+80% -20%	
White	9	.1	$\pm 1\text{pF}$	$\pm 10\%$	3 VDC
None			$\pm 1\text{pF}$	$\pm 10\%$	
Silver				$\pm 10\%$	
Gold				$\pm 5\%$	

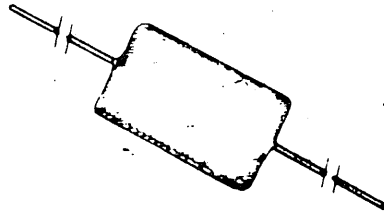
* For dipped tantalum capacitors only

Fig. 4-5

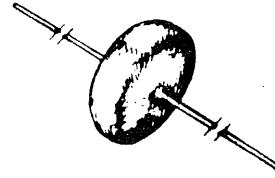
CERAMIC DISC, PLATE, AND SLUG



STYLE A



STYLE B



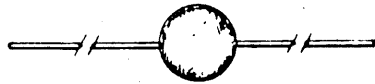
STYLE C



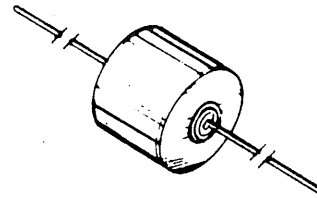
STYLE D



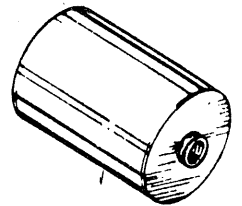
STYLE E



STYLE F



STYLE G



STYLE H

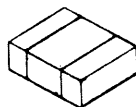


STYLE I



STYLE J

CHIP



LEADLESS DISC

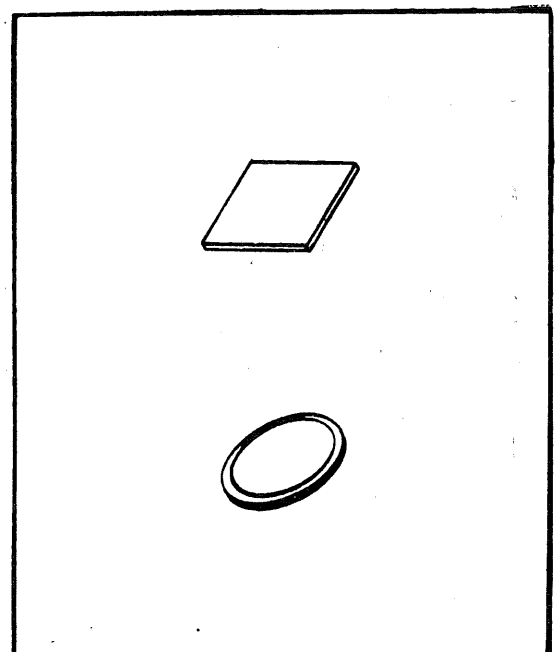


Fig. 4-6

CERAMIC TUBULAR CAPACITORS

These units are usually white enamel coated and have parallel radial leads. "Dog bones" come in several sizes, at least one being too small for a complete code of any kind. The code consists of color dots which show T, capacitance, and tolerance. The smallest style shows only capacitance and tolerance, and none can show the capacitance of a close-tolerance part to greater than two significant figures. The more common examples are illustrated below.

Note: on the smallest size only dots (1), (2), (3) & (4) appear, giving 1st & 2nd sig. fig., mult., & tol.

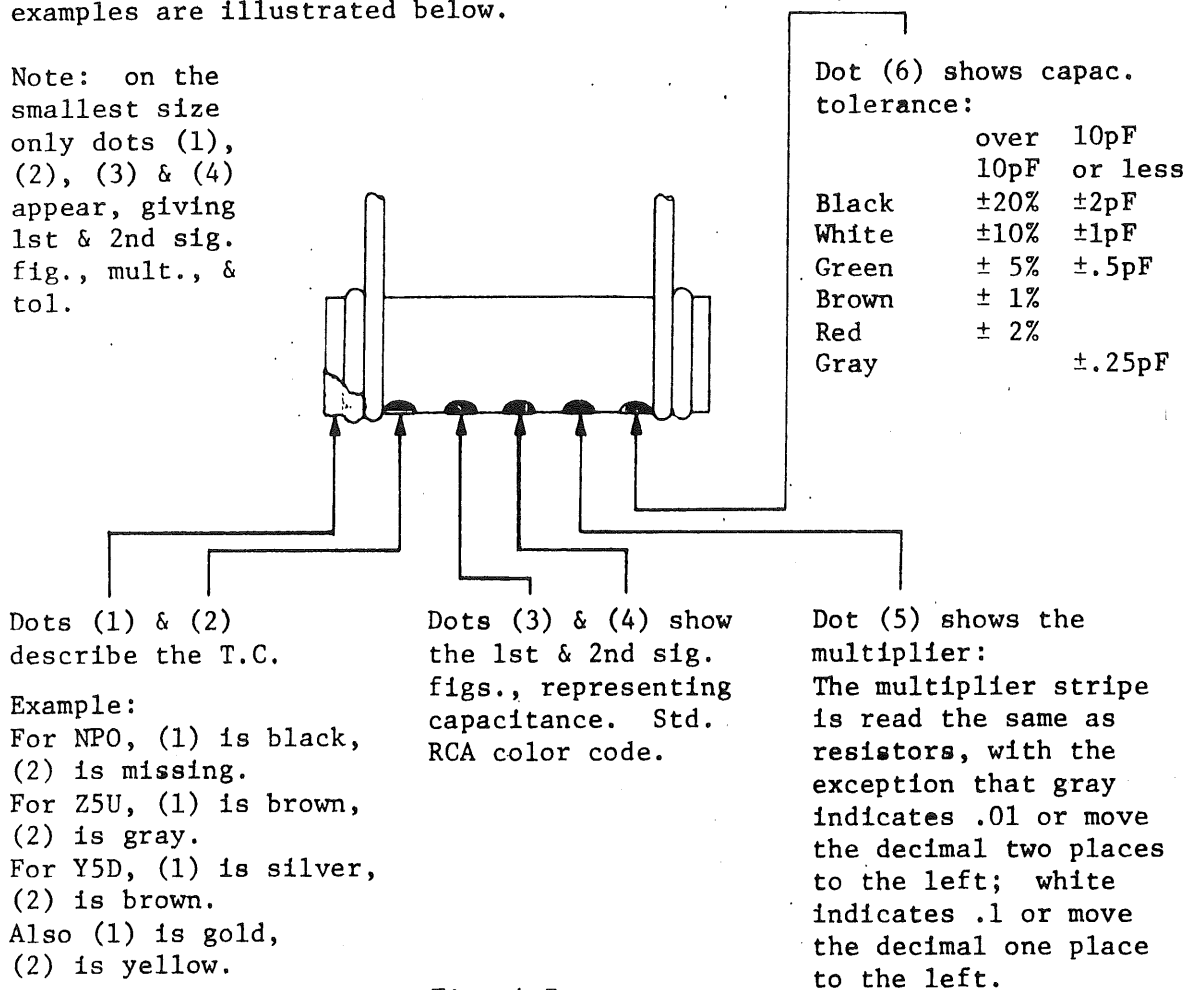


Fig. 4-7

TEMPERATURE COEFFICIENT

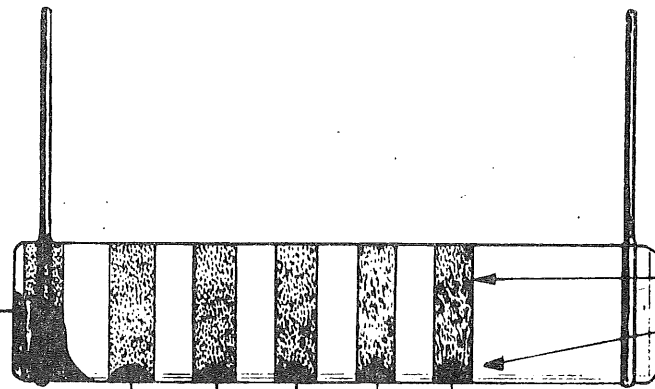
Ceramic capacitors are marked with a temperature coefficient stripe which indicates the amount of change in capacitance per one million units for each degree centigrade change in temperature using 25°C as a reference temperature.

TEMPERATURE COEFFICIENT CODING

In the following chart, "N" indicates negative, "p" positive, and "GP" general purpose

Black	.....	NPO
Brown	.....	N 033
Red	.....	N 075
Green	.....	N 330
White	.....	GP1
Silver	.....	GP2

CAPACITOR, FIXED CERAMIC



COLOR CODE BAND ON AXIAL UNITS.

COLOR CODE DOTS ON RADIAL LEAD UNITS.

TC TYPES TEMPERATURE COEFFICIENT			HI-K TYPES TEMPERATURE CHARACTERISTIC					CAPACITANCE				NOMINAL CAPACITANCE TOL		
T. C.	1st COLOR	2nd COLOR	SYMBOL	TEMPERATURE RANGE	SYMBOL	MAX. CHANGE %	COLOR	1st SIG. FIG.	2nd SIG. FIG.	MULT	COLOR	10 pF OR LESS	OVER 10pF	COLOR
P100 M7	Red	Violet	X5	-55 to +85°C	A	±1.0	Gold	0	0	1	Black	±2.0 pF	±20%	Black
P030 B6	Green	Blue	Y5	-30 to +85°C	B	±1.5	Silver	1	1	10	Brown	±0.1 pF	± 1%	Brown
NP0 C0	Black		W5	-55 to +125°C	C	±2.2	Black	2	2	100	Red		± 2%	Red
N030 B1	Brown		Z5	+10 to +85°C	D	±3.3	Brown	3	3	1000	Orange		± 3%	Orange
N080 U1	Red				E	±4.7	Red	4	4	10k	Yellow		+100% -0%	Yellow
N150 P2	Orange				F	±7.5	Orange	5	5		Green	±0.5 pF	± 5%	Green
N220 R2	Yellow				P	±10	Yellow	6	6		Blue			Blue
N330 S2	Green				R	±15	Green	7	7		Violet			Violet
N470 T2	Blue				S	±22	Blue	8	8	.01	Gray	±0.25 pF	+80% -20%	Gray
N740 U2	Violet		V5	-55 to +150°C	T	+22 -33	Violet	9	9	.1	White	±1 pF	±10%	White
N1500 P3	Orange	Orange			U	+22 -56	Gray							
N2200 R3	Yellow	Orange			V	+22 -82	White							
N3300 S3	Green	Orange												
N4200 G3	Green	Green												
N4700 T3	Blue	Orange												
N5600 H3	Green	Black												
N330 ±500 S2L	White													
N750 ±1000 U2M	Gray													
N3300 ±2500 S3N	Gray	Black												

Ceramic tubular capacitors with radial leads, temperature-compensated (T-C) and general purpose (HI-K), are now coded with a six-dot system to conform with the EIA Standard Color Code.

CAPS WITH A WHITE BODY COLORING MAY OBSCURE A WHITE DOT.

1. All six-dot caps with gold or silver first dot are HI-K caps.
2. HI-K caps may also have a first dot of black, brown or violet.
3. The second dot of a T-C type can only be black, orange, green, blue or violet.
4. The position of the sixth dot is very close to the radial lead.

Fig. 4-8

BUTTON MICA CAPACITORS

The most difficult aspect of understanding the code on these parts is "where do you begin?" The sketch shows that the first dot is keyed to a center terminal lug.

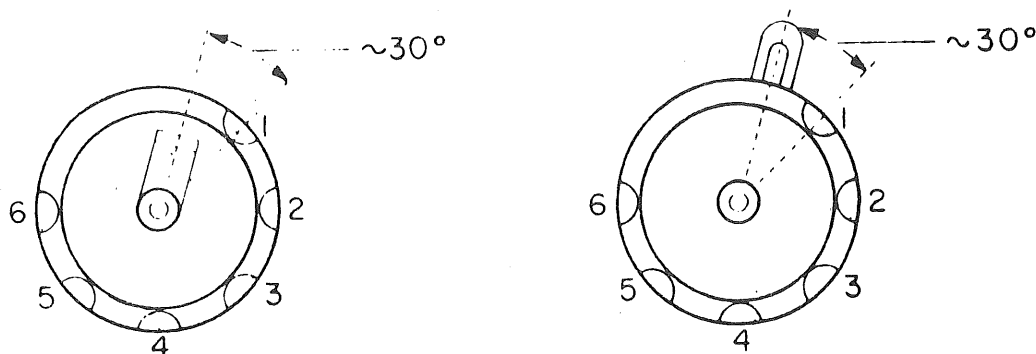


Fig. 4-9

Dot	Meaning
1. Identifier:	Black, except omitted where capacitance must be specified to 3 significant figures.
2. Capacitance:	1st significant figure in pF.
3. Capacitance:	2nd significant figure in pF.
4. Multiplier of Capacitance:	black = X1, brown = X10, red = X1000, etc.
5. Capacitance Tolerance:	black = $\pm 20\%$, silver = $\pm 10\%$, gold = $\pm 5\%$
6. "Characteristic":	black (means a temperature coefficient falling somewhere between -20 and $+100/P/M/^{\circ}C$).

Note: The dots always read in a clockwise direction.

If the button has no center lug terminals, the manufacturer tries to put the dots more on one side than out on the very edge; thus the code can be seen from one side only.

PAPER & FILM CAPACITORS

Aluminum and Tantalum Electrolytic capacitors: In almost all cases, except for the dipped variety, carry printed or stamped labels consisting of capacitance, tolerance, and voltage rating. Other characteristics are either unimportant or are reasonably consistent in all capacitors of the same kind.

Note: See Capacitor Color Code Chart for information concerning the dipped variety.

CAPACITOR, FIXED **ELECTROLYTIC, TANTALUM**

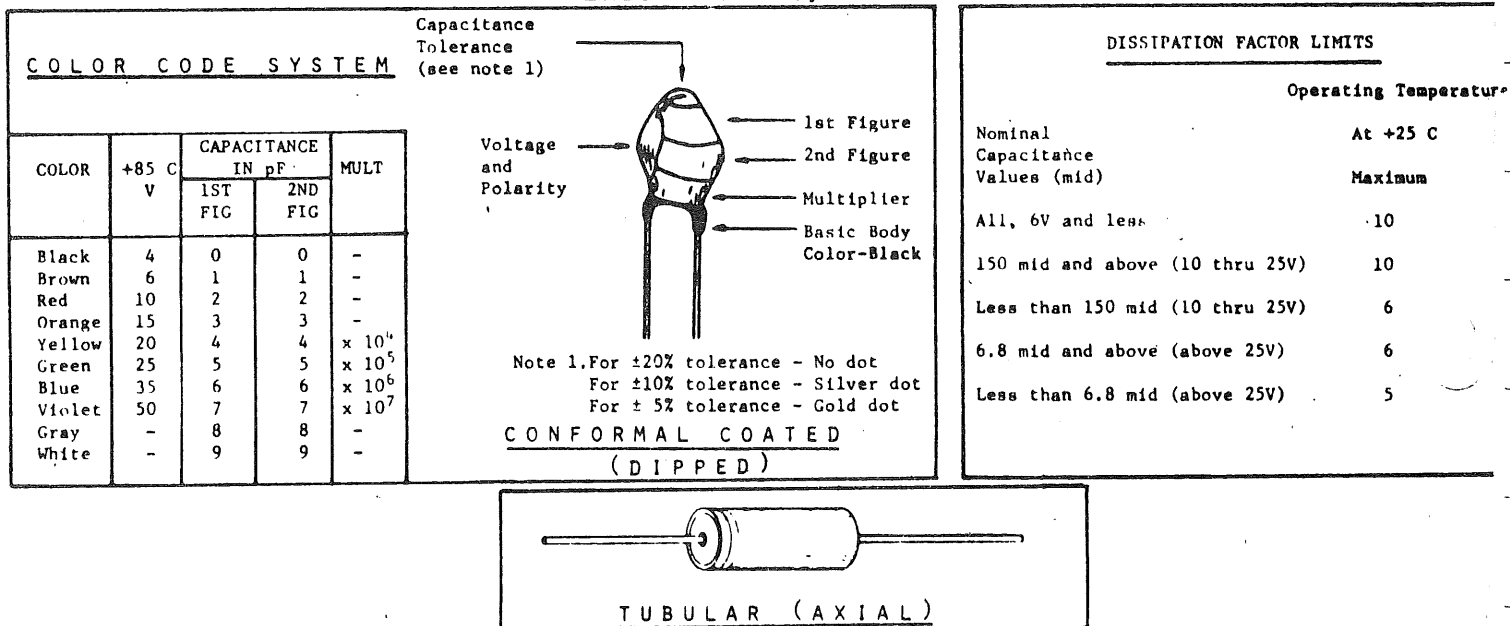
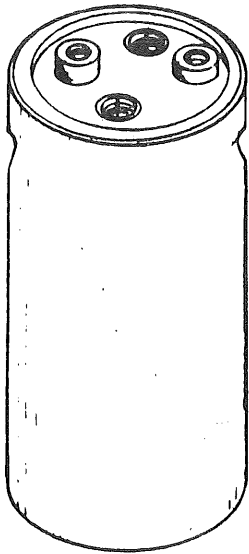


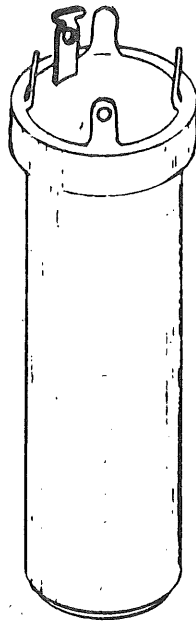
Fig. 4-10

CAPACITOR, FIXED

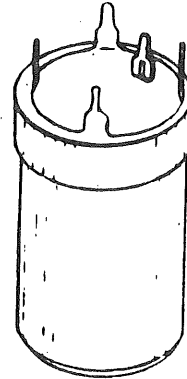
ELECTROLYTIC, ALUMINUM



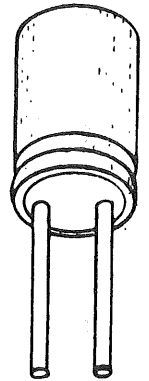
CAN W/SCREW TERMINALS



CAN W/SOLDER LUGS



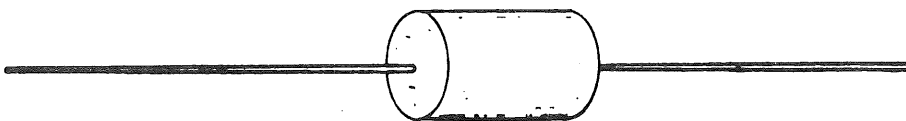
CAN W/CKT BD TERMINALS



SINGLE ENDED
W/ PAR LEADS

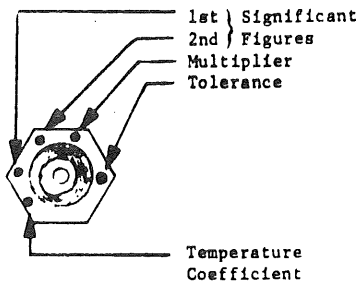
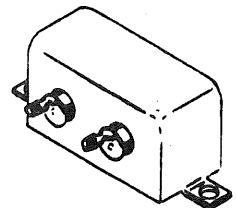


TUBULAR, W/AXIAL LEADS

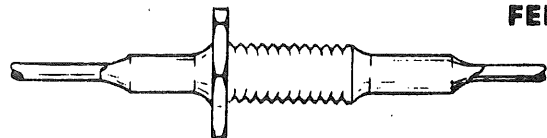


WRAP & FILL

PAPER



COLOR CODE



FEEDTHRU

Fig. 4-11

MOLDED MICA CAPACITORS

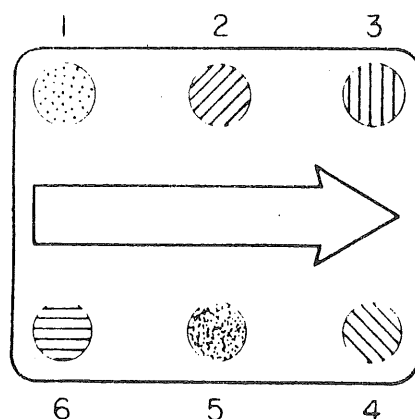


Fig. 4-12

EIA/MIL

Dot	Meaning
1. Identifier:	White if per commercial specification, black if per mil specification.
2. Capacitance:	1st significant figure in pF.
3. Capacitance:	2nd significant figure in pF.
4. Multiplier of capacitance.	
5. Tolerance:	Black = $\pm 20\%$ Silver = $\pm 10\%$ Green = $\pm 5\%$ Brown = $\pm 1\%$
6. "Characteristic":	Brown = B Yellow = E Green = F

Note: "Characteristic" in mica capacitors refers to the temperature coefficient and capacitance drift.

DIPPED MICA CAPACITORS

These parts carry a printed label much like that on ceramic discs. They may include the characteristic letter explained in the table below.

Char.	T_c (P/M/ $^{\circ}$ C)	Drift
B	± 500	$\pm 3\% + 1 \text{ pF}$
C	± 200	$\pm (0.5\% + 0.5 \text{ pF})$
D	± 100	$\pm (0.3\% + 0.1 \text{ pF})$
E	-20 to +100	$\pm (0.1\% + 0.1 \text{ pF})$
F	0 to +70	$\pm (0.05\% + 0.1 \text{ pF})$

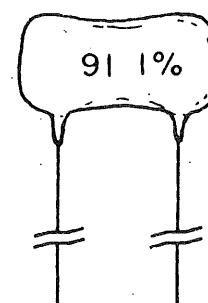


Fig. 4-13

CERAMIC TRIMMERS

The printed-on labels usually show capacitance range and temperature characteristic. TC reads the same as on ceramic discs. The tolerance on TC of ceramic trimmer rotors is much looser than on fixed capacitors, for mechanical reasons.

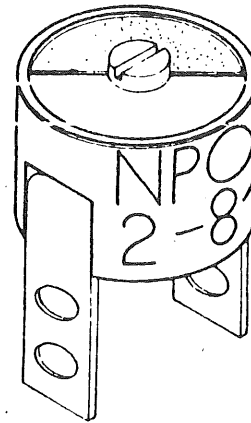
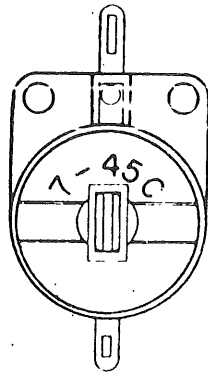


Fig. 4-14

AIR TRIMMERS

The same principle applies as in the case of paper and film capacitors. Only capacitance range need be indicated as TC is essentially uniform in this type.

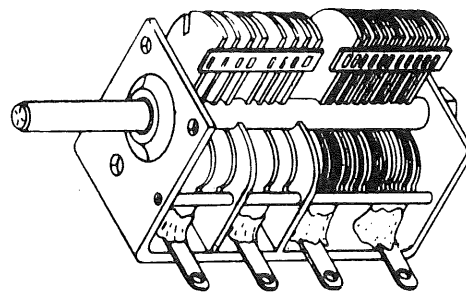
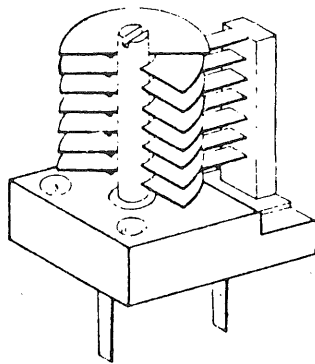
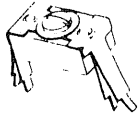


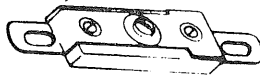
Fig. 4-15

CAPACITOR, VARIABLE

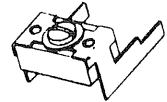
MICA



TOP ADJUST

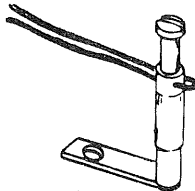
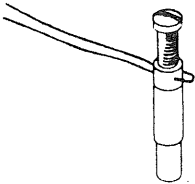


LEAD MOUNT

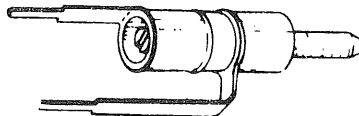


SIDE ADJUST

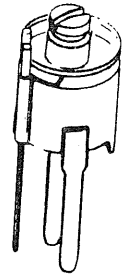
TEFLON



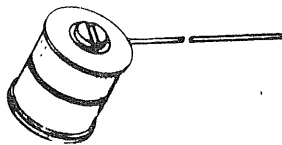
CERAMIC TUBULAR



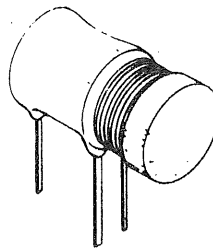
POLYETHYLENE



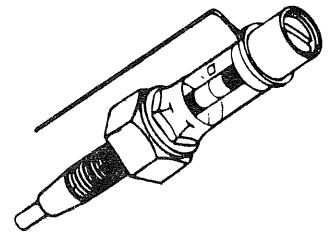
GLASS/AIR



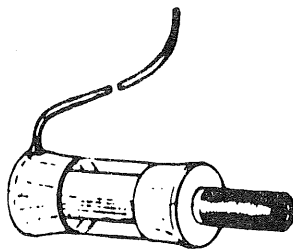
281-0177-00



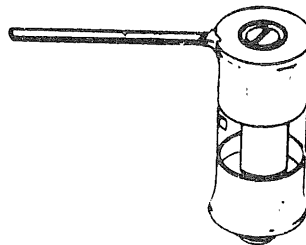
281-0164-00, 281-0165-00



281-0121-00



281-0105-00



281-0152-00



281-0174-00

Fig. 4-16

COILS

The third electrical property, along with resistance and capacitance, present in any electrical circuit is inductance - the property of a coil, also called an inductor. Few circuits can be constructed without coils of some type.

In its simplest form, a coil consists of nothing more than a length of wire wound in the form of a coil. Usually, however, the construction is more complex. When electrons flow through any conductor, a magnetic field is set up around this conductor. As long as the electron flow is steady, the magnetic field is steady and has little effect on the current. However, if the current varies (as in ac), the magnetic field also varies. As the lines of force cut across an adjacent conductor, an electric current, which will be in the opposite direction, will also be set up in this conductor. Therefore, in a coil where the two conductors are close to each other, the lines of force from one turn in the coil will cut across the other turns, and vice versa. Since the magnetic field from each turn tries to set up an opposite current in the other turns, the overall effect will be a "smoothing out" of the variations. Thus, the coil tends to oppose any changes in the current that is flowing through it.

This smoothing out property of a coil is called *inductance*. The larger the coil, the more smoothing action and the more inductance. Inductance is measured in *henrys*. However, like the farad, the henry is a very large unit, so smaller units, the millihenry and microhenry, are commonly used. One millihenry equals one-thousandth of a henry and is abbreviated mH; one microhenry is equal to one-millionth of a henry and is abbreviated μ H.

AIR-CORE COILS

As stated previously, the simplest coil consists of nothing more than a coil of wire. If the wire is heavy enough, the coil will hold in place. However, when finer wire is used, some means of supporting the turns of wire must be employed. Usually the wire is wound on plastic, phenolic, or similar material. As long as the material is nonmetallic

Fig. 5-1 Air-core coil symbols.



it has no effect on the magnetic lines of force. Therefore, such a coil is still considered to be an air-core coil. The symbols for such a coil are shown in Fig. 5-1. It consists of a coil-like drawing, simulating the windings. The shape of the coils may vary but they will all appear somewhat like the ones shown.

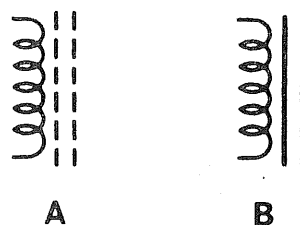
MAGNETIC-CORE COILS

In order to cause more lines of magnetic force to cut across the other windings of the coil and, therefore, increase the amount of inductance in the coil, different type cores can be used. Called magnetic cores, they usually consist of ferrite or powdered-iron molded in the desired shape and fitted inside or near the turns of wire. As the magnetic lines of force touch this type core, they find an easy path to follow and more lines of force will be led to the other turns in the coil and more inductance will be obtained.

In still another type construction, thin sheets of steel, called laminations, are stacked on top of each other, and the coil is wrapped around the sheets of steel. This type of construction is called an iron-core, and usually a coil constructed in this manner is called a choke. Such chokes have a large amount of inductance for their size.

The same symbol used for air-core coils may be used for magnetic-core coils. However, when it is desirable to show that a different type core is used, one of the symbols shown in Fig. 5-2 may be used.

Fig. 5-2 Magnetic-core coil symbols.

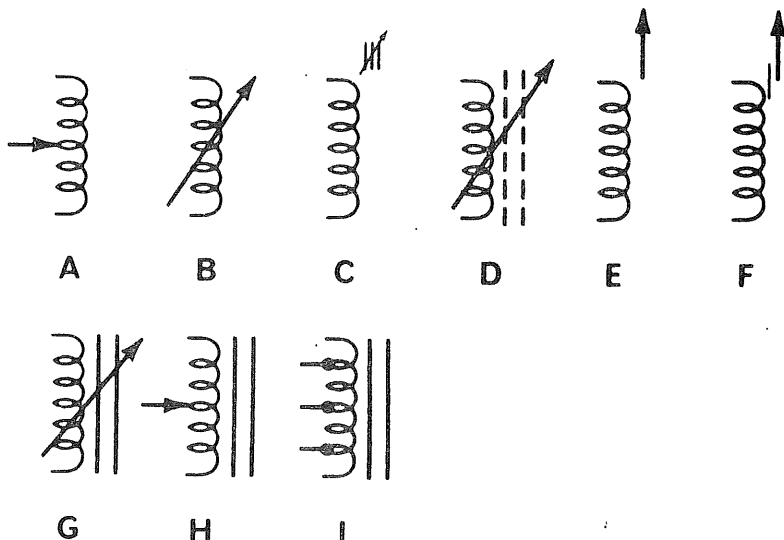


The symbol at A indicates a powdered-iron or ferrite core. The dashed lines symbolize the core. The symbol at B may be used for either this type or for the iron-core choke. The two solid lines symbolize the core material. Other slight variations of these symbols will be used, but they will all be very similar. For example, either type of coil shown in Fig. 5-2 can be used with these symbols.

VARIABLE COILS

Adjustable coils are often used in electronic equipment, so just the right amount of inductance needed to "tune" the circuit is obtained. Fig. 5-3 shows some of the symbols used to denote adjustable coils. The symbols at A and B are used to show adjustable air-core coils. Many methods are used to show adjustable powdered-iron (ferrite) cores. Some

Fig. 5-3
Adjustable-core
coil symbols.



of these are given at C through H in Fig. 5-3. Usually in such coils, the coil remains stationary and the core is moved. While seldom encountered, an adjustable iron-core coil would be represented by the symbols at G or H in Fig. 5-3. More often, taps will be added at different points on the winding. The symbol for this type unit is shown at I in Fig. 5-3.

Quite often a coil does not contain any markings other than possibly a part number. However, the inductance may be stamped on it or a color-code system may be used.

TRANSFORMERS

A transformer is two or more coils placed so that the magnetic lines of force produced by a fluctuating current in one coil (called the primary winding) will cut across the turns in the other coil(s) called the secondary winding(s). This action will cause a like flow of current in the coil that is not connected to the current source. Thus, a transformer can be used to transfer a fluctuating current from one point to another. This current will vary at the same rate as the current which originally produced it. However, by varying the amount of turns in the two windings, the

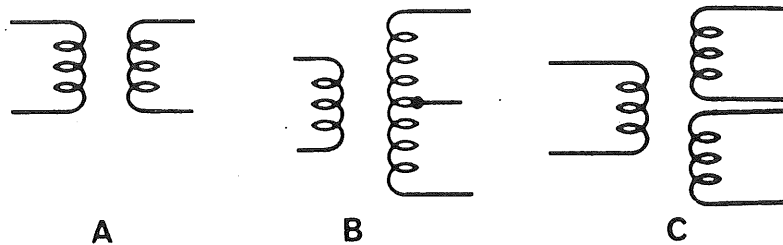


Fig. 5-4 Air-core transformer symbols

voltage and current can be altered. For example, if more turns are included in the secondary winding than in the primary winding, the voltage across the secondary will be greater than that across the primary; the current, however, will be less. If the secondary has fewer turns than the primary, the secondary voltage will be lower but the current will be greater.

Transformers, like coils, are constructed with air cores, powdered-iron or ferrite cores, and iron cores. Air-core transformers are normally used in high-frequency circuits. Fig. 5-4 shows some air-core transformers. As could be expected, the symbol consists of 2 or more coil symbols located adjacent to each other. The symbol at B is for a tapped transformer, where each half of the secondary can be used as a separate winding. The symbol at C is for a transformer having two completely separate secondary windings.

Transformers having ferrite or powdered-iron cores, like the corresponding coils, may use the same symbols as the air-core transformers. At other times, the dashed lines or solid lines shown at A and B in Fig. 5-5 will be added to represent the magnetic core.

The same symbol shown at B in Fig. 5-5 may be used to represent an iron-core transformer. Quite often, more or less turns will be shown in the symbol to denote that one winding had more or less turns than the other. The symbol at A in Fig. 5-6 is commonly used for a power transformer in electronic equipment. The primary winding is at the left.

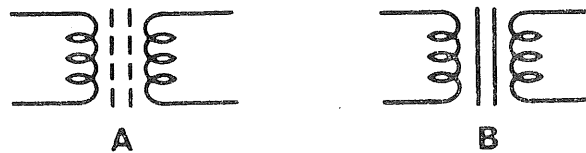


Fig. 5-5 Magnetic-core transformer symbols.

The upper secondary winding at the right is a center-tapped high voltage secondary, the output of which is rectified by two diodes to supply the voltage needed. The lower secondary winding supplies the lower voltage needed. Another type of transformer is shown at B in Fig. 5-6. Called an autotransformer, the primary is between Points 2 and 3, while between Points 1 and 4 a higher voltage can be obtained. The symbol at C in Fig. 5-6 represents an audio-output transformer commonly used in a radio.

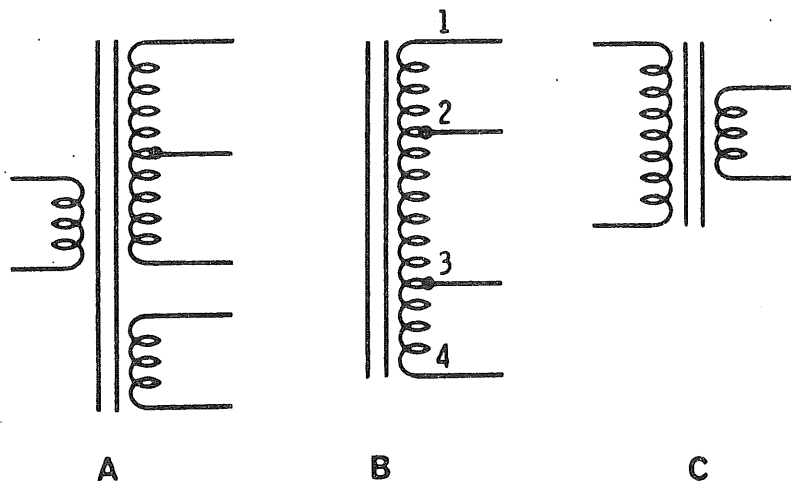


Fig. 5-6 Iron-core transformer symbols.

Here, the primary winding has the most turns, and fewer turns are shown for the secondary which is connected to the speaker.

Like coils, transformers are made adjustable. The symbol at A in Fig. 5-7 represents an adjustable air-core transformer. Many ways are used to denote adjustability in ferrite and powdered-iron core transformers. The principal difference is in the way of representing the core. The symbols at B through F in Fig. 5-7 show some of the methods. Notice that only one adjustment is shown at B through E. This indicates that a single core is varied between the two windings. The symbol at F shows two adjustments, indicating an adjustment for each winding. The same type adjustment symbols shown in the other drawings can be used when both are adjustable.

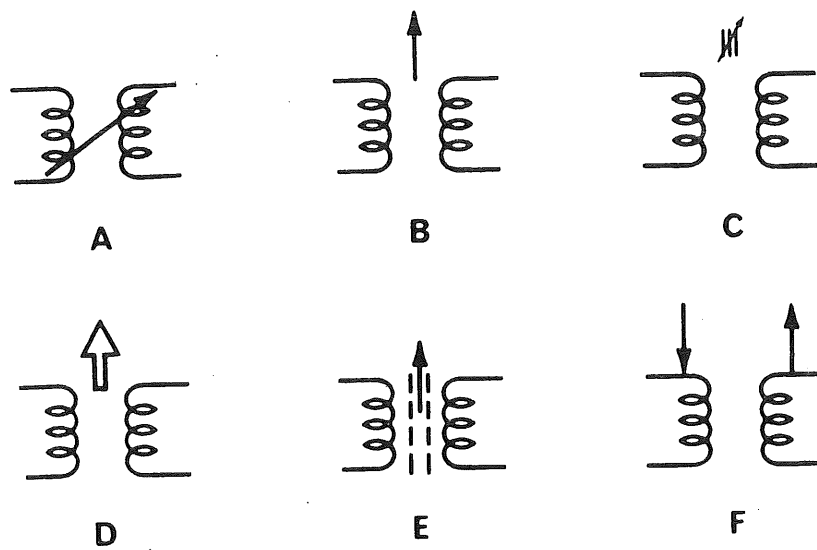
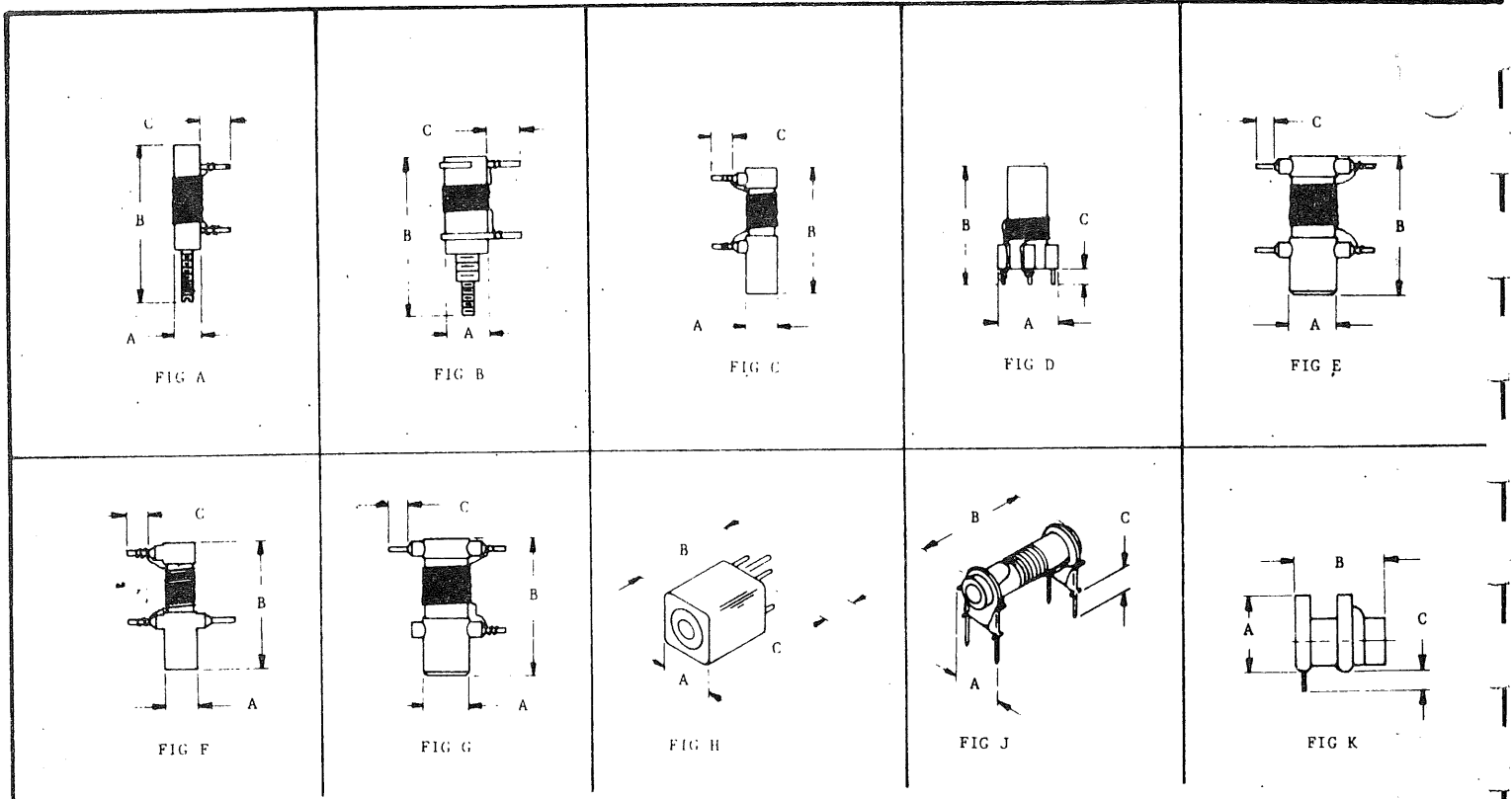


Fig. 5-7 Adjustable-transformer symbols.

COIL, VARIABLE



COIL, FIXED

TUBULAR

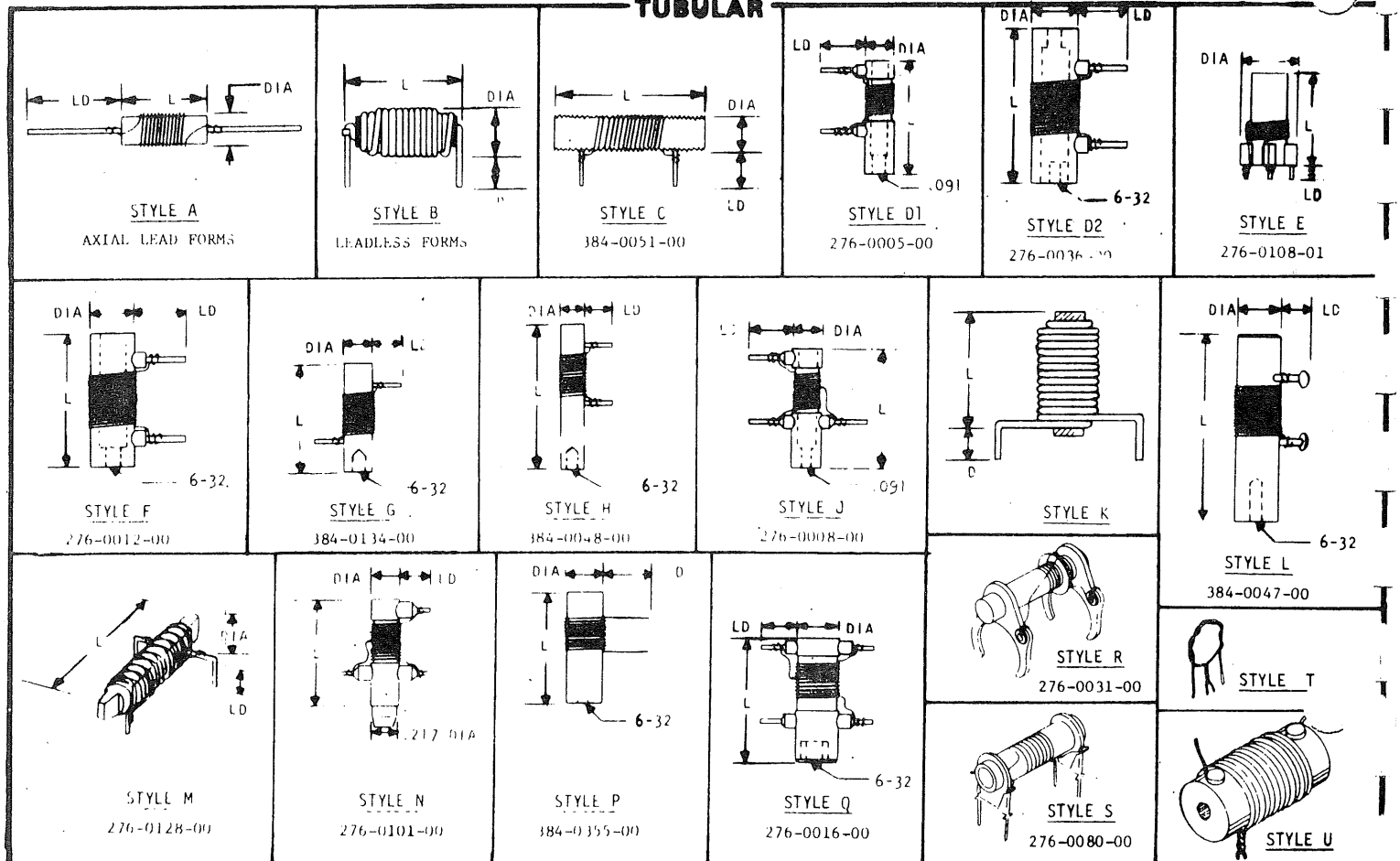


Fig. 5-8

COLOR CODE SYSTEM USED TO IDENTIFY TEK-MADE COILS

Color codes used are based upon ETA Standard GEN-101-A, and denote numerical values. A few variations are employed but for more complete identification purposes only. Read color codes as shown in the examples below.

LR COMBINATIONS

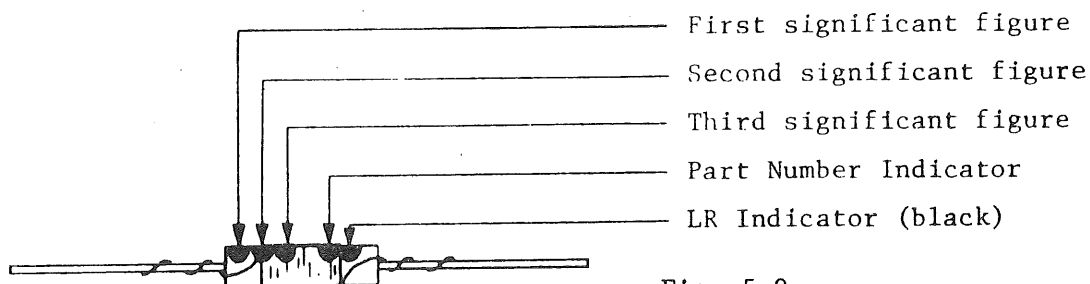


Fig. 5-9

The three dots denoting significant figures do not specify value, but instead the internally assigned plant number.

MARKING

DEFINITION

Single Dot
Stripe & One Dot
Three Dots
PN Indicator Dot

Coil No. LR-1 to LR-9
Coil No. LR-10 to LR-99
Coil No. LR-100 to LR-999
Indicates last digit of our PN, i.e.
108-XXXX-01 would be black. This dot
does not appear on .1 or .125 W res
forms or those with -00 part numbers.
LR Indicator Dot
Black. Denotes a LR combination.
Appears on coil numbers LR-100 and up.

L COMBINATIONS (OTHER THAN LR)

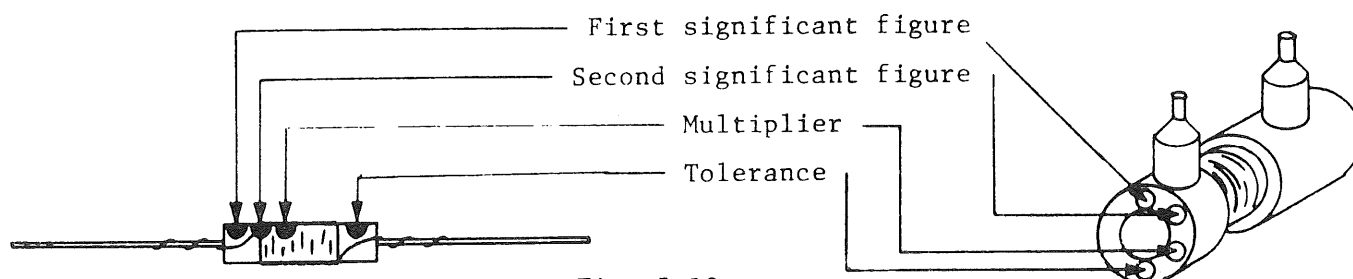


Fig. 5-10

The first two dots, with the multiplier, indicate the nominal coil value in nanohenries (nH). A fourth dot, if used, denotes tolerance (Gold $\pm 5\%$, Silver $\pm 10\%$). If the fourth dot is white, or if there is a fifth dot which is white, the coil is reverse wound.

COLOR CODE SYSTEM USED TO IDENTIFY TEK-MADE COILS

Color codes used are based upon EIA Standard GEN-101-A, and denote numerical values. A few variations are employed but for more complete identification purposes only. Read color codes as shown in the example below.

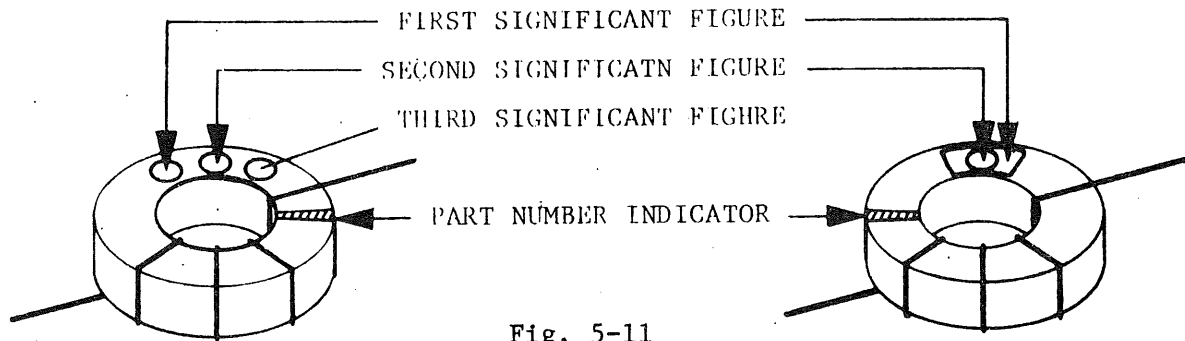


Fig. 5-11

MARKING

Single Dot
Base and Dot, or Two Dots
Three Dots
Additional Mark (Stripe)

DEFINITION

TD-1 to TD-9
TD-10 to TD-99 (Sample at Right)
TD-100 to TD-999 (Sample at Left)
Appears either side of nomenclature, indicates last digit of Tektronix Part Number (ie: 120-XXXX-01, TD-XXX-1) Note: Note used if PN ends in -00

PRINTING SYSTEM USED TO IDENTIFY TEK-MADE COILS

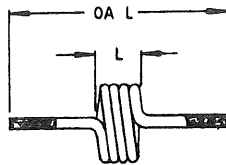
This system is used only on certain .125 W and larger LR combinations. Read as follows:

MARKING

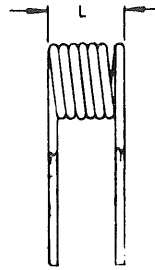
-0XXX Indicates the middle four digits of a 108- number ending with -00
-0XXX-0X Indicates the middle four digits and last two digits of a 108- number.

Some larger LR combinations may be fully marked with company trademark or name, part number, and value.

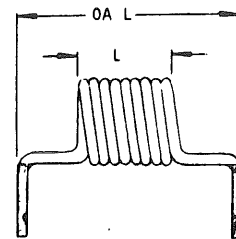
AIRWOUND



STYLE A



STYLE B



STYLE C

COIL, VARIABLE (TAPPED)

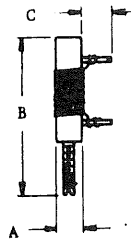


FIG A

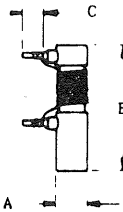


FIG C

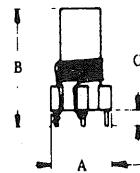


FIG D

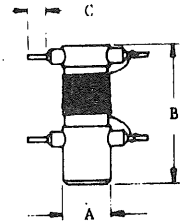


FIG E

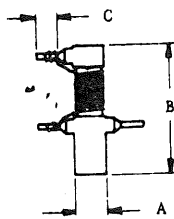


FIG F

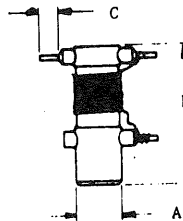


FIG G

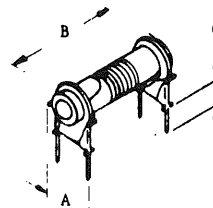


FIG J

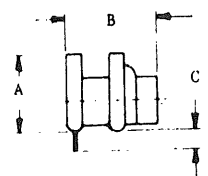
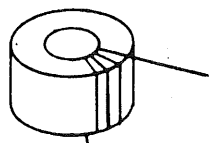
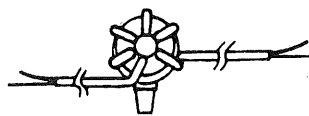


FIG K

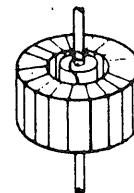
TOROID AND POT CORE



STYLE A



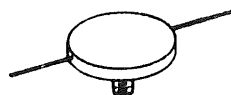
STYLE C



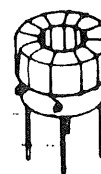
STYLE E



STYLE B



STYLE D



STYLE F

Fig. 5-12

SEMICONDUCTORS

Semiconductor devices can now be used in practically every application where tubes were formerly employed. In fact, they can even be used to fulfill functions where it is impractical to use tubes.

Semiconductors, or solid-state devices as they are sometimes called, are made possible because of the property of some materials such as selenium, silicon, and germanium, when properly treated, to allow electrons to flow through them in one direction but not in the other. The various elements physically touch each other therefore no heater is needed and they usually operate at lower voltages. This allows construction of much smaller equipment and less complicated power supplies.

DIODES

There are basically two types of semiconductor diodes - power and signal. The power diodes can be used to change ac to dc by allowing current to flow in only one direction, as explained for the diode tube. In most equipment designed today - whether tube or solid-state - a semiconductor diode is used in the power supply to rectify (change the ac to dc) the line current to produce the proper voltages to be used by the various circuits in the equipment.

Signal diodes are used in many places in equipment where it is desired to remove a high frequency and produce a correspondingly lower frequency. For example, in the detector stage of a radio, the high-frequency signal from the station, or a similar but lower intermediate-frequency signal, is converted to an audio signal by a signal diode. In other applications, it can serve to conduct whenever the voltage reaches a certain point, thus limiting the voltage to a set value.

The primary difference in the two units is the amount of power they are designed to handle. The power diode is designed to handle relatively large amounts of power, while the signal diode is used in low-power circuits.

They symbols for both types of diode are the same, as shown in Fig. 6-1. The bar portion of the symbol corresponds to the cathode. Thus, the point to remember is that electrons always flow in the direction opposite that indicated by the arrow. The bar end of the diode is usually marked with a colored band or dot, a + sign, or the letters CATH for identification.

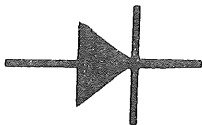


Fig. 6-1. Semiconductor diode symbol.

ZENER DIODE

The zener diode is much like the power or signal diodes discussed previously. Its characteristics are very similar to those of power or signal diodes. Recall that a diode allows current to flow in only one direction. In the reverse direction, the diode has a high resistance. However, if a voltage higher than that at which the diode is designed to operate is applied in this direction, the diode will break down and current will flow. A normal diode may be damaged under these conditions; the zener diode is designed to operate in this manner.



Fig. 6-2 Zener-diode symbols

In operation, the zener diode serves as a voltage regulator; that is when the voltage exceeds a given amount, the zener diode conducts, limiting the voltage to the desired value. Fig. 6-2 shows the symbols used to denote a zener diode. Those at A and C are probably the most popular. Any of the symbols can have the circle as at A, B, E, F, and G or without as at C and D. The zener diode is also known as a backward diode, breakdown diode, avalanche diode, and voltage-regulator diode.

SILICON CONTROLLED RECTIFIER

The silicon controlled rectifier (SCR), also called a *thyristor*, is actually like two transistors in construction. In operation, it is similar to the thyatron. The symbols used to represent an SCR are very similar to those for the diode, as shown in Fig. 6-3. In operation,



Fig. 6-3 Silicon controlled rectifier symbols

the diode will not conduct until a "trigger" current is applied to the added connection, called the gate. Silicon controlled rectifiers are used mostly in AC control applications. They are presently widely used in lighting control and power tools.

TUNNEL DIODE

In the normal semiconductor, it takes a certain amount of time for the current carriers to move through the unit. In the tunnel diode,

however, they appear to move at the speed of light - according to Einstein's theory, the ultimate speed in the universe. At the same time, a tunnel diode is capable of amplifying - a function not normally obtained in a two-element device. Explanation of the tunnel diode is beyond the scope of this book. Tunnel diodes can be used in many types of circuits where usually only a transistor or tube can be used. Temperature extremes



Fig. 6-4 Tunnel-diode symbols.

and nuclear radiation have little effect on them. Fig. 6-4 shows the most common symbols used to depict a tunnel diode on schematics. As with other semiconductor symbols, the circle may or may not be used.

CAPACITIVE DIODE

Also called a varactor, *Varicap*, reactance diode, or parametric diode, the capacitive diode actually functions as a capacitor in the circuit. The symbols for this device are given here instead of in Chapter 4 because most of the symbols used to depict it (Fig. 6-5) resemble those for the semiconductor diode. Recall that a semiconductor diode consists of a layer of P- and a layer of N-type material. When these two materials are joined, a layer forms at the junction which serves as an insulator. This condition is the same as for a capacitor - two conductors separated by an insulator. In the normal diode, steps are taken to minimize this capacitance. In the capacitive diode the

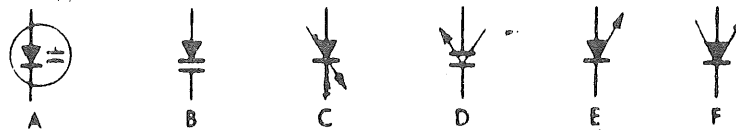


Fig. 6-5 Capacitive-diode symbols.

capacitance is emphasized. The capacitance of a capacitive diode will vary, depending on the voltage across the diode. Thus, by varying the voltage, the capacitance varies, and a circuit can be "tuned." The greatest use of varactors has been in high-frequency applications, but they can be used in any application where a variable capacitor is called for. The limiting factor is the small degree of change in the capacitance of a capacitive diode, but recent developments indicate that this range can be increased.

PHOTODIODES

The semiconductor diode is a very versatile device. There seems to be no end to the uses to which it can be put by simply varying the construction and composition. Silicon diodes are also sensitive to light. In some applications they function as a resistor whose value varies according to the amount of light striking it. In this use, they are usually called light-dependent resistors. Symbols for this use were given in Fig. 6-1.



Fig. 6-6 Solar-cell symbols

In addition, a voltage can be generated when light strikes the diode. In this application it is called a solar cell. Fig. 6-6 shows symbols used to depict the solar cell. The symbols at A, B, and C resemble the diode symbol with the arrows, letter L, or Greek *lambda* (λ) signifying that it is light-sensitive. The symbol at D more nearly represents a battery (to be discussed in a later chapter). As with other diode symbols, the circle enclosing the symbol may or may not be employed, but it is recommended.

LIGHT EMITTING DIODE

Light emitting diodes (LED's) are yet another type of diode that is finding its way into our everyday life. Such items as calculators, watches and clocks are using LED's for the numeric readout. The LED is just what the name implies - a diode that emits light when current flows through it.

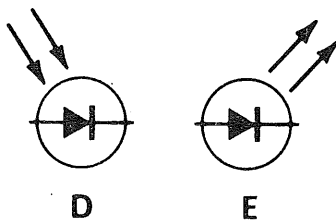
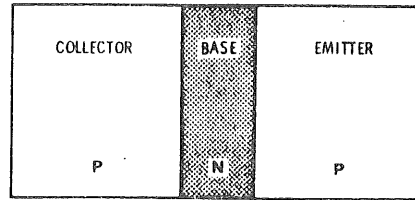


Fig. 6-7. "D" - Light sensitive diode symbol
"E" - Light emitting diode symbol

TRANSISTORS

The transistor performs essentially the same function as the triode vacuum tube. To produce a transistor, the germanium or silicon must be treated with certain impurities before it can be useful. By adding different impurities, the resultant material can be made to contain either an excess or a deficiency of electrons. If it contains an excess of electrons, it is called *n-type material*; if it has a deficiency of electrons, it is called *p-type material*. While different construction methods are used, the end result is somewhat like that illustrated in Fig. 6-8. Here a layer of n material is sandwiched between two layers of p material. The three elements are identified in Fig. 6-8. The emitter is roughly equivalent to the cathode in an electron tube, the base is roughly equivalent to the control grid, and the collector corresponds to the plate. In Fig. 6-8 two p layers and an n layer are shown.

Fig. 6-8 Basic Transistor construction



Thus, this is called a *pn_p transistor*. The layers in a transistor can be reversed, however. Then the collector and emitter would be *n* material and the base would be *p* material. When constructed in this manner, we have an *np_n transistor*. Both types of transistors will perform essentially the same functions, but the applied voltages are just the opposite. In a *pn_p* transistor the emitter is the most positive element, the base is negative in respect to the emitter, and the collector is still more negative than the base. In a *np_n* transistor, the collector is the most positive. The base is negative in respect to the collector, and the emitter is negative in respect to the base. Keep in mind the actual voltage is not important. It may be negative, positive, or zero on a given element. What is important is the relationship of the voltages on a given element with those on the other elements.

Just as the voltages applied to the two types of transistors are opposite, the direction of electron flow through the two types is in opposite directions. In a *pn_p* transistor, it is from collector to base to emitter; in an *np_n* transistor, it is from emitter to base to collector.

Fig. 6-9 gives the symbols for the two types of transistor. The symbol at A is for a *pn_p* transistor while the one at B is for an *np_n* transistor. The various elements are identified by the letters adjacent to them (E = emitter, B = base, and C = collector). Notice that, just as for the semiconductor diode, electrons flow through the transistor in a direction opposite that to which the arrowhead points.

Transistor symbols can be drawn with either element at the top. At C and D in Fig. 6-9 the emitter is shown at the top. Likewise the base connection may be from the right, as shown at E and F in Fig. 6-9. Any way that suits the layout of the remainder of the schematic is suitable. Just remember the element with the arrowhead is the emitter, the one with the flat bar is the base, and the remaining one is the collector.

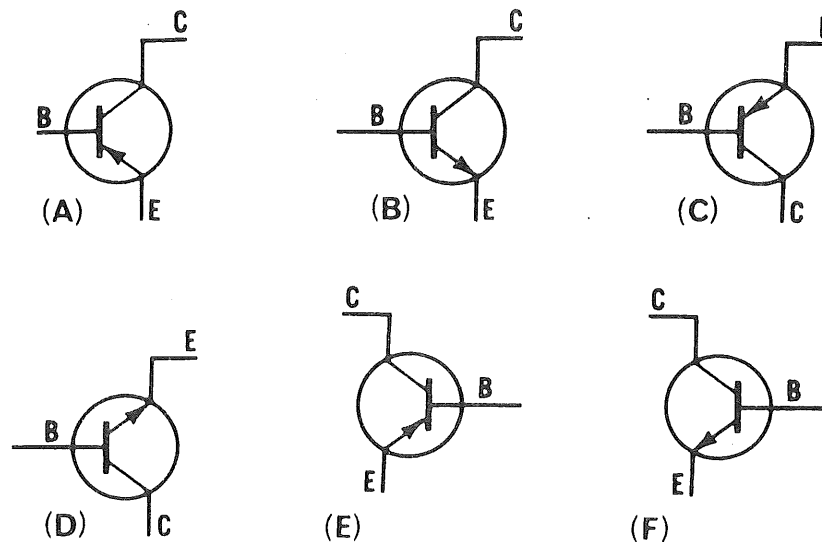


Fig. 6-9 Bipolar transistor symbols.

FIELD-EFFECT TRANSISTORS

The field-effect transistor (FET) is being used more and more in modern circuitry. These units operate very similarly to vacuum tubes. The npn and pnp transistors described previously (called bipolar transistors) are primarily current-operated devices, while the field-effect transistor, like the vacuum tube, is a voltage-operated device. Like other transistors, however, there are both n and p types; there are also many types of construction. The operation and construction of such units is beyond the scope of this book, but the symbols for several types are given in Fig. 6-10. The symbol at A is for n-channel junction gate, while the one at B is for a p-channel junction gate. The symbol at C is for an n-channel insulated-gate, and the one at D is for a p-channel insulated-gate FET. Several other types are given in E through L.

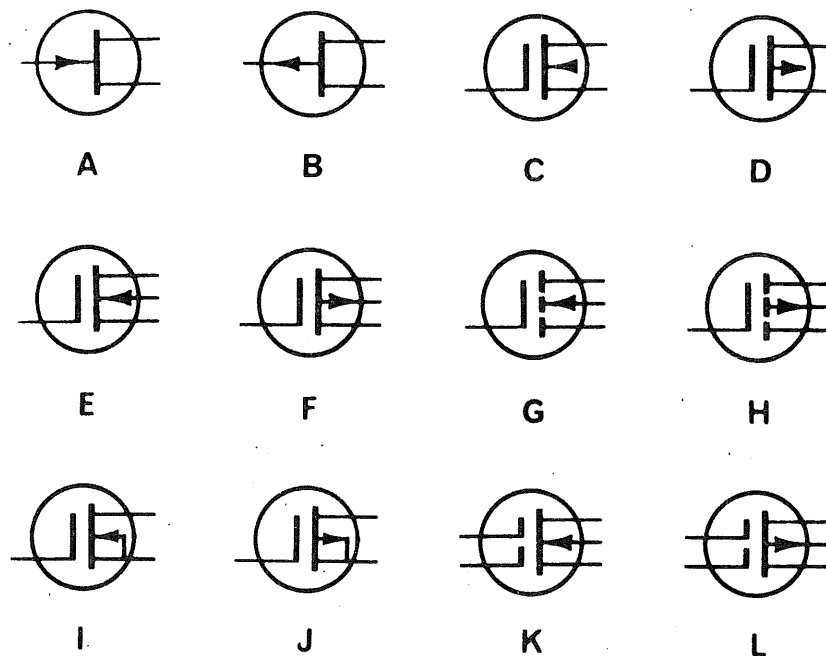


Fig. 6-10 FET symbols.

OTHER TRANSISTORS

Several other types of transistors have been developed to serve applications. In operation, these units serve many special purposes, some of which cannot be obtained with vacuum tubes. The operation of such units is beyond the scope of this book, but Fig. 6-11 gives the symbols for several "special" transistors. The symbol at A is for an N-type unijunction transistor, which essentially has two bases and an emitter but no collector. The symbol at B is for a P-type unijunction transistor. Other names for this device are double-base diode and filamentary diode.

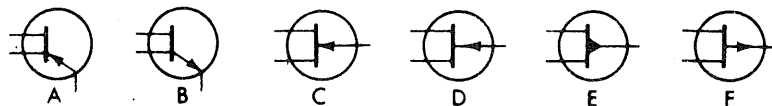


Fig. 6-11 Unijunction and field-effect transistor symbols.

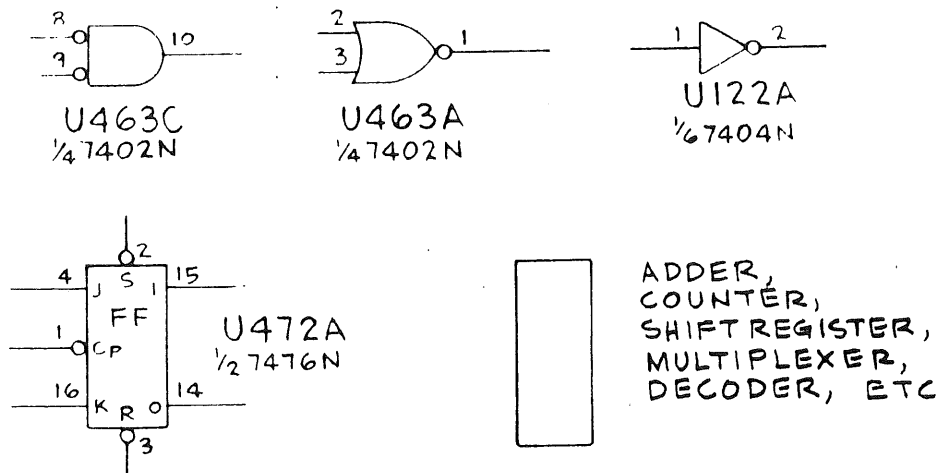
The symbols at C and D in Fig. 6-11 are for an N-type - base field-effect transistor, while those at E and F are for P-type units. The field-effect transistor resembles a vacuum tube in its operation. Other semiconductors are essentially "current-operated" devices. That is, the electron (or hole) flow is the controlling factor. In vacuum tubes and field-effect transistors, the controlling factor is the voltage.

INTEGRATED CIRCUITS

An integrated circuit is a collection of several electronic components such as transistors, diodes and resistors integrated on a single semiconductor substrate. Usually the "chip" or "I.C." can perform at least one electronic function. The I.C.'s come in two classifications, logic and linear. See symbols in Fig. 6-12. Logic I.C.'s are used in such devices as computers, whereas linear I.C.'s can be used in amplifiers such as we have in Tektronix oscilloscopes.

LOGIC and I.C. SYMBOLS

LOGIC



LINEAR I.C.'S

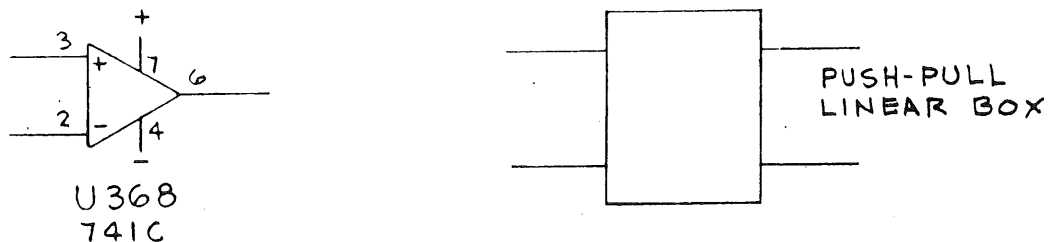


Fig. 6-12

LOGIC SYMBOLS

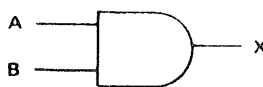

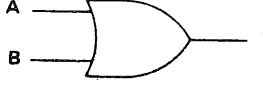

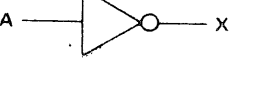

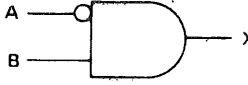

Device	Symbol	Description	Input/Output Table																																				
AND gate		A device with two or more inputs and one output. The output of the AND gate is HI if and only if all of the inputs are at the HI state.	<table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>LO</td></tr><tr><td>LO</td><td>HI</td><td>LO</td></tr><tr><td>HI</td><td>LO</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td>HI</td></tr></table>	Input		Output	A	B	X	LO	LO	LO	LO	HI	LO	HI	LO	LO	HI	HI	HI																		
Input		Output																																					
A	B	X																																					
LO	LO	LO																																					
LO	HI	LO																																					
HI	LO	LO																																					
HI	HI	HI																																					
NAND gate		A device with two or more inputs and one output. The output of the NAND gate is LO if and only if all of the inputs are at the HI state.	<table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>HI</td></tr><tr><td>LO</td><td>HI</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>HI</td></tr><tr><td>HI</td><td>HI</td><td>LO</td></tr></table>	Input		Output	A	B	X	LO	LO	HI	LO	HI	HI	HI	LO	HI	HI	HI	LO																		
Input		Output																																					
A	B	X																																					
LO	LO	HI																																					
LO	HI	HI																																					
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HI	HI	LO																																					
OR gate		A device with two or more inputs and one output. The output of the OR gate is HI if one or more of the inputs are at the HI state.	<table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>LO</td></tr><tr><td>LO</td><td>HI</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>HI</td></tr><tr><td>HI</td><td>HI</td><td>HI</td></tr></table>	Input		Output	A	B	X	LO	LO	LO	LO	HI	HI	HI	LO	HI	HI	HI	HI																		
Input		Output																																					
A	B	X																																					
LO	LO	LO																																					
LO	HI	HI																																					
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HI	HI	HI																																					
NOR gate		A device with two or more inputs and one output. The output of the NOR gate is LO if one or more of the inputs are at the HI state.	<table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>HI</td></tr><tr><td>LO</td><td>HI</td><td>LO</td></tr><tr><td>HI</td><td>LO</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td>LO</td></tr></table>	Input		Output	A	B	X	LO	LO	HI	LO	HI	LO	HI	LO	LO	HI	HI	LO																		
Input		Output																																					
A	B	X																																					
LO	LO	HI																																					
LO	HI	LO																																					
HI	LO	LO																																					
HI	HI	LO																																					
Inverter		A device with one input and one output. The output state is always opposite to the input state.	<table><tr><th>Input</th><th>Output</th></tr><tr><th>A</th><th>X</th></tr><tr><td>LO</td><td>HI</td></tr><tr><td>HI</td><td>LO</td></tr></table>	Input	Output	A	X	LO	HI	HI	LO																												
Input	Output																																						
A	X																																						
LO	HI																																						
HI	LO																																						
LO-state indicator	<div></div> <div></div> <div></div>	<p>A small circle at the input or output of a symbol indicates that the LO state is the significant state. Absence of the circle indicates that the HI state is the significant state. Two examples follow:</p> <p>AND gate with LO-state indicator at the A input.</p> <p>The output of this gate is HI if and only if the A input is LO and the B input is HI.</p> <p>OR gate with LO-state indicator at the A input:</p> <p>The output of this gate is HI if either the A input is LO or the B input is HI.</p>	<table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>LO</td></tr><tr><td>LO</td><td>HI</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td>LO</td></tr></table> <table><tr><th colspan="2">Input</th><th>Output</th></tr><tr><th>A</th><th>B</th><th>X</th></tr><tr><td>LO</td><td>LO</td><td>HI</td></tr><tr><td>LO</td><td>HI</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td>HI</td></tr></table>	Input		Output	A	B	X	LO	LO	LO	LO	HI	HI	HI	LO	LO	HI	HI	LO	Input		Output	A	B	X	LO	LO	HI	LO	HI	HI	HI	LO	LO	HI	HI	HI
Input		Output																																					
A	B	X																																					
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Input		Output																																					
A	B	X																																					
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Fig. 6-13

Fig. 6-13

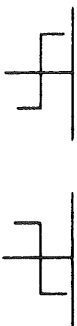
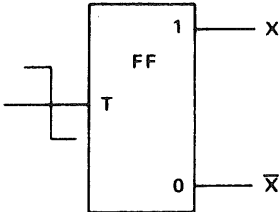
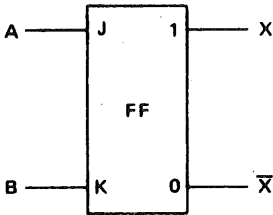
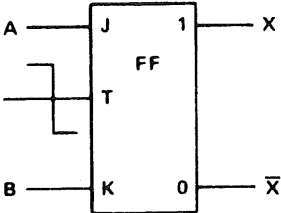
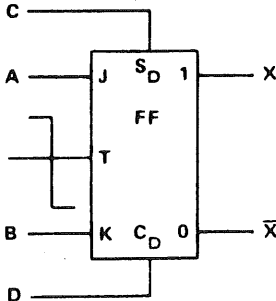
Device	Symbol	Description	Input/Output Table																																				
Edge symbol		Normally superimposed on an input line to a logic symbol. Indicates that this input (usually the trigger input of a flip-flop) responds to the indicated transition of the applied signal.																																					
Triggered (toggle) Flip-Flop		A bistable device with one input and two outputs (either or both outputs may be used). When triggered, the outputs change from one stable state to the other stable state with each trigger. The outputs are complementary (i.e., when one output is HI the other is LO). The edge symbol on the trigger (T) input may be of either polarity depending on the device.	<table><tr><th colspan="2">Input</th><th colspan="2">Output</th></tr><tr><th>Condition before trigger pulse</th><th></th><th>Condition after trigger pulse</th><th></th></tr><tr><td>X</td><td>\overline{X}</td><td>X</td><td>\overline{X}</td></tr><tr><td>LO</td><td>HI</td><td>HI</td><td>LO</td></tr><tr><td>HI</td><td>LO</td><td>LO</td><td>HI</td></tr></table>	Input		Output		Condition before trigger pulse		Condition after trigger pulse		X	\overline{X}	X	\overline{X}	LO	HI	HI	LO	HI	LO	LO	HI																
Input		Output																																					
Condition before trigger pulse		Condition after trigger pulse																																					
X	\overline{X}	X	\overline{X}																																				
LO	HI	HI	LO																																				
HI	LO	LO	HI																																				
Set-Clear (J-K) Flip-Flop		A bistable device with two inputs and two outputs (either or both outputs may be used). The outputs change state in response to the states at the inputs. The outputs are complementary (i.e., when one output is HI the other is LO).	<table><tr><th colspan="2">Input</th><th colspan="2">Output</th></tr><tr><th>A</th><th>B</th><th>X</th><th>\overline{X}</th></tr><tr><td>LO</td><td>LO</td><td colspan="2">No change</td></tr><tr><td>LO</td><td>HI</td><td>LO</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>HI</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td colspan="2">Changes state</td></tr></table>	Input		Output		A	B	X	\overline{X}	LO	LO	No change		LO	HI	LO	HI	HI	LO	HI	LO	HI	HI	Changes state													
Input		Output																																					
A	B	X	\overline{X}																																				
LO	LO	No change																																					
LO	HI	LO	HI																																				
HI	LO	HI	LO																																				
HI	HI	Changes state																																					
Triggered Set-Clear (J-K) Flip-Flop		A bistable device with three or more inputs and two outputs (either or both outputs may be used). When triggered, the outputs change state in response to the states at the inputs prior to the trigger. The outputs are complementary (i.e., when one output is HI the other is LO). The edge symbol on the trigger (T) input may be of either polarity depending on the device.	<table><tr><th colspan="2">Input</th><th colspan="2">Output</th></tr><tr><th>A</th><th>B</th><th>X</th><th>\overline{X}</th></tr><tr><td>LO</td><td>LO</td><td colspan="2">No change</td></tr><tr><td>LO</td><td>HI</td><td>LO</td><td>HI</td></tr><tr><td>HI</td><td>LO</td><td>HI</td><td>LO</td></tr><tr><td>HI</td><td>HI</td><td colspan="2">Changes state</td></tr></table> <p>Output conditions shown after trigger pulse</p>	Input		Output		A	B	X	\overline{X}	LO	LO	No change		LO	HI	LO	HI	HI	LO	HI	LO	HI	HI	Changes state													
Input		Output																																					
A	B	X	\overline{X}																																				
LO	LO	No change																																					
LO	HI	LO	HI																																				
HI	LO	HI	LO																																				
HI	HI	Changes state																																					
Flip-Flop with Direct Inputs (may be applied to all triggered flip-flops)		For devices with direct-set (S_D) or direct-clear (C_D) inputs, the indicated state at either of these inputs over-rides all other inputs (including trigger) to set the outputs to the states shown in the input/output table.	<table><tr><th colspan="4">Input</th><th colspan="2">Output</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>X</th><th>\overline{X}</th></tr><tr><td>1</td><td>1</td><td>LO</td><td>LO</td><td colspan="2">No change¹</td></tr><tr><td>Φ</td><td>Φ</td><td>LO</td><td>HI</td><td>LO</td><td>HI</td></tr><tr><td>Φ</td><td>Φ</td><td>HI</td><td>LO</td><td>HI</td><td>LO</td></tr><tr><td>Φ</td><td>Φ</td><td>HI</td><td>HI</td><td colspan="2">Undefined</td></tr></table> <p>Φ = Has no effect in this case</p> <p>¹Output state determined by conditions at triggered inputs</p>	Input				Output		A	B	C	D	X	\overline{X}	1	1	LO	LO	No change ¹		Φ	Φ	LO	HI	LO	HI	Φ	Φ	HI	LO	HI	LO	Φ	Φ	HI	HI	Undefined	
Input				Output																																			
A	B	C	D	X	\overline{X}																																		
1	1	LO	LO	No change ¹																																			
Φ	Φ	LO	HI	LO	HI																																		
Φ	Φ	HI	LO	HI	LO																																		
Φ	Φ	HI	HI	Undefined																																			

Fig. 6-13 (Cont.)

Fig. 6-13 (Cont.)

SEMICONDUCTOR DEVICES

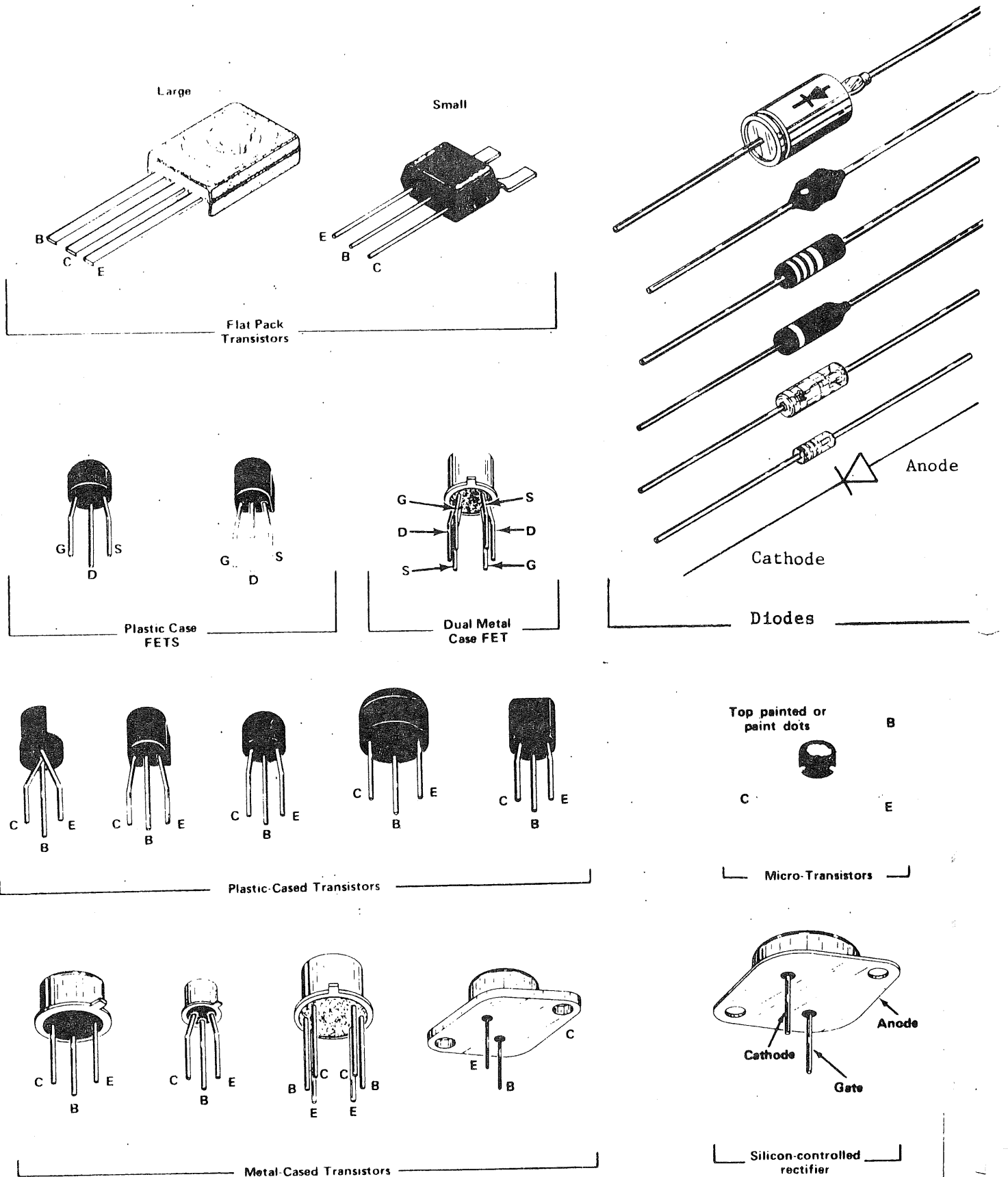
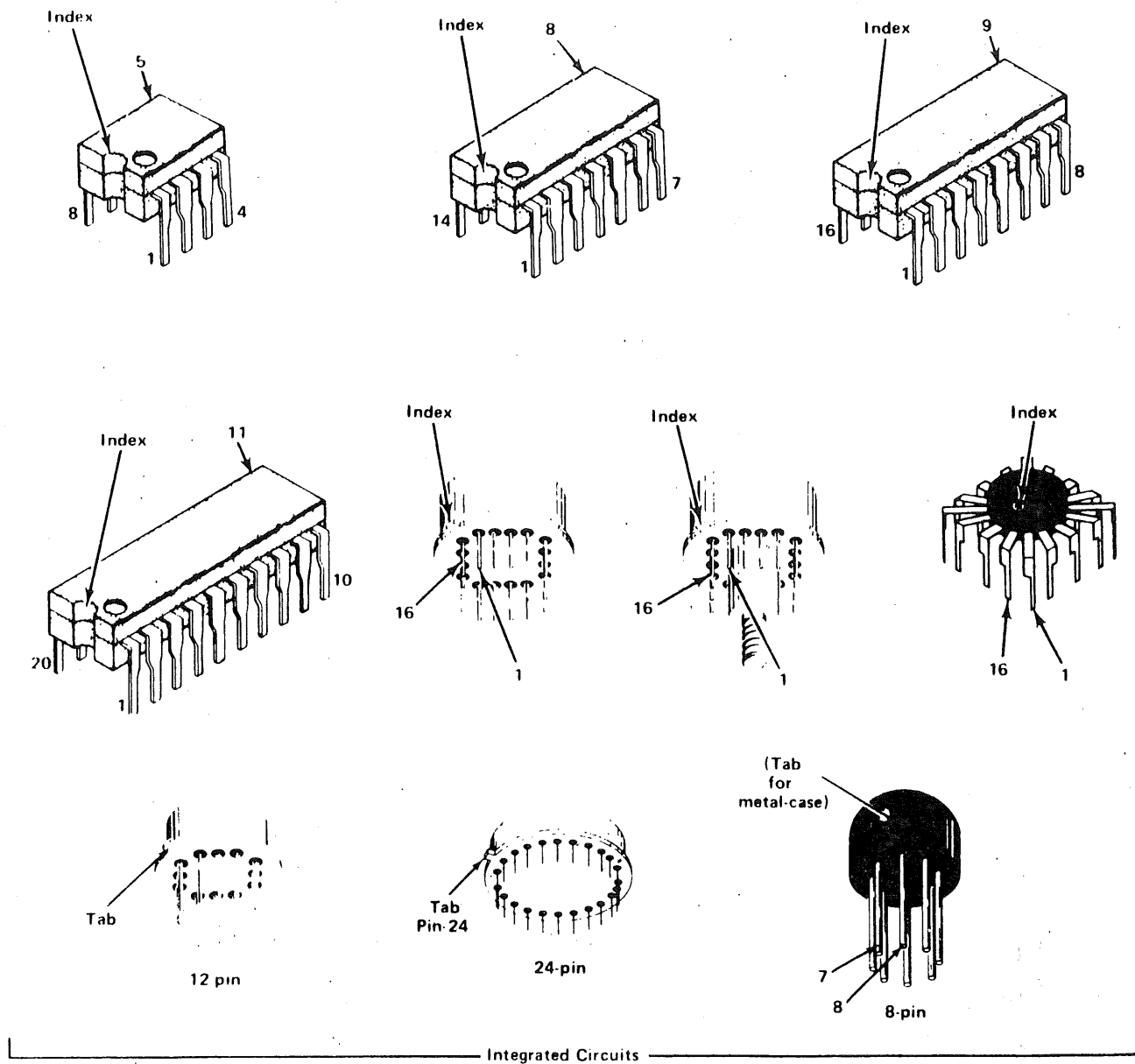


Fig. 6-14



NOTE: Circuit board is keyed with arrow (➤) or dot to locate either pin 1 or tab of integrated circuit.

Fig. 6-15

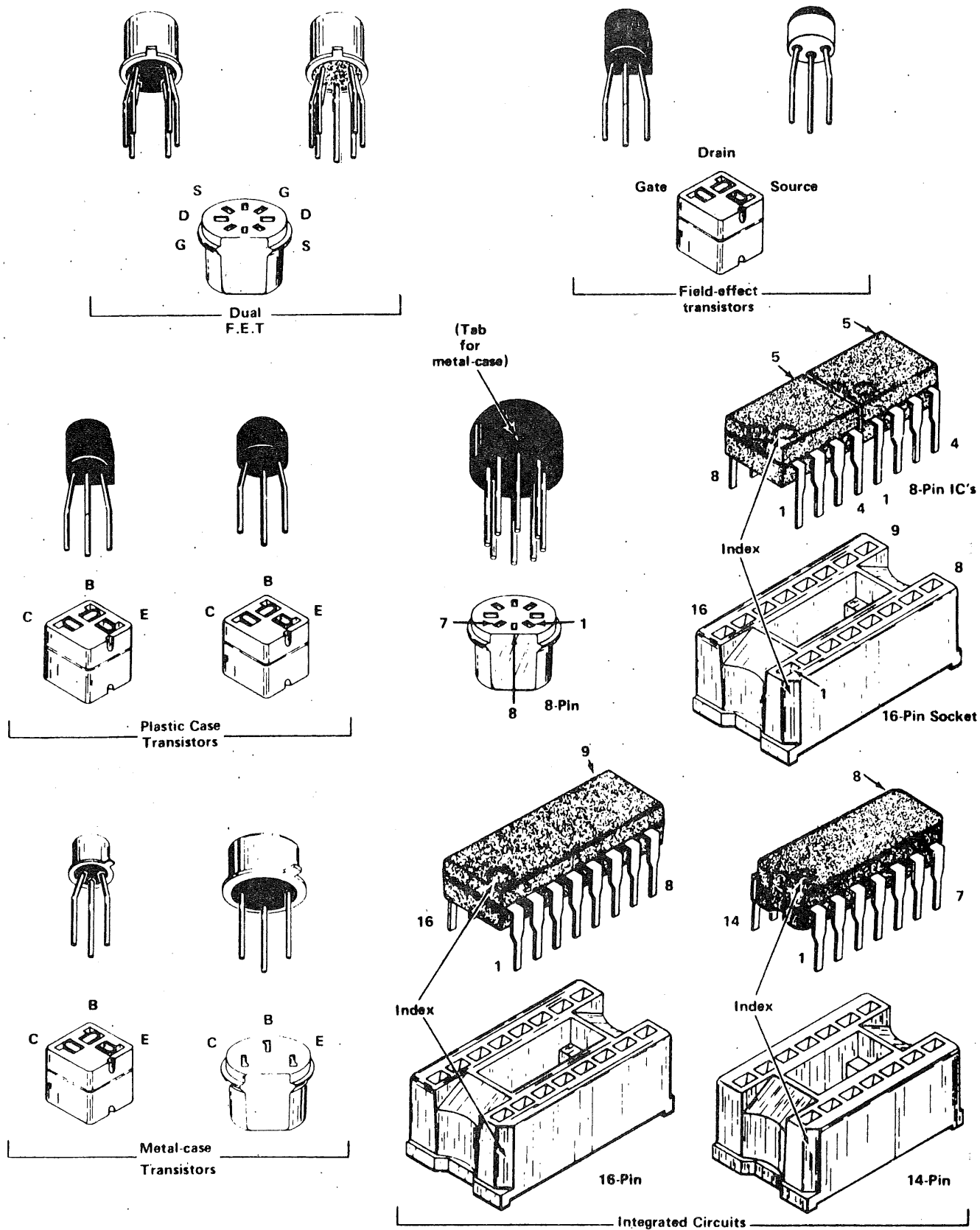
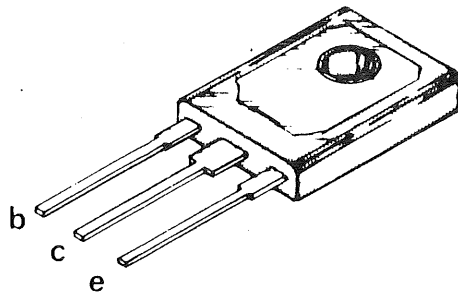


Fig. 6-16

TO-127

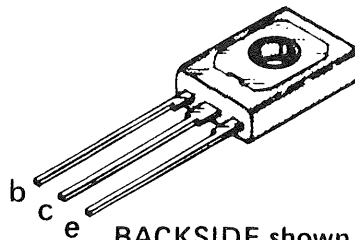
(Motorola case 90)



BACKSIDE shown

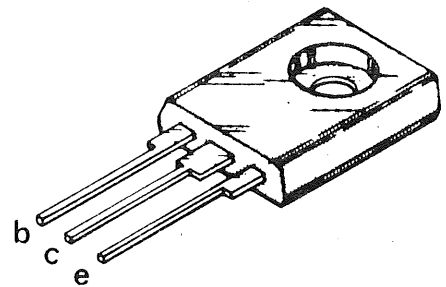
TO-126

(Motorola case 77)



BACKSIDE shown

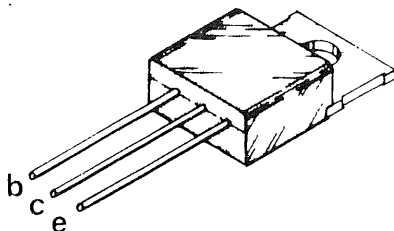
Motorola case 199



POWER TRANSISTOR CASE STYLES

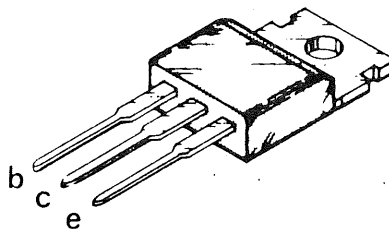
TO-220

(GE only)

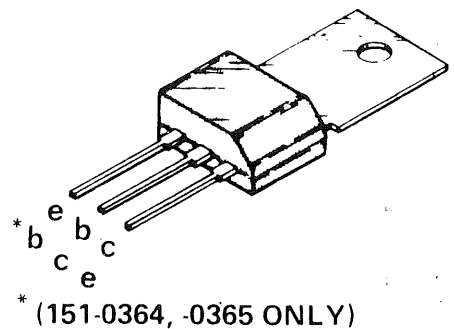


TO-220

(All others)

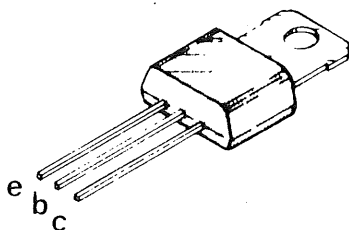


TO-202



*(151-0364, -0365 ONLY)

Motorola "Uniwatt"



T.I. "Plastic TO-3"

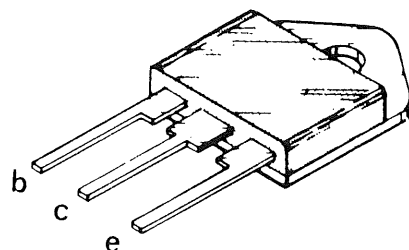


Fig. 6-17

THE OTHER COMPONENTS

THEY MAKE IT WORTHWHILE

In the preceding two chapters, those devices that are used in every piece of electronic equipment have been discussed. Even the smallest electronic device will use several of these items. The components to be discussed in this chapter are not used in such great numbers; in fact, often only one of a given item will be used in a piece of equipment. But these units are the ones that make all the others worthwhile. They are the ones that provide the input and output to a device, and the miscellaneous components without which the equipment would be useless.

BATTERIES

Many types of batteries are used in portable electronic equipment to supply the power needed for operation. They power tiny hearing aids - and television sets. They supply from slightly over one volt to hundreds of volts. Some are designed to supply high current for short periods of time; others supply very small current continuously.

Regardless of the intended use, all batteries are constructed using two different materials immersed in a solution. The chemical reaction obtained produces the voltage. The materials used differ and the construction varies, but all batteries use this same basic design.

The five types of batteries used in electronics - carbon-zinc, mercury, nickel-cadmium, alkaline-magnesium, and lead-acid - are classified by the materials used in their construction. The symbols used to represent all types are the same.

The cell is the basic unit for any battery. Each cell supplies from 1.2 to 2.1 volts, depending on the material used. Cells are connected in various ways to obtain the desired voltage and current. The common 1.5 volt flashlight "battery" is not actually a battery; it is a cell, since it consists of only one cell. Technically a battery consists of two or more cells connected internally. In practical use, however, the term battery is used to designate single cells also.

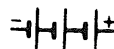
The symbol for a single cell is given at A in Fig. 7-1. The two bars signify the two electrodes of the cell, with the shortest one representing the negative terminal. The + and - signs shown here may or may not be included with the symbol. Remember, the short bar is always negative and the



A



B



C

Fig. 7-1 Battery symbols.

longer one is always positive. Sometimes, a two-, three-, or four-cell battery is represented by a like number of cells in the symbol. More

often, however, a standard symbol having three or four cells, as shown at B in Fig. 7-1, is used to represent a battery, regardless of the number of cells. Another system sometimes used is shown at C in Fig. 7-1. This symbol represents three separate cells used to power a piece of portable electronic equipment.

PROTECTIVE DEVICES

To prevent a short or other malfunction in a piece of equipment from destroying the entire unit and possibly starting a fire, some type of protection against excessive current is usually provided.

Often a fuse or circuit breaker is used for this protection. It may be inserted in the power line so the entire unit is protected, or separate units may be added at various points in the circuit.



Fig. 7-2 Fuse symbols

FUSES

There are several types and shapes of fuses, but essentially all are the same. They consist of a short length of wire, usually encased in a glass container with metal ends for connections. The internal wire is selected so that it will melt when the current exceeds a certain amount. This opens the circuit, thus preventing other components from being destroyed. The low-cost fuse is destroyed but valuable components are protected.

Fig. 7-2 shows some of the symbols used for fuses. The current necessary to open the fuse is usually added beside the symbol on the schematic.

LAMPS

Lamps are used for dial lighting and for many types of indicators in electronic equipment. The most common type - the incandescent lamp - is similar to the ordinary household light bulb, except smaller. Many special shapes and bases may be used but these lamps all operate on the same principle - heating a wire white hot so it glows. The symbols for such lamps are given at A and B in Fig. 7-3. The outside circle represents the glass envelope, and the inner loop represents the filament.

A neon lamp, which gives off a soft red glow when lit, is often used for an indicator in electronic equipment. These lamps consist of two electrodes separated by the rare gas, neon. As electrons flow through the

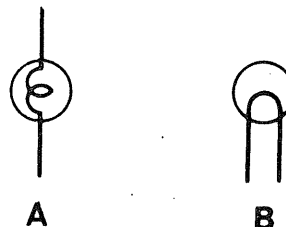


Fig. 7-3 Incandescent lamp symbols.

gas from one electrode to the other, the gas glows. Some are designed for dc operation and others for ac. The symbols at A and B in Fig. 7-4 are general-purpose symbols for either type. The symbols at C and D are for ac types, and the one shown at E is for the dc type.

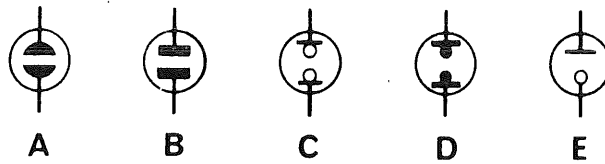


Fig. 7-4 Neon lamp symbols.

THE MISSING LINK

CONNECTING DEVICES

In the preceding chapter practically all of the components have been discussed - and the symbols used to represent the components have been given - but there is still something missing! No wires, cables, or plugs and sockets have been shown. Also, no switches to make the proper connection have been included. These items are the subject of this chapter.

WIRES AND CONNECTIONS

As you no doubt know, an ordinary wire is represented by a line, whether it is an actual separate wire, a printed-circuit connection, or the leads of a component such as a resistor or capacitor. Three systems are used to denote the connection or nonconnection of crossing leads on a schematic. One system is shown at A in Fig. 8-1. In this system, the half-circle device at the point where the two lines cross at the top denotes no connection. At the bottom in A when the two lines cross, the two points are connected.

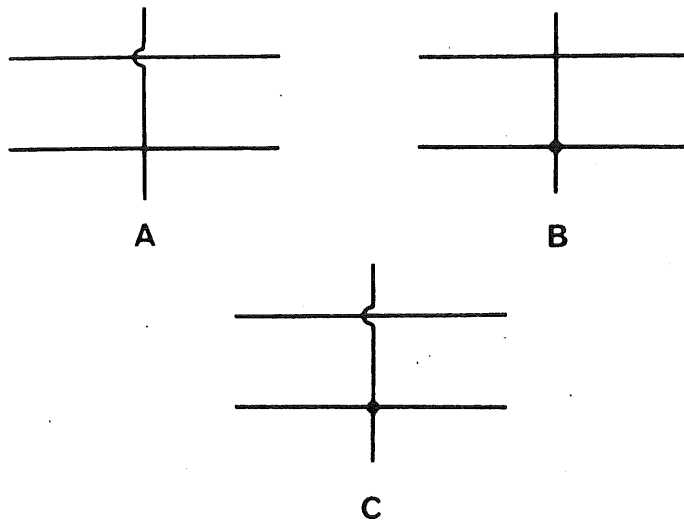


Fig. 8-1 Methods of showing lead connections on schematics.

Another system of showing crossing leads is given at B in Fig. 8-1. Here, at the top where the two leads cross, no connection is indicated. At the bottom in B, a dot is added at the point where the two leads cross, indicating a connection.

Notice that the two crossed lines at the bottom of A indicates no connection, while at the top in B the same thing indicates a connection. This can cause confusion unless the system used is understood.

The system at C in Fig. 8-1 avoids this confusion. Here, at the top, the half circle at the point where the lines cross is used, indicating no connection. At the bottom a dot is added at the crossing point to indicate there is a connection. This is the system used in this book.

Normally, the weight of the line has no meaning - a heavy or a thin line has the same meaning. However, at times a line heavier than the others may be added to indicate a common return or "zero-voltage" point on a schematic. The appearance of such a line, called a *bus bar*, with several leads connected to it is given in Fig. 8-2.

At times it might be difficult to locate a lead running from one side of a schematic to another. At other times, not all of the circuit may be shown, or the item connecting to a given point may be on another

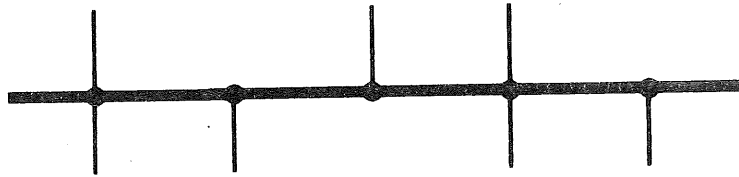


Fig. 8-2 Use of a heavy line to indicate a common point on a schematic.

schematic. To indicate this, an arrow may be added to the end of the line and a note added to indicate where this point is connected. At other times, the line may be stopped and a letter placed at the end of the line. This indicates that this point connects to another place on the schematic which has the same letter.

Normally lines are not drawn from a transistor emitter or collector circuit all the way to the power supply. Instead, a dot, a circle, or an arrow will indicate the voltage connected to this point. In the power supply then, the points where each of the voltages is obtained will be indicated. The purpose of all these devices is to reduce the number of long lines, which serve to clutter the schematic and make it difficult to follow.

GROUNDS

Often one side of the power supply is connected to the chassis, if a metal chassis is used. Thus, instead of connecting leads from this side of the power supply to all of the various stages, all that is needed is a connection to the chassis (called ground). In ac/dc power supplies, an isolation network (usually a resistor and capacitor) is added between this common point and the chassis.

Regardless of which system is used, instead of running leads on the schematic back to this common point, the ground symbol shown at A in Fig. 8-3 is used. This symbol is used to designate the common return point on the schematic. Normally, it is the negative side of the power supply, but in transistor circuitry, it can be the positive side. Just consider all points where the ground symbol appears to be connected.

It may be an actual connection, or a connection through the chassis.

In instances where the common return point is not the actual chassis ground, as mentioned in the foregoing for ac/dc sets, the symbol at B in Fig. 8-3 is used to designate the chassis. Sometimes there may be more

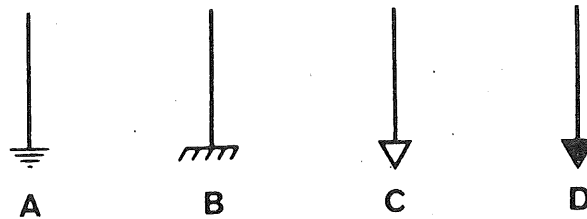


Fig. 8-3 Ground and chassis symbols.

than one common return point on the equipment. In this case, the symbol at C may be used as an alternate ground symbol. Where still more points are needed, identification numbers or letters may be placed within the enclosed triangular area of the symbol at C. All points with the same identification will be connected to the same point. At other times a solid symbol, as shown at D in Fig. 8-3, may be used to designate a ground.

CABLES AND CONNECTORS

If more than one lead is included in a twisted or covered cable, they may be shown as separate leads, if the fact, they are in a cable is not important. Where needed, however, the leads can be drawn as shown at A in Fig. 8-4. Here three leads are shown, but any number can be

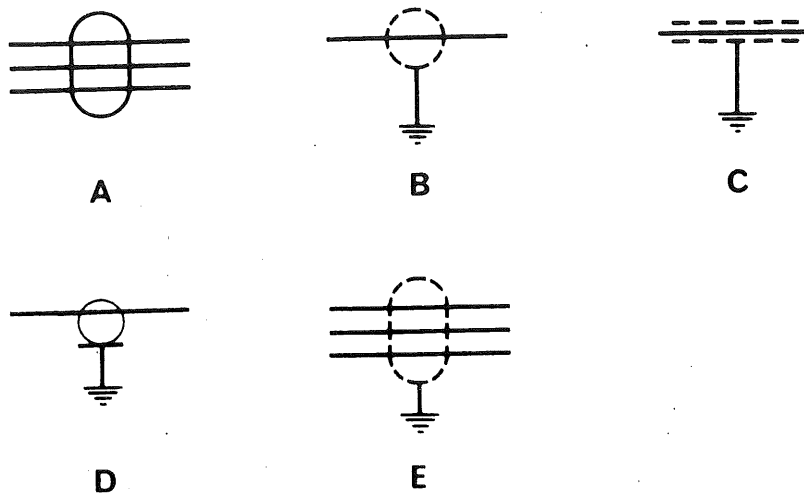


Fig. 8-4 Cable symbols.

shown in the same manner. The elongated circle across the leads designates that they are contained within a cable.

Often such cables are covered with a metallic outer cover, called a shield. Such a shield prevents any inductive or capacitive coupling to other circuits. The symbols at B and C in Fig. 8-4 show two ways of designating a single shielded lead. The dashed line symbolizes the shield, and the conductor is shown through it. Since the shield is normally connected to ground, the ground is shown connected to the shield here.

The symbols at B and C in Fig. 8-4 can be used to designate any type of shielded lead. One specific type of shielded cable is the coaxial cable sometimes used as a tv lead-in and in other applications, such as two-way radio and tv. The symbols at B and C can be used to represent coaxial cable, and the symbol at D is also used.

If more than one lead is included in a cable, more than one lead is included within the dashed-line area, as shown at E in Fig. 8-4. Three leads are shown here but any number of leads can be shown in this manner.

CONNECTORS

Often a method of providing a quick means of disconnecting and reconnecting a lead must be provided. All types of connectors have been provided for this purpose. The symbols at A and B in Fig. 8-5 show two methods of designating connectors for a single lead. The solid dot at the top in A represents the plug, or male, portion of the

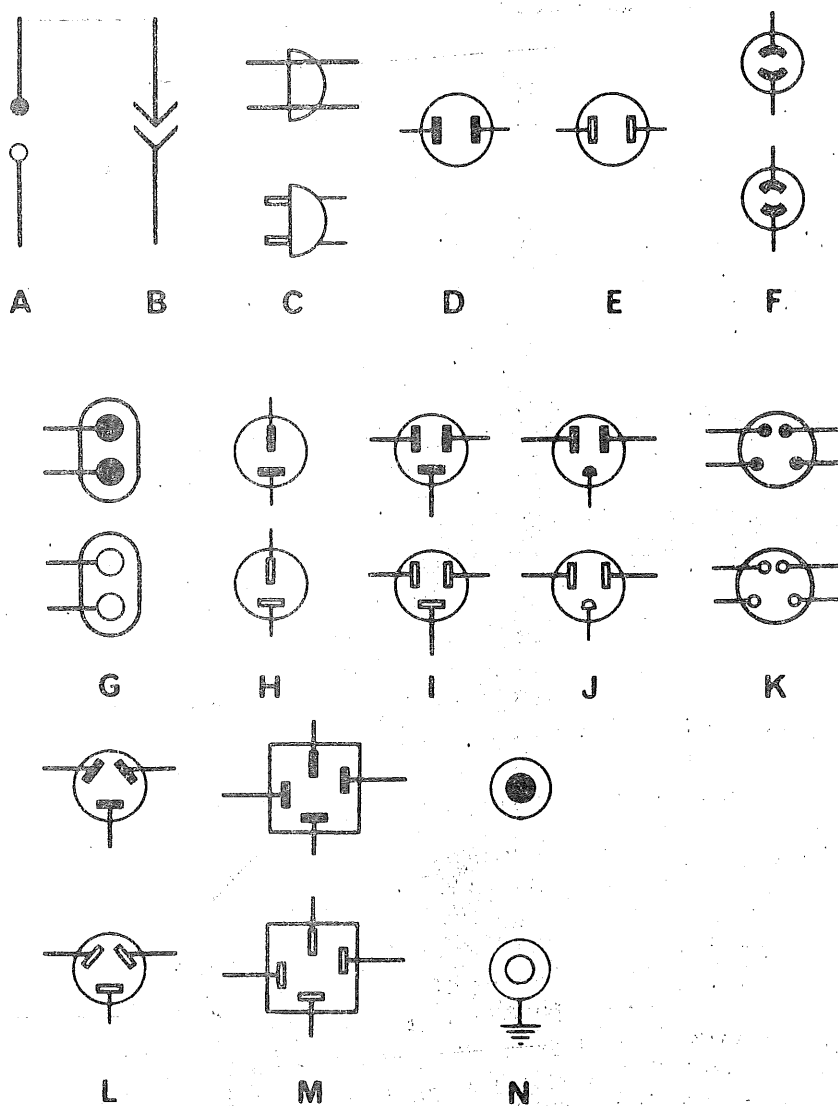


Fig. 8-5 Connector symbols.

connector. That is, it is the portion of the connector that is inserted in the socket, or female, portion of the connector, which is represented by the open circle at the bottom in A. Another system is shown at B. Again the top portion represents the male plug and the bottom portion, the female socket. Two ways of indicating the normal 2-wire, 117-V ac, line-cord plug are shown at C and D in Fig. 8-5. The symbols at C are a drawing of the plug viewed from the side, while the one at D is a straight-on view. The symbol at E is the female receptacle which matches the male plug shown at D. The symbols at F, G, and H in Fig. 8-5 show some other possible ways of depicting two-conductor connectors. In each case, the male plug is shown at the top and the female at the bottom. The arrangement corresponds with the actual position of the prongs and socket holes. Some possible arrangements for three and four conductor connectors are given at I through M in Fig. 8-5. Again, the drawing conforms to the actual arrangement on the unit. Such drawings can be used to show any number of connections. However, if a large number of connections are included, it becomes difficult to show all coming into a single circle or square. In this case, individual connections, such as shown at A or B, may be shown at various points on the schematic, or they may be arranged in a vertical or horizontal row. The individual connections are then numbered, and a separate drawing showing the actual arrangement in the connector is given elsewhere on the schematic.

The symbol at N in Fig. 8-5 is for a phono input on a radio, tuner or amplifier. Here a single conductor is included in a shielded cable. The male plug at the top is inserted in the female socket at the bottom. The shield of the cable is connected to the outer ring of the plug. When it connects to the socket, the shield will be connected to ground through the outer portion of the female socket which is fastened to the chassis.

SWITCHES

Practically every piece of electronic equipment incorporates at least one switch - to turn it on. But there are many other types of switches. They range from the very simple to large intricate devices. Usually, switches are classified by the type of construction used to make the switch and by the type of connections that can be made by the switch. Fig. 8-7 shows some of the many types of switch construction.

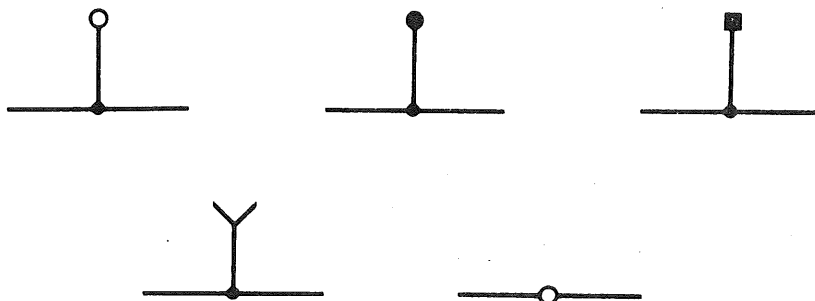


Fig. 8-6 Test point symbols.

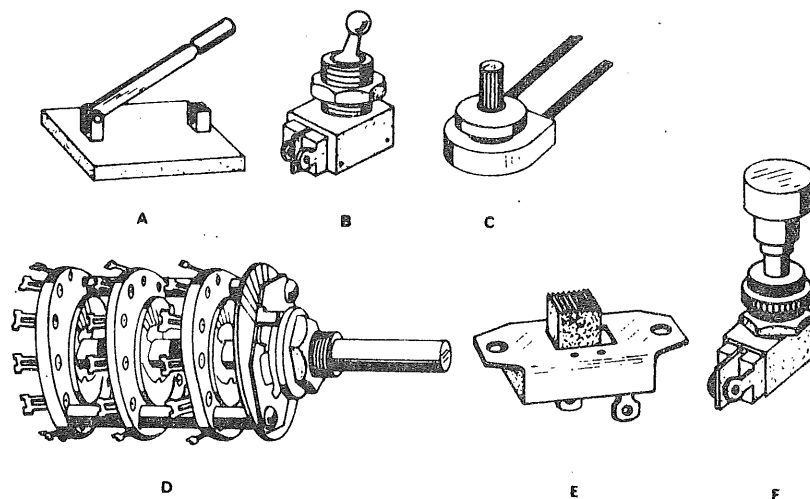


Fig. 8-7 Typical switches

The one at A is a knife switch, while a toggle switch is shown at B. Two types of rotary switches are illustrated at C and D. The one at C is a simple switch such as might be used to turn something on or off, and the one at D is a wafer switch that can be used to make many different connections in several circuits. The switch at E is a slide switch which is actuated by sliding the button back and forth. A push-button switch is shown at F in Fig. 8-7. There are many other types used in electronic equipment, but Fig. 8-7 shows the basic ones.

Switches are also classified by the type of connections that can be made with them. For example it is apparent from looking at A in Fig. 8-7 that when the knife is lowered so it engages the terminal at the right, the two points are connected. When the knife is raised, as shown, no connections are made. Such a switch is called a single-pole, single-throw switch (abbreviated spst). The same type of action can be obtained with the switches at B, C, E, and F in Fig. 8-7.

In Fig. 8-8, the symbols at A and B are a general type to designate a spst switch and may be used for any type of switch construction. The symbol at C, however, is a specific type to represent a knife switch. The symbols at D and E are for push-button switches. The one at D is for a switch that is normally open and the two points are connected when the button is depressed. Just the opposite is true with the switch at E; here the two points are normally connected and depressing the switch opens the circuit.

A switch can also be used to connect one point to either one of two separate points. Such a switch is called a single-pole, double-throw switch (abbreviated spdt). The symbols at F, G, and H. depict this type of switch. As can be seen, the movable arm can connect to either one, but not both, of the points at the same time.

The symbol at I is for a double-pole, single-throw switch (abbreviated dpst). Here two separate switching actions are obtained; each is the same as those accomplished by the ones at A, B, and C. That is, the upper portion is used to connect two points, while the lower portion can be used to connect two other points at the same time. The dashed

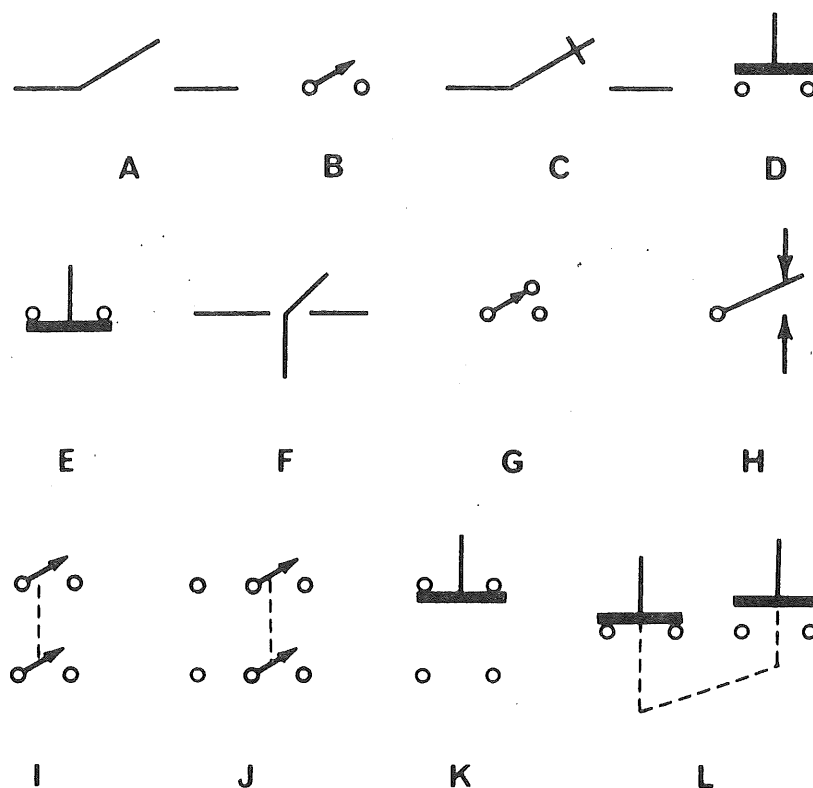


Fig. 8-8 Two-position switch symbols.

line between the two halves of the symbol designates a mechanical, but no electrical, connection. Thus, both sections of the switch close or open at the same time, but there is no electrical connection between the two sections. The arrowheads shown at B may or may not be included in the symbol at I.

The symbol at J is for a double-pole, double-throw switch (abbreviated dpdp). Thus, it accomplishes the same action in two separate circuits as the symbols at F and G did for a single circuit. The circuit connected to the center terminals can be connected either to the circuit connected to the left-hand or right-hand terminals.

Other combinations can be used for switches. Usually, the action can be understood by carefully examining the way the symbol is drawn. The portion of the switch that moves will usually be represented by a slanted line or an arrowhead symbol. The point or points to which connections are made are represented by a straight line or a small circle.

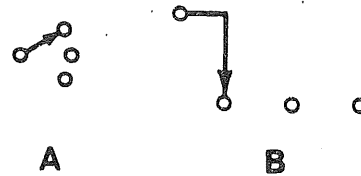
The symbol at K in Fig. 8-8 is for a push-button switch where, when the button is depressed, the connection between two upper terminals is broken and connection is made between the two lower terminals. Another push-button switch symbol is given at L. Here, two buttons are used. When one is depressed, connecting two terminals, the other button is released, disconnecting the other two terminals. Again, the dashed line denotes the mechanical connection.

MULTIPOSITION SWITCHES

The switches described in the foregoing all had only two positions. That is, they were either open or closed, or one circuit or another was connected. Many switches have more than two positions. The wafer switch that was pictured at D in Fig. 8-7, for example, can be constructed with as many as 24 or more positions, although usually a lesser number is employed.

The symbols in Fig. 8-9 represent a three-position switch. Here the movable arm represented by the portion with the arrowhead can be connected to any of the three points represented by the circles. Thus, a point in the circuit connected to the terminal with the arrowhead can be connected to any of three other points connected to the terminals represented by the small circles. Similar type symbols are employed to

Fig. 8-9 Three-position switch symbols.



represent switches with more positions. The symbol is made to represent the construction of the switch. As many terminals as there are positions on the switch are used. Also, such switches can be constructed so that a separate, like switching action can be mechanically connected to the same shaft. For example, the switch at D in Fig. 8-7 has three separate wafer sections, each capable of two or more separate switching actions. When such a switch is used, the arrowhead portions of the separate switches may be connected with a dashed line similar to that used for a double pole switch to represent the mechanical connection. This dashed line may be omitted, however, and a note someplace on the schematic will tell you that all of the switches are mechanically connected.

Examination of the section of a wafer switch at A in Fig. 8-10 will reveal another type of switch. The shaded area in the center of the drawing is a metal ring that rotates when a shaft is fitted through the slotted hole in the center of the wafer. At first glance this might

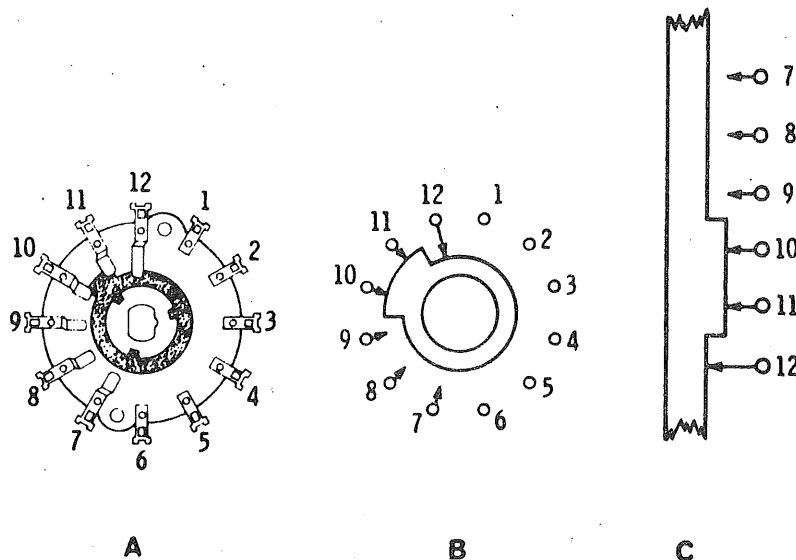


Fig. 8-10 The wafer switch and symbol.

appear to be a 12-position switch, since there are 12 terminals connected around the outside of the switch. Actually, it probably has only four or five positions. We will assume it is a five-position switch in our explanation, and that the ring shown only makes connections between the numbered terminals on the left of the wafer. Then a similar ring on the opposite side of the wafer makes connections to the terminals on the right-hand side of the wafer. In this manner, a single wafer can be used to perform switching action in two separate circuits.

The symbol at B in Fig. 8-10 represents this wafer. The numbers on the symbol show the same points as the numbered points on the wafer. Notice at A that Terminal 12 has a longer connector to the ring and is always touching it. This is represented by the longer arrowhead in the symbol at B. Also, notice that a protruding section of the center ring is touching the connections to Terminals 10 and 11. Thus, through the switch, Terminals 10, 11, and 12 are connected - no other connections are made through the switch in this position. If the shaft were to be rotated one position clockwise from the position shown, only Terminals 11 and 12 would be connected since the ring would move one position, moving the protruding section to the point where only these two terminals would be connected.

If the switch were rotated one position counterclockwise from the position shown, Terminals 9, 10, and 12 would be connected, since the protruding section would be touching the connections to Terminals 9 and 10, and Terminal 12 is always connected to the ring. Rotating the shaft another position counterclockwise connects Terminals 8, 9, and 12. In the remaining position, Terminals 7, 8, and 12 are connected.

Another method of representing the wafer switch is given in the symbol at C in Fig. 8-10. Here the ring is represented by the vertical bar at the left. Just imagine the ring is being broken and stretched out in a vertical plane. Note the protruding section of this bar also contacts the connections to Terminals 10 and 11, and that the connection to Terminal 12 is always in contact with the bar. The jagged line at the top and bottom of the bar denotes the breaking of the ring for illustration purposes. Just remember, it is a continuous ring and when moved up a position, there will still be a portion of the ring in contact with Terminal 12.

By changing design of the ring portion of the wafer switch, and the number of terminals and positions it can be rotated, a wafer switch can be designed to fit almost any type of switching application. The symbol will be a pictorial representation of the actual switch, as shown at B and C in Fig. 8-10. In simple applications, where only two points are connected by the wafer section, the symbols in Fig. 8-9 can also be used.

SPECIAL SWITCHES

The symbols for several special types of switches are given in Fig. 8-11. Although these switches will not be encountered often, especially in entertainment-type equipment, they are included here for reference. No attempt will be made to explain their operation. The symbol at A is for a safety-interlock switch which opens the circuit when a cover is removed. The symbols at B and C are for a limit switch. Time-delay switch symbols are given at D and E. Flow-actuated switches are

depicted by the symbols at F and G, while H and I are for liquid-level switches, and J and K are for pressure-operated or vacuum-operated switches. The symbols for temperature-actuated switches are given at L and M. The symbols at N and O are for thermostats. A self-interrupting switch, such as a flasher, is represented by the symbol at P or Q.

RELAYS

A relay is a form of electronic switch, incorporating a coil, a magnetic core and switch contacts. When a switch is closed, or the current or voltage through the coil exceeds the design amount, the current through the coil forms an electromagnet with the core. This electromagnet attracts a metal arm located near it. When the arm (called the armature) is attracted to the core, a mechanical switching action can be accomplished. Referring to Fig. 8-12, notice that if the current through the coil causes the electromagnet to attract the armature above it, the armature will move down, closing the two contacts.

Any number of switching arrangements can be connected to the relay. The symbol for the action of Fig. 8-12 is shown by the symbols at A, B, and C in Fig. 8-13. The symbols differ in the means of showing the coil.

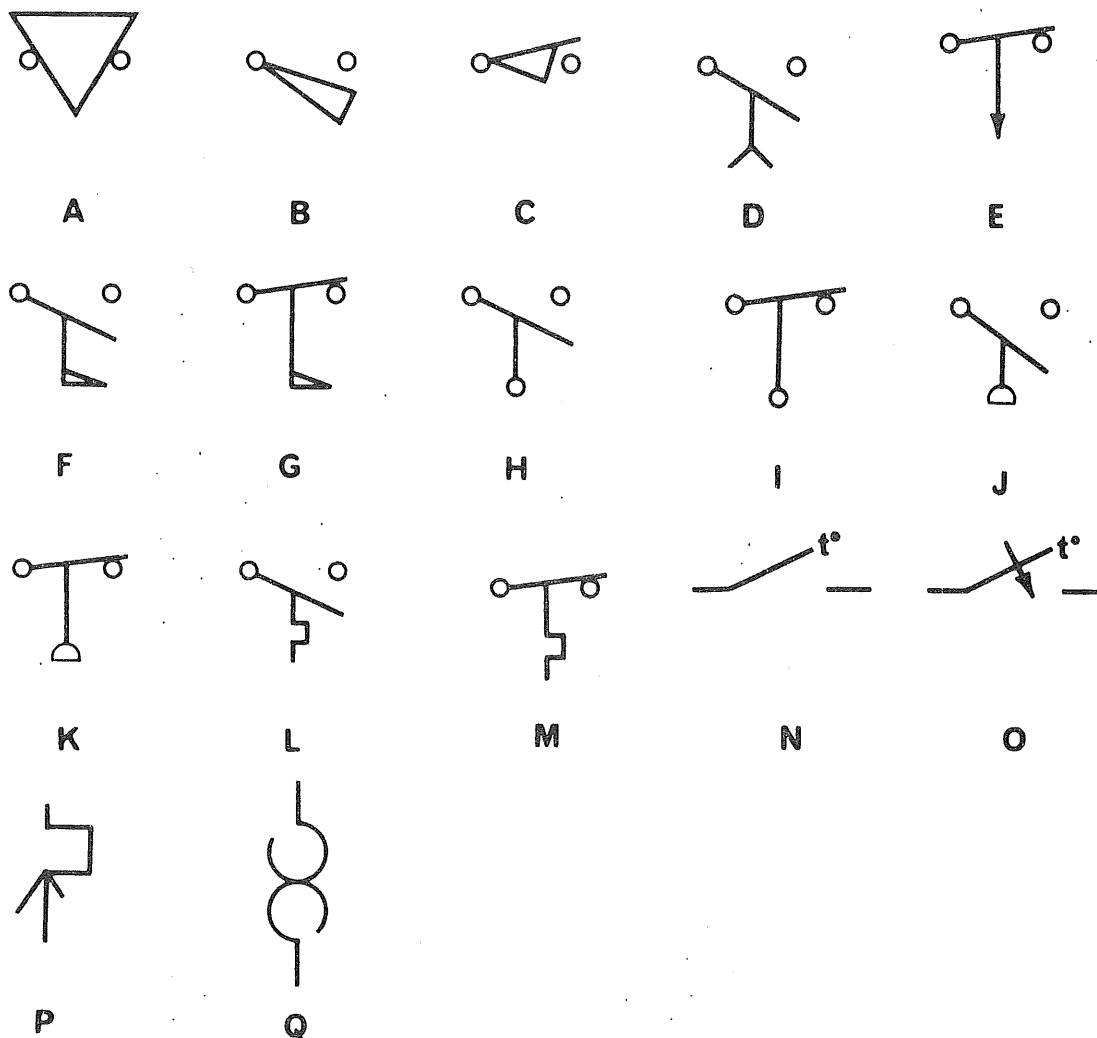


Fig. 8-11 Miscellaneous switch symbols

A conventional coil symbol is shown at A. Here, as the relay operates, the armature (represented by the heavy line) is pulled down, closing the contacts. At B the coil is represented by the rectangle with the wire coiled around it. At C just a rectangle is used to represent the coil; here the switch contacts are shown differently also. Many different types of switching arrangements are possible. Double-pole switches, where one circuit is disconnected while another is connected when the relay operates, and many other arrangements are used. To understand what happens, just view the switch portion and determine what happens when the armature moves. Another way of showing the switch contacts is given at D in Fig. 8-13. Here the portion of the symbol on the left represents a set of contacts that is normally open, and the portion on the right represents a normally closed set of contacts. In other words, using conventional switch symbols, the arrangement at D represents the switches shown at E in Fig. 8-13. The numbers are included on the symbols at D and E to help you identify the various points. They are not part of the symbol.

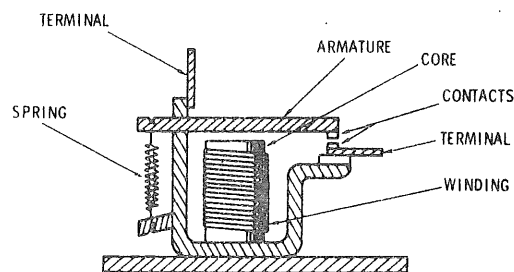


Fig. 8-12 Relay construction.

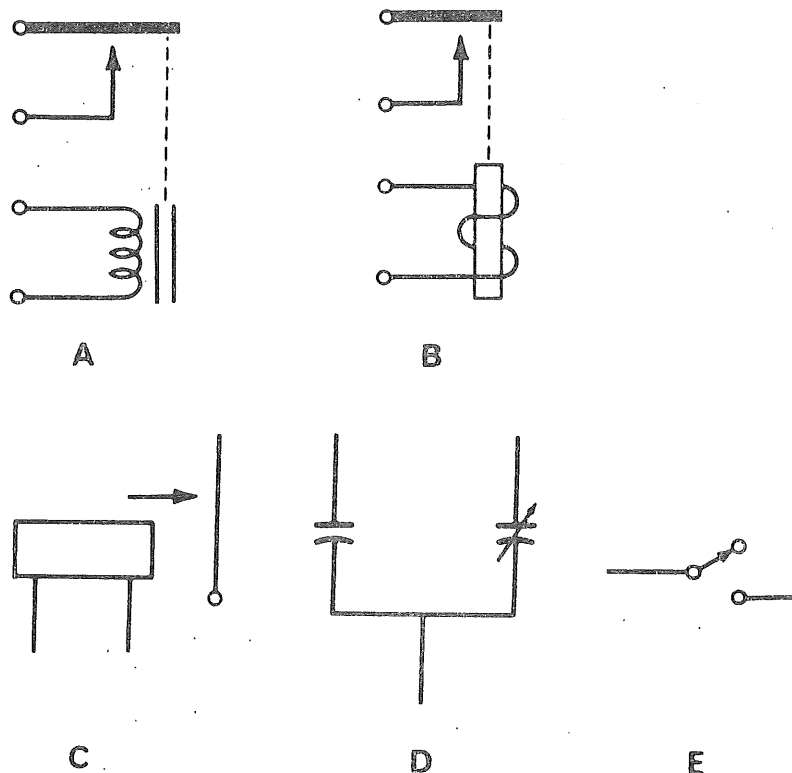


Fig. 8-13 Relay symbols.

POWERS OF TEN - SIGNIFICANT FIGURES

Powers of Ten. The powers of ten are sometimes termed the "engineer's shorthand." A thorough knowledge of the powers of ten and the ability to apply the theory of exponents will greatly assist in determining approximate values.

Some of the multiples of 10 are represented as follows:

Number Power of Ten

0.000001	=	10^{-6}	=	ten to the negative <i>sixth</i> power
0.00001	=	10^{-5}	=	ten to the negative <i>fifth</i> power
0.0001	=	10^{-4}	=	ten to the negative <i>fourth</i> power
0.001	=	10^{-3}	=	ten to the negative <i>third</i> power
0.01	=	10^{-2}	=	ten to the negative <i>second</i> power
0.1	=	10^{-1}	=	ten to the negative <i>first</i> power
1	=	10^0	=	ten to the <i>zero</i> power
10	=	10^1	=	ten to the <i>first</i> power
100	=	10^2	=	ten to the <i>second</i> power
1000	=	10^3	=	ten to the <i>third</i> power
10,000	=	10^4	=	ten to the <i>fourth</i> power
100,000	=	10^5	=	ten to the <i>fifth</i> power
1,000,000	=	10^6	=	ten to the <i>sixth</i> power

Thus it is seen that any decimal may be expressed as a whole number times some negative power of ten.

Rule: to express a decimal as a whole number times a power of ten, move the decimal point to the right and count the number of places to the original point. The number of places counted is the proper negative power of ten.

Examples.	0.00687	=	6.87×10^{-3}	0.346	=	34.6×10^{-2}
	0.0000482	=	4.82×10^{-5}	0.08643	=	86.43×10^{-3}

Also, any large number may be expressed as some smaller number times the proper power of ten.

Rule: to express a large number as a smaller number times a power of ten, move the decimal point to the left and count the number of places to the original deminal point. The number of places counted will give the proper positive power of ten.

EXERCISE

Express the following as numbers between 1 and 10, times the proper power of ten:

- | | |
|----------------------------|-------------------------------|
| 1. 643,000,000 | 2. 4356 |
| 3. 0.0136 | 4. 14 |
| 5. 0.000250 | 6. 0.0369 |
| 7. 48,900 | 8. 0.000000643 |
| 9. 0.0000000000125 | 10. 59,300 |
| 11. 0.259 | 12. 1890×10^3 |
| 13. 259×10^{-4} | 14. 0.000086×10^{-4} |
| 15. 56,500,000 | 16. 1,684,000,000 |
| 17. 0.367×10^{-6} | 18. 8420×10^{-12} |
| 19. 256×10^{-8} | 20. 0.000399×10^3 |

Multiplication with Powers of Ten.

$$a^m \cdot a^n = a^{m+n} \quad (\text{where } a \neq 0)$$

This law is directly applicable to the powers of ten.

example 1. Multiply 1000 by 100,000.

solution: $1000 = 10^3$ and $100,000 = 10^5$

Then $1000 \times 100,000 = 10^3 \times 10^5 = 10^{3+5} = 10^8$

example 2. Multiply 0.000001 by 0.001.

solution: $0.000001 = 10^{-6}$ and $0.001 = 10^{-3}$

Then $0.000001 \times 0.001 = 10^{-6} \times 10^{-3} = 10^{-6-3} = 10^{-9}$

example 3. Multiply 23,000 by 7000.

solution: $23,000 = 2.3 \times 10^4$ and $7000 = 7 \times 10^3$

Then $23,000 \times 7000 = 2.3 \times 10^4 \times 7 \times 10^3$

example 4. Multiply 0.000037 by 600.

solution: $0.000037 \times 600 = 3.7 \times 10^{-5} \times 6 \times 10^2$
 $= 3.7 \times 6 \times 10^{-3} = 22.2 \times 10^{-3}, \text{ or } 0.0222$

example 5. Multiply 72,000 X 0.000025 X 4600.

solution: $72,000 \times 0.000025 \times 4600 = 7.2 \times 10^4 \times 2.5 \times 10^{-5} \times 4.6 \times 10^3$
 $= 7.2 \times 2.5 \times 4.6 \times 10^2$
 $= 82.8 \times 10^2, \text{ or } 8280$

METRIC UNIT PREFIXES

Prefix	Symbol	Power of 10		Numerical Value
tera	T	10^{12}	trillion	1,000,000,000,000
		10^{11}	hundred-billion	100,000,000,000
		10^{10}	ten-billion	10,000,000,000
giga	G	10^9	billion	1,000,000,000
		10^8	hundred-million	100,000,000
		10^7	ten-million	10,000,000
mega	M	10^6	million	1,000,000
		10^5	hundred-thousand	100,000
myria	my	10^4	ten-thousand	10,000
kilo	k	10^3	thousand	1,000
hecto	h	10^2	hundred	100
deka	da	10^1	ten	10
		10^0	one	1
deci	d	10^{-1}	tenth	.1
centi	c	10^{-2}	hundredth	.01
milli	m	10^{-3}	thousandth	.001
		10^{-4}	ten-thousandth	.000 1
		10^{-5}	hundred-thousandth	.000 01
micro	μ	10^{-6}	millionth	.000 001
		10^{-7}	ten-millionth	.000 000 1
		10^{-8}	hundred-millionth	.000 000 01
nano	n	10^{-9}	billionth	.000 000 001
		10^{-10}	ten-billionth	.000 000 000 1
		10^{-11}	hundred-billionth	.000 000 000 01
pico	p	10^{-12}	trillionth	.000 000 000 001
		10^{-13}	ten-trillionth	.000 000 000 000 1
		10^{-14}	hundred-trillionth	.000 000 000 000 01
femto	f	10^{-15}	quadrillionth	.000 000 000 000 001
		10^{-16}	ten-quadrillionth	.000 000 000 000 000 1
		10^{-17}	hundred-quadrillionth	.000 000 000 000 000 01
atto	a	10^{-18}	quintillionth	.000 000 000 000 000 001

OHM'S LAW FORMULAE

W = WATTS	EI	$I^2 R$	$\frac{E^2}{R}$			
E = VOLTS		IR		$\sqrt{\frac{W}{R}}$		$\frac{W}{I}$
I = AMPS			$\frac{E}{R}$	$\sqrt{\frac{W}{R}}$	$\frac{W}{E}$	
R = OHMS	$\frac{E}{I}$				$\frac{E^2}{W}$	$\frac{W}{I^2}$

1 Ampere = 1,000 milliamperes

1 megohm = 1,000,000 ohms

TEK PART NUMBER SYSTEM

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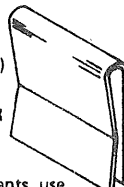
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ENG STOCK TAB SYSTEM

RED = LOW STOCK (or out of stock)

YELLOW = PARTS ARE ON ORDER
(Used only by Stock Accountants)



If anyone other than stock accountants use the Yellow tabs, new stock does not get ordered. The Yellow tabs are placed only after new stock has been ordered.

TEK PART NUMBER SYSTEM (CONT)

ALPHABETICAL (CONT)

TYPE OF PARTS	CATEGORY	TYPE OF PARTS	CATEGORY
COIL, FIXED	108-0000-00	FORM, COIL (SEE ALSO CORE)	276-0000-00
COIL, FIXED, REED SWITCH	108-0000-00	FRAME AND FRAME SECTIONS	426-0000-00
COIL, VARIABLE	114-0000-00	FRAME, MOUNTING (ACCESSORY)	014-0000-00
COLLAR	343-0000-00 (NEW) and 214-0000-00 (OLD)	FRAME-PANEL, CABINET (FRONT, REAR, ETC.)	426-0000-00
COLUMN	426-0000-00	FUSE	159-0000-00
COMPENSATOR (ACCESSORY)	011-0000-00	GASKET	214-0000-00 (OLD) and 348-0000-00 (NEW)
CONNECTOR (GENERAL)	131-0000-00	GEARS	214-0000-00 (OLD) and 401-0000-00 (NEW)
CONNECTOR (GR AND ASSOCIATED GR SUBPARTS)	132-0000-00	GEAR RACK	214-0000-00
CONTACT	131-0000-00 (NEW) and 214-0000-00 (OLD)	GEAR STOCK (BULK) (SEE ROD, PINION)	
COPPER (BULK)	251-0300-00 and 258-0300-00	GRATICULE	331-0000-00
CORD, LACING	253-0000-00	GRILLE, (FAN, ETC.)	378-0750-00
CORD, POWER (SEE CABLE, POWER)		GRIP	367-0000-00
CORE (XMFR, COIL, FERRITE, ETC.)	276-0500-00	GROMMET	348-0000-00
COUNTER	331-0000-00	GUARD	200-0000-00
COUPLING AND COUPLER	376-0000-00	GUIDE	351-0000-00
COVER	200-0000-00	GUIDE, RM (SEE ALSO SLIDE, RM)	351-0000-00
COVER, PROTECTIVE, (OSCP)	016-0000-00	HANDLE	367-0000-00
CRADLE	426-0000-00	HARDWARE KIT	016-0000-00
CRT's (SALEABLE)	154-0000-00	HARDWARE (SEE WASHER, TERMINAL, NUT SCREW, OR SPECIFIC ITEM)	214-0000-00
CRT MATERIAL	439-0000-00 and 440-0000-00	HARNES, WIRING (SEE WIRING HARNES)	
CRT MESH FILTER (SEE FILTER, MESH, CRT)		HEADER	131-0000-00
CRYSTAL UNITS	158-0000-00	HEATSINK	214-0000-00
CUP	201-0000-00	HINGE	214-0000-00
CUSHION	348-0000-00	HOLDER	352-0000-00
DELAY LINE (COAX CABLE TYPE & ACCESSORY)	015-1000-00	HOLDER, LAMP (W/O ELEC CONTACTS. USE LAMPHOLDER IF CONTACTS INCLUDED)	352-0000-00
DELAY LINE	119-0000-00	HOOD, VIEWING (ACCESSORY, SEE VIEWING HOOD)	
DETENT, CAM SWITCH	214-0000-00	HOUSING	380-0000-00
DIAL	331-0000-00	HUB	401-0000-00
DIODE (SEE SEMICONDUCTOR DEVICE, DIODE)		HYBRID CIRCUIT (TEKMADE)	155-0000-00
DISK OR DISC	214-0000-00	IDENTIFICATION PLATE (SEE PLATE, IDENT)	
DOOR	200-0000-00	IMPELLER (AIR FAN)	369-0000-00
DRAWER	436-0000-00	INSERT	377-0000-00
DRUM	105-0000-00	INSERT, SCREW THREAD	377-0000-00
DRUM, CAM SWITCH	105-0000-00	INSULATION SLEEVING (HI-TEMP, SHRINK, ETC.)	162-0500-00
ELECTRON TUBES (CHECKED, ETC.)	157-0000-00	INSULATION SLEEVING (PLAIN)	162-0000-00
ELECTRON TUBES (INCL CRT)	154-0000-00	INSULATOR	342-0000-00 (NEW) and 214-0000-00 (OLD)
ETCHED CIRCUIT BOARD/CARD (SEE CIRCUIT BOARD/CARD)		INTEGRATED CIRCUITS (PURCHASED)	156-0000-00
EXTENDER (ACCESSORY TYPE)	013-0000-00	INTEGRATED CIRCUITS (TEKMADE)	155-0000-00
EXTENSION SHAFT (SEE SHAFT, EXTENSION)		INTERFACE UNITS	021-0000-00
EYELET	210-0600-00	JACK (TELEPHONE OR TIP)	131-0000-00
FAN	119-0000-00	KEY (CONNECTOR AND LOCK)	214-0000-00
FASTENERS (SEE ALSO SCREW, NUT, LATCH, CATCH, ETC.)	214-0000-00	KNOB	366-0000-00
FELT (BULK)	252-0500-00	KNOB-DIAL ASSEMBLY	366-0500-00
FERRULE	166-0000-00	KNOB SKIRT (SEE RING, KNOB SKIRT)	
FIBER OPTIC, BULK (SEE LIGHT CONDUCTOR)		LABELS (IDENTIFICATION)	334-0000-00
FILM, IDENTIFICATION	334-0000-00	LAMP, CARTRIDGE (NONREMOVABLE LAMP)	150-0000-00
FILTER, AIR	378-0000-00	NOSE, PROBE	206-0000-00
FILTER, (ELECTRONIC)	119-0000-00	NUT	220-0400-00 and 210-0400-00
FILTER, LIGHT	378-0500-00	NUT BAR	220-0400-00
FILTER, MESH, CRT	378-0500-00	MANUAL, TECHNICAL	070-0000-00
FLANGE	386-0000-00	OPTIC COMPONENTS	122-0500-00
FLIP-STAND, CABINET	348-0000-00	OSCILLATORS	119-0000-00
FOOT	348-0000-00		

TEK PART NUMBER SYSTEM (CONT)

ALPHABETICAL

TYPE OF PARTS	CATEGORY	TYPE OF PARTS	CATEGORY
ACCESSORIES - SEE PROBE, CABLE OR SPECIFIC PART		CABINET AND CABINET SUBASSEMBLY	437-0000-00
ACCESSORIES (SPECTROMETER)	016-1000-00	CABINET PARTS (SIDES, TOPS, ETC.)	390-0000-00 (NEW) and 386-0000-00 (OLD) and 387-0000-00 (OLD)
ACCESSORY PACKAGE	020-0000-00	CABINET WRAPAROUND, (INSTRUMENT TYPE)	390-0000-00
ACTUATOR ASSY, CAM SWITCH	263-1000-00	CABLE (BULK) & CABLE ASSEMBLY	175-0000-00 and 175-1000-00
ACTUATOR (GENERAL)	214-0000-00	CABLE ASSEMBLY, (ACCESSORY)	012-0000-00
ACTUATOR, CAMERA (ACCESSORY)	016-0200-00	CABLE ASSEMBLY, GR (ASSEMBLY)	017-0500-00
ADAPTER (GENERAL PARTS, NOT ACCESSORY)	103-0000-00	CABLE ASSEMBLY, PROBE	175-0000-00 and 175-1000-00
ADAPTER, CAMERA (ACCESSORY)	016-0200-00	CABLE HARNESS (SEE WIRING HARNESS)	
ADAPTER, ELECTRICAL (ACCESSORY)	013-0000-00	CABLE, ELECTRODE ADAPTER (ACCESSORY)	012-0000-00
ADAPTER, GR CONNECTOR (ACCESSORY)	017-0000-00	CABLE, INTERCONNECTING (ACCESSORY)	012-0000-00
ADAPTER, INSTRUMENT (ACCESSORY)	015-0000-00	CABLE, POWER (PROCESSED)	161-0000-00
ADAPTER, MECHANICAL (ACCESSORY)	014-0000-00	CABLE, NIPPLE	200-0000-00
ADAPTER, PROBE (ACCESSORY)	015-0000-00	CAM	401-0000-00
ADAPTER, RACK MOUNT (ACCESSORY)	016-0000-00	CAM SWITCH ACTUATOR ASSEMBLY (SEE ACTUATOR ASSY, CAM SWITCH)	
ADHESIVE	006-0000-00	CAMERA PARTS & ASSEMBLIES (PURCHASED)	122-0500-00
ANGLES (SEE ALSO FRAME AND FRAME SECTIONS)	122-0000-00	CAMERA ACCESSORIES	016-0200-00
ANVIL (SOLENOID, ETC.)	119-0000-00	CAN	202-0000-00
ALUMINUM (BULK)	251-0000-00 and 251-1000-00	CAP	200-0000-00
ATTENUATION HEAD, PROBE (ACCESSORY)	010-0000-00	CAPACITOR, CHECKED, ETC.	295-0000-00
ATTENUATOR, FIXED AND VARIABLE (ACCESSORY)	011-0000-00	CAPACITOR, COUPLING (ACCESSORY)	011-0000-00
ATTENUATOR, 3mm (ACCESSORY)	015-1000-00	CAPACITOR, FIXED CERAMIC DIELECTRIC	281-0500-00
ATTENUATOR, GR (ACCESSORY)	017-0000-00	CAPACITOR, FIXED, CERAMIC DIELECTRIC (DISC TYPE)	283-0000-00
ATTENUATOR STRIP, DUMMY	124-0000-00	CAPACITOR, FIXED, ELECTROLYTIC	290-0000-00
ATTENUATOR, TURRET SWITCH	263-0000-00	CAPACITOR, FIXED, (GLASS & PORCELAIN DIELECTRIC)	285-0000-00
ATTENUATOR, PROBE HEAD (ACCESSORY)	010-0300-00	CAPACITOR, FIXED, MICA DIELECTRIC	283-0500-00
AIR	378-0750-00	CAPACITOR, FIXED, (PLASTIC & PAPER DIELECTRIC)	285-0500-00
A JACK (SEE JACK OR PLUG)		CAPACITOR, FIXED, PLASTIC (TEKMADE)	291-0000-00
BAND (MARKING)	334-0000-00	CAPACITOR, VARIABLE	281-0000-00
BAR (OTHER THAN BULK)	381-0000-00	CAPACITOR WINDINGS	291-0200-00
BASE	432-0000-00	CAPACITORS, MATCHED	295-0000-00
BATTERY	146-0000-00	CARTON (SHIPPING)	004-0000-00
BEARING	401-0000-00	CARTS (OSCILLOSCOPE)	016-0000-00
BELTS (PULLEY, POSITIVE DRIVE, ETC.)	214-0000-00	CASE	202-0000-00
BEZEL (ACCESSORY)	014-0000-00	CASE, CARRYING	016-0000-00
BEZEL	200-0000-00	CASE, TRANSISTOR	202-0000-00
BINDER, LOAD	214-0000-00	CASTER	401-0000-00
BLADDER	214-0000-00 and 341-0000-00	CATCH	105-0000-00
BLADE, SHUTTER	122-0000-00	CATHODE RAY TUBE	154-0000-00
BLOCK	391-0000-00	CERAMIC MATERIAL (BULK)	256-0000-00
BOARD, CIRCUIT (SEE CIRCUIT BOARD)		CERAMIC STRIP (SEE TERMINAL STRIP, CERAMIC)	
BOARD, TERMINAL (SEE TERMINAL BOARD)		CHAIN	214-0000-00
BODY	204-0000-00	CHASSIS	441-0000-00
BOLT	214-0000-00	CHASSIS-TRACK (SEE SLIDE, RM AND GUIDE, RM)	
BOX	202-0000-00	CHOPPER	119-0000-00
BRACE	122-0000-00	CIRCUIT BOARD (UNWIRED)	388-0000-00
BRACKET	406-0000-00 and 407-0000-00	CIRCUIT BOARD ASSEMBLY (WIRED)	670-0000-00
BRASS (BULK)	251-0300-00 and 258-0300-00	CIRCUIT BOARD ASSEMBLY	675-0000-00
BRONZE (BULK)	251-0300-00 and 258-0300-00	CIRCUIT BOARD ASSEMBLY	700-0000-00
BUSHING	358-0000-00	CIRCUIT BOARD SUBASSEMBLY	673-0000-00
BUTTON, PLUG	134-0000-00	CIRCUIT BREAKER	260-0000-00
		CIRCUIT CARD (ACCESSORY)	018-0000-00
		CLAMP	343-0000-00
		CLIP	344-0000-00

TEK PART NUMBER SYSTEM (CONT)

ALPHABETICAL (CONT)

TYPE OF PARTS	CATEGORY	TYPE OF PARTS	CATEGORY
OSCILLOSCOPE CART	016-0000-00	RESISTOR, FIXED, COMP (0.5W, 5%)	301-0000-00
PAD	348-0000-00	RESISTOR, FIXED, COMP (0.5W, 10%)	302-0000-00
PAINT (BULK)	252-0000-00	RESISTOR, FIXED, COMP (1.0W, 5%)	303-0000-00
PANEL, (ETCHED AND ANODIZED) (FRONT, REAR, ETC)	333-0000-00	RESISTOR, FIXED, COMP (1.0W, 10%)	304-0000-00
PANEL (NOT ANODIZED) (REAR, SUB-, ETC)	387-0000-00 and 386-0000-00	RESISTOR, FIXED, COMP (2.0W, 5%)	305-0000-00
PAPER (BULK)	252-0500-00	RESISTOR, FIXED, COMP (2.0W, 10%)	306-0000-00
PARTITION	386-0000-00	RESISTOR, FIXED, HV (SEE 307-)	314-0000-00
PART REPLACEMENT KITS	050-0000-00	RESISTOR-KNOB, MATCHED	312-0100-00
PHOTO COMPONENTS	122-0500-00	RESISTOR, (FIXED-MATCHED, SELECTED, SETS, ETC. AT TEK)	312-0500-00
PIGMENT, PLASTIC MOLDING MATERIAL	255-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.125W, 1% & LESS, STD RES VALUES)	321-0000-00
PIN, CONNECTING (SEE TERMINAL PIN)		RESISTOR, FIXED, FILM (METAL FILM 0.125W, 1% & LESS, SPECIAL VALUES)	321-0600-00
PIN	214-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.125W, 1% & LESS, STD RES VALUES)	321-1000-00
PINION ROD (SEE ROD, PINION)		RESISTOR, FIXED, FILM (METAL FILM 0.25W, 1% & LESS, STD RES VALUES)	322-0000-00
PIVOT ARM	367-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.25W, 1% & LESS, SPECIAL VALUES)	322-0600-00
PLASTIC SHEET AND STRIP, ROD, MOLDING MATERIAL (ALL BULK)	254-0500-00 and 255-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.25W, 1% & LESS, STD RES VALUES)	322-1000-00
PLATE, (IDENTIFICATION AND INSTRUCTION)	334-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.5W, 1% & LESS, STD RES VALUES)	323-0000-00
PLATE, (MISC)	386-0000-00 and 387-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.5W, 1% & LESS, SPECIAL VALUES)	323-0600-00
PLUG (TELEPHONE OR TIP)	134-0000-00	RESISTOR, FIXED, FILM (METAL FILM 0.5W, 1% & LESS, STD RES VALUES)	323-1000-00
PLUNGER, SOLENOID	119-0000-00	RESISTOR, FIXED, FILM (METAL FILM 1.0W, 1% & LESS, SPECIAL VALUES)	324-0000-00
POINTER	331-0000-00	RESISTOR, FIXED, FILM (METAL FILM 1.0W, 1% & LESS, SPECIAL VALUES)	324-0600-00
POST	129-0000-00	RESISTOR, FIXED, FILM (METAL FILM 1.0W, BELOW 1%, STD RES VALUES)	324-1000-00
POT (SEE RESISTOR, VARIABLE)		RESISTOR, FIXED, FILM (METAL FILM-MISC NOT FITTING IN 321-THRU 324 CATEGORIES)	325-0000-00
POWER SUPPLY (HV) INTERNAL INST COMPONENT	119-0000-00	RESISTOR, FIXED, FILM (ALL FILM NOT FITTING IN ANY PRECEDING CATEGORIES)	307-0000-00
POWER SUPPLY (ACCESSORY)	016-0000-00	RESISTOR, FIXED, FOIL	307-0000-00
PRECIOUS METALS	257-0000-00	RESISTOR, FIXED, THICK FILM	307-0000-00
PROBE	010-0000-00	RESISTOR, FIXED, WIREWOUND	308-0000-00
PROBE HEADS	010-0300-00	RESISTOR, VARIABLE	311-0000-00
PROBE PACKAGE	010-0000-00	RESISTOR, VARIABLE, (SELECTED FROM 311-RES)	312-0000-00
PULLEY (SEE ALSO SPROCKET WHEEL)	214-0000-00(OLD) and 401-0000-00(NEW)	RETAINER	343-0000-00
PUSHBUTTON/PUSHBUTTON ASSY	366-0000-00	RING	354-0000-00
RACK	405-0000-00	RING, KNOB SKIRT	354-0000-00
RAIL	122-0000-00	RING, RETAINING	354-0000-00
RECEPTACLE (CONNECTOR)	131-0000-00	RING, TRIM	354-0000-00
RECEPTACLE (MECH ONLY)	136-0000-00	RIVET	210-0600-00
RECTIFIER (SELENIUM)	106-0000-00	ROD, (MISC)	385-0000-00
RECTIFIER (SEMICONDUCTOR, GENERAL)	152-0000-00	ROD, PINION	251-0000-00
RECTIFIER (SEMICONDUCTOR, SELECTED, ETC.)	153-0000-00	ROTATING MECHANICAL PARTS	401-0000-00
REDUCER	102-0000-00	ROTOR, VARIABLE RESISTOR	401-0000-00
REFLECTOR	378-0500-00	RUBBER (BULK)	252-0500-00
RELAY	148-0000-00	SCALE	331-0000-00
RELAY, MAGNETIC REED (SEE ALSO SWITCH, MAG REED)	148-0000-00	SCREEN	378-0750-00
REPLACEMENT PARTS FOR IDD PURCH. ASSYS.	118-0000-00 348-0000-00	SCREW (UP THRU 5-40)	211-0000-00
RESILIENT MOUNT		SCREW (6-32)	211-0500-00
RELAY COMPONENTS (TEKMADE)	148-3000-00	SCREW (8-32)	212-0000-00
RESISTOR (ATTENUATOR STRIPS)	307-1000-00	SCREW (10-24, 10-32, 12-24 & 12-32)	212-0500-00
RESISTOR, FIXED, FILM (CARBON 0.5W)	309-0000-00	SCREW (ABOVE 12-32 & TAPPING, SETSCREWS, ETC)	213-0000-00
RESISTOR, FIXED, FILM (CARBON 1.0W)	310-0000-00		
RESISTOR, FIXED FILM (CARBON 1.0W)	310-0500-00		
RESISTOR, FIXED, FILM (CARBON 0.125W, 1%)	318-0000-00		
RESISTOR, FIXED, COMP (0.125W, 5%)	317-0000-00		
RESISTOR, FIXED, FILM (CARBON 0.25W, below 5%)	319-0000-00		
RESISTOR, FIXED, COMP (0.25W, 5%)	315-0000-00		
RESISTOR, FIXED, COMP (0.25W, 10%)	316-0000-00		

TEK PART NUMBER SYSTEM (CONT)

ALPHABETICAL (CONT)

TYPE OF PARTS	CATEGORY	TYPE OF PARTS	CATEGORY
SEMICONDUCTOR DEVICE, DIODE	152-0000-00	TERMINAL STRIP (OTHER)	124-0000-00
SEMICONDUCTOR DEVICE, DIODE (CHECKED, ETC.)	153-0000-00	TERMINAL, STUD	131-0000-00
SCREW	213-0000-00	TERMINATION (ACCESSORY GENERAL)	011-0000-00
SHAFT, EXTENSION & SPACING	384-0000-00	TERMINATION (ACCESSORY 3mm)	015-1000-00
SHAFT (OTHER)	384-0500-00	TERMINATION (ACCESSORY GR)	017-0000-00
SHEET, NONMETALLIC (PAPER, FELT, LINOLEUM, PLASTIC)	107-0000-00	THUMBSCREW	213-0000-00(NEW) and 214-0000-00(OLD)
SHELF	436-0000-00	TIE PLATE, (CABINET, ETC)	344-0000-00
SHELL, (GENERAL)	205-0000-00	TIE STRIP, (CIRCUIT BOARD, ETC)	344-0000-00
SHELL, KNOB	366-0000-00	TIN (BULK)	251-0500-00
SHIELD (ELEC AND MECH)	337-0000-00	TIP, PROBE (ALL EXCEPT BELOW)	206-0000-00
SHIELD, IMPLSION	337-0000-00	TIP, PROBE (REMOVABLE, RETRACTABLE ONLY)	013-0000-00
SHIELDING GASKET, ELECT	348-0000-00	TRANSISTOR (CHECKED)	153-0500-00
SHIM	361-0000-00	TRANSISTOR (FE)	151-1000-00
SHOCKMOUNT	348-0000-00	TRANSISTOR (GENERAL)	151-0000-00
SHUTTER (CAMERA)	122-0500-00	TRANSISTOR (SPECIAL)	151-0500-00
SLEEVE (MARKING)	334-0000-00	TRANSISTORS, MATCHED	153-0500-00
SLEEVE, SPACER	361-0000-00	TRANSFORMER	120-0000-00
SLIDE	351-0000-00	TRAY	436-0000-00
SLIDE, RM	351-0000-00	TRIM	101-0000-00
SLIDE, GUIDE, RM (ASSEMBLY)	361-0000-00	TUBE, SPACER	166-0000-00
SLUG (CORE)	276-0000-00	TUBE, VACUUM (CHECKED, ETC., SEE ELECTRON TUBE)	
SOCKET	136-0000-00	TUBES, VACUUM AND CRT (SEE ELECTRON TUBE & CATHODE RAY TUBE)	
SOLDER (BULK)	251-0500-00	TUBING, INSULATION (SEE INSULATION SLEEVING)	
SOLDER LUG (SEE TERMINAL, LUG)		TURRET SWITCH (SEE SWITCH, TURRET)	
SOLENOID	119-0000-00	VALVE	214-0000-00(NEW) and 341-0000-00(OLD)
SPACER (UNTHREADED)	361-0000-00	VARNISH (BULK)	252-0000-00
SPACER (THREADED)	129-0000-00	VIEWING HOOD, CRT (ACCESSORY)	016-0000-00
SPRING	214-0000-00	WASHER (OTHER THAN LOCK)	210-0800-00
SPCKET WHEEL	401-0000-00	WASHER, LOCK	210-0000-00
STAINLESS STEEL (BULK)	251-0500-00	WHEEL	401-0000-00
STANDARDIZERS (ACCESSORY)	011-0000-00	WINDOW	331-0000-00
STEEL (BULK)	251-0500-00	WIRE, ELECTRICAL (BULK-BARE)	176-0000-00
STEM	355-0500-00	WIRE, ELECTRICAL (BULK-INSULATED)	175-0500-00
STIFFENER	386-0000-00	WIRE (BULK-COLOR CODED)	177-0000-00
STOP	105-0000-00	WIRE SWITCHED (SEE SWITCH ASSEMBLY)	
STRAIN RELIEF (SEE BUSHING)	358-0000-00	WIRING HARNESS	179-0000-00
STRAP	346-0000-00		
STRIKE	105-0000-00		
STRIP (CERAMIC TRIM, FELT, TRIM, METAL, RUBBER, ETC)	124-0000-00		
STUD	353-0000-00		
SUBPANEL	386-0000-00 and 387-0000-00		
SUBSTRATE	204-0000-00		
SUPPORT	386-0000-00 and 387-0000-00		
SWITCH	260-0000-00		
SWITCH, MAGNETIC REED	260-0000-00		
SWITCH ASSEMBLY (WIRED)	262-0000-00		
SWITCH, TURRET	263-0000-00		
TAG	334-0500-00		
TANK	202-0000-00		
TAPE (PUNCHED OR MAGNETIC PROGRAM)	016-0000-00		
TAP	253-0000-00		
TERMINAL (ELECTRICAL)	131-0000-00		
TERMINAL, BLADE	131-0000-00		
TERMINAL BOARD	392-0000-00		
TERMINAL, LUG	210-0200-00		
TERMINAL, PIN	131-0000-00		
TERMINAL STRIP, CERAMIC	123-0000-00 and 124-0000-00		

TEK PART NUMBER SYSTEM (CONT)

NUMERICAL

CATEGORY	TYPE OF PARTS	CATEGORY	TYPE OF PARTS
002-0000-00	OFFICE SUPPLIES	134-0000-00	PLUGS (SEE ALSO 131- & 136)
001-0000-00	HAND TOOLS	136-0000-00	SOCKET; LAMPHOLDER (W/CONTACTS); & LIGHT, INDICATOR (SEE ALSO 131- & 134-)
004-0000-00	SHIPPING SUPPLIES	146-0000-00	BATTERY
006-0000-00	OPERATING SUPPLIES	147-0000-00	MOTORS
007-0000-00	FURNITURE	147-0200-00	MOTOR BRUSHES
010-0000-00	ACCESSORIES (PROBES & PROBE PACKAGES)	148-0000-00	RELAYS (INCL MAG REED)
010-0300-00	ACCESSORIES (PROBE HEADS, ATTEN HEADS)	148-3000-00	COMPONENTS FOR TEK MADE RELAYS
011-0000-00	ACCESSORIES (TERMINATIONS, ATTENUATORS, STANDARDIZERS UHF & BNC)	149-0000-00	METERS
012-0000-00	ACCESSORIES (CABLE ASSEM & LEADS)	150-0000-00	LAMPS & LIGHTS (INCL LAMP, CARTRIDGE; GLOW; & INCAND)
013-0000-00	ACCESSORIES (CONNECTING, ADAPTING, & EXTENDING UNITS NOT CABLES)	150-1000-00	LAMP, LED (LIGHT EMITTING DIODES)
014-0000-00	ACCESSORIES (MECH: MTG FRAMES, BEZELS, ADAPTERS, ETC)	151-0000-00	TRANSISTORS (GENERAL)
015-0000-00	ACCESSORIES (ELEC: PROBE & INST ADAPT UNITS)	151-0500-00	TRANSISTORS (SPECIAL)
015-1000-00	ACCESSORIES (TERMINATIONS, ATTENUATORS, ETC. WITH 3mm CONNECTORS)	151-1000-00	TRANSISTORS (FIELD EFFECT)
016-0000-00	ACCESSORIES (MISC: OSP CARTS, CARRY CASES, VIEWING HOODS, TAPES, RACK ADAPTERS, INSTRUMENT PROTECTIVE COVERS, POWER SUPPLY, CAMERA ADAPT, ACTUATORS, ETC.)	152-0000-00	DIODES
016-1000-00	ACCESSORIES (SPECTROMETER)	153-0000-00	DIODES (MATCHED, SELECTED, SETS, ETC. FROM 152- DIODES)
017-0000-00	ACCESSORIES (TERMINATIONS, ATTEN, ADAPT, ETC. WITH GR CONNECTORS)	153-0500-00	TRANSISTORS (MATCHED, SELECTED, SETS, ETC. FROM 151- TRANSISTORS)
017-0500-00	ACCESSORIES (GR TERMINATED CABLES)	154-0000-00	ELECTRON TUBES (VACUUM & CRT)
018-0000-00	ACCESSORIES (SALEABLE CIRCUIT CARDS)	155-0000-00	MICROCIRCUIT (TEKMADE)
020-0000-00	INSTRUMENT ACCESSORY PACKAGE	156-0000-00	MICROCIRCUIT (PURCHASED)
021-0000-00	INTERFACE UNITS	157-0000-00	ELECTRON TUBES (MATCHED, SELECTED, SETS, ETC. FROM 154- TUBES)
030-0000-00 to		158-0000-00	CRYSTAL UNITS
038-0000-00	CUSTOM ENGINEERING PARTS	159-0000-00	FUSES
039-0000-00	SYSTEM PARTS	161-0000-00	CABLES (POWER - BULK & PROCESSED)
040-0000-00	MODIFICATION KITS (CS)	162-0000-00	INSULATION SLEEVING (PLAIN)
050-0000-00	PARTS REPLACEMENT KITS (CS)	162-0500-00	INSULATION SLEEVING (HI TEMP, HT SHRINK, ETC.)
061-0000-00	SPECIAL PRINTED ITEMS	166-0000-00	TUBES, SLEEVES, & FERRULES (MECH)
062-0000-00	SPECIAL PRINTED ITEMS, DATA SHEETS	175-0000-00 to	
065-0000-00	CMS CARTON PACKAGES	175-0499-00 and	
067-0000-00	CALIBRATION FIXTURES	175-1000-00 up	CABLES (BULK & PROCESSED)
070-0000-00	MANUAL, TECHNICAL	175-0500-00	WIRE & LEADS (INSULATED)
101-0000-00	TRIM (SEE ALSO 124- & 107-)	176-0000-00	WIRE & LEADS (BARE)
102-0000-00	REDUCERS	177-0000-00	WIRE, ELECTRICAL: BULK (COLOR CODED)
103-0000-00	ADAPTERS	179-0000-00	WIRING HARNESS
105-0000-00	CATCH, LATCH, LOCK, STOP, DRUM, ETC.	195-0000-00	LEADS (FORMED, SETS, SPL PATTERNS, ETC.)
106-0000-00	RECTIFIERS (SELENIUM)	200-0000-00	COVERS, CAPS, BEZELS, CABLE NIPPLES, DOORS, ETC.
107-0000-00	NONMETALLIC SHEETS (PAPER, FELT, LINOLEUM, PLASTIC, ETC.; NOT BULK, SEE 252-0500-00)	201-0000-00	CUPS
108-0000-00	COILS (FIXED)	202-0000-00	CANS, BOXES, CASES, ETC.
114-0000-00	COILS (VARIABLE)	204-0000-00	BODY, BODY HALF, & SUBSTRATE
118-0000-00	REPLACEMENT PARTS FOR IDD PURCH. ASSYS.	205-0000-00	SHELLS & SHELL HALVES
119-0000-00	MISC ELEC COMP (DELAY LINE, FILTER, CHOPPER, OSCILLATOR, POWER SUPPLY, ETC.)	206-0000-00	NOSES & TIPS (PROBES)
120-0000-00	TRANSFORMERS (FIXED & VARIABLE)	210-0000-00	LOCK WASHERS
122-0000-00	ANGLES & RAILS (STRUCTURAL--SEE ALSO 426-)	210-0200-00	LUG TERMINALS
122-0500-00	PHOTO & OPTIC COMPONENTS (CAMERA)	210-0400-00	NUTS
123-0000-00	TERMINAL STRIP, CERAMIC (TURRET)	210-0600-00	EYELETS & RIVETS
124-0000-00	STRIPS (CERAMIC TERMINAL, PAPER, FELT, TRIM, METAL, RUBBER, ATTENUATOR, ETC.)	210-0800-00	WASHERS (NOT LOCK TYPE)
129-0000-00	POSTS (ELEC & MECH)	211-0500-00	SCREWS (6-32)
131-0000-00	CONNECTORS, CONTACTS, TERMINALS, HEADERS, ETC. (SEE ALSO 134- & 136-)	212-0000-00	SCREWS (8-32)
132-0000-00	GR CONNECTORS & PARTS	212-0500-00	SCREWS (10-24, 10-32, 12-24, & 12-32)
		213-0000-00	SCREWS (ABOVE 12-32, & TAPING, SETSCREWS, ETC.)
		214-0000-00	MISC HARDWARE
		220-0400-00	NUTS
		251-0000-00	ALUMINUM (BULK MTL: EXTRUSIONS, SHEETS, ETC.)

TEK PART NUMBER SYSTEM (CONT)

NUMERICAL (CONT)

CATEGORY	TYPE OF PARTS	CATEGORY	TYPE OF PARTS
0300-00	BRASS, COPPER, BRONZE (BULK MATL: SEE 358-0300-00)	321-0000-00	RESISTORS (FIXED MET FILM - 0.125W, 1% & LESS, STD RES VALUES)
0500-00	STEEL, TIN, SOLDER, SST ETC. (BULK MATL)	321-0600-00	RESISTORS (FIXED MET FILM - 0.125W, 1% & LESS, SPECIAL VALUES)
251-1000-00	ALUMINUM (BULK MATL: EXTRUSIONS, SHEETS, FOIL, ROD, TUBE, ETC.)	321-1000-00	RESISTORS (FIXED MET FILM - 0.125W, 1% & LESS, STD RES VALUES)
252-0000-00	VARNISH, PAINT, ETC.	322-0000-00	RESISTORS (FIXED MET FILM - 0.25W, 1% & LESS, STD RES VALUES)
252-0500-00	NONMETALLIC SHEETS (BULK: PAPER, FELT, LINOLEUM, RUBBER, FIBER--SEE 107-)	322-0600-00	RESISTORS (FIXED MET FILM - 0.25W, 1% & LESS, SPECIAL VALUES)
253-0000-00	LACING CORD, TAPE, THREAD, LIGHT CONDUCTOR, ETC. (BULK)	322-1000-00	RESISTORS (FIXED MET FILM - 0.25W, 1% & LESS, STD RES VALUES)
254-0500-00	PLASTIC SHEETS & STRIPS (BAKELITE, EPOXY, FORMICA, COPPER CLAD, GLASS LAM, ETC.--(BULK))	323-0000-00	RESISTORS (FIXED MET FILM - 0.5W, 1% & LESS, STD RES VALUES)
254-0900-00 to 255-0000-00	PLASTIC ROD, SHEET & STRIP (PLAIN), FILM, MOLDING MATERIAL, ETC. (ALL BULK)	323-0600-00	RESISTORS (FIXED MET FILM - 0.5W, 1% & LESS, SPECIAL VALUES)
256-0000-00	CERAMIC BULK MATERIAL	323-1000-00	RESISTORS (FIXED MET FILM - 0.5W, 1% & LESS, STD RES VALUES)
257-0000-00	PRECIOUS METALS	324-0000-00	RESISTORS (FIXED MET FILM - 1.0W, 1% & LESS, STD RES VALUES)
258-0300-00	BRASS, COPPER, BRONZE (BULK MATL: SEE 251-0300-00)	324-0600-00	RESISTORS (FIXED MET FILM - 1.0W, 1% & LESS, SPECIAL VALUES)
260-0000-00	SWITCHES (PURCHASED)	324-1000-00	RESISTORS (FIXED MET FILM - 1.0W, 1% & LESS, STD RES VALUES)
262-0000-00	WIRED SWITCHES	325-0000-00	RESISTORS (FIXED MET FILM - MISC NOT FITTING IN 321-THRU 324- CATEGORIES)
263-0000-00	WIRED ROTARY SWITCHES, TURRETS (SEE 262-)	331-0000-00	DIALS, GRATICULES, SCALES, WINDOW, MASK (GRAT) ETC.
263-0500-00	SWITCH WAFER SECTIONS	333-0000-00	PANELS (ETCHED & ANODIZED - FRONT, REAR, ETC.)
263-1000-00	CAM SWITCH ACTIVATOR ASSY	334-0000-00	IDENTIFICATION ITEMS (PLATES, LABELS, ETC.)
276-0000-00	FORMS (COILS, TRANSFORMERS, DELAY IN, ETC.)	337-0000-00	SHIELDS (ELEC & MECH - SEE ALSO 200-)
276-0500-00	CORES (COILS, TRANSFORMERS, FERRITE, ETC.)	341-0000-00	VALVE & BLADDER (CANCELED - USE 214-)
281-0000-00	CAPACITORS (VARIABLE)	342-0000-00	INSULATORS
281-0500-00	CAPACITORS (FIXED CERAMIC)	343-0000-00	CLAMPS & RETAINERS
283-0000-00	CAPACITORS (FIXED CERAMIC DISC TYPE)	344-0000-00	CLIPS, TIE STRIP, TIE PLATE, ETC.
283-0500-00	CAPACITORS (FIXED MICA)	346-0000-00	STRAPS
283-0000-00	CAPACITORS (FIXED GLASS & PORCELAIN)	348-0000-00	CUSHION, FOOT, GROMMET, GASKET, RESIL MT, FLIP-STAND, ETC.
285-0500-00	CAPACITORS (FIXED PAPER & PLASTIC) (INCLUDES TUBULAR TEKMADE)	351-0000-00	GUIDES & SLIDES (INCLUDING CHASSIS TRACK TYPE)
290-0000-00	CAPACITORS (FIXED ELECTROLYTIC)	352-0000-00	HOLDERS
291-0000-00	CAPACITORS (FIXED PLASTIC - TEKMADE IN OVAL CAN)	354-0000-00	RING (INCL RING, KNOB SKIRT & RING, TRIM)
291-0200-00	CAPACITOR WINDINGS (TEKMADE)	355-0000-00	STUDS
295-0000-00	CAPACITORS (MATCHED, SELECTED, SETS, ETC.)	355-0500-00	STEMS
301-0000-00	RESISTORS (FIXED COMP - 0.5W, 5%)	358-0000-00	BUSHINGS
302-0000-00	RESISTORS (FIXED COMP - 0.5W, 10%)	361-0000-00	SPACERS & SHIMS
303-0000-00	RESISTORS (FIXED COMP - 1.0W, 5%)	366-0000-00 and 366-1000-00	KNOBS, PUSHBUTTONS, & KNOB SHELLS
304-0000-00	RESISTORS (FIXED COMP - 1.0W, 10%)	366-0500-00	KNOB-DIAL ASSY (ASSY OF 331- & 366-)
305-0000-00	RESISTORS (FIXED COMP - 2.0W, 5%)	367-0000-00	HANDLES, GRIPS, PIVOT ARMS, ETC.
306-0000-00	RESISTORS (FIXED COMP - 2.0W, 10%)	369-0000-00	IMPELLERS
307-0000-00	RESISTORS (FIXED SPECIALS)	376-0000-00	COUPLINGS
307-1000-00	RESISTORS (ATTENUATOR STRIPS)	377-0000-00	INSERT, (KNOB, SCREW THD, ETC.)
308-0000-00	RESISTORS (FIXED WIRE WOUND)	378-0000-00	FILTERS (AIR)
309-0000-00	RESISTORS (FIXED CARBON FILM - 0.5W)	378-0500-00	FILTERS (LIGHT & CRT MESH), & REFLECTOR (LIGHT)
310-0000-00	RESISTORS (FIXED CARBON FILM - 1.0W)	378-0750-00	SCREENS, GRILLES, & BAFFLES (AIR)
310-0500-00	RESISTORS (FIXED CARBON FILM - ABOVE 1.0W)	380-0000-00	HOUSINGS
311-0000-00	RESISTORS (VARIABLE)	381-0000-00	BARS (COMPONENT - USE 251- & 258- FOR BULK)
312-0000-00	RESISTORS (VARIABLE - SELECTED FROM 311-RES)	384-0000-00	EXTENSION SHAFTS
312-0100-00	RESISTOR-KNOB, MATCHED	384-0500-00	SHAFTS & RODS (NOT EXTENSION OR SPACING)
312-0500-00	RESISTORS (FIXED - MATCHED, SELECTED, SETS, ETC. AT TEK)	385-0000-00	RODS (SPACING: THREADED ENDS)
314-0000-00	RESISTORS (FIXED HV - SEE 307-)	386-0000-00 to 387-0000-00	SUBPANELS, REAR PANELS, PLATES, SUPPORTS, STIFFENERS, LIGHT CONDUCTORS (NOT BULK) ETC.
315-0000-00	RESISTORS (FIXED COMP - 0.25W, 5%)		
316-0000-00	RESISTORS (FIXED COMP - 0.25W, 10%)		
317-0000-00	RESISTORS (FIXED COMP - 0.125W, 5%)		
318-0000-00	RESISTORS (FIXED CARBON FILM - 0.125W, 1%)		
319-0000-00	RESISTORS (FIXED CARBON FILM - 0.25W, BELOW 5%)		

TEK PART NUMBER SYSTEM (CONT)

NUMERICAL (CONT)

CATEGORY	TYPE OF PARTS	CATEGORY	TYPE OF PARTS
388-0000-00	NOT ASSIGNED	436-0000-00	STORAGE ITEMS (DRAWER, TRAY, SHELF, ETC.)
388-0500-00	CIRCUIT BOARDS & CARDS (UNWIRED)	437-0000-00	CABINETS & CABINET SUBASSEMBLIES
390-0000-00	CABINET PARTS (BOTTOM, TOP, SIDE, WRAPAROUND, ETC.)	439-0000-00	CRT MATERIALS
391-0000-00	BLOCK	440-0000-00	CRT ASSEMBLIES
392-0000-00	BOARD & TERMINAL BOARD	441-0000-00	CHASSIS
401-0000-00	ROTATING DEVICES (WHEELS, CASTERS, BEARINGS, CAMS, PULLEYS, HUBS, ETC.)	670-0000-00	CIRCUIT BOARD (WIRED 388-)
406-0000-00 to		672-0000-00	CIRCUIT BOARD (2 OR MORE 670-)
407-0000-00	BRACKETS	673-0000-00	CIRCUIT BOARD SUBASSEMBLIES
426-0000-00	FRAMES, FRAME SECTIONS, & FRAME-PANELS	675-0000-00	CIRCUIT BOARD ASSEMBLIES
432-0000-00	BASES	700-0000-00	CIRCUIT BOARD ASSEMBLIES

GLOSSARY OF COMMONLY USED ELECTRONIC TERMS

ABERRATION Distortion caused by non-linear reproduction of an input signal.

A.C. Alternating current. Sometimes abbreviated ac or a-c.

ac The dynamic or changing condition of a circuit. Also the abbreviation for alternating current.

ac COUPLING A method of transferring a signal from one stage of a circuit to another without passing direct current (see D.C.). This may be accomplished by means of a capacitor in series with the signal path, or by use of a transformer.

ac DIVIDER Series connected capacitors used to cause the same voltage division for ac signals as resistances cause for D.C. levels.

ac GROUND Any point in the circuit where the circuit signal will not cause a change in the D.C. level.

ac VALUE Those values of current, voltage, or power which are continuously changing, or are instantaneous values.

ACTIVE DEVICE A device which has gain (amplification).

ALPHA (Symbol α) The ratio of collector current to emitter current in a transistor. $\alpha = I_c / I_e$

ALTERNATING CURRENT Abbreviated A.C., ac, or a-c. An electric current which is continually varying in value and reversing its direction of flow at regular intervals, usually in a sinusoidal manner. Each repetition, from a mean value to a maximum in one direction, back through the mean to a maximum in the other direction, and back to the mean again, is called a cycle. The number of cycles occurring in one second is called the frequency and is measured in hertz (Hz) or cycles per second (cps or c/s). The average value of an alternating current is zero.

AMBIENT Surrounding.

AMPERE The unit of measure for electric current. A current of one ampere is the movement of 6.28×10^{18} electrons (one coulomb of charge) past a given point in one second, and can be expressed as one coul/sec.

AMPLIFIER A device using an electron tube, transistor, magnetic unit, or other amplification-producing component to increase the strength

AMPLIFIER (cont'd) of a signal without appreciably altering its characteristic waveform. An amplifier transfers power to the signal from an external source, whereas a transformer changes signal voltage or current without adding power.

AMPLITUDE The amount of change at a given point in a circuit, measured with respect to a reference point. The change may be positive and/or negative with respect to the reference.

ANALOG The condition wherein the output of a device or circuit is continuously proportional to the input.

ANODE The positive element in a semiconductor or electron tube. It attracts and receives electrons from the negative element(s).

ASTABLE MULTI A type of amplifier circuit using two active devices wherein the output of each device is ac coupled to the input of the other device. The output waveform is repetitive.

ATTENUATE To reduce in amplitude.

BANDPASS The band of frequencies that exists between the lower and upper limits of an amplifier. The 3db attenuation level is a common reference limit. For our considerations the lower limit is usually D.C., so the bandpass is considered to be from D.C. to some frequency limit.

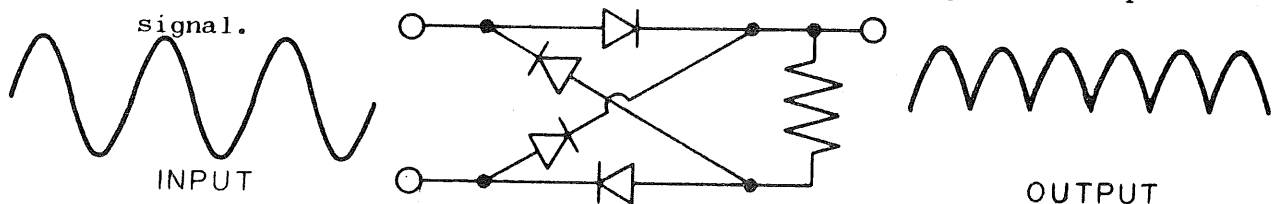
BASE The current controlling element of a transistor. Equivalent in function to the grid of a triode electron tube.

BETA (Symbol β) The forward current transfer ratio of a transistor.
$$\beta = I_c / I_b$$

BIAS The voltage difference between the two elements of an active device, which determines the conduction of the device.

BISTABLE MULTI A type of multivibrator circuit which will remain in one of two stable states until a trigger pulse is applied to make the circuit switch to the other stable state

BRIDGE RECTIFIER A voltage rectifier circuit composed of four diodes connected in such a manner that full wave rectification results. The output ripple frequency is double the frequency of the input signal.



BY-PASS The process of shunting a signal around an element or group of elements in a circuit. As an example, a capacitor placed in a circuit around a resistor will provide a very low opposition to ac current flow.

CAPACITANCE The ability of any two conductors separated by an insulator to have an electrostatic field between them. The basic unit of capacitance is the farad.

CAPACITOR (Symbol C) A device consisting essentially of two conducting surfaces separated by a dielectric material such as air, paper, mica, ceramic, glass, or Mylar. A capacitor stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on its frequency and the capacitance of the device. Also called condenser (deprecated).

CASCADE A method of connecting amplifier stages in series with each other. The output of one stage is connected to the next input.

CASCODE A common emitter input stage driving a common base output stage. This configuration improves the high frequency response.

CATHODE The negative element in a semiconductor or electron tube. In a vacuum tube the cathode is heated until it throws off electrons, much like a light bulb filament is heated and throws off light (see THERMIONIC EMISSION). When the "emitted" electrons are focused into a ray, we have a cathode ray, or electron beam.

CATHODE RAY TUBE (CRT) A vacuum tube with a heated cathode that provides an electron beam and a phosphor "target" or screen. The electron beam hits the phosphor which then radiates light. Used in oscilloscopes, television receivers, and radar.

CHARGE The electrical energy stored in a capacitor or battery.

CIRCUIT A complete path of conductors, resistors, tubes, etc. through which electrons may flow. A complete circuit may be described as one in which an electron at any point may leave that point, pass through every other element in the circuit, and return to its origin. An analogy in nature would be the cycle of water droplets from the forest to the river to the sea, thence in the form of vapor to the clouds from which to fall as rain once again to the forest.

CLAMP A circuit designed to hold the voltage or current at a fixed

CLAMP (cont'd) positive or negative level.

COLLECTOR An element of a bi-polar transistor through which the current flows which is passed through the emitter by the base. Equivalent in function to the plate of a triode electron tube. The current may be found by multiplying the base current by the beta (β) for the transistor.

COMMON BASE A transistor amplifier in which the base element is common to both the input and output circuits.

COMMON COLLECTOR A transistor amplifier in which the collector element is common to both the input and output circuits. Also known as an emitter follower.

COMMON DRAIN An FET (field effect transistor) amplifier in which the drain element is common to both the input and output circuits. Also known as a source follower.

COMMON EMITTER A transistor amplifier in which the emitter is common to both the input and output circuits.

COMMON GATE An FET (field effect transistor) amplifier in which the gate is common to both the input and output circuits.

COMMON SOURCE An FET (field effect transistor) amplifier in which the source is common to both the input and output circuits.

COLOR CODE A system of colored markings used for the identification of values and other operational parameters on electronic components.

The standard code is:

Black.....0	Yellow.....4	Gray.....8
Brown.....1	Green.....5	White.....9
Red.....2	Blue.....6	Gold.....5% tolerance
Orange.....3	Violet.....7	Silver.....10% tolerance

COMPARATOR An application of an emitter coupled amplifier that is used to compare D.C. levels or signals or both and to provide an output signal that indicates the relationship of the compared inputs.

COMPENSATION The placing of reactance in a circuit to offset a condition that is inherent in the circuit.

CONDUCTANCE The ability of a conductor to allow the movement of electrons. Equivalent to the reciprocal of resistance, and measured in mhos (mho is ohm spelled backwards).

CONDUCTOR Any material that will allow free movement of electrons.

CURRENT A term that describes what electricity is thought to be-- a flow (or current) of electrons. Similarly water current is a flow of drops of water. Alternating current flows first one way, then back the other. Direct current flows in one direction only.

CYCLE One complete excursion of voltage or current from a reference level to a more positive level, back through the reference level to a more negative level, and back to the reference level. (see ALTERNATING CURRENT)

D.C. Direct current, a movement of electrons in one direction only.

D.C. COUPLING A method of coupling one stage of a circuit to the next stage. In effect, it is simply the absence of any ac coupling elements in the signal path.

D.C. VALUES Those values of current, voltage, or power which are usually considered as being at a given amplitude for an extended period of time. These are called static condition values. They are represented by upper case letters (E, I, and P).

DEFLECTION The movement up or down or from side to side of an electron beam in a CRT. (From deflect, to turn aside)

DELAY LINE We often want to see the signals that "trigger" the "sweep" across a CRT. We will have to delay the signal until the sweep gets started. For this we use a delay line. All it is is a big long electronic detour that gives the sweep a chance to get moving.

DIFFERENCE AMPLIFIER A type of emitter coupled amplifier where the output is a function of the difference between the signals applied at the input terminals.

DIELECTRIC The insulating material that separates the plates of a capacitor.

DIODE An electronic component that normally passes current in only one direction. Often used as rectifiers. It has only two elements, the cathode and the anode.

DISCHARGE The return of a capacitor from a charged condition to a neutral condition wherein both plates have equal numbers of electrons.

DRAIN The element of a field effect transistor which is equivalent to the collector of a normal bi-polar transistor or the plate of a triode electron tube.

DYNAMIC The signal condition of a circuit. The conditions that result due to the changing levels of i, e, and p.

E_{out} The quiescent level of a D.C. voltage with respect to ground.

e_{out} Signal voltage of an output.

e_{in} Signal voltage of an input.

ELECTRON The smallest practical quantity of electricity, just as a water droplet might be considered the smallest practical quantity of water. An electron possesses a negative charge of 1.59×10^{-19} coulomb.

ELECTRON BEAM The result of electrostatically or electromagnetically focussing the electrons emitted from a heated cathode. Analogous to the focussing of light into a beam by a spotlight. Light beams and electron beams are often called rays. (see CATHODE RAY TUBE, THERMIONIC EMISSION)

ELECTROSTATIC FIELD The force that exists between bodies when a difference in charge exists between them. This is the field that exists across a charged capacitor.

E.M.F. Electromotive force or the potential that is present at the terminals of any type generator. This force is measured in volts.

EMITTER The element of a bi-polar transistor that provides the major source of current. Equivalent to the cathode of a triode electron tube in function, but not heated.

EQUATION A mathematical expression wherein the value on the left side of a symbol of equality has the same value as the expression on the right side of the equality sign. Ohm's law is an example: $E=IR$

EQUIVALENT CIRCUIT An arrangement of common circuit elements with electrical characteristics, equivalent to those of a more complicated circuit or device.

EXPONENT A number showing how many times a base number is to be multiplied by itself. Example: 2^4 , where 4 is the exponent.

FEEDBACK A configuration in which a portion of the output signal is returned to the input to aid or oppose the input signal.

FEEDBACK AMPLIFIER A type of amplifier in which feedback is employed. The feedback opposes the input signal and normally improves the stability of the amplifier.

F.E.T. Field effect transistor.

FILTER A selective network of resistors, inductors, and/or capacitors which offers comparatively little opposition to alternating current at certain frequencies while blocking or attenuating other frequencies.

FREQUENCY The number of cycles that occur in a unit of time, usually one second. The letter *f* is used to designate frequency.

FULL WAVE RECTIFIER A rectifier that has an output voltage for every half cycle of input voltage. The output ripple frequency is double the input frequency. (see **BRIDGE RECTIFIER**)

GAIN The amount of amplification that occurs in any amplifying circuit. This may apply to voltage, current, or power. Gain is designated by the letter *A*.

GATE The control element of a field effect transistor. Equivalent in function to the base of a bi-polar transistor.

GENERATOR Any device that will produce a potential difference which causes a movement of electrons.

gm A ratio of output current to input voltage.

GRAPH A pictorial representation of the relationship between two or more variables.

GRID An element used to control current flow from the anode of an electron tube to its cathode. It can control a lot of current, but requires very little power to operate. Much like a water valve.

MEGA- or MEG- The prefix used to represent 1,000,000 or 10^6 times the basic unit of measure with which it is used. For instance, when used with the root word "ohm" in "megohm" it means one million ohms, and can be written 1,000,000 ohms, 1M ohm, or 1×10^6 ohms.

MHO The unit of measure of conductance. (see **CONDUCTANCE**)

MICRO- The prefix used to represent 1/1,000,000, .000001, or 10^{-6} times the basic unit of measure with which it is used. For instance, when used with the root word "farad" in "microfarad" it means one one-millionth of a farad, and can be written $1 \mu\text{F}$, .000001 farad, or 1×10^{-6} farad.

MILLER EFFECT The effective change in the input capacitance of an active device when it is amplifying a signal.

MILLI- The prefix used to represent 1/1,000 or .001 or 10^{-3} times the basic unit of measure with which it is used. For instance,

MILLI- (cont'd) when used with the root word "ampere" in "milliamperere" it means one one-thousandth of an ampere, and may be written .001 A, 1 mA, or 1×10^{-3} A.

MONOSTABLE MULTIVIBRATOR A type of multivibrator that has one stable state. An output pulse occurs only when the circuit is properly triggered. The time duration of the output pulse is determined by a resistive-capacitive (RC) network.

MULTIVIBRATOR A type of circuit used to produce a non-sinusoidal output waveform. This output may be repetitive or may occur only after the proper trigger has been applied to the circuit.

MUTUAL INDUCTANCE A condition where the electrical energy from one coil is transferred to another coil by means of the moving magnetic field produced around the first coil.

NANO- The prefix used to designate $1/1,000,000,000$ or 10^{-9} times the basic unit of measure with which it is used. For instance, when used with the root word "second" in "nanosecond" it means one billionth of a second, and may be written .000000001 sec, 1 nanosec, or 1×10^{-9} sec.

NEGATIVE FEEDBACK Also called degeneration or degenerative feedback. A process in which a portion of the output signal of an amplifier is fed back with the proper phase relationship to oppose the input signal, reducing amplification and improving stability.

NEGATIVE POTENTIAL A voltage with its positive terminal at the common reference point. The negative terminal is a source of electrons to an external circuit. This is designated with a minus sign (-) preceding the voltage amplitude. Example: -150 v.

N-CHANNEL (F.E.T.) A unipolar semiconductor device having a source-drain channel of N-type material, and a gate of P-type material.

N-TYPE MATERIAL Semiconductor material doped with elements that cause a surplus of electrons which are the major source of current in the material.

NPN (TRANSISTOR) A bi-polar semiconductor device with emitter and collector of N-type material, and a base of P-type material.

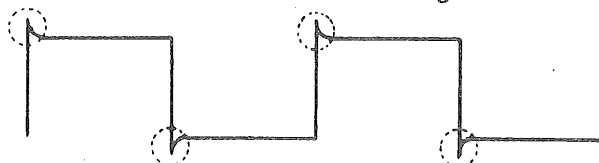
OHM The unit of measurement for the opposition to electron movement (resistance) in a circuit. (see RESISTANCE)

OHM'S LAW The relationship that exists among the voltage, current, and

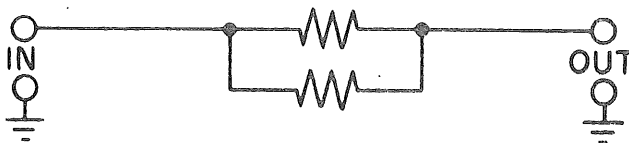
OHM'S LAW (cont'd) resistance characteristics of a circuit, as expressed in the general equation $E=IR$ (also $I=E/R$ and $R=E/I$), where E represents voltage, I current, and R resistance.

OSCILLOSCOPE An electronic instrument that uses a cathode ray tube (CRT) to display the electrical phenomena of a circuit or device. Any type of physical measurement that can be changed to an electric current by a suitable transducer may be displayed. Generally, the vertical displacement indicates the amplitude of the signal and the horizontal displacement indicates the amount of time represented.

OVERSHOOT A condition wherein the leading edge of a pulse rises to a higher level than the desired or average level of the waveform.



PARALLEL A circuit that has at least two paths for the current to flow. The resistors in this circuit provide a parallel path for current flow.



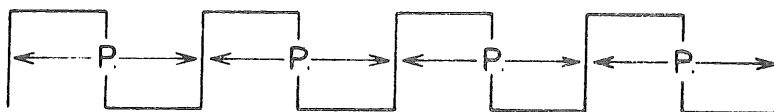
PARAMETER A variable circuit condition which can be held constant while the effects of an independent variable can be observed on a dependent variable.

PARAPHASE AMPLIFIER A configuration of an emitter couples amplifier that has an input signal applied to one base and the output signal taken from both collectors. The collector signals are 180° out of phase with each other.

PEAK The highest instantaneous value of a waveform. This peak may be in either the positive or negative direction from a reference level.

PEAK-TO-PEAK The amplitude of a waveform measured from the maximum positive to the maximum negative value.

PERIOD The time required for a repetitive waveform to make one complete cycle. (see CYCLE, ALTERNATING CURRENT)

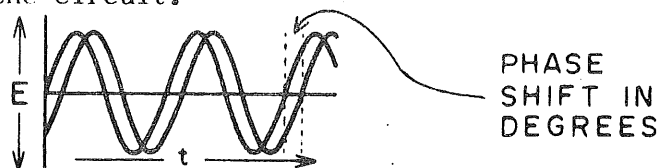


P-CHANNEL (F.E.T.) A unipolar semiconductor device having a source-

P-CHANNEL (F.E.T.) (cont'd) drain channel of P-type material and a gate of N-type material.

PHASE The angular relationship of a periodic quantity to a common reference point. The fractional part of a cycle, or the number of electrical degrees through which the quantity has progressed from an arbitrary zero.

PHASE SHIFT This may also be referred to as phase difference. It is the angular difference between two periodic quantities in a circuit. The shift is caused by a reactive component in the circuit. The phase angle is dependent upon the relative value of reactance and resistance in the circuit.



PI (Symbol π) The ratio of the circumference of a circle to the diameter of that circle. Numerically, it is approximately 3.1416.

PICO- The prefix used to represent .000000000001 or 10^{-12} times the basic unit of measure with which it is being used. For instance, when used with the root word "farad" in "picofard" it means one millionth of one millionth of a farad, and can be written 1 pF, .000000000001 F, or 1×10^{-12} F.

PNP (TRANSISTOR) A bi-polar semiconductor device with emitter and collector of P-type material and a base of N-type material.

P-TYPE MATERIAL Semiconductor material which has been doped with elements that cause a deficiency of electrons. "Holes" or areas with the ability to accept electrons are the major source of current in the device.

POLARITY The relative indicated condition of a signal or voltage. The signal may be negative (-) or positive (+) with respect to a reference.

POSITIVE POTENTIAL A voltage with its negative terminal at the common reference point. The positive terminal is a place showing a lack of or deficiency of electrons, to an external circuit. Designated by a plus (+) sign before the voltage amplitude. Example: +100 v.

POWER (ELECTRICAL) The amount of electrical energy expended in a circuit in a unit period of time. Power is designated by the letter P,

POWER (ELECTRICAL) (cont'd) and the unit of value is the watt. Formulae for power are: $P=I^2R$, and $P=E^2/R$.

POWER SUPPLY That part of electronic equipment that provides the AC and DC voltages necessary for the operation of that equipment. This may be a simple battery or it may be a transformer with rectification, filtering, and regulation.

PREFIXES Units of measure are often very large or very small compared to what we want to measure. We use prefixes as a special kind of electronic "shorthand". Examples:

Kilo- represents a multiplication of the unit by 1,000:

25 kilowatts (KW) is 25,000 watts.

Micro- represents a division of the unit by 1,000,000:

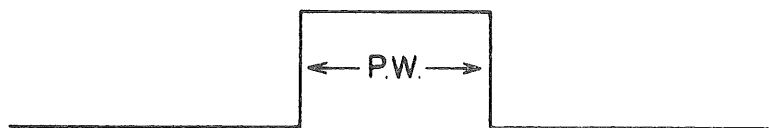
15 microamperes (μA) is 15 millionths of an ampere.

PRIMARY The input side of a transformer.

PROBE A kind of "signal extension cord." Usually a pen-shaped device with a contact at its tip that permits us to reach into confined areas within an instrument to feed a signal from that instrument into an oscilloscope.

PULSE An abrupt change in voltage or current, either positive or negative, which conveys information to a circuit.

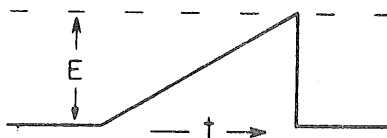
PULSE WIDTH The time interval between the points at which the instantaneous value on the leading and trailing edges bears a specified relationship to the peak pulse amplitude.



PUSH PULL A circuit having two like elements producing coincident but opposite phase signals. The output signals are algebraically additive.

QUIESCENCE The D.C. condition of a circuit. This may be referred to as a passive or static condition.

RAMP VOLTAGE A voltage that changes linearly with time. This waveform may also be referred to as a sawtooth voltage.



REACTANCE The opposition to electron movement that is offered by an inductor or capacitor to A.C. Reactance is measured in ohms and is designated by the letter X. Capacitive reactance is X_C and inductive reactance is X_L .

RECIPROCAL The inverse of a function or number. Unity divided by any number is the reciprocal of that number. Examples: The reciprocal of 5 is $1/5$ or .2; the reciprocal of $1/2$ is 2.

RECTIFIER A vacuum tube or semiconductor device that will allow current conduction in one direction only. When used in series with an A.C. source, the output will be pulsating D.C.

REPETITION FREQUENCY The number of complete cycles produced by a repetitive waveform in one second. Measured in cycles/second, or hertz. Also known as repetition rate.

RESISTANCE The property of conductors which depends upon their dimensions, temperature and material and which determines the amount of current which will be produced in them by a given difference of potential across them.

RESISTOR An electrical component specifically designed to resist current flow. Rated in ohms. The more ohms, the more resistance.

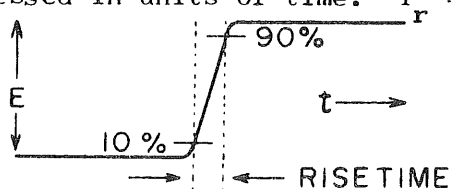
RESONANCE A circuit condition such that the capacitive reactance and the inductive reactance are equal.

RESONANT FREQUENCY The frequency at which resonance occurs in a capacitive and inductively reactive circuit.

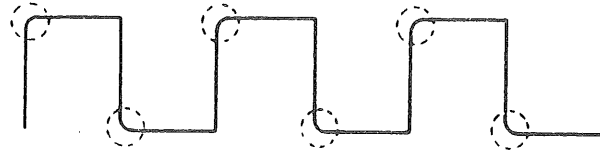
RIPPLE The alternating current component present in the output of a direct current generator, rectifier system, or power supply.

RMS VALUE This refers to the effective value of an A.C. voltage or current. The root-mean-square or rms value is 0.707 times the peak value. This effective value will have as much ability to perform work as the same level of D.C. Example: An alternating current has a peak value of 170 v. $0.707 \times 170 \text{ v} = 120 \text{ v}$. This A.C. at 170 v. peak value will do the same work as D.C. at 120 v.

RISE TIME (Symbol T_r) The time required for a transient signal to change its voltage level from 10% to 90% of its total amplitude. This value is expressed in units of time. $T_r = 2.2 RC$.



ROLL OFF The condition that occurs when the leading edge does not reach the desired D.C. level instantly. The amount of time during which this occurs is important in circuit considerations. The trailing edge may also roll off, and the time for this to occur is important.



SCHEMATIC A diagram or drawing of a circuit where symbols are used to represent the components that are actually used in the circuit.

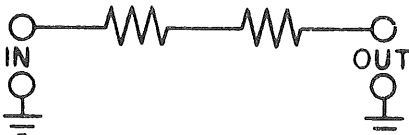
SECONDARY The output side of a transformer.



SECONDARY EMISSION Emission of electrons from an electrode due to bombardment by high energy electrons from another source.

SELF INDUCTANCE The induction that results in a coil as a result of the moving magnetic field created by the changing electron flow within the coil.

SERIES A circuit wherein the components are connected end to end to provide a single path for electron flow. The resistors in this circuit provide a series path for electron flow.



SEMICONDUCTOR A material with an electrical conductivity between that of a conductor and an insulator. This conductivity is generally very sensitive to the presence of impurities and is directly proportional to the temperature.

SIGNAL Changes in voltage or current amplitude with respect to time.

SINE WAVE The output of a typical A.C. generator or oscillator. This can be plotted graphically with amplitude versus the angular measurement. The result is a plot of the sine function of an angle, or a sine wave.

SOURCE An element of a field effect transistor (F.E.T.). Equivalent in function to the emitter of a bi-polar transistor.

SPEED-UP CAPACITOR A capacitor that by-passes a portion of a resistive network to facilitate the high frequency response of the network. Often used in multivibrators and other switching devices.

SQUARE (MATH) The result of multiplying any number by itself. Example: The square of eight, or eight squared, is $8 \times 8 = 8^2 = 64$.

SQUARE ROOT (of a number) The number which when multiplied by itself gives the original number. Example: the square root of 64 = $\sqrt{64} = 64^{1/2} = 8$.

STATIC CONDITION The D.C. condition, or a circuit condition that is not changing.

STEP INPUT VOLTAGE A voltage that changes from one D.C. level to another D.C. level instantaneously. This is a theoretical condition.

SWEEP A term describing the motion of a broom AND the motion of an electron beam. In this course it refers to the motion (from left to right) of the spot of light across the CRT face.

THERMAL Pertaining to heat or temperature.

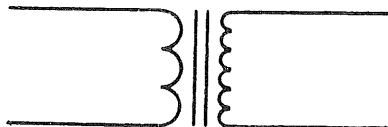
THERMAL COMPENSATION Techniques employed to nullify or minimize the changes in electronic circuit parameters due to temperature changes.

THERMIONIC EMISSION The emission of particles (such as electrons) from materials at high temperatures due to the heat imparted to them.

THERMISTOR A semiconductor device having a large variation in electrical resistance with respect to temperature changes. The temperature coefficient of the resistance is negative. As temperature increases, resistance decreases.

TIME CONSTANT One time constant in seconds is the product of resistance in ohms times capacitance in farads, or the quotient of inductance in henries divided by resistance in ohms. $T = RC$, or $T = L/R$. This is the time required for the circuit to change 63.5% of the total possible change for existing conditions.

TRANSFORMER An electrical device that transfers electrical energy by means of magnetic fields. It uses two or more coils to change voltage levels or to electrically isolate circuits.



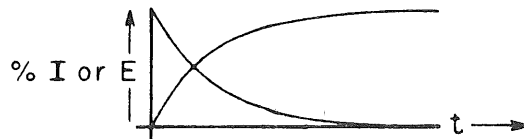
TRANSIENT A momentary change in voltage in a circuit that is non-sinusoidal in nature. It lasts an extremely short period of time. It usually results when the operation of the circuit adjusts to changed loading conditions.

TRANSISTOR An active semiconductor device normally having three terminals. The two basic types of transistors are bi-polar and field effect.

TUNED CIRCUIT A circuit consisting of inductance and capacitance which can be adjusted for desired response at a specified frequency.

UNIT The basic accepted measurement for any quantity. The ohm, farad, volt, watt, ampere, henry, second, mho, and cycle are the most common units of measure encountered in electronics.

UNIVERSAL TIME CONSTANT CURVES A set of exponential curves where the percentage of change of a current or voltage is plotted against the RC time constant. The percentage values are on the vertical or Y axis, and the RC time is on the horizontal or X axis.



VIRTUAL GROUND A point in electronic circuitry that does not change voltage when a signal is applied to the circuit. Although this point is not an actual ground connection, it behaves in a similar manner. Examples would include regulated power supplies, emitters of grounded base amplifiers, and input terminals to certain types of feedback amplifiers.

VOLT The unit of measure for the potential difference of the electromotive force that exists as the result of some type of generator action. A flashlight cell will measure about 1.5 v, a car battery about 12 v, and a household wall outlet about 120 v.

V_{BB} The base return supply voltage for a bi-polar transistor.

V_{BE} The voltage measured from base to emitter for a bi-polar transistor.

V_{CC} The collector return supply voltage for a bi-polar transistor.

V_{CE} The quiescent voltage measured from the collector to emitter of a bi-polar transistor.

V_{DD} The drain return supply voltage for a field effect transistor.

V_{DS} The quiescent voltage measured from drain to source of a field effect transistor.

V_{EE} The emitter return supply voltage for a bi-polar transistor.

V_{GS} The quiescent voltage measured from gate to source of a field effect transistor.

V_{SS} The source return supply voltage for a field effect transistor.

VOLTAGE DROP The amount of voltage required to cause the current of a circuit to flow through a given resistance. In a series circuit the voltages across any resistance will vary directly with the value of the resistance. In a parallel circuit the voltage will be the same across each resistance.

WATT The basic unit of power measurement. One watt of electrical power is expended when a voltage of 1 volt causes a current flow of 1 ampere. The formulae: $P = EI$, $P = I^2R$, or $P = E^2/R$.

X AXIS The horizontal plane of a graph or CRT display. Also referred to as the abscissa.

X_C Symbol for the reactance of a capacitor.

X_L Symbol for the reactance of an inductor.

Y AXIS The vertical plane of a graph or CRT display. Also referred to as the ordinate.

Z The symbol for impedance.

Z AXIS The third dimensional plane of a graph extending outward 90° from both the X and Y axes. In the CRT display this dimension is represented by variations in intensity.