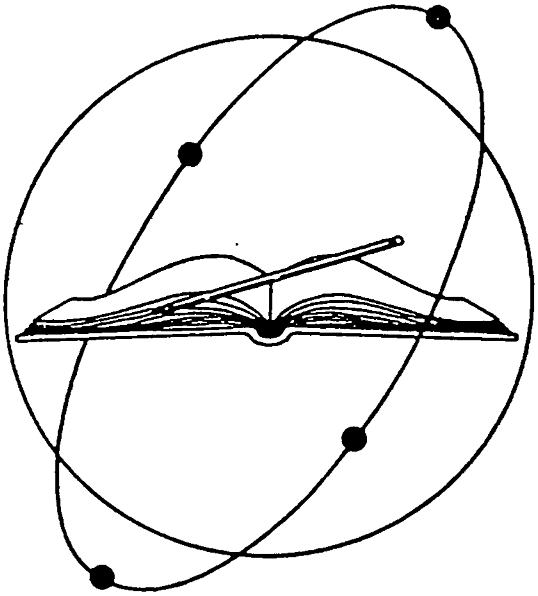
Part No. 46961

TECHNICAL
Information

CONTROLLING ELECTRICITY



Revison 1 (12/07/90)

Printed in U.S.A.

FORWARD

Electricity is a form of energy. Like any other form, it can be useful only when it is properly and precisely controlled. The "state of the art" today has advanced to a high level, where accurate control is achieved through a wide variety of devices. This manual discusses only those devices that are common to GENERAC systems.

Not all of the devices discussed in this book can be classified as strictly "controllers" of electricity. For example, the rotor and stator of a revolving field alternator might be more accurately classified as "producers" of electricity, although by nature of their construction and operation they do, to a large extent, "control" electricity.

Some of the controlling devices are transformers, resistors, condensors, rectifiers (or diodes), transistors and switches.

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Section 1 — ROTORS OR REVOLVING FIELDS

The rotor may be defined as a revolving magnetic field. Its lines of magnetic flux, moving across the stationary windings of a stator assembly, cause electromotive force (EMF) to be induced into those stationary windings.

ELECTROMAGNETIC INDUCTION

In 1831, scientists observed that a conductor moving across a magnetic field would have a voltage or electromotive force (EMF) induced into itself. Electromagnetic induction may be defined as the inducing of a voltage into a conductor that moves across a magnetic field. This principle is illustrated in Figure 1-1.

A straight wire conductor is moving across the magnetic field of a horseshoe magnet. If a sensitive voltmeter were attached to the ends of the wire conductor, a small voltage would be indicated as the wire moved across the magnetic field. However, if the wire conductor were moved parallel to the lines of magnetic force, no voltage would be indicated. The greater the strength of the magnetic field through which the wire conductor is moved, the greater the induced voltage in the conductor.

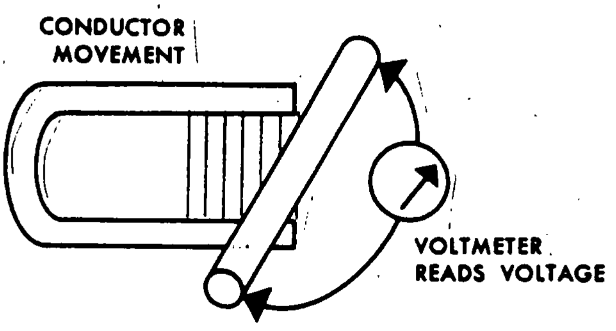


Figure 1-1 — Electromagnetic Induction

NOTE: The principles of electromagnetic induction are explained in greater detail in the manual *BASIC ELECTRICTY* (Manual Part No. 46941).

ELECTROMAGNETISM

In the previous paragraph, we explained that magnetic lines of force cutting across the stationary windings of the stator assembly would induce an EMF into those windings. Conversely, when a current flows through a wire conductor, this creates a magnetic field around that wire. The number of lines of magnetic force, or strength of the magnetic field, increases as the current is increased through the conductor.

When a current-carrying wire is wound into a number of loops to form a coil, the magnetic field created is the sum of all the single loop magnetic fields added together. With lines of magnetic force entering the coil at one end and leaving at the other end, a north and south pole are formed at the coil ends as in a bar magnet (Figure 1-2).

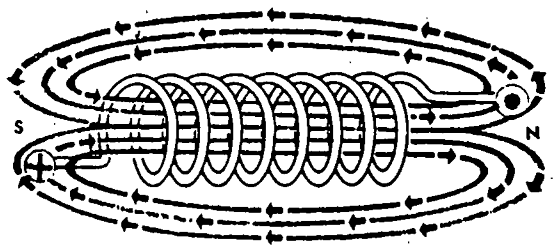


Figure 1-2 — Magnet Field Around Coil of Wire

If the coil is wound around a core of magnetic material, such as iron, the strength of the magnetic field at the north and south poles is greatly increased (Figure 1-3). This happens because air a poor conductor of magnetic lines and iron is a very good conductor. Using iron in a magnetic path may increase the magnetic strength of a coil by 2500 times over that of air.

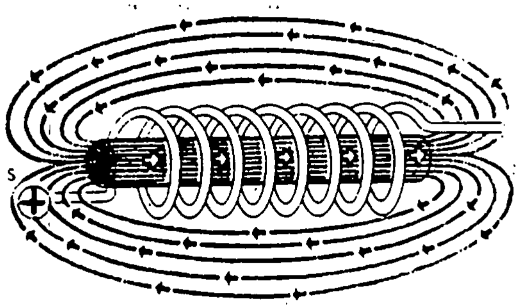


Figure 1-3 — Iron Core Increases Strength of Field

The strength of the magnetic poles in a coil of wire is directly proportional to (a) the number of turns of wire, and (b) the current in amperes flowing through the wire (Figure 1-4 on Page 3). A coil with a current of one ampere flowing through 1000 turns of wire and another coil having 10 amperes through 100 coils of wire will each create a magnetic field strength of 1000 ampere-turns. The term "ampere-turns" is a measure of the strength of the magnetic field.

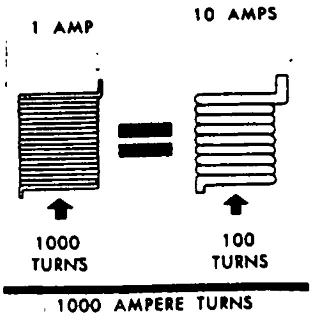


Figure 1-4 — Example of "Ampere-Turns"

THE ROTOR AND ELECTROMAGNETISM

A simple rotor may be a rotating permanent magnet having no electrical current flow. In practice, most rotors are a rotating electromagnet with a direct current flowing through its coiled wires. Concerning electromagnetism, these statements can be made:

- The strength of the magnetic field is directly proportional to the number of turns of wire in the rotor.
- The strength of the magnetic field is directly proportional to the current (in amperes) flowing through the rotor windings.

From these statements we can deduce that the strength of the rotor's magnetic field may be increased by (a) increasing the numbe of turns of wire in the Rotor, and (b) increasing the current flow (in amperes) through the rotor windings.

A TYPICAL ROTOR

NOTE: The operation of a rotor assembly in a revolving field alternator is more thoroughly covered in the manual *BASIC ELECTRICITY* (Part No. 46941) in Section 5.

Two-Pole Rotors: A 2-pole rotor has a single north and a single south magnetic pole. One revolution of the 2-pole rotor creates a single cycle of alternating current flow in the stator windings. To determine the rotor speed required for a given a-c frequency, use the following formula:

RPM = DESIRED FREQUENCY times 60

EXAMPLE: A alternator with a 2-pole rotor must produce the European standard of 50 Hertz. To find the required driven speed of the rotor, multiply 50 times 60 to obtain 3000. The required driven speed of the rotor is 3000 rpm.

Four-Pole Rotors: A 4-pole rotor has two south and two north magnetic poles. These rotors provide the same a-c frequency as the 2-pole rotor, but at half the driven speed of the 2-pole rotor.

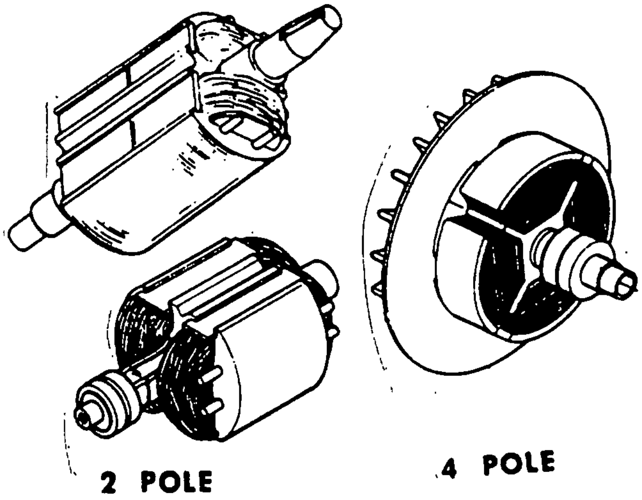


Figure 1-5 — Typical 2-Pole and 4-Pole Rotors

REVOLVING FIELD EXCITATION METHODS

Up to this point we have observed the following:

- The strength of the revolving magnetic field is directly proportional to the current flow (in amperes) through the field windings.
- The electromotive force, or voltage, induced into the stator windings is directly proportional to the strength of the revolving field.

With these observations in mind, it is then possible to regulate voltage induced into the stator windings by regulating current flow through the rotor windings. Several methods are available to accomplish such voltage regulation including the following:

- Direct excitation
- Reactor method
- Electronic voltage method

Each of these regulation methods is discussed in Section 5 of *BASIC ELECTRICITY* (Part No. 46941). A fourth method is called the **brushless excitation method.**

THE BRUSHLESS EXCITATION METHOD

This method of field excitation eliminates the need for brushes and slip rings, which are required when other excitation methods are used to permit the flow of excitation current from a stationary into a rotating member. The brushless excitation method employs (a) an **exciter field**, (b) an **exciter armature**, and (c) a **full wave rectifer** to excite the **alternator field.**

Figure 1-6 illustrates a typical brushless excitation unit. Figure 1-7 represents the unit schematically. The **exciter armature** (EA) is physically connected to the rotating **rotor** (AF), and rotates with the rotor along with the full-wave **rectifier**. The **exciter field** (EF) is stationary and acts to induce a regulated voltage into the **exciter armature** during alternator operation. System operation may be described as follows:

1. The rotor and exciter armature rotate at a pre-determined speed.
2. A voltage is induced into the stator windings by residual magnetism in the rotor.
3. The solid-state voltage regulator (VR) "senses" stator a-c output voltage and frequency, through sensing leads that attach to the stator a-c output leads.
4. Excitation winding (DPE) output is delivered to the voltage regulator. Based on the sensing voltage and frequency from the stator a-c output leads, the voltage regulator delivers a current flow through the windings of the exciter field.
5. A magnetic field is created around the exciter field windings that is proportional in strength to the current flow through its windings.
6. Exciter field magnetic lines of force induce a voltage and current flow into the exciter armature that is proportional to the strength of exciter field's magnetic field.
7. Exciter armature output current is rectified by six diodes (full wave rectification) and delivered to the alternator rotor.

As described in Steps 1 through 7 above, the voltage regulator acts to increase or decrease current flow to the alternator rotor based on the demands of the loads connected to the stator a-c output leads. It does this by regulating current flow through the exciter field windings. The regulated current flow through the exciter field windings, in turn, induces a voltage and current flow into the exciter armature windings, which is rectified and delivered to the rotor. In this manner the strength of rotor's magnetic field and the voltage induced into the stator windings are regulated.

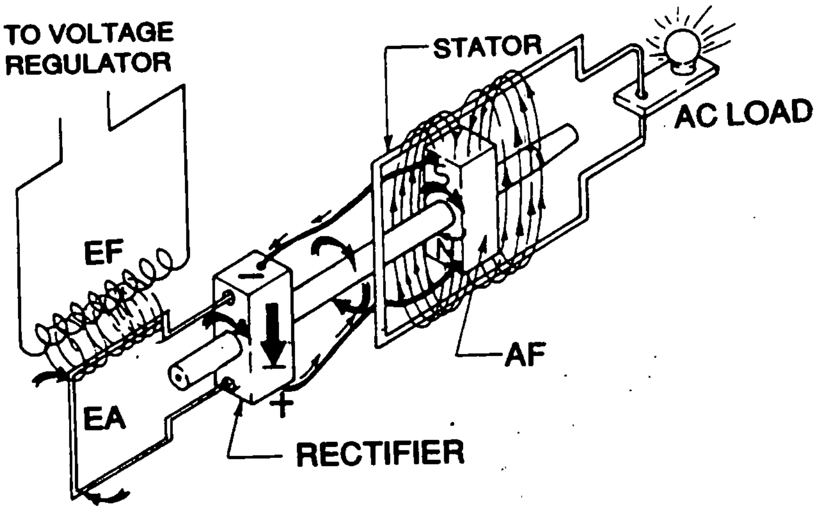


Figure 1-6 — A Brushless Exclation System

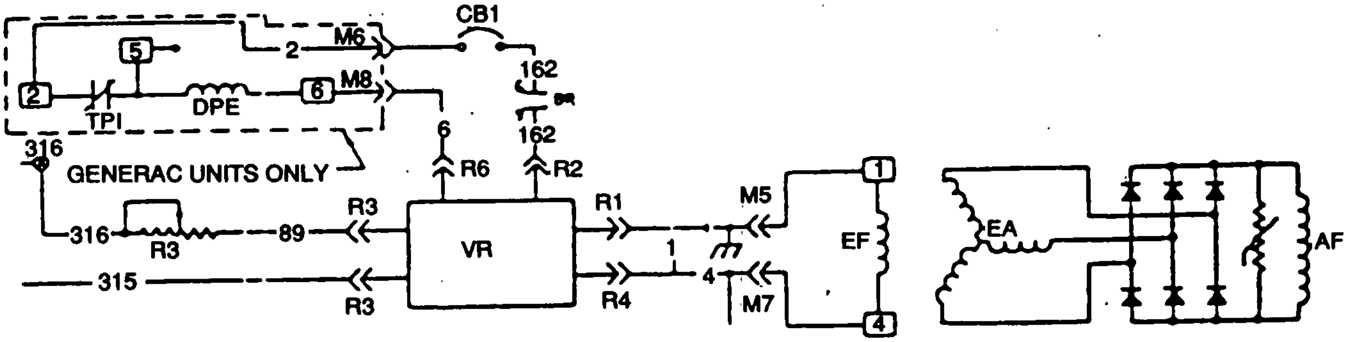


Figure 1-7 — Schematic of Brushless Excitation System

Section 2 — STATORS

The word *stator* means "stationary winding". A voltage or electromotive force is induced into the stator by the action of the rotating rotor's magnetic field. A typical stator assembly is shown in Figure 2-1.

Stators differ greatly, depending on the ratings and design of the specific alternator model on which they will be used.

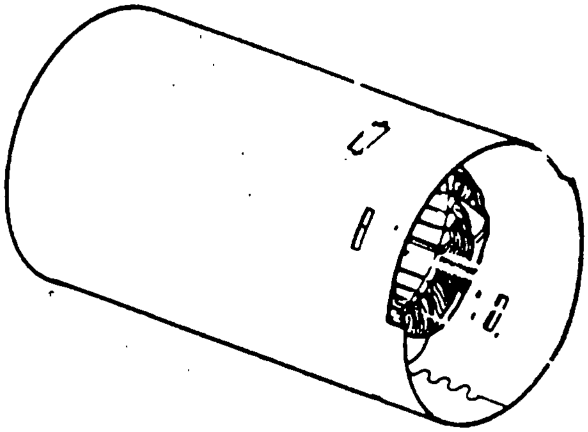


Figure 2-1 — Typical Stator Assembly

SINGLE PHASE, SINGLE VOLTAGE STATORS

A more simple stator assembly may consist of a single a-c power output winding, designed to produce 120 volts of single phase alternating current (Figure 2-2).

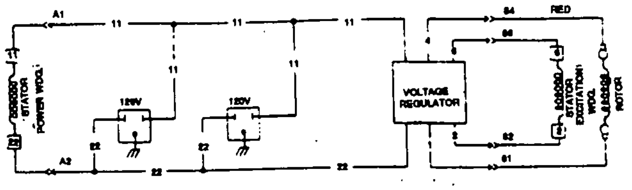


Figure 2-2 — Single Phase, Single Voltage Stator

SINGLE PHASE, DUAL VOLTAGE STATORS

When the design of the alternator calls for powering both 120 and/or 240 volts, two single phase stator windings can be used (Figure 2-3)

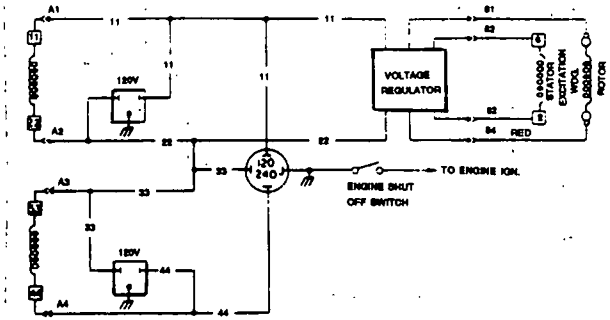


Figure 2-3 — Single Phase, Dual Voltage Stator

THREE-PHASE STATORS

Stators may be designed as either WYE or DELTA-CONNECTED stators. The more common types of 3-phase connection systems are discussed in Section 4 of *BASIC ELECTRICITY* (Part No. 46941).

STATOR BATTERY CHARGE WINDINGS

Some alternator units may be equipped with battery charging capability. These units may be used to charge a connected battery. Figure 2-4 shows a schematic of a typical battery charging circuit. The stator battery charge winding delivers a rectified 12 volts d-c through a fuse to the connected battery.

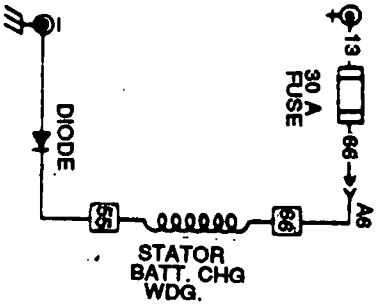


Figure 2-4 — Stator Battery Charge Circuit

STATOR EXCITATION WINDING

Direct Excited Units: Excitation winding a-c output is delivered to a plug-in Bridge Rectifier (Figure 2-5), which converts its output to direct current. From the rectifier direct current output is delivered to the rotor windings. Also see "The Brushless Excitation System" in Section 1.

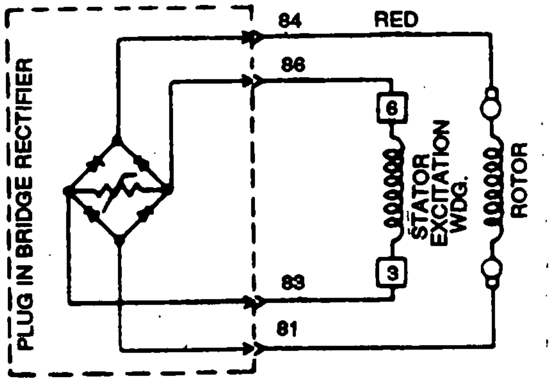


Figure 2-5 — Direct Excited Units

Solid-State Voltage Regulator Units: Excitation Winding a-c output is delivered to the voltage regulator (Figure 2-6), where a-c output is regulated and rectified. The regulated, rectified output is then delivered to the rotor windings.

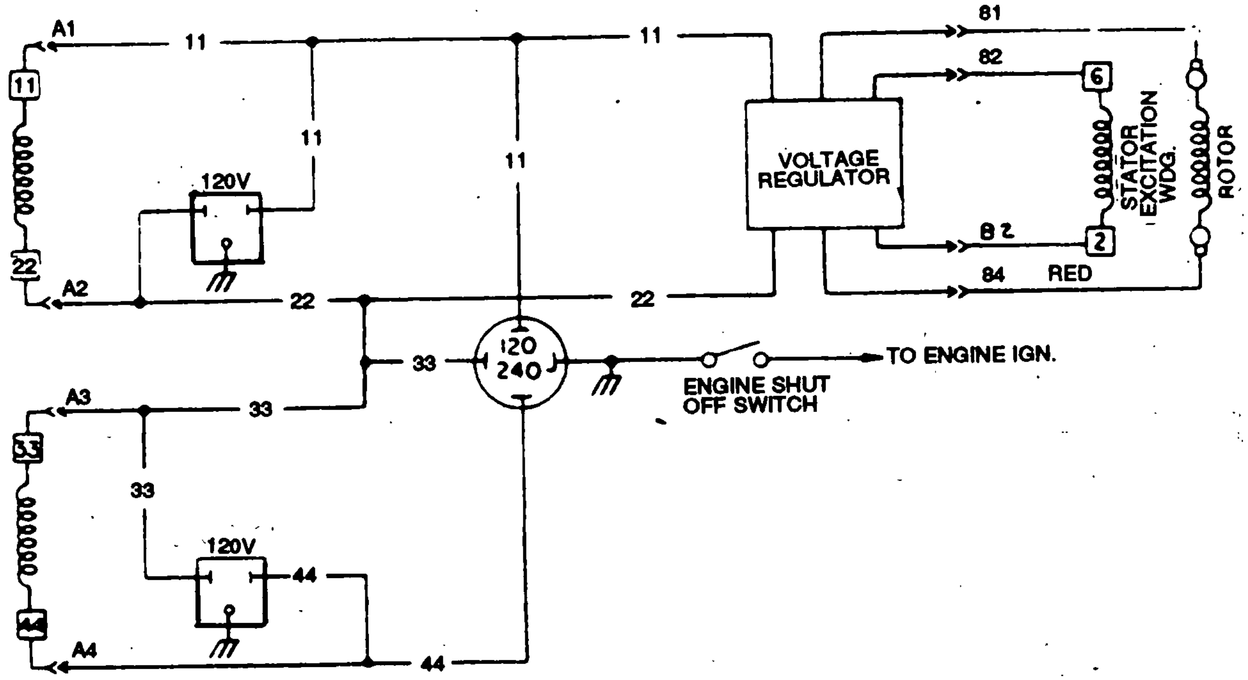


Figure 2-6 — Units with Solid-State Voltage Regulator

Section 3 — SWITCHES

A switch may be defined as a device used to open, close, or divert an electrical circuit. You can actuate switches manually or automatically. This section is devoted solely to the manually operated switches.

Generally, switches are classified according to how they are actuated, the number of poles, and the number of throws.

ACTUATING SWITCHES

Figure 3-1 shows (a) TOGGLE switch, (b) ROCKER switch, and (c) PUSH BUTTON switch. These switches are named by how they are actuated.

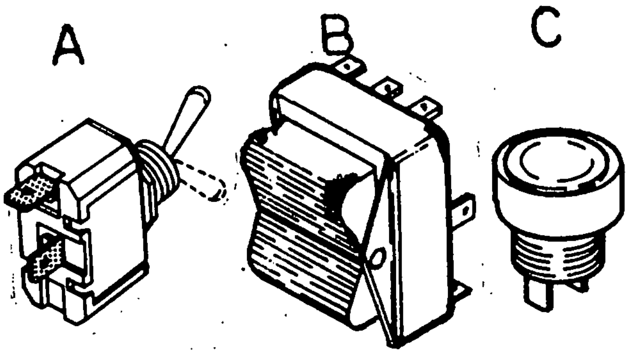


Figure 3-1 — Switches Classified by Actuation

SWITCHES CLASSIFIED BY POLES AND THROWS

The following types of switches are shown in both pictures and schematics (Figures 3-2 through 3-7)

- Single Pole, Single Throw (SPST, Figure 3-2)
- Single Pole, Double Throw (SPDT, Figure 3-3)
- Double Pole, Single Throw (DPST, Figure 3-4)
- Doulbe Pole, DoubleThrow (DPDT, Figure 3-5)
- Three Pole, Double Throw (3PDT, Figure 3-6)
- Four Pole, Double Throw (4PDT, Figure 3-7)

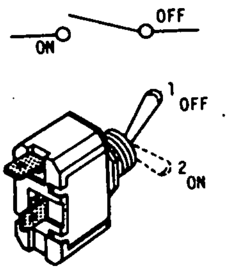


Figure 3-2 — Single Pole, Single Throw Switch

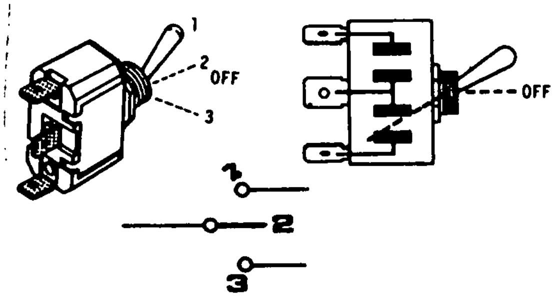


Figure 3-3 — Single Pole, Double Throw Switch

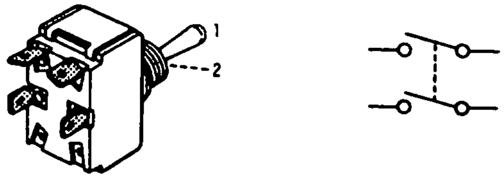


Figure 3-4 — Double Pole, Single Throw Switch

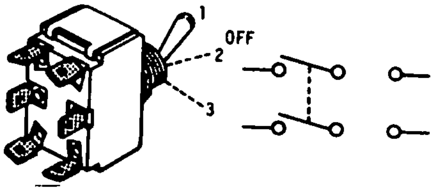


Figure 3-5 — Double Pole, Double Throw Switch

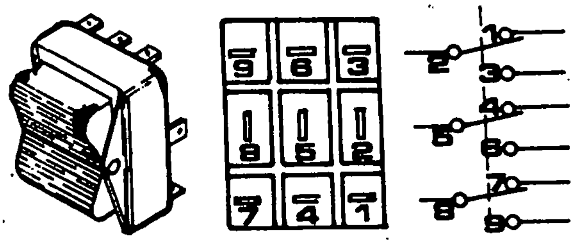


Figure 3-6 — Three Pole, Double Pole Switch

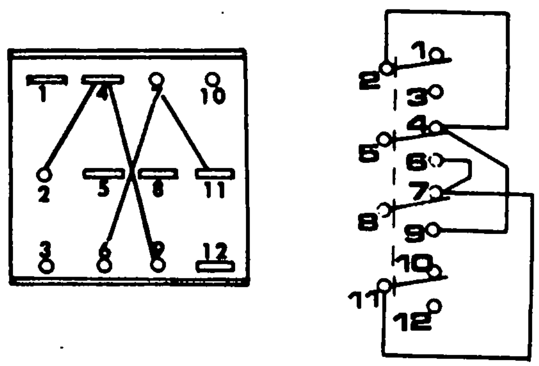


Figure 3-7 — Four-Pole, Double Throw Switch

PUSH BUTTON SWITCHES

Push button switches may be classified generally as "normally-open" or "normally-closed" type switches. Both types are illustrated in Figure 3-8.

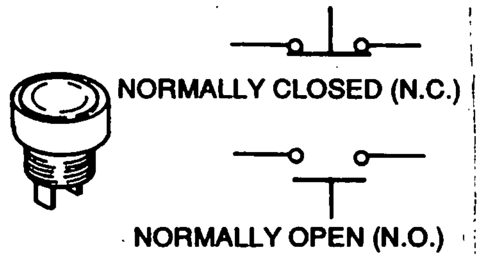


Figure 3-8 — Push Button Switches

ROTARY SWITCHES

Some typical rotary switches are shown in Figure 3-9. In general, this type of switch may be classified by (a) number of poles, and (b) number of positions. Figure 3-10 illustrates single-pole, double-pole, 3-pole and 4-pole rotary switches.

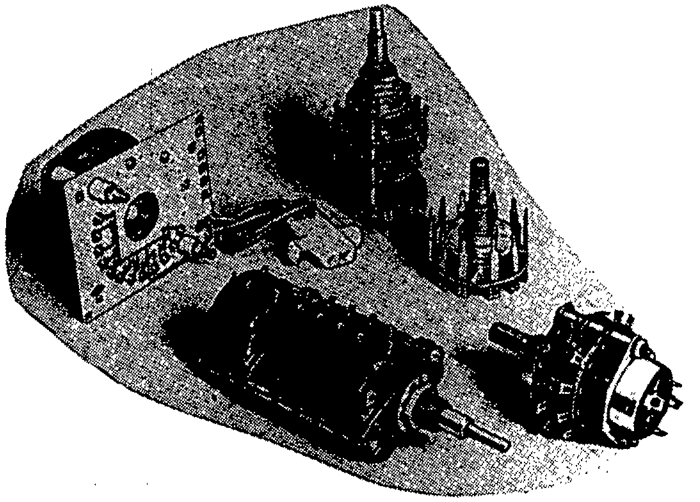
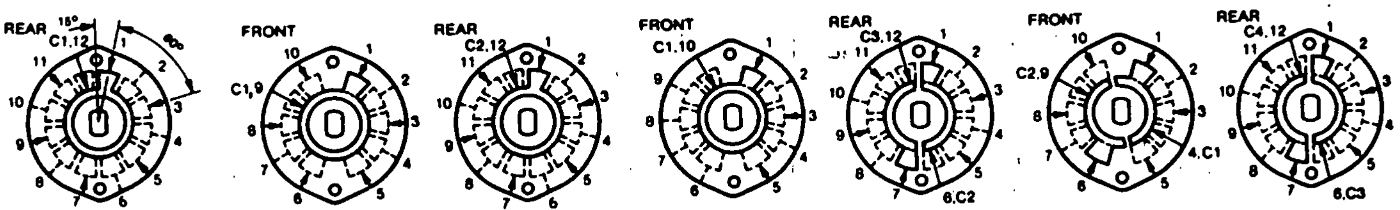


Figure 3-9 — Some Typical Rotary Switches



ONE POLE, 2-6 POSITION

TWO POLE, 2-6 POSITION

THREE POLE, 2-3 POSITION

FOUR POLE, 2-3 POSITION

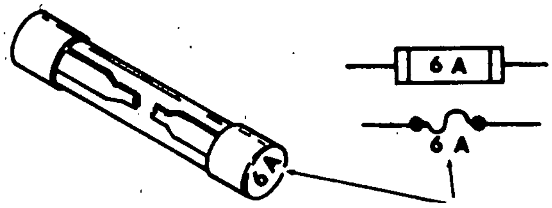
Figure 3-10 — Examples of Rotary Switch Classifications

Section 4 — PROTECTIVE SWITCHES

FUSES

A fuse could be called a switch, since it functions to open an electrical circuit when current flow becomes excessive. The fuse (Figure 4-1) is a strip of metal with a known melting point that has been installed in series with the circuit it is meant to protect.

Should current flowing through the fuse exceed a specific value, the fuse element melts to open the circuit. Generally, fuses are rated at the current value (in amperes) at which its element will melt open.



FUSE RATING INDICATES AMPERAGE AT WHICH FUSE WILL MELT.

Figure 4-1 — A Typical Fuse

CIRCUIT BREAKERS

Circuit breakers (Figure 4-2) protect one or more circuits against overloading or short circuits. One type of circuit breaker consists of an electromagnet with coil windings that are in series with the load to be protected. When current flow exceeds a pre-determined value, the coil's magnetic field becomes strong enough to open a set of contact points and break the circuit to connected loads.

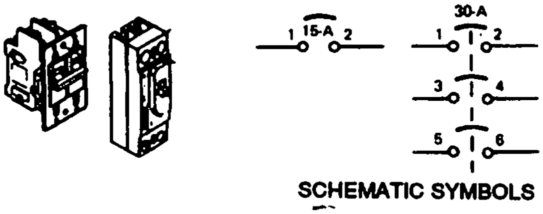


Figure 4-2 — Typical Circuit Breakers

THERMAL SWITCHES

Thermal switches are those kind that react to changes in temperature. One type of thermal switch consists of a fine metal strip in which two different metals having different expansion rates are welded together. When the two different metals are heated, the metal bands bend, which then opens a set of contacts.

Figure 4-3 illustrates two different types of thermal switches. The switch shown in "A" must be reset manually, once it has tripped. In "B", the thermal switch resets automatically after the metal has cooled to a pre-established temperature.

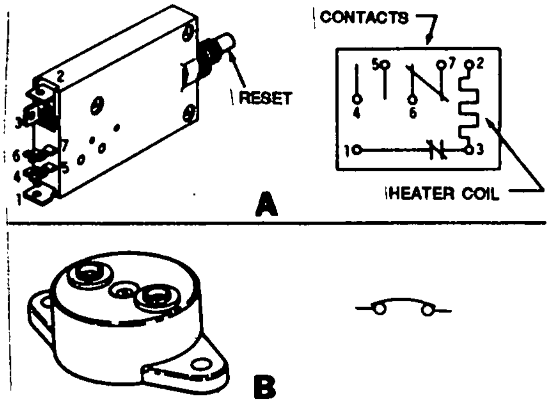


Figure 4-3 — Examples of Thermal Switches

Alternator stators usually have a thermal protector imbedded in their wire windings and electrically connected in series with the excitation winding output to the voltage regulator. This thermal switch opens at a predetermined temperature to terminate excitation current output to the rotor. The switch closes automatically when internal stator temperatures decrease to a safe value (Figure 4-4).

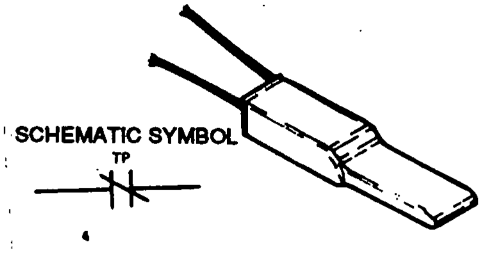


Figure 4-4 — Thermal Protector

Another type of thermal switch senses engine coolant temperature. This switch is the normally-open (N.O.) type but closes if coolant temperature exceeds a predetermined safe value to ground the engine's ignition circuit and cause the engine to shut down automatically.

PRESSURE SWITCHES

One example of a pressure switch is the low oil pressure shutdown switch used on some generator engines. This type of switch is normally-closed (N.C.), but is held open by engine oil pressure during engine operation. Should engine oil pressure drop below a pre-determined safe value, the switch closes to ground the engine ignition circuit and cause the engine to shut down automatically (Figure 4-5).

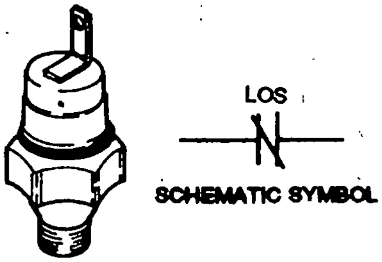


Figure 4-5 — Typical Pressure Switch

Section 5 — SOLENOIDS

A solenoid is a device used to convert electrical energy into mechanical movement. It is based on the principle that when current flows through a conductor, a magnetic field is created around that conductor. Solenoids may be used in the following applications:

- Fuel shutoff valves
- Electric chokes
- Engine throttle control
- Engine anti-dieseling devices

FUEL SHUTOFF VALVES

This type of valve is energized open by +12 volts d-c signal during engine cranking and starting. It is spring-loaded closed when the +d-c signals is removed as the engine shuts down (Figure 5-1).

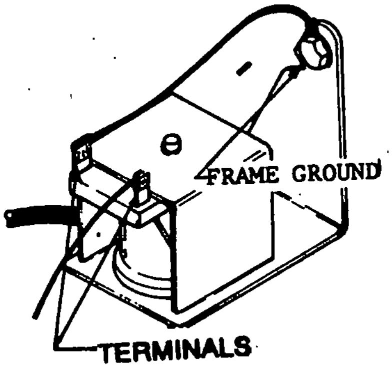


Figure 5-1 — Typical Fuel Shutoff Valve

THE SISSION TYPE CHOKE

This type of engine carburetor choke combines a solenoid with a thermal spring. It may be used on engines equipped with with an electric start cranking circuit. When the engine is cranked, a +d-c signal is applied to the choke solenoid to close the carburetor choke plate. As engine temperature increases after starting, thermal spring opens choke plate (Figure 5-2).

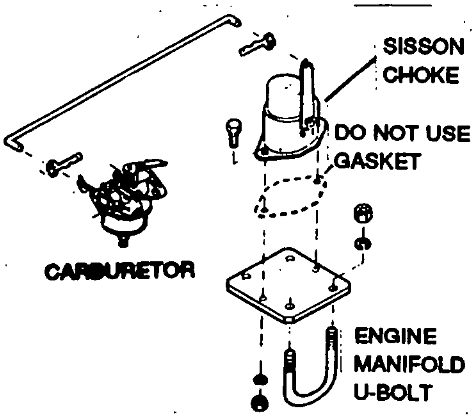


Figure 5-2 — Sission Type Choke

THE GENERAC AUTOMATIC CHOKE

The Generac electronic, automatic choke (Figure 5-3) is controlled by a solid-state circuit board that responds to ambient temperature. Voltage (+d-c) is delivered to the circuit board only when the engine's starter solenoid contacts are closed (engine cranking).

Solid state components on the circuit board then complete the +d-c circuit to the choke solenoid in "pulsing" fashion, at a pulse rate dependent on ambient temperature. Thus, the colder the temperature, the more rapid the carburetor choke opens and closes. A bi-metal spring controls the distance the carburetor choke plate moves toward its closed positon.

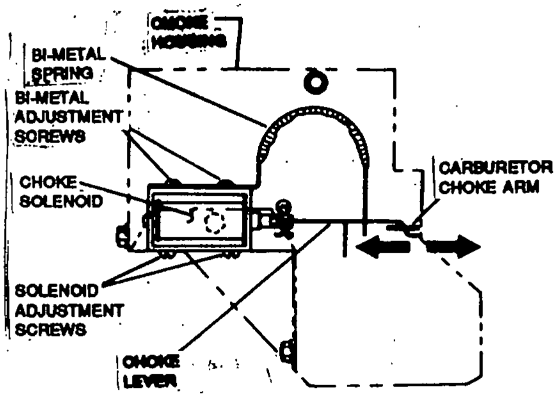


Figure 5-3 — Generac Automatic Choke

IDLE CONTROL SOLENOID

Some alternator units may be equipped with an automatic idle control device. This device uses a solenoid to pull the carburetor throttle lever against its idle stop when the alternator unit is not powering any electrical loads. When an electrical load is connected to the the stator a-c output, the solenoid is de-energized and the engine governor takes control of engine speed. Thus, the unit operates at its governed speed only when electrical loads are connected and turned ON. The engine decelerates to idle speed when loads are disconnected (Figure 5-4).

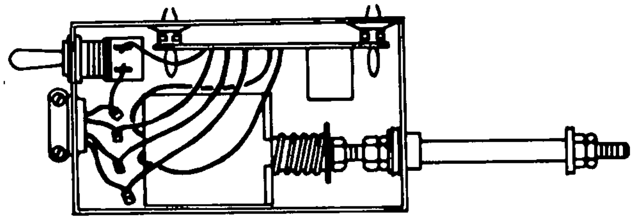


Figure 5-4 — Typical Idle Control Solenoid

Section 6 — RELAYS

You can compare relays to solenoids, since a relay is an electromagnet that creates mechanical movement. The relay, however, utilizes its magnetic field to close a set (or sets) or electrical contacts.

RELAY OPERATION

A typical relay operates as follows (Figure 6-1):

1. With no voltage applied to the relay winding, the spring holds the armature contacts against the upper fixed contact.
2. When current flow is applied to the winding, a magnetic field is created. The winding becomes an electromagnet that overcomes spring tension and pulls down the armature contacts against the lower fixed contact.
3. Removing the current collapes the magnetic field. The spring then acts to return the armature contacts to their original position against the upper fixed contacts.

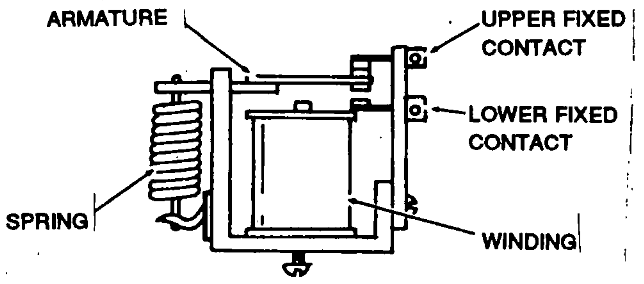


Figure 6-1 — Construction of Typical Relay

A relay thus functions as an electrically actuated switch to open or close a circuit.

A typical relay is shown in Figure 6-2, along with the schematic symbols for the Relay's winding (engergizing coil) and contacts. The terms "normally-open" (N.O.) and "normally-closed" (N.C.) refer to the condition of the contacts when no current is flowing through the energizing coils.

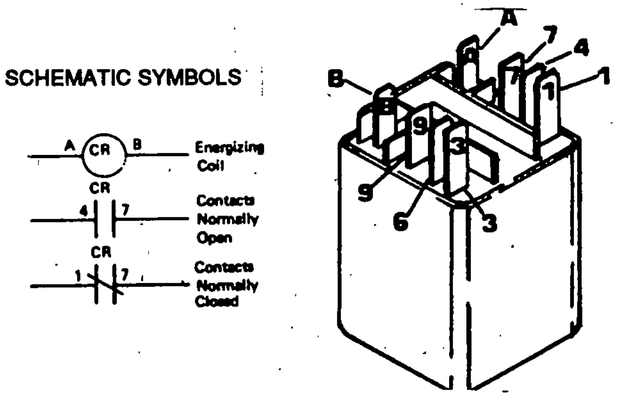


Figure 6-2 — Typical Relay with Schematic Symbols

Section 7 — TRANSFORMERS

A transformer increases (steps up) or decreases (steps down) an applied voltage. Transformers use the principles of ELECTROMAGNETIC INDUCTION and, more precisely, MUTUAL INDUCTION. An automobile ignition coil is just one example of a Transformer. A typical transformer consists of a metal core, which has two coils of wire wrapped around it. These are called the PRIMARY and SECONDARY windings.

MUTUAL INDUCTION

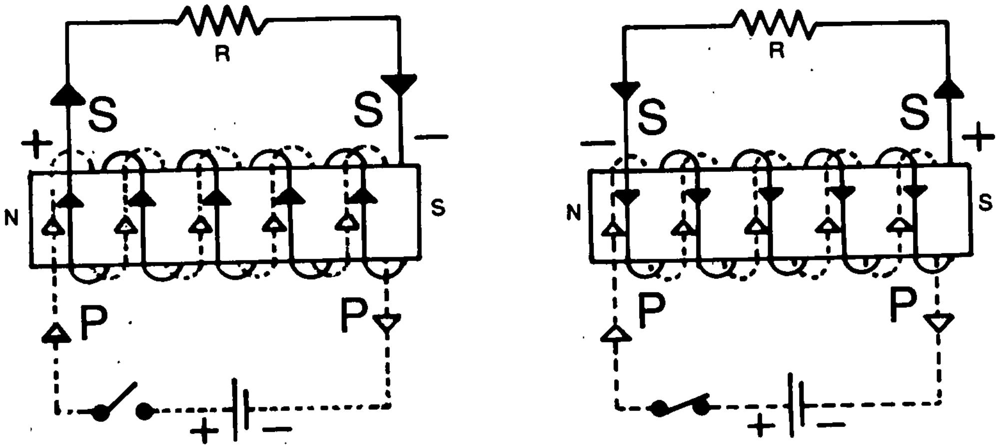
If a changing magnetic flux created by current flow in one coil cuts across the windings of a second coil, a voltage is induced into the second coil. This is the principle of mutual induction.

The winding in Figure 7-1 indicated by the letter "S" is wound over an iron core. This is the secondary winding. Another winding called the primary winding is wound over the first winding and is indicated by the letter "P." When the switch is closed, current flow through the primary winding increases, which expands lines of magnetic force that cut across the secondary winding. This then causes a voltage to be induced into the secondary winding.

If the switch is opened, however, the sudden decrease in current flow through the primary winding induces a voltage into the secondary winding. The secondary winding then becomes a source of voltage and supplies current to resistor "R". The magnitude of the voltage induced into the secondary winding (S) is primarily determined by the number of turns in the primary (P) and the secondary (S) windings.

For example, if 12 volts is applied across the primary winding and the secondary winding has 100 times as many turns of wire as the primary, the secondary voltage is about 12 x 100 = 1200 volts.

NOTE: You may also want to investigate the principle of self-induction, which also affects secondary voltage.



CURRENT DECREASING

CURRENT INCREASING

Figure 7-1 — The Principle of Mutual Induction

Section 8 — RESISTORS

Resistors are used to introduce resistance into a circuit, thereby limiting current flow. Resistance is dependent upon the length, cross-sectional area, and physical properties of a conductor. These factors are used in construction of resistors.

The physical size of a resistor depends on its **wattage rating**, not on its resistance value in **ohms**. For example, 10 watt resistors are generally the same size, while 10 ohm resistors are of varying sizes.

A resistor may have fixed or variable resistance. A fixed resistor (Figure 8-1) establishes a certain fixed resistance in a circuit. A variable resistor is provided with some means of varying length of the resistor element. One type of variable resistor is called a **potentiometer** or **rheostat**, which is usually wire-wound. The amount of resistance provided by the rheostat (Figure 8-2) can be varied by means of a moveable wiper arm which varies the number of turns of wire through which current is permitted to flow.

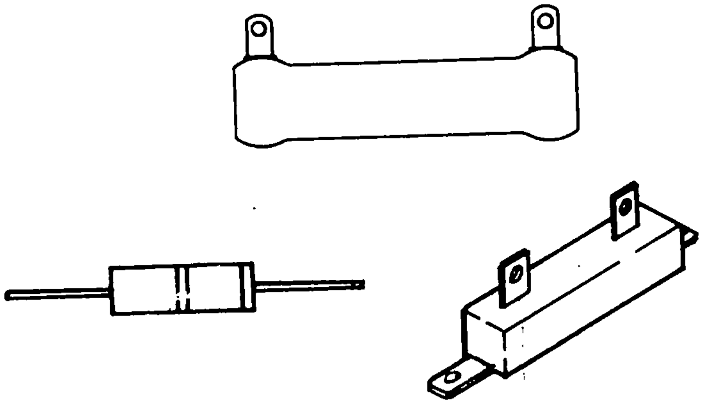


Figure 8-1 — Some Typical Fixed Resistors

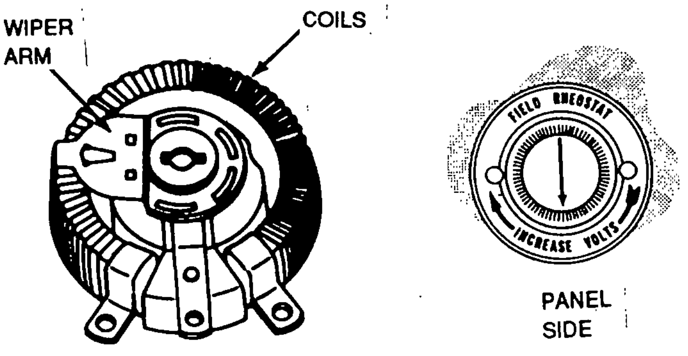


Figure 8-2 — Typical Rheostat

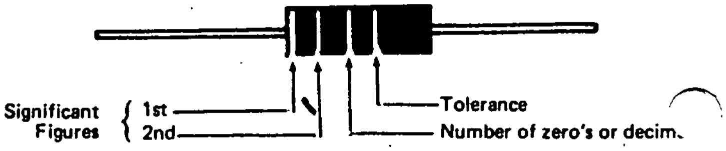
IDENTIFICATION OF RESISTORS

Resistors may be marked with their resistance, tolerance and wattage values or they may be color-coded. Figure 8-3 shows the method used to color code a resistor. The accompanying chart gives the value for each color band.

COLOR	SIGNIFICANT FIGURE OR NUMBER OF ZEROS
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

COLOR	DECIMAL MULTIPLIER	RESISTANCE TOLERANCE
Gold	0.1	±5%
Silver	---	±10%
(No Color)	---	±20%

Figure 8-3 — Resistor Color Coding



EXAMPLE: Hold the resistor with its color bands nearest its left end. If the first significant color band is brown, the second is blue, the number of zero bands is yellow, and the tolerance is silver, the resistor may be identified as follows:

BROWN...1
BLUE 6
YELLOW..0000
RESISTANCE equals................................160,000 ohms

The silver tolerance band indicates a tolerance of plus or minus 10%.

THE VARISTOR

Varistors are unique types of resistors that present high resistance to normal voltages and a low resistance to excessive voltages in circuits. You could call them "voltage-sensitive, nonlinear resistors." Figure 8-4 shows a silicone carbide resistor, along with its schematic symbol. This type of varistor is often used to protect diodes in a bridge rectifier by permitting normal voltage to pass through diodes, but shunting excessively high voltages to ground.

Figure 8-4 — A Silicone Carbide Varistor

Section 9 — CONDENSORS

Condensors and capacitors are one and the same. They are electrical devices that store energy within a circuit (Figure 9-1). A simple condensor (capacitor) consists of two metal plates separated by a small air space or a layer of insulating material called a "dielectric."

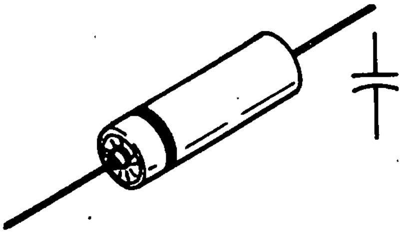


Figure 9-1 — Typical Condensor with Symbol

CONDENSOR OPERATION

When a source of current is attached to the condensor plates, a current flow occurs from the positive (+) plate into a dry cell (Figure 9-2). This causes a shortage of electrons on the positive plate, while the negative (—) plate gains a surplus of electrons. When the dry cell is disconnected, the plates store these charges for a considerable length of time.

However, if a wire is connected between the two plates, the excess electrons of the negative plate pass through the wire as current flow to neutralize the positive charge on the positive plate.

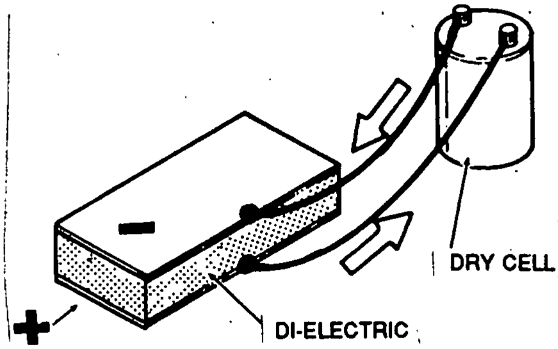


Figure 9-2 — Charge and Discharge of a Condensor

CONDENSORS IN A D-C CIRCUIT

A condensor in a d-c circuit permits current to flow only while the plates are being charged, which is momentarily. After the plates are fully charged, the condensor becomes an effective open-circuit in d-c.

CONDENSORS IN AN A-C CIRCUIT

In an a-c circuit, the continuous reversal of polarity causes the plates to charge first in one direction, then the other. Thus, in an a-c circuit, there is a constant current flow to and from the plates, although current does not actually flow through the dielectric.

USES OF CONDENSORS

Condensors can cause current to "lead" voltage. They are sometimes used in a-c circuits to neutralize the undesireable effects of lagging current or inductive reactance. Condensors are also used to block d-c current from entering a circuit.

Section 10 — RECTIFIERS (or diodes)

Rectifiers, also known as diodes, are used to convert alternating current (a-c) to direct current (d-c). A simple rectifier consists of a thin film of metallic oxide which is imposed on a thicker plate of metal such as iron. Selenium is often used as the oxide in a rectifier.

RECTIFIER OPERATION

A copper oxide rectifier is illustrated in Figure 10-1. When alternating current is applied to the opposite faces of the two discs, current can flow from the copper to the copper oxide face; it cannot flow in the opposite direction. The rectifier thus permits one alternating current to pass but blocks the reverse alternation. This action results in a "pulsating" direct current flow. A rectifier that allows only one alternation of current flow to pass is called a "blocking" diode or "half-way" rectifier (Figure 10-2).

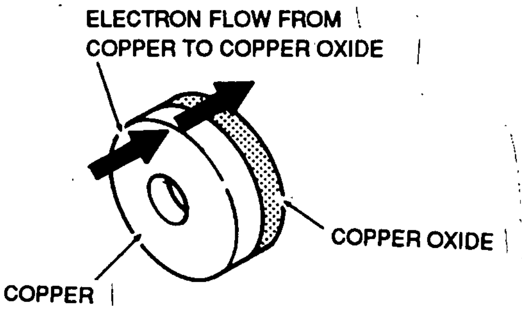


Figure 10-1 — Example of Copper Oxide Rectifier

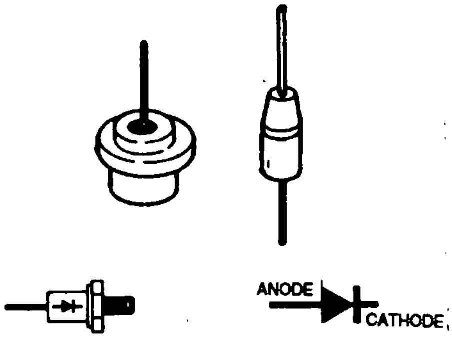


Figure 10-2 — Typical Blocking Diodes

FULL WAVE BRIDGE RECTIFIERS

By electrically bridging a series of discs, such as those used in a half-wave rectifier, both alternations of current flow can be permitted to pass. This results in a smooth, uninterrupted flow of direct current. Full-wave bridge rectifiers are often used to power circuits that require high current draw at a low voltage.

Figure 10-3 shows one type of full-wave bridge rectifier. Alternating current is applied at the terminals indicated by "a-c". Direct current is taken off the terminals indicated by a "+" and a "—".

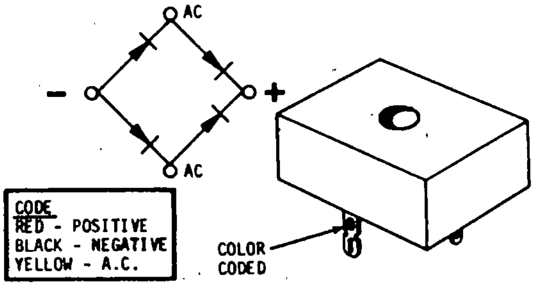


Figure 10-3 — Typical Full-Wave Bridge Rectifier

A "plug-in" type of bridge rectifier is shown in Figure 10-4. Notice the a VARISTOR has been added to this rectifier, to protect the diodes against voltage surges.

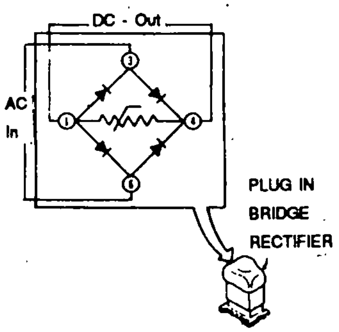


Figure 10-4 — Plug-In Bridge Rectifier with Varistor

SILICONE-CONTROLLED RECTIFIERS

The silicone-controlled rectifier is often referred to as simply an "SCR" (Figure 10-5). The SCR permits current to flow in one direction when a voltage is applied at its "gate." Applying a voltage to the SCR gate is said to "turn on" the SCR; it then permits direct current flow only.

Reverse currrent alternations are blocked by the diode action of the SCR. When the current again reverses itself, a voltage must pulse the gate once more before current can flow. Thus, the SCR acts much like a hydraulic check valve that must be opened to permit fluid flow but blocks the flow of fluid in the opposite direction.

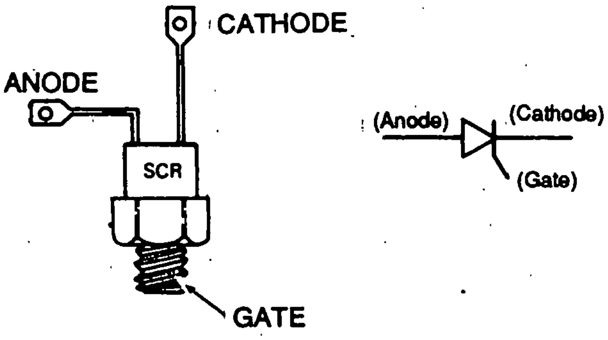


Figure 10-5 — Silicone-Controlled Rectifier

THE ZENER DIODE

The zener diode is often used to provide protection against over voltage that might damage some components in a circuit, or to protect transistors against excessive current flow. For example, a zener diode rated at 10 volts acts much like any other diode at up to 10 volts. However, if the applied voltage should exceed 10 volts, the diode begins to pass current to maintain the 10 volts level. Thus, if 15 volts is applied to the 10 volts zener diode, it shunts five volts to ground while permitting 10 volts to pass.

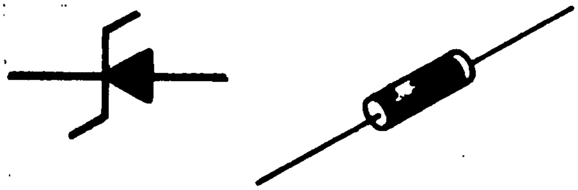


Figure 10-6 — The Zener Diode

Section 11 — TRANSISTORS

The construction of a transistor is similar to that of a diode. A diode is made up of two layers of metal, however, while a transistor consists of three metallic layers called a "triode."

As illustrated in Figure 11-1, a triode, (or transistor) consists of a wafer "N-type" material sandwiched between two thicker sections of "P-Type" material. It might also be a wafer of "P-Type" material sandwiched between two sections of "P-Type" material. The thin part of the transistor is called the **base**; the left portion is the emitter; the portion on the right is the collector.

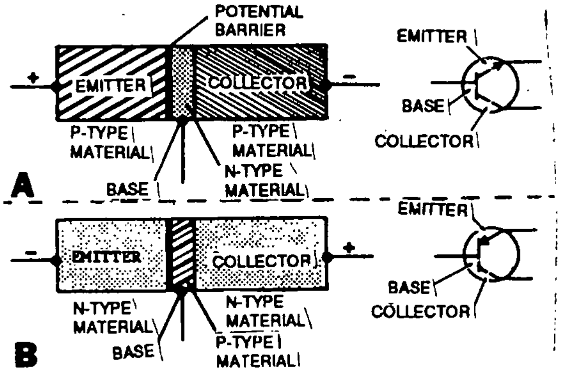


Figure 11-1 — Construction of a Transistor

The term "P-Type" material identifies a material that contains positively charged (+) electrons. The term "N-Type" material denotes the presence of negatively charged (—) electrons. Certain manufacturing processes cause "P-Type" atoms to seize electrons from the "N-type" atoms at the junction of the two materials. This action causes the "P" atoms to gain a negative (—) charge, while the "N" atoms gain a positive (+) charge. The negatively charged "P" atoms tend to repel any electrons that seek to pass from the "N" side, resulting in a potential barrier to electron or current flow.

FUNCTIONS OF A TRANSISTOR

Transistsors may be used in a circuit to amplify or step up voltage. You may also use them as switches (i.e., to open or close a circuit). By changing the voltage applied to the transistor base, you can turn ON or OFF current flow across the emitter/collector.

SOME TYPICAL TRANSISTORS

Some typical transistors are displayed in Figure 11-2. Generally, the larger the transistor's physical size, the more current it can allow to pass. Sometimes the transistor is mounted onto a metal plate called a "heat sink." The heat sink dissipates heat and increases the ability of the transistor to carry current.

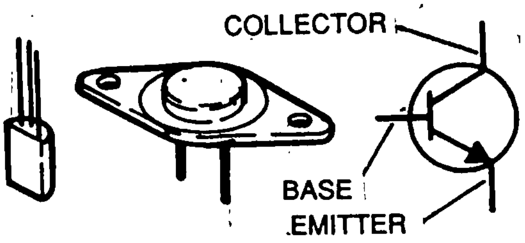


Figure 11-2 — Some Typical Transistors

ELECTRICAL FORMULAS

TO FIND	KNOWN VALUES	1-PHASE	3-PHASE
KILOWATTS (kW)	Volts, Current, Power Factor	$\frac{E \times I}{1000}$	$\frac{E \times I \times 1.73 \times PF}{1000}$
KVA	Volts, Current	$\frac{E \times I}{1000}$	$\frac{E \times I \times 1.73}{1000}$
AMPERES	kW, Volts, Power Factor	$\frac{kW \times 1000}{E}$	$\frac{kW \times 1000}{E \times 1.73 \times PF}$
WATTS	Volts, Amps, Power Factor	Volts x Amps	$E \times I \times 1.73 \times PF$
NO. OF ROTOR POLES	Frequency, RPM	$\frac{2 \times 60 \times \text{Frequency}}{\text{RPM}}$	$\frac{2 \times 60 \times \text{Frequency}}{\text{RPM}}$
FREQUENCY	RPM, No. of Rotor Poles	$\frac{\text{RPM} \times \text{Poles}}{2 \times 60}$	$\frac{\text{RPM} \times \text{Poles}}{2 \times 60}$
RPM	Frequency, No. of Rotor Poles	$\frac{2 \times 60 \times \text{Frequency}}{\text{Rotor Poles}}$	$\frac{2 \times 60 \times \text{Frequency}}{\text{Rotor Poles}}$
kW (required for Motor)	Motor Horsepower, Efficiency	$\frac{HP \times 0.746}{\text{Efficiency}}$	$\frac{HP \times 0.746}{\text{Efficiency}}$
RESISTANCE	Volts, Amperes	$\frac{E}{I}$	$\frac{E}{I}$
VOLTS	Ohm, Amperes	$I \times R$	$I \times R$
AMPERES	Ohms, Volts	$\frac{E}{R}$	$\frac{E}{R}$

E = VOLTS

I = AMPERES

R = RESISTANCE (OHMS)

PF = POWER FACTOR

NOTES

NOTES

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