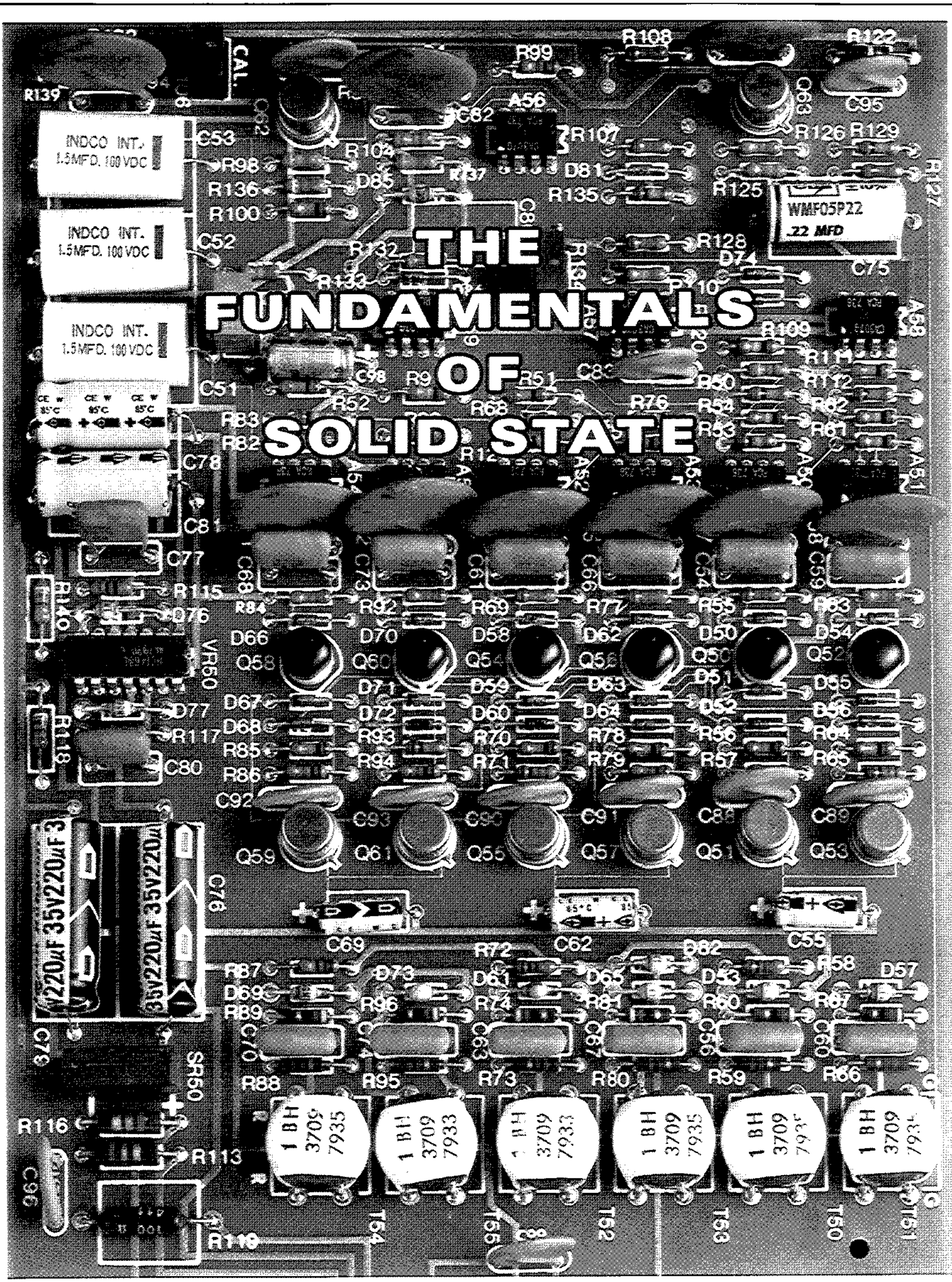
# THE FUNDAMENTALS OF SOLID STATE



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# THE FUNDAMENTALS OF SOLID STATE

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# INTRODUCTION

**With todays growing demand for solid state welding equipment and the projected greater usage, a basic understanding of solid state equipment can be very beneficial.**

**The information provided in this book includes basic electricity, solid state components, the benefits of solid state, and a discussion of fundamental circuit diagrams.**

**It is important to emphasize that there are two theories pertaining to electricity.**

**The conventional theory indicates that current flows from + (positive) to – (negative).**

**The electron theory indicates that the current flows from – (negative) to + (positive). The electron theory is the primary theory used in this book.**


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# CHAPTER 1
# BASIC ELECTRICITY

**Electricity is defined as the movement of electrons along a conductor. When referring to alternating current (AC) electrons move in two different directions. In direct current (DC) the electrons move in the same direction.**

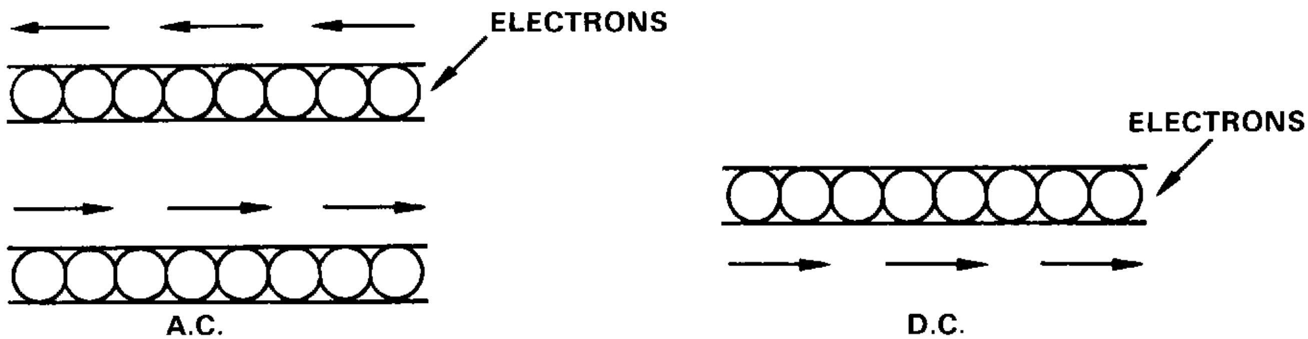



**FIGURE 1-1**
**ALTERNATING CURRENT— ELECTRONS MOVE IN TWO DIRECTIONS**
**DIRECT CURRENT— ELECTRONS MOVE IN ONE DIRECTION**

## ALTERNATING CURRENT

The term alternating current refers to one complete alternation, or double reversal of the waveform.

Follow the alternating current through a complete cycle in Figure 1-2 and it will be found that at one instant the current is increasing and at another instant it begins to decrease. At one point the current is actually zero, then the wave form reverses direction and the current begins to flow in the opposite direction. The value of the current in the same waveform is constantly changing.

The number of cycles completed per second is referred to as "Hertz". Sixty cycles per second is called "60 Hertz".

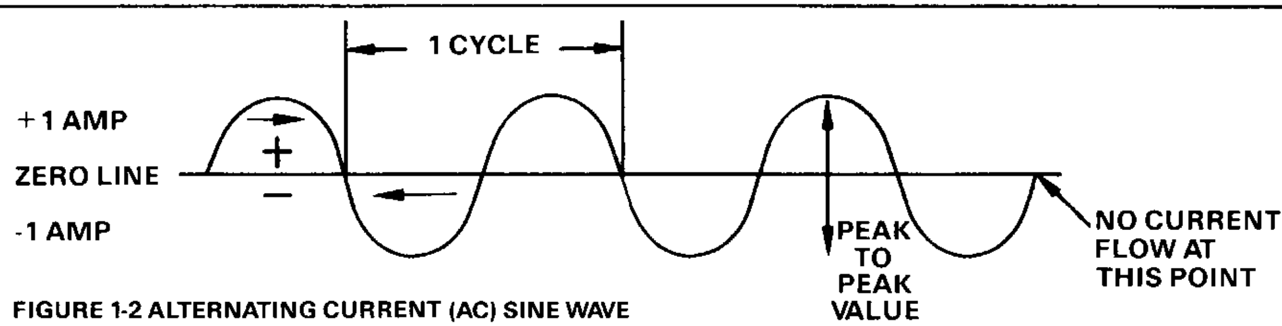



**FIGURE 1-2 ALTERNATING CURRENT (AC) SINE WAVE**

## THREE BASIC ELEMENTS IN ELECTRICITY

The following elements are present in electrical circuits:

### Electromotive Force (Voltage)

The electromotive force (E.M.F.) pushes and pulls electrons (current) through the conductors in an electrical circuit as shown in Figure 1-3.

When one volt of electromotive force is applied to a circuit, a certain number of electrons are freed from their atomic structure. When the voltage is increased to two volts, twice as many free electrons will travel thru the circuit.

One volt is defined as the pressure which will force one ampere of current through a resistance of one ohm.

The impulse of energy is transferred from one electron to the next almost instantaneously, so that even though the electrons are moving relatively slowly, the electric current travels 186,000 miles per second.

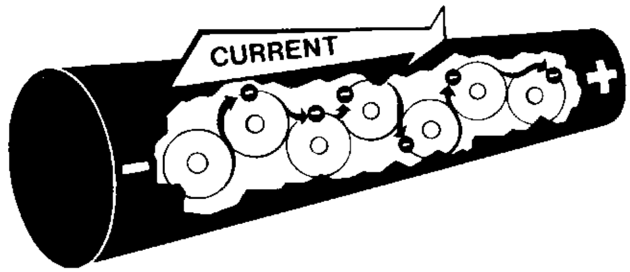



**FIGURE 1-3 ELECTRON FORCE OR VOLTAGE**

Whenever there is a difference in the amount of positive and negative electrons, an E.M.F. or potential difference exists. If a conducting material is placed between these two points current will begin to flow from negative to positive as shown in Figure 1-4.

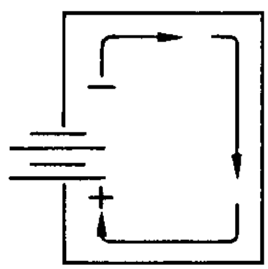



**FIGURE 1-4 BASIC ELECTRIC CIRCUIT SHOWING ELECTRON MOVEMENT FROM NEGATIVE TO POSITIVE.**

## Current

The ampere is a unit of electrical current flow created by a progressive movement of free electrons along a wire or other conductor. The electron movement in Figure 1-5 is shown as balls in a row.


A good analogy of this *impulse transfer* is a long row of billiard balls. When a ball is hit into one end of the row of balls, its striking force is transmitted from ball to ball until the ball at the other end is knocked free. The last ball is released at almost the same time that the first ball is struck.

**FIGURE 1-5 MOTION OF ELECTRONS THROUGH A CONDUCTOR.**

## Resistance

Resistance refers to an opposing effect that hinders free electron progress through wires when the electromotive force is attempting to produce current in the circuit.

The basic unit of resistance is the ohm, and the factors which affect the resistance of a conductor are the length, cross sectional area, temperature and the type of conductor used.

# BASIC ELECTRIC CIRCUIT

A simple electric circuit is made up of: (1) An electromotive force or voltage source, such as a battery; (2) a load, such as a light bulb; (3) and wiring with a switch to open and close the circuit.

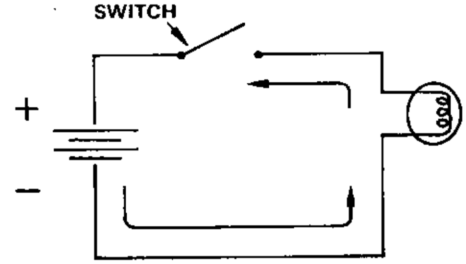



**FIGURE 1-6 BASIC ELECTRIC CIRCUIT CONSISTING OF A BATTERY, LIGHT BULB AND A SWITCH.**

The battery provides the electromotive force which *pulls* electrons to its positive terminal through the light's filament, and *pushes* them out the negative terminal to replace electrons which were moved by the pull of the positive terminal. When enough current flows in this circuit the filament wires become white hot and the light will shine.

The switch controls the current flow in the circuit. When the switch is closed, electrons can move through the circuit from negative to positive through the load. If the switch is opened, the electromotive force of the battery is not great enough to force the electrons to jump across the switch gap and electron movement is stopped.

# TYPES OF MATERIALS

There are three basic types of materials used in electrical circuits. They are classified as conductors, insulators and semiconductors.

## Conductors

Conductors are materials which have electrons that are easy to free, allowing current to pass through them very easily.

## Insulator

Insulators such as glass, wood, rubber and plastic have very few free electrons, and these electrons are difficult to free.

Current flow through insulators is difficult.

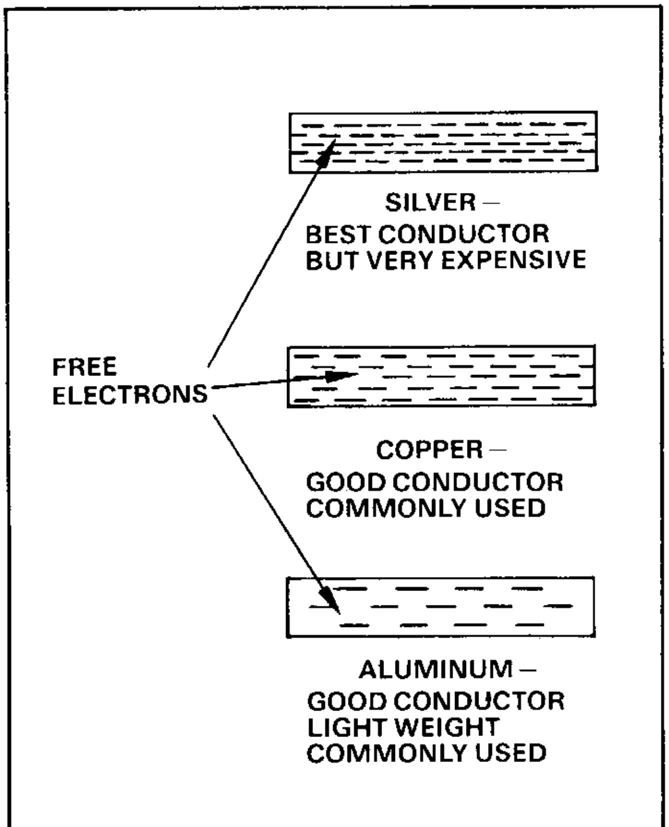



FIGURE 1-7 CONDUCTOR MATERIALS

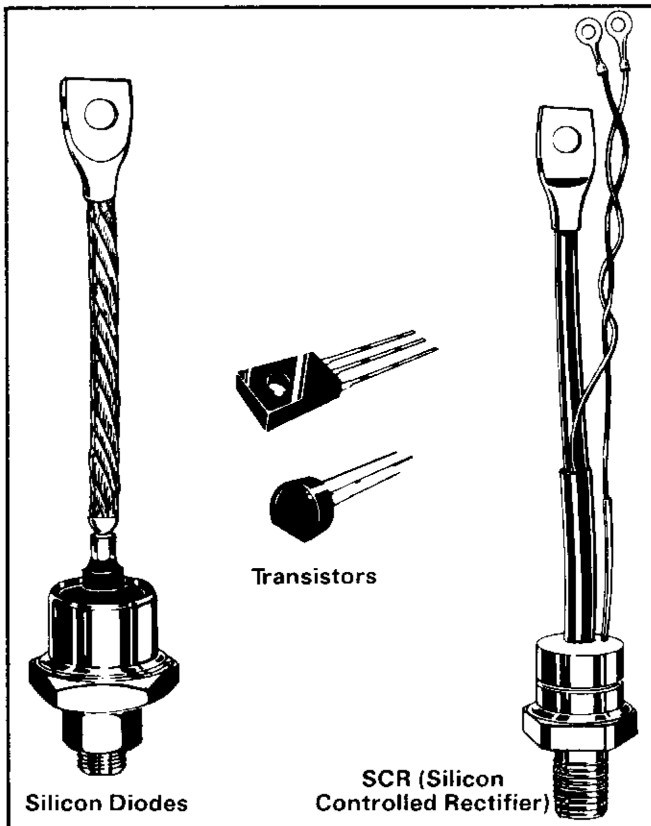



FIGURE 1-8 TYPICAL SEMICONDUCTORS

## Semiconductor

Semiconductor material conducts better than an insulator, but not as good as the best conductors.

At normal temperatures semiconductors have very few free electrons and are good insulators. By increasing the temperature and adding various types of impurities (doping) many more electrons are made available and the semiconductor begins to conduct.

Some examples of semiconductors are transistors, diodes and silicon controlled rectifiers (SCR's).

# POINTS TO REMEMBER

- ☐ **Electricity is defined as the movement of electrons along a conductor.**
- ☐ **60 Hertz alternating current changes direction 120 times per second.**
- ☐ **Three basic elements in electricity are electromotive force (voltage) current (amperes), and resistance (ohms).**
- ☐ **Potential difference (E.M.F.) is measured in volts. It is the energy difference between electrons in two different locations in an electrical circuit.**
- ☐ **The three basic materials used in electrical circuits are conductors, insulators, and semiconductors.**

# CHAPTER 2
# UNDERSTANDING SOLID STATE COMPONENTS

**Electronics has to do with the application and theory of semiconductor devices which control current. Included among these semiconductor devices are transistors, diodes, silicon controlled rectifiers (thyristors) and integrated circuits (chips).**

**Semiconductor components perform a variety of control functions. They can be used as amplifiers, oscillators, detectors and switching devices.**

Some of the characteristics which make the semiconductor applicable to the welding power source are as follows:

1. Semiconductors provide the means to design solid state contactors, solid state timers, and line voltage compensation circuitry.
2. Semiconductors are lightweight and small.
3. Semiconductors require very little power to operate.
4. Semiconductor technology has provided higher amperage capacities.
5. Semiconductors are enclosed components and can be better protected against external environmental conditions.
6. Semiconductors have led to integrated circuitry (I.C. chips) which include miniature transistors, resistors, diodes, and related wiring, all on one very small silicon chip.
7. Semiconductors permit the use of miniature remote controls due to the low amperage requirements needed to control or regulate the solid state circuitry.

Silicon is used most commonly in construction of today's semiconductor devices because that material is less heat sensitive than previously used materials and lends itself to many design variations.

For example, to improve conductivity of the silicon material, impurities are added in small amounts. This is called "doping" and it is done for good reason.

Impurities such as arsenic, antimony, and phosphorous are added to silicon to increase the number of negative (N) electrons. This is referred to as "N" type silicon.

Impurities such as indium, gallium, and boron increase the conductivity of silicon by increasing the number of positive (P) carriers (holes). This is referred to as "P" type silicon.

## Diodes

The joining of the "P" and "N" type silicon provide a two element device referred to as the Silicon Diode.

The diode is unique in that it has the ability to pass current in one direction but not in the other. On the diode the direction in which electrons can pass is opposite the direction in which the arrow points. In figure 2-1 electrons pass within the diode from cathode to anode.

The primary function of the diode is to convert alternating current (AC) into direct current (DC), as shown in Figure 2-2.

The silicon diode is an electrical conductor under certain conditions, but it is an insulator under other conditions, hence the term "semiconductor".

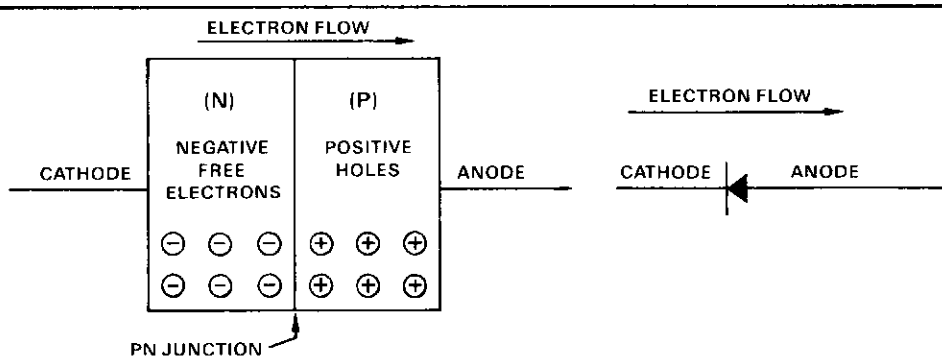



FIGURE 2-1 JUNCTION DIODE—AND SCHEMATIC SYMBOL

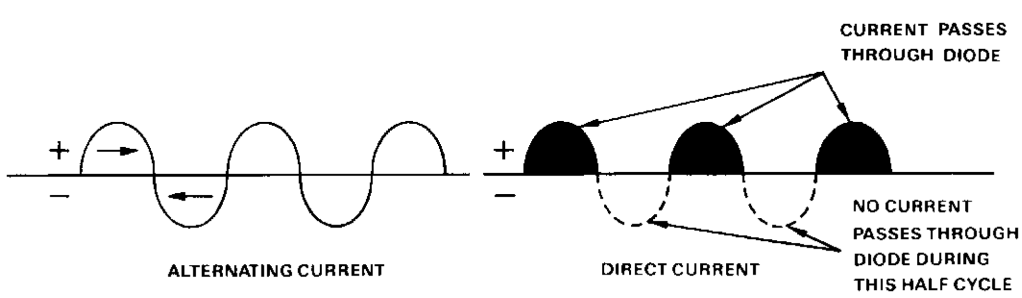



FIGURE 2-2 ALTERNATING CURRENT CONVERTED TO DIRECT CURRENT.

Proper connection of diodes in an electrical circuit make up a full wave bridge rectifier as shown in Figures 2-3 and 2-4. The output of this rectifier provides direct current.

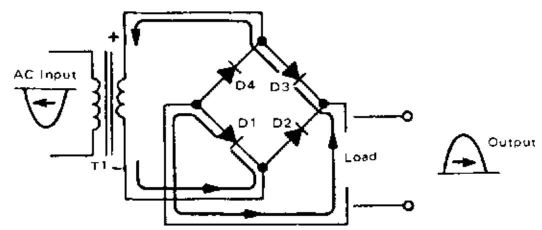



**FIGURE 2-3 FULL WAVE BRIDGE RECTIFIER (NEGATIVE HALF CYCLE)**

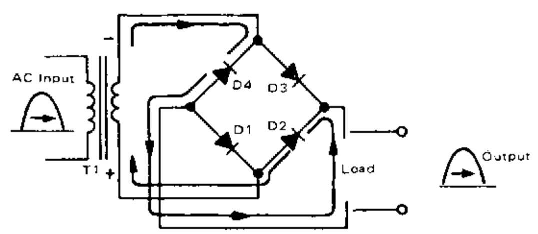



**FIGURE 2-4 FULL WAVE BRIDGE RECTIFIER (POSITIVE HALF CYCLE)**

In figure 2-3 on the negative half cycle, current flows from negative through $D_1$, through the load resistor and back through $D_3$ to positive. $D_2$ and $D_4$ act as open switches and block the current. In figure 2-4 during the opposite or positive half cycle, current passes from negative through $D_4$, through the load to $D_2$ and then to positive. $D_1$ and $D_3$ represent open switches and block current from passing through them.

In figure 2-5 both the positive and negative AC cycles are applied to the rectifier. The output is shown as direct current.

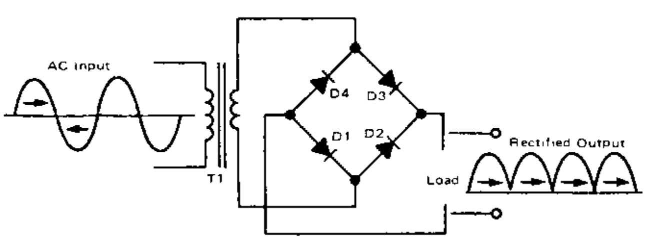



**FIGURE 2-5 FULL WAVE BRIDGE (FULL OUTPUT)**

**TRANSISTOR**

The transistor is a three layer semiconductor device which uses a small amount of current to produce a large change in voltage, current, or power.

Basically there are two types of transistors. The PNP and NPN types as shown in Figure 2-6.

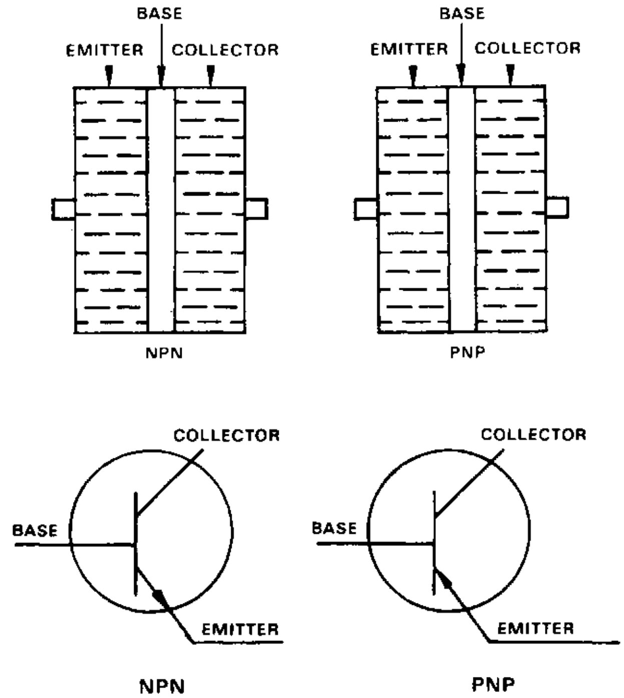



**FIGURE 2-6 PNP AND NPN TRANSISTORS AND SCHEMATIC SYMBOLS**

The transistor is an extension of the semiconductor diode except for the addition of a very thin element called the base which is placed between the emitter and collector. The transistor can be considered the same as two diodes fastened together.

Control of the transistor output is achieved by applying a small, low current signal to the base lead, which in turn controls a large amount of working current at the output of the transistor.

## Silicon Controlled Rectifier (SCR)

The SCR semiconductor is a four layer device. The SCR can be triggered, or turned on, when a momentary, low pulse signal is received on the gate lead as shown in Figure 2-7. It does not require any control current once it is triggered.

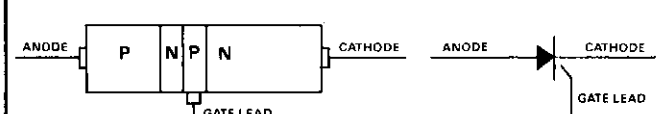



**FIGURE 2-7 SILICON CONTROLLED RECTIFIER & SCHEMATIC SYMBOL**

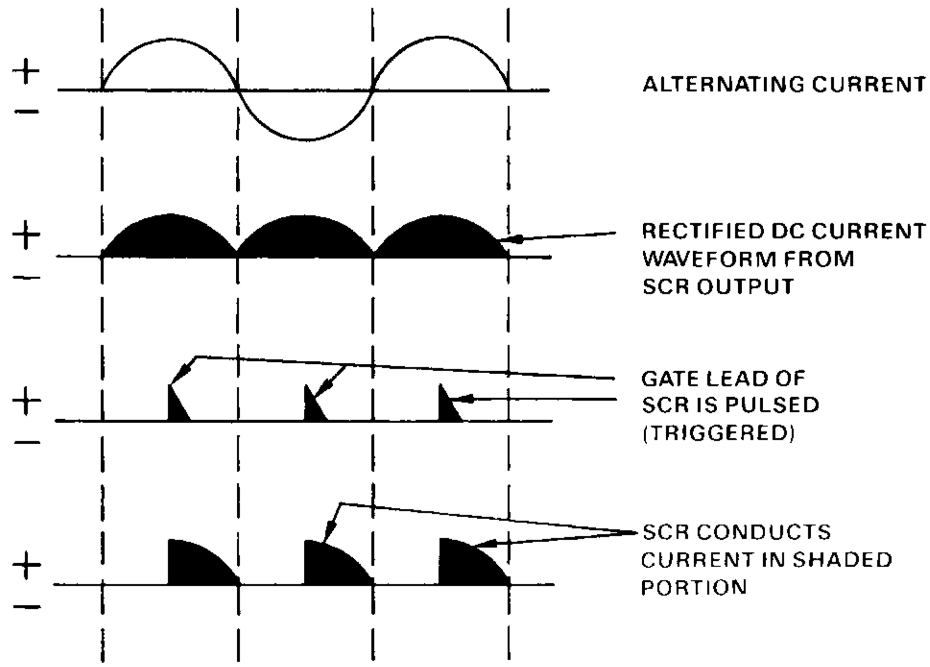



**FIGURE 2-8 SCR PHASE CONTROL AND RECTIFIED DC OUTPUT**

Normally the SCR blocks current attempting to pass either way between the anode and cathode. However, when a pulse of current is applied to the gate lead, the SCR begins to conduct. More importantly, the SCR will stay on after the gate signal has stopped, as long as working current is being applied. If the working current is turned off, another gate pulse is necessary to turn this device "on" again.

One of the distinctive physical features of the SCR is a gate lead connection by which this device can be triggered into action. The timing of the gate triggering, controls the output of the SCR.

In Figure 2-8 it can be seen that the pulsing or triggering of the SCR, controls the output current. Varying the point in the AC cycle at which the SCR is triggered is referred to as phase control and is used to control the amount of current the SCR will pass. Shifting the gate pulse can result in all or part of the cycle being used to conduct current. If there is no gate pulse, the SCR does not conduct during that particular half-cycle. The SCR, when not triggered acts as an open switch. Because of this gate lead control feature, the SCR can be used as a solid state switch or solid state contactor.

## Integrated Circuits

The integrated circuit (IC), Figure 2-9, is a complete electronic circuit consisting of miniature resistors, transistors, and diodes. These miniature components and the related electrical wiring are contained and formed within a single, very small silicon chip mounted in one common case.

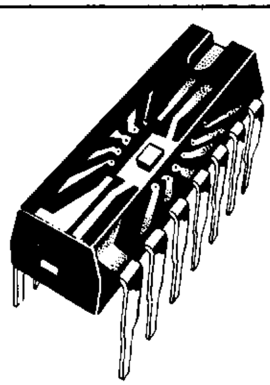


**FIGURE 2-9 INTEGRATED CHIP**

The internal electrical circuitry of the IC is very similar to a circuit made up of discrete (individual) components except for the miniature size.

Because of the small size of the integrated chip, the applications are limited to low voltage, low current applications.

Integrated circuits require fewer solder joints and fewer separately assembled components which saves time and minimizes errors in assembly of solid state circuits.

## Printed Circuits

The printed circuit (PC) board shown in Figure 2-10 is an insulated surface on which conductors and other circuit components are mounted. The conductors (copper strips) are chemically etched on the PC board to provide the necessary electrical path to perform a specific job. The printed circuit wiring has low resistance and passes the desired current to various components mounted on the PC board.

Components, such as resistors, capacitors, transistors, and integrated chips, are mounted on the PC board, then soldered in place.

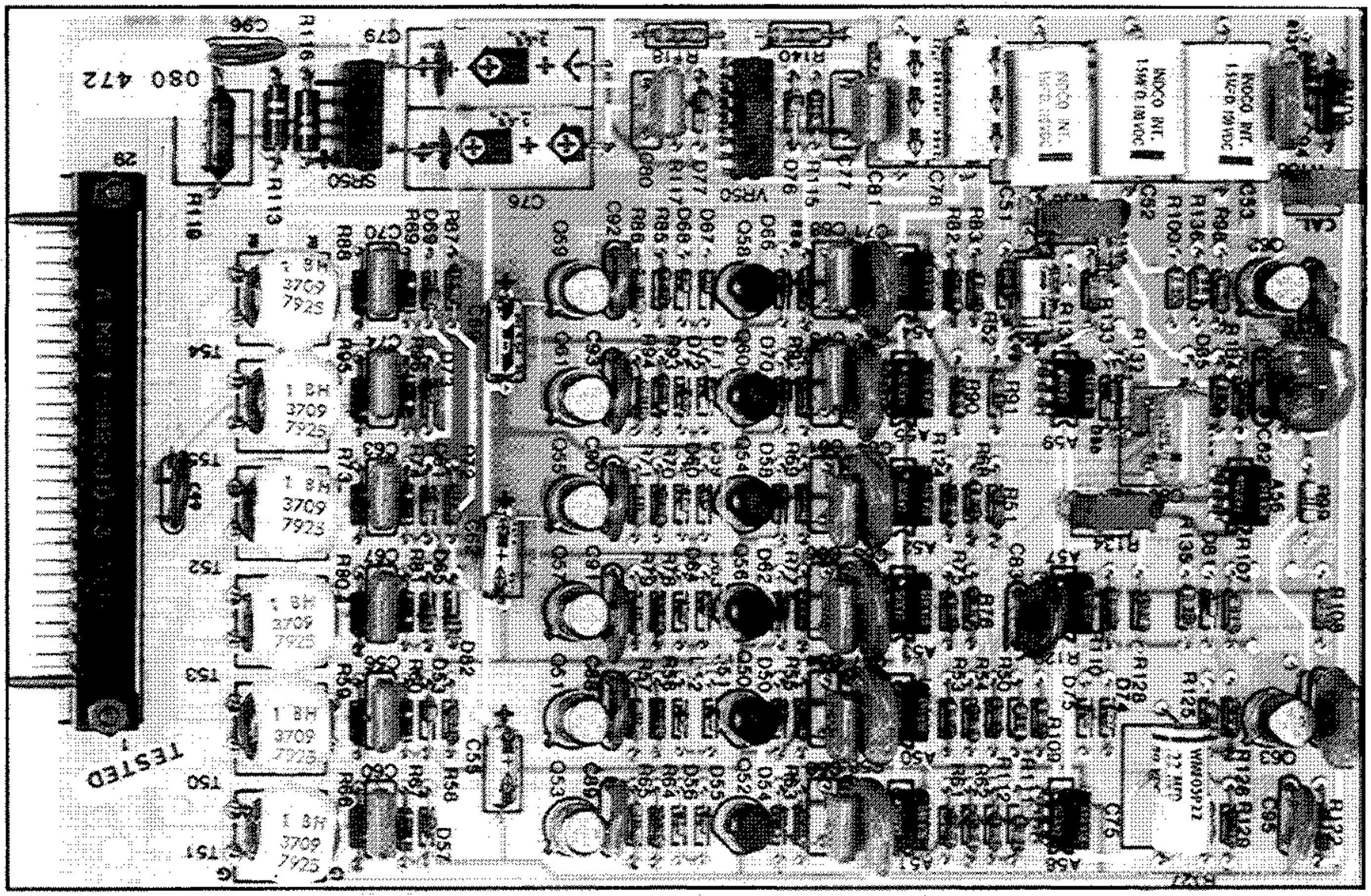


**FIGURE 2-10 TYPICAL PRINTED CIRCUIT BOARD**

Printed circuit boards are easily adapted to plug-in edge connectors and, therefore, reduce the number of terminal strips and tie points.

Connection of the PC board to the associated circuitry is important due to the low voltage signals transferred at that point. Gold plated edge connectors are used in many applications where low voltage signals and maximum protection against adverse environments is required.

The PC board can be considered the "brains" of the complete system because it controls, regulates and sends signals to various other components which make up the remainder of the solid state circuit.

## POINTS TO REMEMBER

- ☐ **Semiconductor devices are completely enclosed, small, lightweight, and have no moving parts.**
- ☐ **Silicon material is used to manufacture diodes, transistors, silicon controlled rectifiers, and integrated chips.**
- ☐ **Silicon diodes convert alternating current to direct current.**
- ☐ **Two types of transistors are NPN and PNP and use small amounts of current to regulate or control large amounts of current, voltage or power.**
- ☐ **SCR's can be triggered, or turned on by applying a low level signal pulse to the gate lead.**
- ☐ **Integrated circuits are complete miniature electronic circuits formed on very small silicon chips.**
- ☐ **Printed circuits use discrete (individual) components which are separately mounted and soldered to the insulator type board.**

# CHAPTER 3
# HOW A SOLID STATE CIRCUIT WORKS

The solid state circuit operation is not difficult to understand, when it is divided into sections. The block diagram shown in Figure 4-1 includes the main components which make up the solid-state circuit.

The sequence of operation of Figure 4-1 is as follows:

1. Input power is applied to the machine. The contactor contacts close when the ON button is pushed.
2. When the line contactor closes, the main transformer $T_1$ becomes energized. At the same time the control circuitry on the printed circuit board $PC_1$ is energized, which can provide "gate pulses" to energize the solid state contactor $SR_1$.
3. The current control adjustment $R_5$ sets the weld output by varying a reference signal to components on the $PC_1$ board.
4. The feedback current transformers ($CT_1$, $CT_2$, $CT_3$) sense the level of current in the weld output. The AC signal they produce is rectified on $PC_2$ to a DC signal representative of the output current level.
5. The feedback board $PC_2$ sends a DC signal to the main $PC_1$ board. This feedback signal is compared to the set reference or amperage level from $R_5$. If the output current is too high or too low, the $PC_1$ board adjusts the trigger point of the SCR's, earlier or later in the cycle. This compensates for any change in the output current compared to the setting on the main current control $R_5$.
6. The syncronization signal is sent to the $PC_1$ board. This signal is used to determine the proper triggering sequence of the SCR's. The syncronization winding is wound on the secondary of the main transformer $T_1$.
7. The function of the $PC_1$ board is to use the information received from the main current adjustment ($R_5$), the syncronization signal, and the feedback signal, to determine when the SCR's in the main rectifier $SR_1$ should be triggered.
8. The stabilizer "Z" (inductor) is designed to smooth the welding current. The characteristic of an inductor is that it opposes changes in current flow in the circuit. Through constant building up and collapsing of the magnetic field the stabilizer acts as a shock absorber. An inductor, or stabilizer, "takes the bumps out of the road" so to speak, and smoothes the welding arc.

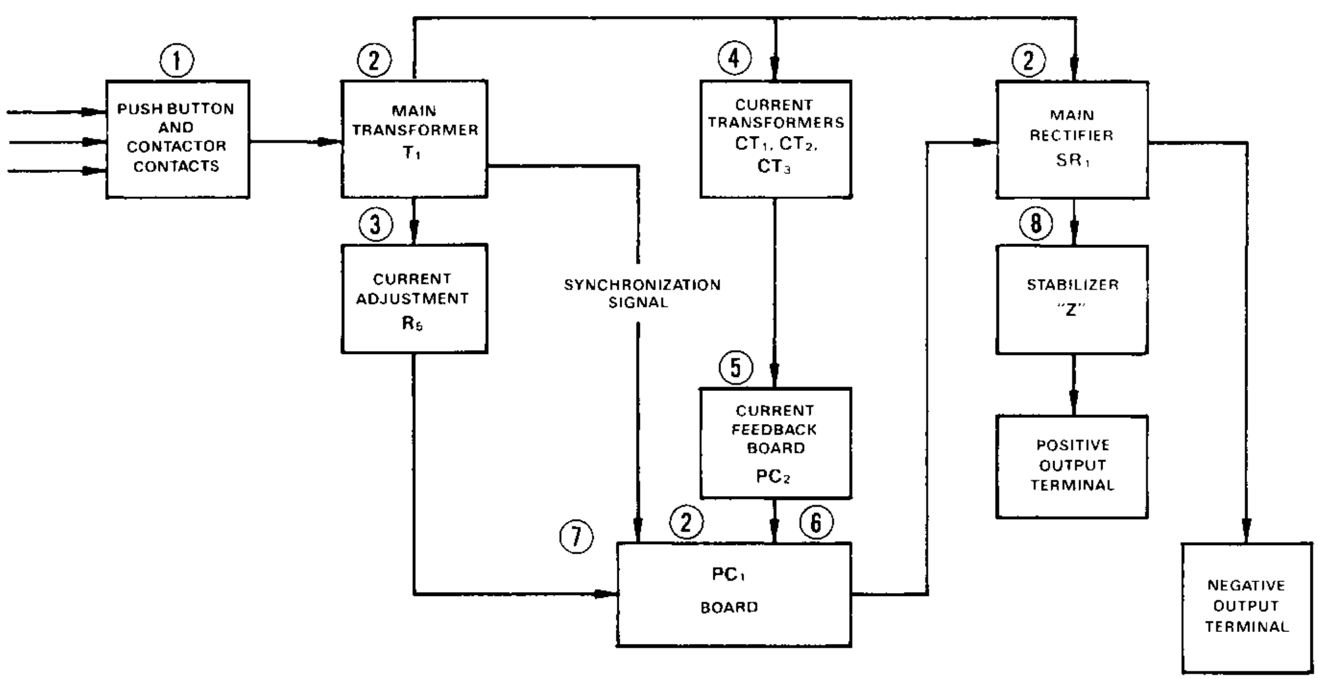



**FIGURE 4-1 BLOCK DIAGRAM OF A SOLID STATE POWER SOURCE**

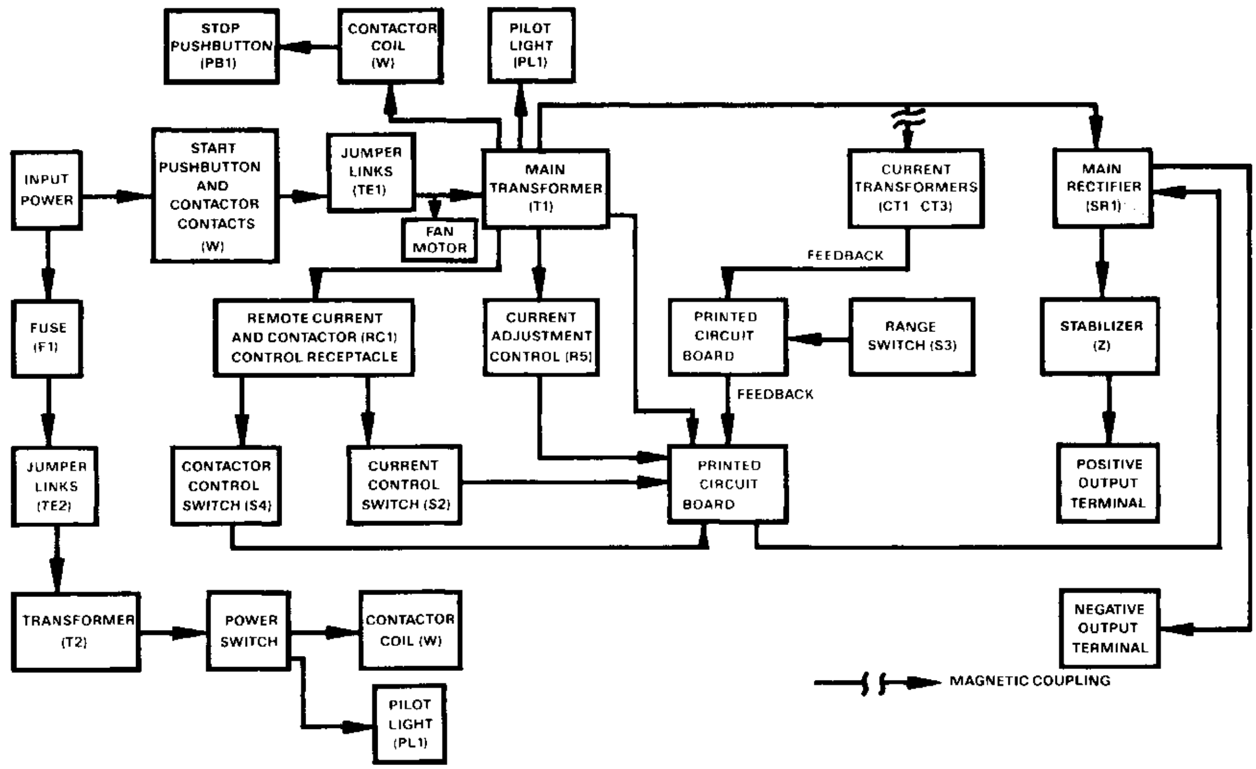



**FIGURE 4-2 COMPLETE BLOCK DIAGRAM OF A SOLID STATE WELDING MACHINE**

After examining the basic block diagram, additional components and controls are included as shown in Figure 4-2. These items include fuses, pilot lights, a fan and switches.

To understand solid state diagrams it is easiest to discuss important sections of the circuit separately. These sections include the primary circuit, control circuit, the SCR control circuit, and the main rectifier.

The primary circuit shown in Figure 4-3 consists of the incoming primary line, which is connected to the contactor points (W) and then to the primary board. The primary voltage links are located on this board and are used to change the machine primary voltage as indicated by a label attached near the primary board.

The primary of the transformer is also connected to this board. The transformer is commonly referred to as a step-down transformer, because the primary line voltage (normally 230 or 460 volts) is stepped down to a lower voltage of 80 volts or less depending on the design of the machine.

The fan motor (FM) is also connected to the primary of the transformer $T_1$.

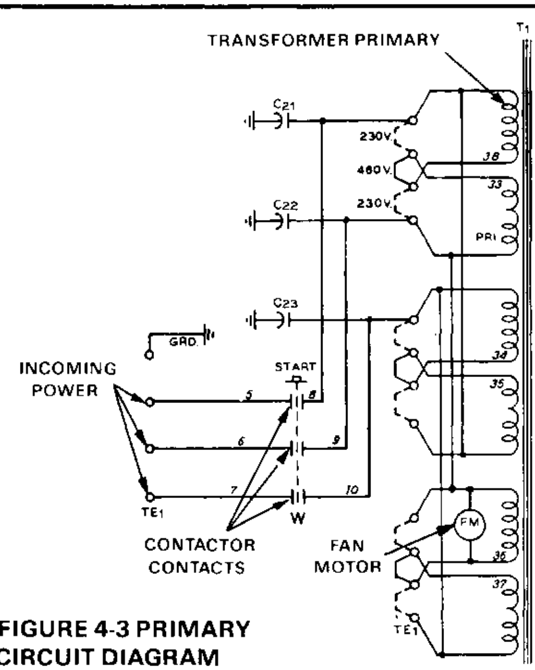



**FIGURE 4-3 PRIMARY CIRCUIT DIAGRAM**

## Control Circuit

The control circuit, Figure 4-4 is powered by the line voltage through the terminal board $TE_1$.

For additional overload protection a thermostat $TP_1$ is mounted in the main rectifier $SR_1$. If any overheating occurs in this rectifier, the control circuit will open, the line contactor coil (W) will open and the machine will shut down.

## SCR Control Circuit

The current control adjustment $R_5$ shown in Figure 4-5 regulates the output by varying the voltage supplied to the components on $PC_1$.

Syncronization windings are wound on the secondary of $T_1$. The syncronization signal is fed to the $PC_1$ board and is used to trigger or fire the SCR's in their proper sequence of order.

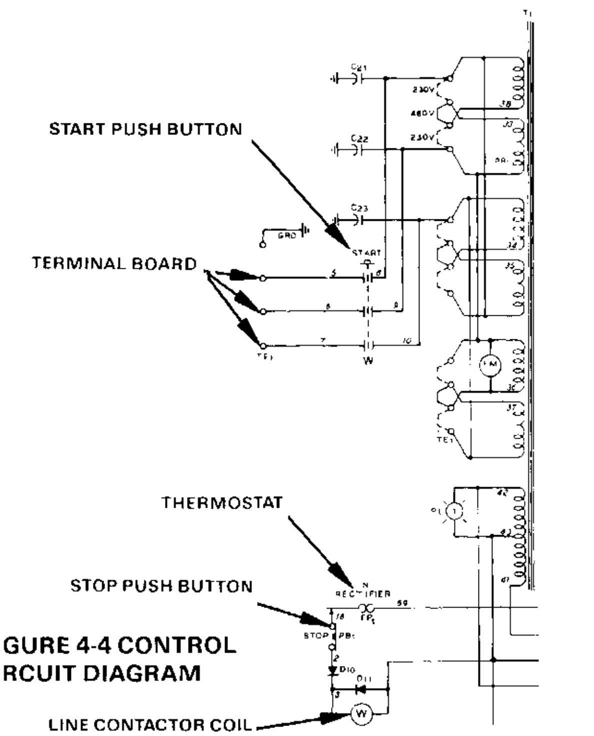


FIGURE 4-4 CONTROL CIRCUIT DIAGRAM

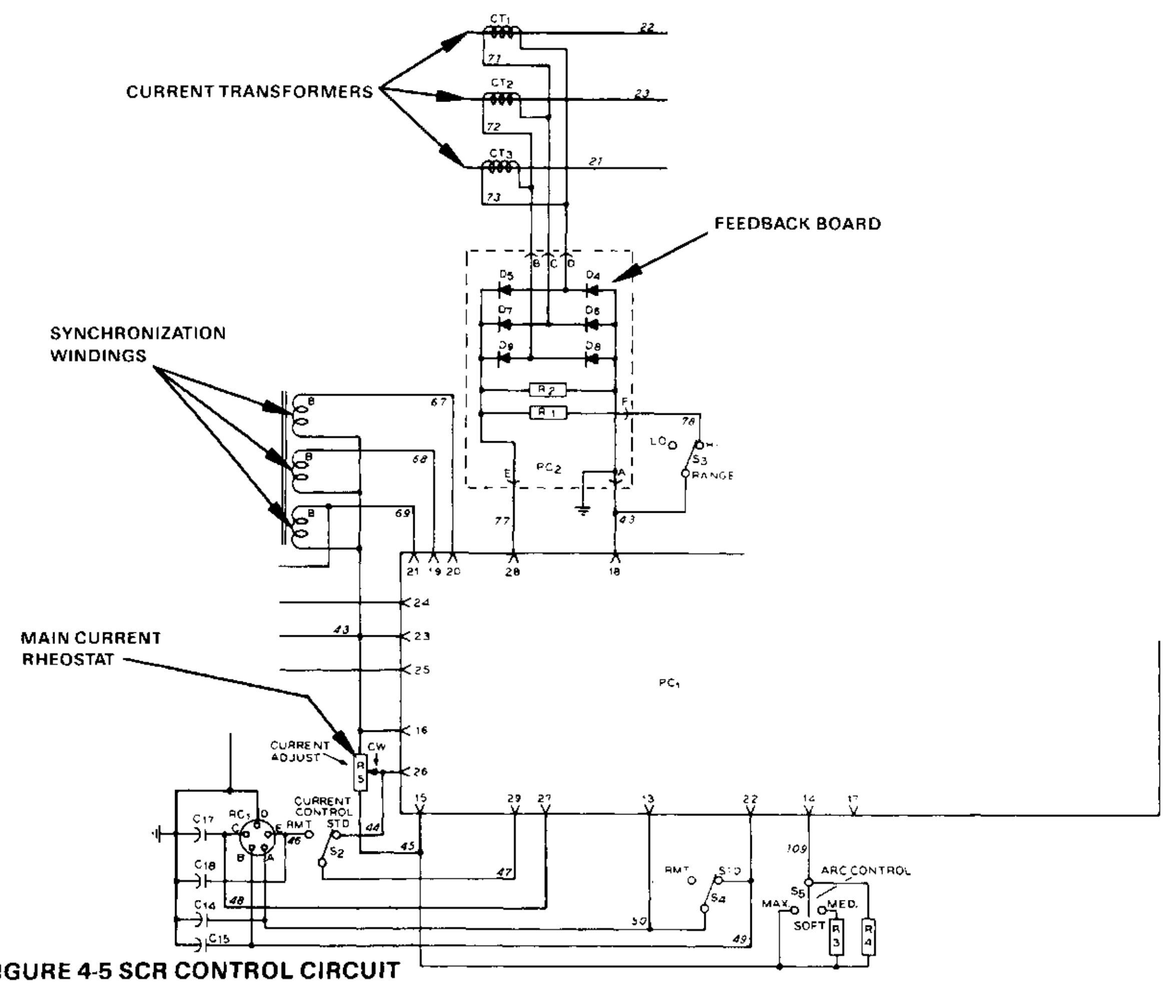


FIGURE 4-5 SCR CONTROL CIRCUIT

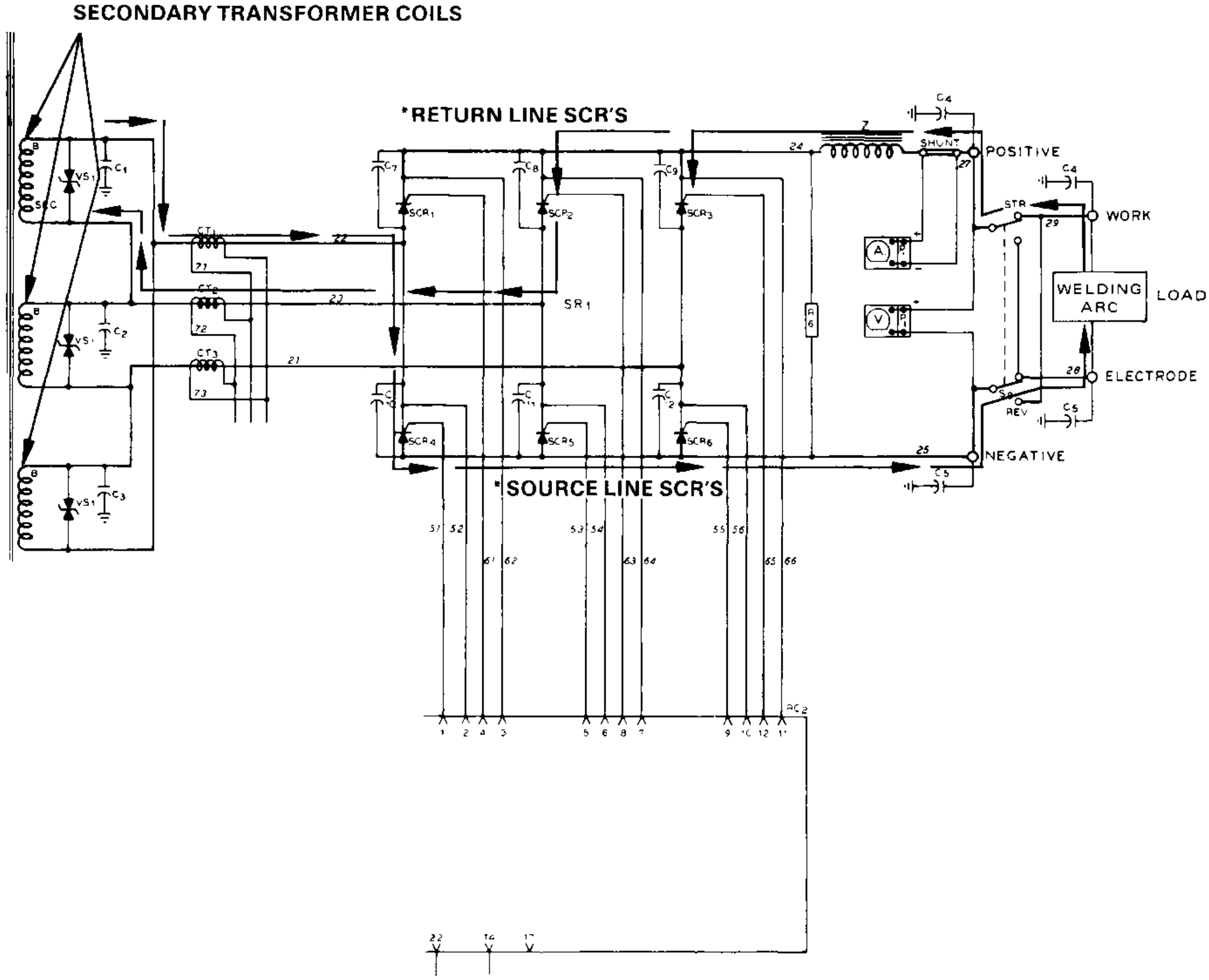



**FIGURE 4-6 SCR RECTIFIER**

## SCR Rectifier

The Alternating current (AC) from the transformer $T_1$ is converted to Direct current (DC) thru the main rectifier $SR_1$, which is a three phase, full wave Silicon Controlled Rectifier.

As shown in Figure 4-6, during one half cycle of AC, current passes from line #22 through $SCR_4$, through the load (welding arc), the stabilizer "Z," $SCR_2$* or $SCR_3$* and back to the main transformer secondary.

During the opposite half cycle, from line #23 current passes through $SCR_5$ through the load (welding arc) in arc) in the same direction as the previous half cycle, through the stabilizer "Z", and returns through $SCR_1$*.

## *IMPORTANT

The return path for the current is determined by the input phase relationship. Since there are several ways to connect a three phase line, the return path cannot be determined unless the input phase relationship is known.

In other words, the return line must be different than the source line. $SCR_1$, $SCR_2$, and $SCR_3$ are the return lines, and $SCR_4$, $SCR_5$, and $SCR_6$ are the source lines.

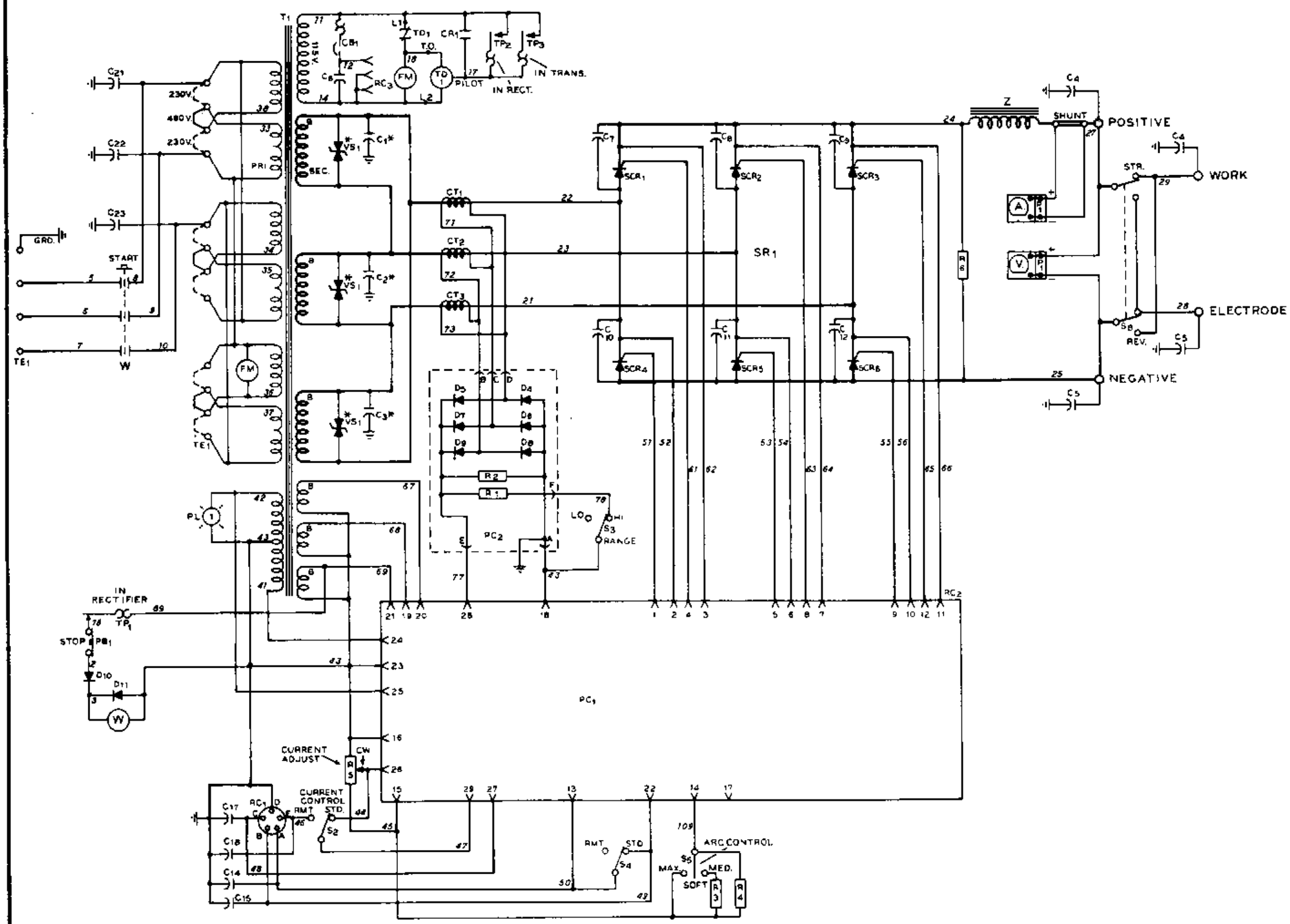



**FIGURE 4-7 COMPLETE CIRCUIT DIAGRAM OF SOLID STATE POWER SOURCE**

The complete circuit diagram shown in Figure 4-7 includes each section as previously discussed. By analyzing specific sections of a circuit diagram it is much easier to understand how the power source works.

NOTE: The information contained within this booklet discusses the fundamentals of Solid State, and may not apply to all solid state welding power sources presently available.

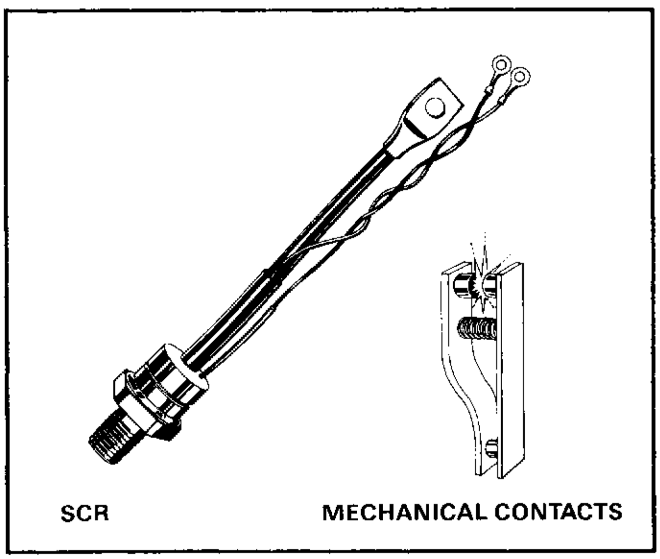
# CHAPTER 4
# WHO USES SOLID STATE AND WHY!

**Because of the rapid acceptance of solid state, progressive, growing companies are purchasing machines which offer the benefits, features, and the latest technology available. What they are finding are the features and benefits of solid state.**

**Some of these solid state features and benefits are:**

- ☐ Solid state contactor
- ☐ Line voltage compensation
- ☐ Adjustable arc characteristics
- ☐ Versatility of equipment
- ☐ Improved arc characteristics
- ☐ Lower maintenance costs
- ☐ Equipment can be mechanized, automated, programmed
- ☐ Wireless remote control
- ☐ Miniature remote control
- ☐ Lower open circuit voltage
- ☐ Fast machine response to operator demands (man-machine relationship)
- ☐ Excellent pulsing characteristics
- ☐ Solid state timers
- ☐ Lighter weight

Here are some detailed benefits of the previously mentioned solid state features:

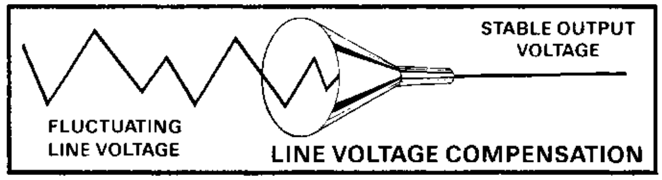



### Solid State Contactor

- ☐ It does not require replacement of contact points
- ☐ It is ideally suited when the welding process requires high cycling rates (turning the contactor on and off) such as stud welding, spot welding and short tack welding applications.
- ☐ It is totally enclosed so dirt, dust, and adverse environment conditions have less affect on its performance.

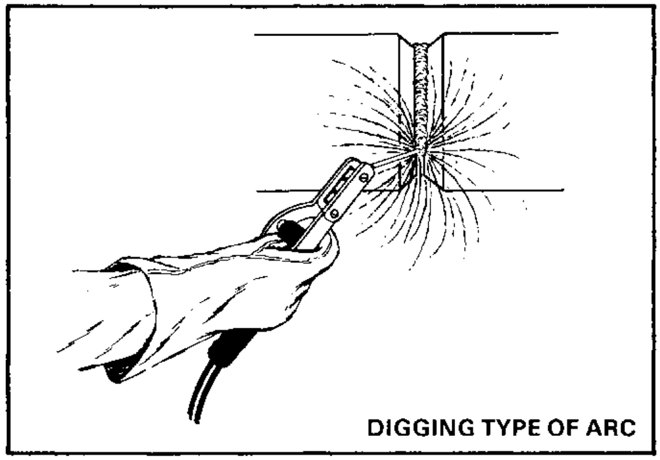
### Line Voltage Compensation (L. V. C)

- ☐ Provides a more stable welding arc if the line voltage fluctuates.

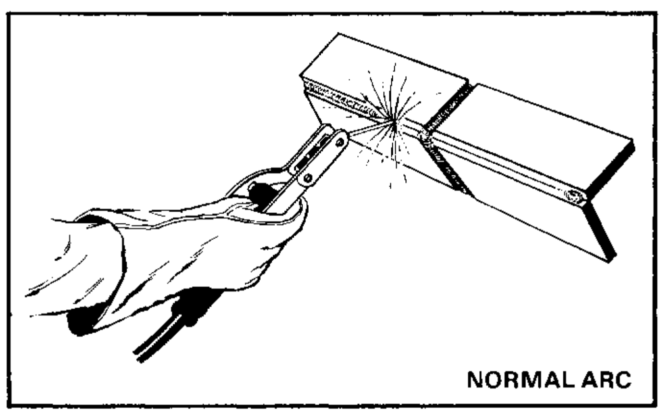



- ☐ Generally plus or minus 10% line voltage changes can be compensated for, which means a primary line of 230 volts could drop to 207 volts or rise to 253 volts and the welding arc would only change approximately 2 percent.

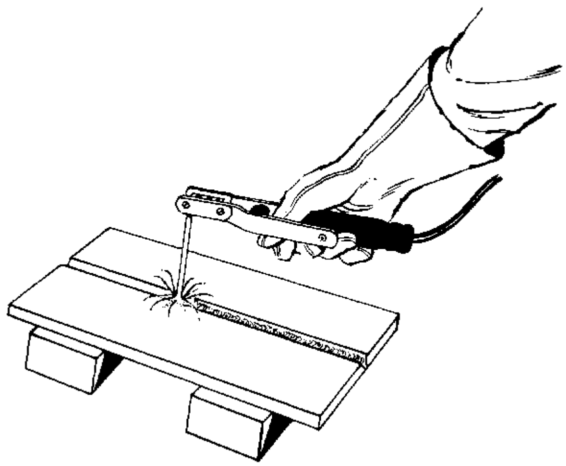
### Adjustable Arc Characteristics




- ☐ Some solid state machines provide arc adjustments such as the soft, normal, and "digging" type of arc conditions. This is accomplished by the flip of a switch; and is easy to adjust.




- ☐ Operators can select the type of arc to match a welding requirement. For example; high alloy electrodes using the soft arc condition produce less spatter, but another welder using a mild steel electrode might prefer to use the "digging" type of arc for his application. Arc performance can be tailored to the job at hand.



**SOFT ARC—MINIMUM SPATTER**

☐ When TIG welding aluminum or magnesium an adjustable alternating current "balance control" provides variable arc conditions on some AC/DC solid state machines.

**Versatility of Equipment**

☐ Most solid state machines include contactors as standard equipment, NOT as an option.

☐ Welding ranges on solid state machines are low enough to use for many TIG welding applications.

☐ Add on modules provide high frequency, gas and water solenoids for TIG welding, and auxiliary AC power for grinders or hand power tools (optional).

☐ Pulsing and upslope/downslope current control is available (optional)

☐ Can be remotely controlled using a wireless remote amperage control or with torch mounted miniature remote control (optional).

☐ Perform high quality TIG welding on the first pass, then change to stick on remaining passes, quickly and easily.

☐ Convenient toggle switch changes ranges.

☐ Many options can be field installed—when the need arises.

**Improved Arc Characteristics**

☐ Less spatter, smooth arc conditions on TIG and Stick applications

☐ Easy arc starting

☐ Minimum current drift—"what you set is what you get" through use of solid state feedback controls.

**Lower Maintenance Costs**

☐ No mechanical contactor wear—no contact points to arc or fuse together

☐ Solid state contactor is less susceptible to dirt, grinding dust, or external environments, because the components which make up the contactor are enclosed.

☐ Solid state components have no moving parts to malfunction.

☐ Solid state contactors used in production, where rapid cycling is required.

☐ Less heat generated by solid state components prolong life of equipment.

☐ Printed circuit boards are assembled and dipped in protective sealant for maximum protection.

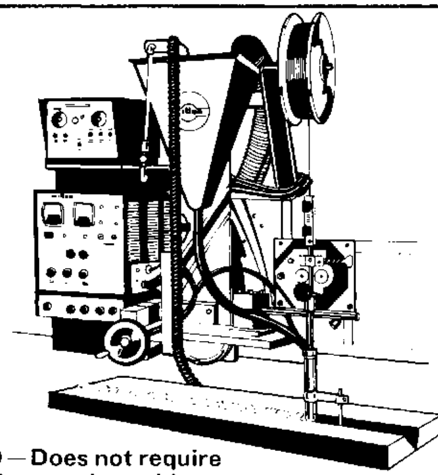
**Solid State Equipment Can Be Automated/ Mechanized**

☐ Programmers using solid state timers are adaptable to solid state power supplies.

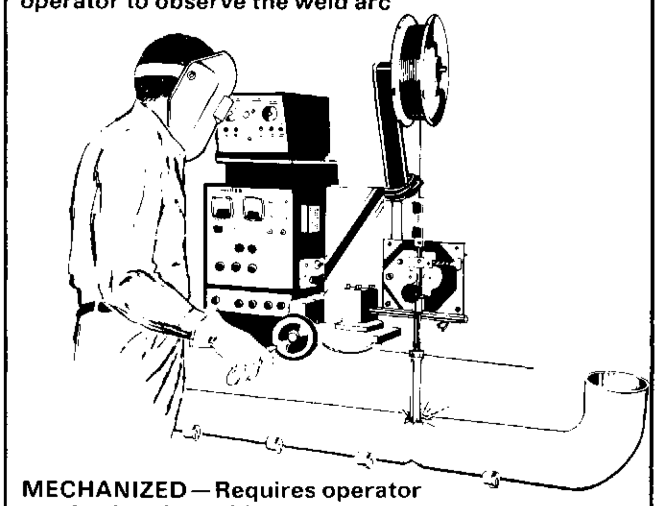
☐ Automating/mechanizing reduces need for highly skilled weldors, of which there is always a shortage.

☐ Automated/mechanized equipment increases production and minimizes rejection rates.

☐ Solid state timers are generally used to program the weld cycle.



**AUTOMATED—Does not require operator to observe the weld arc**

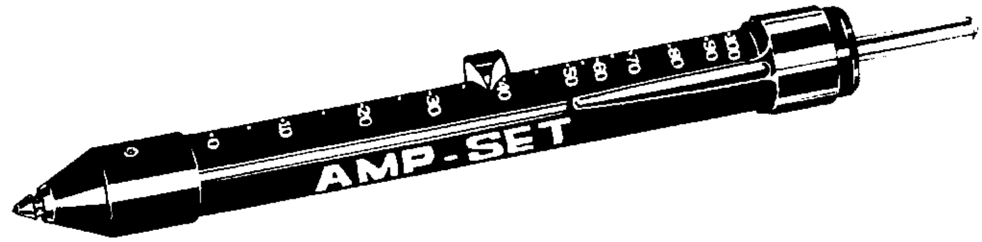


**MECHANIZED—Requires operator monitoring the weld arc.**

☐ Digital timers with accuracies of $\pm$ .008 seconds are readily available.

☐ Open style relays are no longer required, so the effects of dirt, dust and external contamination is eliminated.

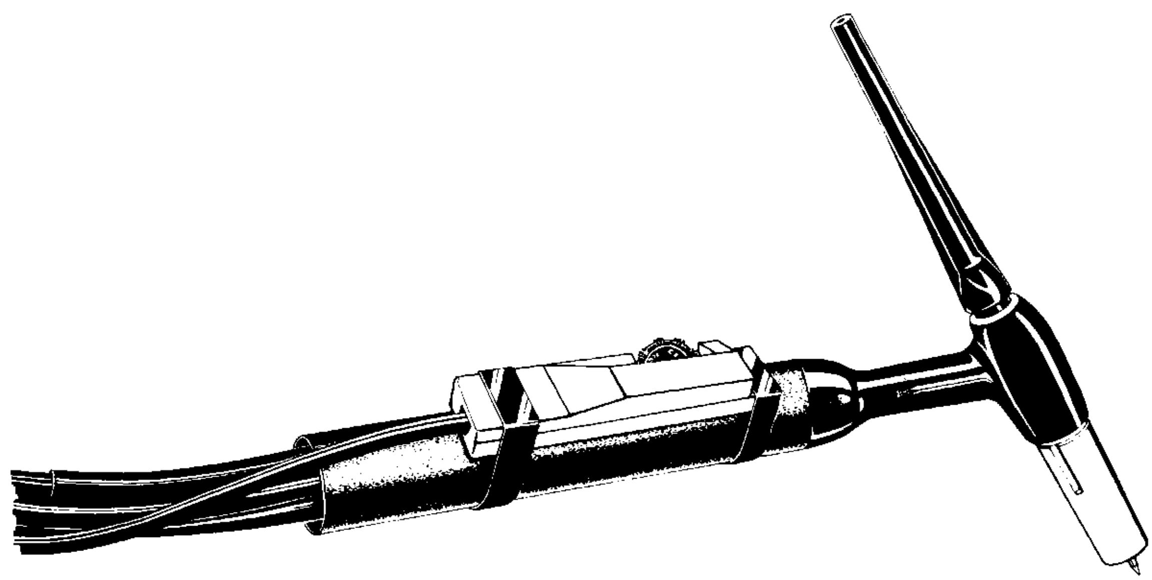
☐ Precise, repeatable weld conditions are produced with solid state programmers, and power sources.




**AMP SET WIRELESS REMOTE CONTROL PEN**

### Wireless Remote Control

- ☐ Provides welding operator opportunity to change current setting without returning to his machine.
- ☐ No wires or hand control at work station
- ☐ Operator can change current easily and fast
- ☐ Ideal when different welding positions are encountered and current must be changed frequently, such as pipe welding.
- ☐ Convenient when machine is located at some remote distance from the operator.
- ☐ *Fast* when changing electrode diameters, which usually requires a current change, or changing processes such as stick to arc-air and back to stick.
- ☐ Welders will be more relaxed and perform better as the result of not having to climb or walk back to the welding machine.
- ☐ Welders do not need to compromise or "make do" with the wrong current just because they dread a trip back to the power source.



**MINIATURE FINGER TIP CONTROL**

### Miniature Remote Controls

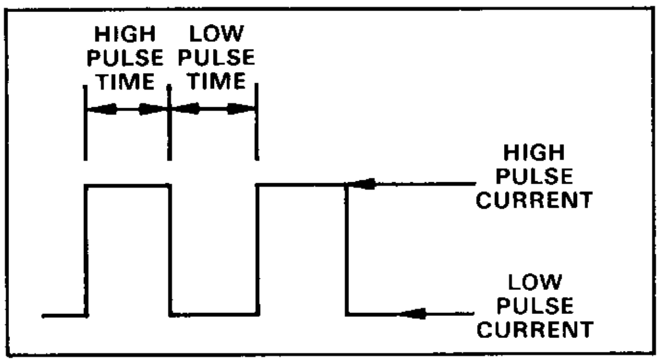
- ☐ Miniature controls can be used because very low current (milliamps) are used to regulate the control circuit.
- ☐ Eliminates large higher wattage rheostats which means remote controls operate cooler.
- ☐ Smaller remote control cables and miniature, low power switches can be used because less power is required to operate solid state devices.
- ☐ Contactor and current control switch can be mounted on the welding torch for maximum operator control without the need to stop welding for readjusting current.
- ☐ Can be used at longer distances from power source without increasing remote cable size.

### Lower Open Circuit Voltage

- ☐ Using solid state circuitry arc starting characteristics are good.
- ☐ The lower open circuit voltage allows many of the same welding processes to be performed without sacrificing the quality of the weld.

### Fast Machine Response to the Operator's Demand (Man-Machine Relationship)

- ☐ When using remote controls, solid state machines respond very rapidly to changes made by the operator.
- ☐ Fast response is also advantageous when the amperage must be precisely controlled and adjusted immediately-- as required when pulsing is used.




### Excellent Pulsing Characteristics

- ☐ Solid state machines when used for pulsing from background to peak currents, respond very fast. This provides excellent bead appearance with close ripple spacing when required.
- ☐ Provides good width to depth ratio and penetration.
- ☐ Provides narrow heat affected zone.
- ☐ Minimized distortion due to less heat input to work
- ☐ Provides good stirring or mixing action in the puddle—beneficial when welding dissimilar materials which must be forced or mixed together.
- ☐ Good for controlling out of position welding—the rapid heating and cooling provides additional arc control.
- ☐ Pulsing may be used to control bead configuration—as required in tube mill applications.

### Solid State Timers

- ☐ Are extremely accurate
- ☐ Can be cycled rapidly
- ☐ Have excellent repeatability
- ☐ Have a longer lifespan than mechanical timers
- ☐ Are not affected by dirt, dust, and external environment
- ☐ Are compact, lightweight, and rugged

### Lighter Weight

- ☐ A typical conventional magnetic amplifier weighs approximately 175 pounds and a comparable solid state circuit weighs about 40 pounds.
- ☐ Easier to move equipment.
- ☐ Lower transportation/shipping costs.

### Who is Buying Solid State Equipment?

- ☐ Shipyards
- ☐ Nuclear power plants
- ☐ Automotive/trucking industry
- ☐ Aircraft
- ☐ Tube mills
- ☐ Construction/bridges and buildings
- ☐ Refineries
- ☐ Metal fabricating
- ☐ Pipe fabricating
- ☐ Pressure vessel/boiler fabrication
- ☐ Maintenance welding
- ☐ Railroads
- ☐ Aerospace industry
- ☐ Chemical plants
- ☐ Government installations

### Related Welding Industry Now Using Solid State

- ☐ Stud welding equipment
- ☐ Automated robots
- ☐ Stress relieving
- ☐ Flame cutting equipment
- ☐ Induction heating equipment
- ☐ Electron beam
- ☐ Positioning equipment
- ☐ Fixture builders/motor speed controls
- ☐ Non-destructive testing equipment (X-ray and Ultrasonics)
- ☐ Digital voltmeter/ammeter in repair shops
- ☐ Oscilloscopes in repair shops
- ☐ Computers for inventory, pricing/total system control
- ☐ Automatic weld controls
- ☐ Oscillators/torch manipulators
- ☐ Weld simulators

### What is the Future of Solid State?

Without a doubt, solid state is here to stay. The benefits of solid state are just beginning to change the welding industry. There will be new developments, better performance, greater reliability and better welders as a result of solid state in the years to come.

# GLOSSARY OF TERMS

**Alternating Current:** (AC) Electric current which changes direction, rising from zero to a maximum in the positive direction, falling to zero and then increases to maximum in the negative direction, before returning to zero, after which the cycle repeats.

**Ampere:** A measurement of electric current. It represents the rate at which current is caused to flow through a conductor.

**Anode:** The positive electrode of a semiconductor.

**Cathode:** The negative electrode of a semiconductor.

**Conductor:** Materials such as copper and aluminum which allow electrons to flow easily.

**Control Circuit:** A low voltage, low power circuit used for controlling other portions of a circuit which contain larger amounts of power.

**Current:** The flow of electrons, also expressed in amperes.

**Cycle:** A complete operation, in electricity both positive and negative half cycles constitute one complete cycle.

**Diode:** A semiconductor device that allows current flow in the forward direction while blocking it in the reverse direction.

**Direct Current:** (DC) Electricity that flows in only one direction.

**Frequency:** The number of times per second an alternating current goes through a complete cycle. Referred to as "Hertz" (hz).

**Gate:** The control lead of an SCR.

**Hertz (hz):** A term that means the same as cycles per second.

**Impedance:** The total opposition to current flow in an AC circuit, which consists of reactance and resistance.

**Insulator:** Materials such as glass and porcelain that have a high resistance to current flow.

**Integrated Circuit:** A miniature solid state circuit made up of miniature resistors, diodes, and transistors. These components and related wiring are processed within a single silicon chip.

**Phase Control:** A means of controlling alternating current using an SCR. By varying the triggering (firing) point of the SCR, in each AC half cycle, phase control is accomplished.

**Resistance:** Opposition to current flow inherent in any material. Measured in OHMS.

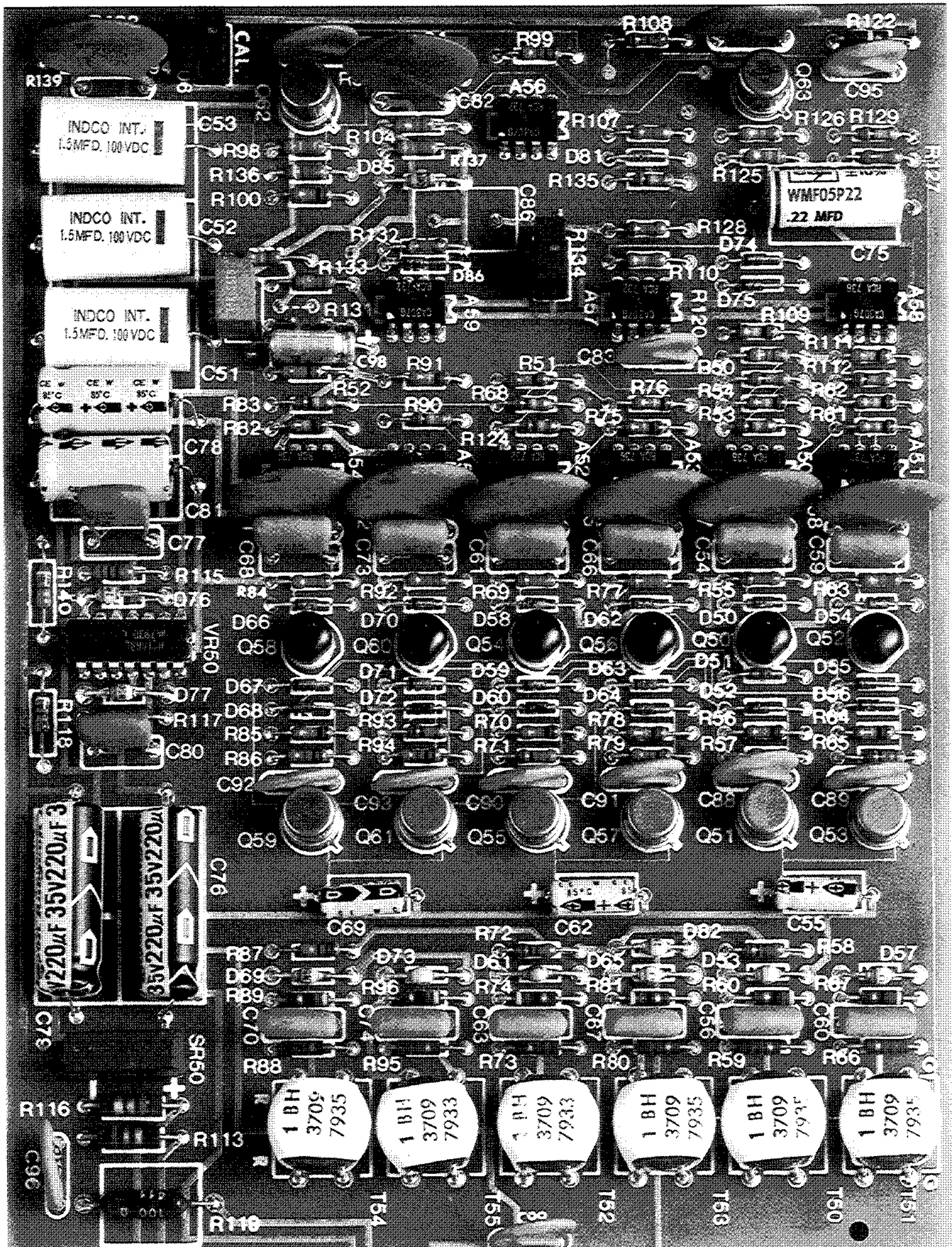
**Rectifier:** A device to convert alternating current to direct current.

**Semiconductor:** A material having electrical properties between those of conductors and insulators.

**Stabilizer:** A coil with an iron core used in the secondary portion of a DC power source to smooth the ripple.

**SCR (Silicon Controlled Rectifier):** A variation of the diode with a gate terminal. Triggering the gate lead turns the device on.

**Voltage:** Voltage is the force, pressure, or electromotive force (EMF) which causes electric current to flow in an electric current.



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D85
R137
R107
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R135
R126
R129
R125
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1.5MFD. 100 VDC
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INDCO INT.
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WMF05P22
.22 MFD
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