IBM Customer Engineering

Manual of Instruction

7090 Power Supply

Control and Distribution

IBM Customer Engineering Manual of Instruction

7090 Power Supply Control and Distribution

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FOREWORD

This manual has been prepared for teaching purposes and as an aid for learning the IBM 7090 Converter Power Supplies. All material is related to production at a given engineering change level; use of this manual as a reference is subject to changes in the system.

Text and illustrations explain the theory and logic of the modular power supplies, the power control unit, the power converter unit, and tape unit power supplies.

MAJOR REVISION (February 1961)
This edition, Form 223-6904, obsoletes Form 223-6839.
Significant changes have been made throughout the manual, and this new edition should be reviewed in its entirety.

Printed in U.S.A.
Form 223-6904

POWER SUPPLY CONTROL AND DISTRIBUTION

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1.0.00 INTRODUCTION

THE POWER SUPPLY used with transistorized circuits in standard modular systems (SMS) has four major parts:

1. The IBM 7608, a power converter or motor-generator set which converts incoming 60-cycle, three-phase (3∅), 208 v power to regulated 400-cycle, 3∅, 208v power.
2. Power supplies in each modular frame which supply voltage to all circuits in that frame.
3. The IBM 7618, a power control unit (PCU) which contains system power control circuits, motor-generator (M-G) regulator and marginal check Variacs*.
4. Marginal check (M/C) controls located in the main console.

The output voltage of the motor-generator set, a commercially available unit, is regulated, eliminating the need for voltage regulation in most of the modular power supplies. Using 400-cycle AC to rectifiers means fewer filter capacitors are required in the modular power supplies, as well as smaller transformers.

Figure 1.0-1 shows the logic of the power system. Two power supplies are located in each modular frame; one supply (power supply A) is for gates A and B; the other (power supply C) is for gates C and D. The power supplies are three-phase, full-wave rectifiers using the 400-cycle output of the generator. All rectifiers are silicon diodes which have large current carrying capacities. The power supplies are physically located at the rear of each slide in the modular frame.

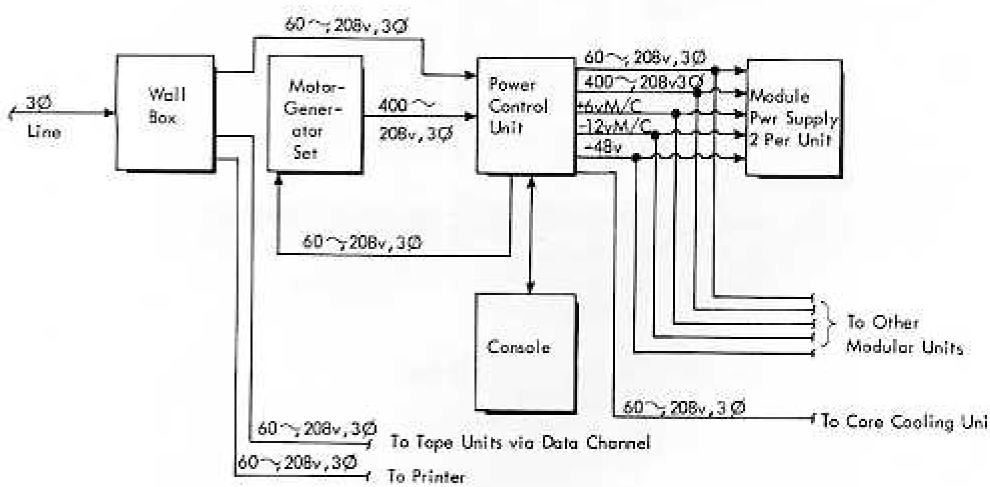


FIGURE 1.0-1. 7090 POWER SUPPLY SYSTEM

* Trademark of General Radio Company

Marginal checking may be performed on part of the +6v supply, part of the -12v supply, and core storage driver collector voltages. Marginal check controls for all units are mounted on the console unit.

Each modular power supply has its own open-fuse detection circuit. In 7090 systems, a blown fuse drops power to only its own frame. Interlock circuits drop power to the second half of the unit when a fuse blows.

The PCU is a separate frame containing circuits which control power to all modular units. Power sequence contactors, power-on and marginal check Variacs, blower relays and their overload circuit breakers (CB), and system power control keys are the major circuits in the PCU.

Power is brought up in the system by closing a power-on key, which starts the motor-generator. A power-on Variac, through contactors for the modular frames, brings all voltages, except core storage power transistor collector voltage, up slowly. A second Variac cycle brings up collector voltage to the core storage power transistors through a special power supply in the core storage module.

Power for the tape drives is from the wall outlets through the channel module, where the power is interlocked with a data channel power-on relay.

A 55 volt supply and a 48 volt supply located in the printer furnish necessary DC voltages to the card machines.

2.0.00 MODULAR POWER SUPPLIES

2.1.00 STANDARD MODULAR POWER SUPPLY UNIT

Each SMS unit contains two independent standard power supply units. Supply voltage for the units is 400 cycle, 3-phase, 208v power from the power converter unit. Each standard power supply unit controls two of the SMS unit's four gates: one power supply unit supplies gates A and B; the second unit supplies gates C and D.

7090 Standard Modular Power Supply

A typical standard modular supply is shown in Figure 2.1-1.

Figure 2.1-2 shows the logic of a standard power supply unit. A single transformer feeds all rectifiers in the unit. Each unit (Figure 2.1-3) develops nine separate voltages. Marginal check voltages M/C-1 and M/C-2 are voltages that may be varied to marginal-check the unit. M/C-1 voltages vary the voltage in gate A; M/C-2 voltages vary the voltage in gate B. (The power supply that feeds gates C and D uses M/C-1 for gate C and M/C-2 for gate D.)

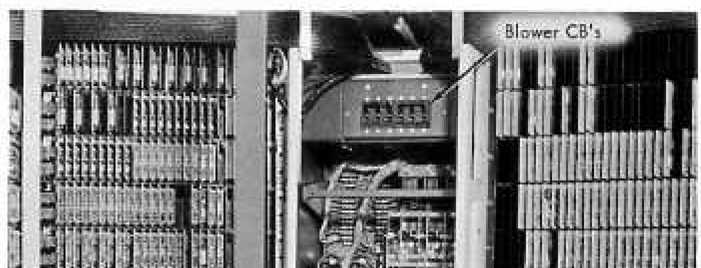


FIGURE 2.1-1. 7090 STANDARD MODULAR SUPPLY - INSTALLED IN 7607

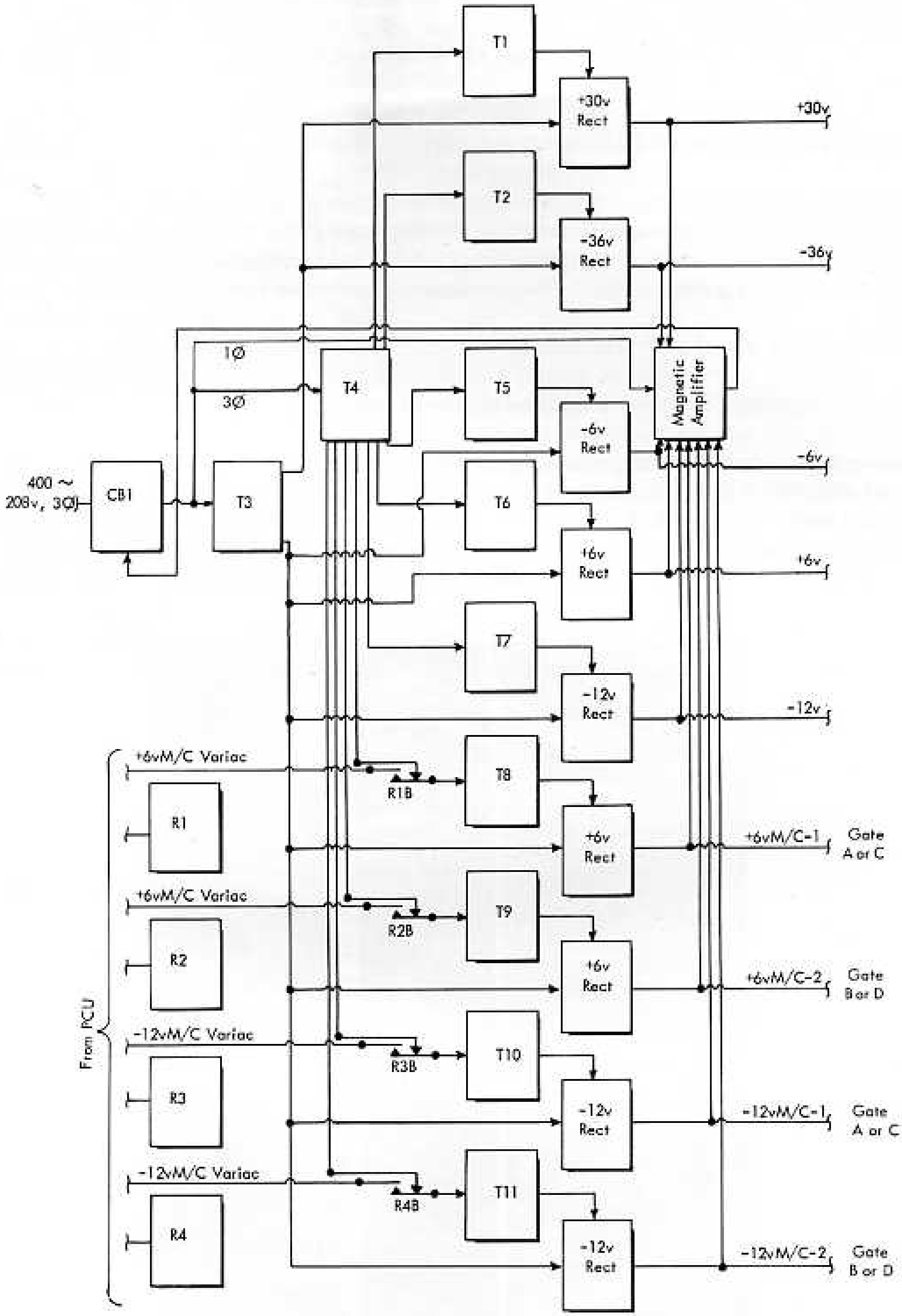


FIGURE 2.1-2. STANDARD POWER SUPPLY UNIT

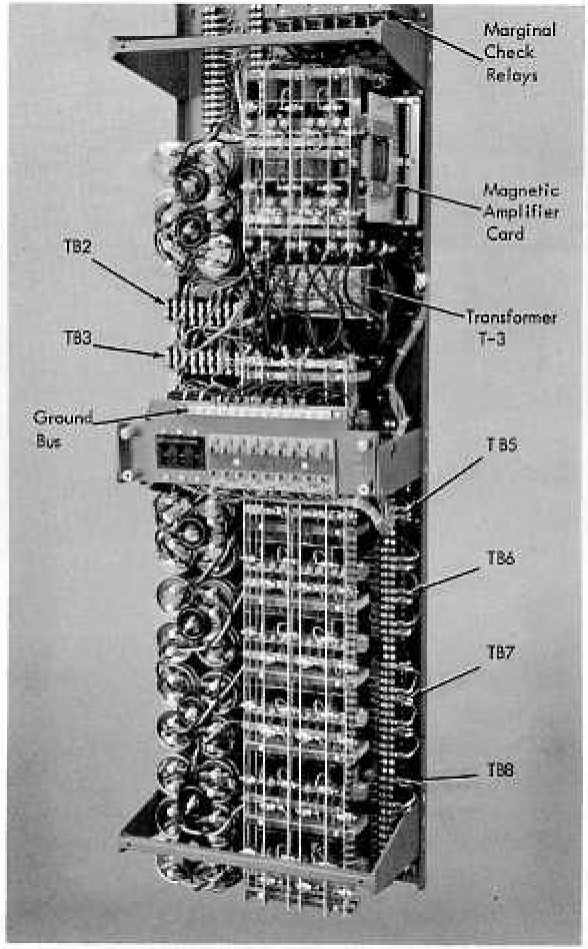


FIGURE 2.1-3. STANDARD MODULAR SUPPLY

Schematically, each of the nine separate voltage supplies are identical. Each supply feeds a magnetic amplifier, which opens the CB points (feeding the input of T3) if a fuse opens. Another point on the CB drops all DC power to the SMS unit in which the fuse opened.

2.1.01 Rectifier Voltage Supplies

A typical voltage supply is shown in simplified form in Figure 2.1-4A. When the positive-going pulse A is seen at the plate of rectifier C, electrons flow from point E through the load, half of the secondary winding of T5, rectifier C, the secondary of T3, and back to point E. When the plate of diode D goes positive, current again flows from point E through R_L, half of the secondary winding of T5, rectififer D, the secondary of T3, and back to point E. The result is a full-wave rectifier.

In the Figure 2.1-4A, any action of T5 is ignored. With T5 in the circuit, the output voltage V_L can be varied under control of the primary winding of T5.

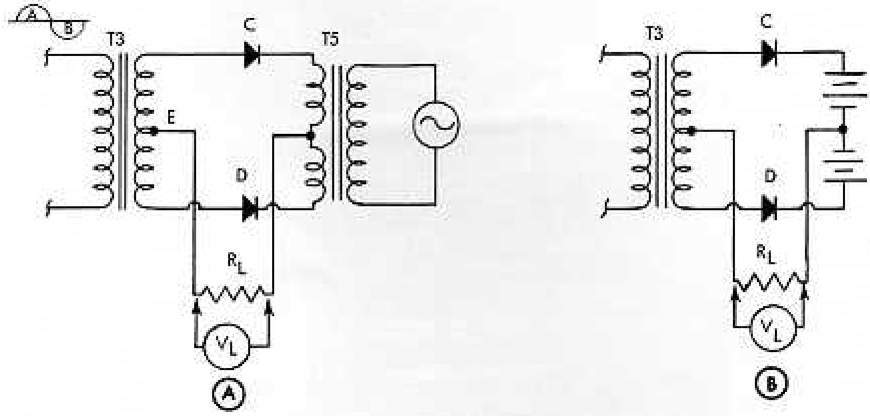


FIGURE 2.1-4. SIMPLIFIED VOLTAGE SUPPLY

If a voltage source is applied to the primary winding of T5, a voltage is developed across the secondary windings of T5. The polarity of this voltage either aids or opposes the output voltage of the rectifier. When a positive-going pulse appears at rectifier C (Figure 2.1-4B) conduction cannot begin until the voltage level of the pulse at the plate overcomes the bias of the battery in the cathode circuit. As a result, current flows for a shorter period of time during each cycle and, V_L decreases. The reverse is true if the voltage source is added with opposite polarity; the rectifier conducts at a lower plate voltage and V_L increases.

Several advantages are obtained from this type of circuit:

1. In actual 6v and 12v power supply circuits, the voltage on the primary of T3 is such that V_L should be 9v. By bucking or boosting 3v, it is then possible to obtain both 6 and 12v supplies with identical circuitry and parts.
2. By replacing the voltage source in the primary winding of T5 with a tapped output transformer, changing the tap settings adjusts voltage V_L for exact values to compensate for variations in component values and line loss.
3. Replacing the voltage source in the primary winding of T5 with a Variac allows the voltages to be varied either up or down for marginal checking.

2.1.02 Three-Phase Variac

A three-phase Variac (Figure 2.1-5A) is analogous to a three-phase potentiometer. The movable point taps off a voltage somewhere between the incoming line voltage and AC neutral. The line-to-line output voltage is shown in Figure 2.1-5B. With the movable point of the Variac at the bottom of the coil, or point A in Figure 2.1-5A or B, all output lines are effectively tied to the AC neutral line and no voltage exists between lines. As the movable point is moved up along the resistance coil to point B, a gradual increasing voltage develops between output lines. The voltage between points B-B is the voltage between output lines; the voltage A-B is the output line-to-AC neutral voltage. As the movable point is moved up the coil to point C, the output-to-line voltage increases until it is the same value as the input voltage.

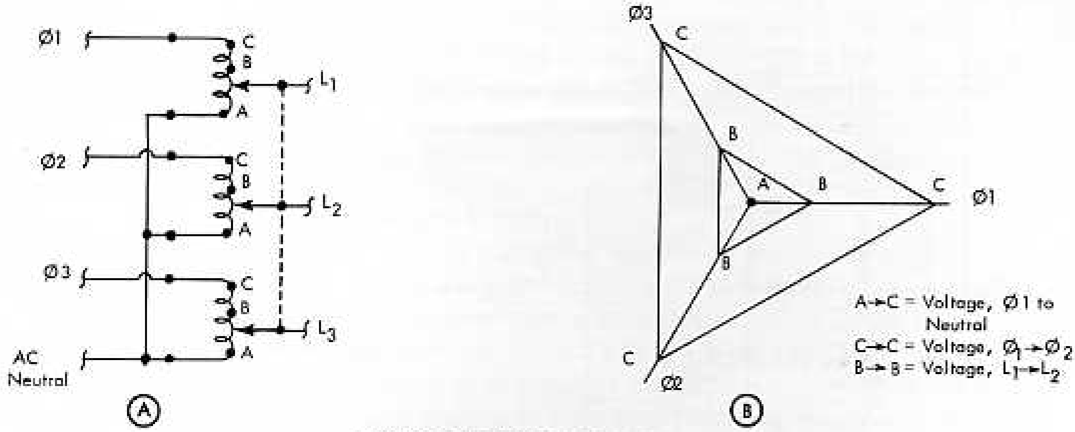


FIGURE 2.1-5. THREE-PHASE VARIAC

Variacs are used to bring circuit voltages up slowly and to vary individual supply voltages for marginal testing.

2.1.03 Marginal Voltage Development

Marginal voltages are developed by varying the amount of buck or boost voltage in the rectifier circuit. A typical marginal voltage supply is shown in Figure 2.1-6. Notice that the primary winding of T5 can be energized from two sources under control of relay R1. Under normal operation, R1 is de-energized as shown and T5 primary voltages are supplied from the tapped outputs of T4 as shown in Figure 2.1-2. When R1 is energized, the primary of T5 is then under control of the Variac; the amount of buck or boost voltage in the rectifier circuit can now be varied to change the output voltage to marginal limits. The Variac is approximately in the center of its operating range with circuit voltages at normal values; this allows a full range of upper and lower voltage limits. Relays R1, R2, R3 and R4 are constructed so that the n/o points close before the n/c points open.

2.1.04 Magnetic Amplifiers

Magnetic amplifiers are variable impedance devices. The impedance offered by the amplifier is varied by an independent source of control power; amplification occurs because the power requirements of the control source may be many times less than the power being controlled. By varying the controllable impedance, output circuit current and voltage are controlled.

Magnetic amplifiers vary widely in size and shape, depending on their use, but all use a saturable core with one or more control windings. Magnetic amplifiers may be classified in two types: saturable reactor or self-saturating.

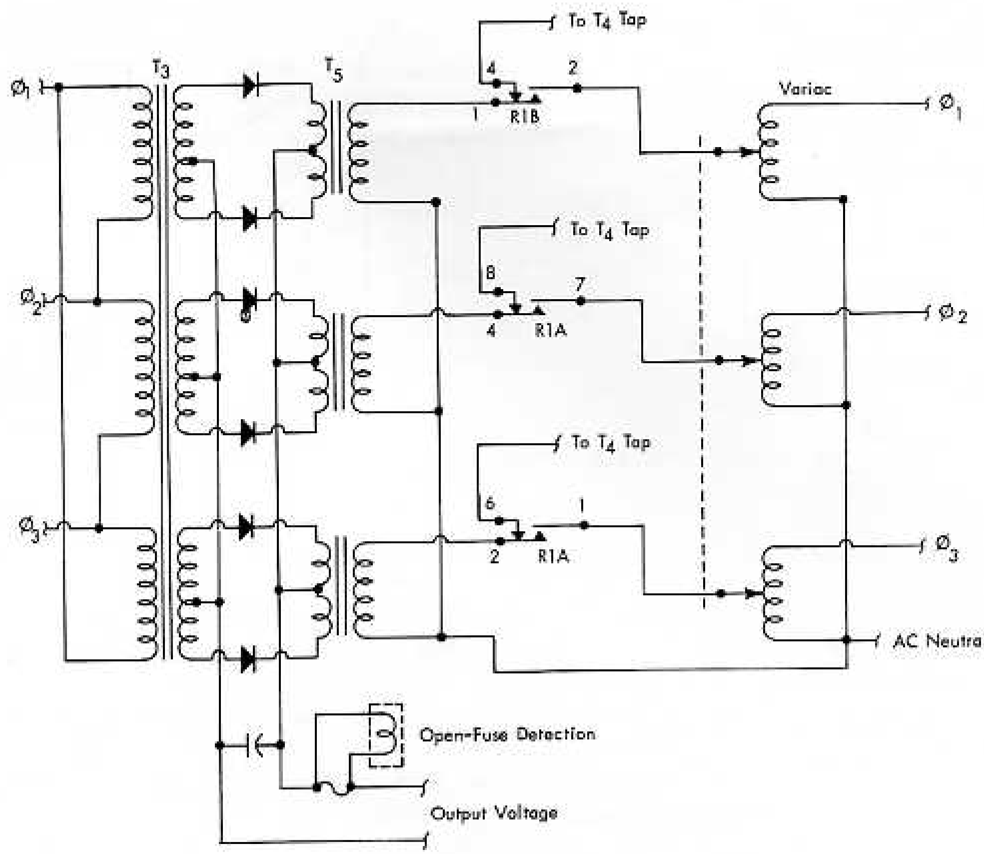


FIGURE 2.1-6. MARGINAL VOLTAGE DEVELOPMENT

2.1.05 Saturable Reactor

A saturable reactor (SR) is an inductor in which the impedance is controlled by varying the amount of flux in the core. Figure 2.1-7A uses an adjustable impedance (X_1) to represent a saturable reactor. By moving the adjustable tap A, the amount of impedance may be varied, controlling the voltage across R_L. Assume that R_L can be varied and that it is desired to have V_L remain constant. Reducing R_L tends to reduce V_L but, if X_1 is adjusted at the same time so that it has less impedance, more current flows through the circuit and V_L can be held constant.

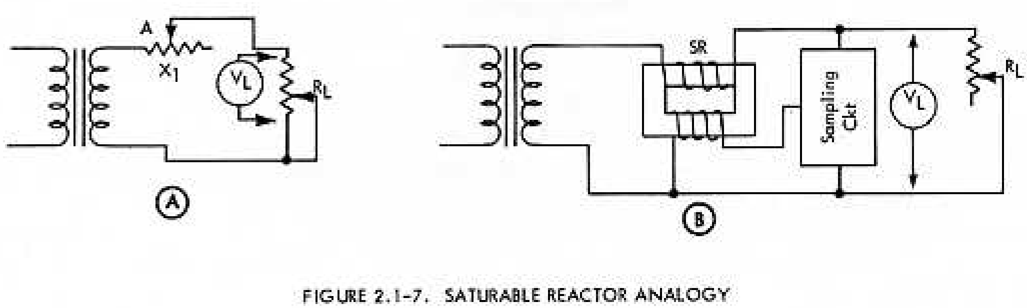


FIGURE 2.1-7. SATURABLE REACTOR ANALOGY

In Figure 2.1-7B, a saturable reactor replaces impedance X_1. The impedance of a saturable reactor is controlled by varying the magnetic flux in the core of the inductance coil. Because the impedance of an inductance coil is a function of the change in magnetic flux, the greater the change in flux, the greater the impedance. If the core of the SR is saturated (can hold no more flux) there can be no change in flux and the impedance is only the DC resistance of the coil. The farther away from saturation, the greater the impedance.

Assume that R_L (Figure 2.1-7B) is variable, but that it is desired to keep the voltage across R_L constant. A sampling circuit is used to measure the voltage across R_L. The output of the sampling circuit feeds a second (control) winding on the SR. This control winding determines how far the core is from its saturation point. Flux from the control winding can oppose or aid that of the inductance coil. Whether the flux from the control winding aids or opposes the flux from the inductance winding is determined by circuit design.

If R_L (Figure 2.1-7B) is increased, the sampling circuit detects the increase in voltage across R_L and causes the impedance of the SR to increase. The change in impedance of the SR allows less current to flow in the circuit and the voltage across R_L returns to its controlled value.

The operation of the SR can be explained in greater detail by use of a hysteresis loop. (Figure 2.1-8A shows two windings on a laminated saturable core; for the first portion of the discussion, disregard any action of the control winding.)

An alternating current A (Figure 2.1-8C) is applied to the circuit. As the current progresses from point a, b, c, d, to a', the core material (Figure 2.1-8B) has completed one progression around its hysteresis loop (points a, b, c, d, and back to a). The hysteresis loop shown is an ideal loop. An ideal loop is used because many factors (predominantly heat and frequency) can alter its shape.

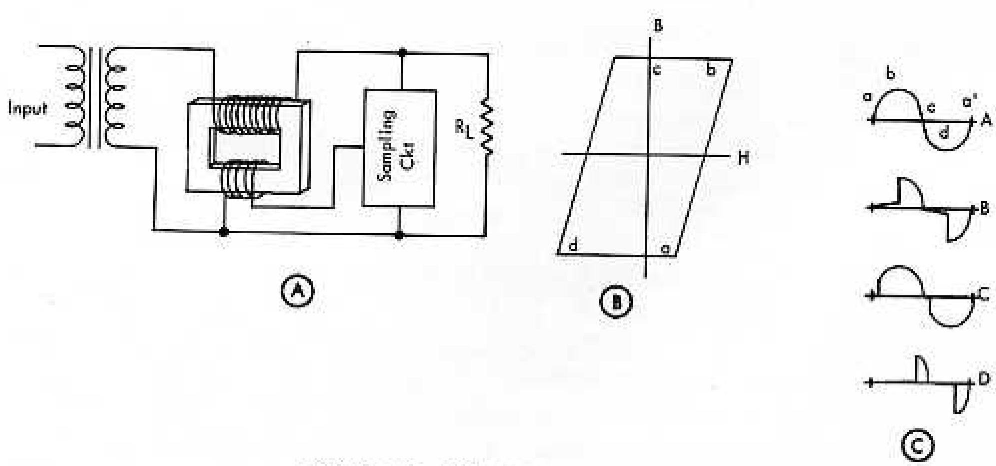


FIGURE 2.1-8. SATURABLE REACTOR CHARACTERISTICS

The output current wave form is shown at B in Figure 2.1-8C. During the first half cycle, the core follows the path ab on the hysteresis loop (Figure 2.1-8B). The changing flux in the core causes a high impedance in the inductance coil and little current flows. When the saturation point of the hysteresis loop is reached, there can be no additional change in flux. With no changing flux, the impedance of the inductance coil drops sharply; conversely, the output current rises sharply and follows the input current. As the input current goes from point b to c (Figure 2.1-8C), the operating point on the hysteresis curve goes from point b to c (Figure 2.1-8B). The movement from point b to c on the hysteresis curve involves such a small change in flux that the induced voltage is negligible and output current follows input.

The control winding controls the point along the input wave form at which the core goes into saturation. By driving current through the control winding, the amount of impedance in series with R_L is effectively changed. Waveform C (Figure 2.1-8C) shows the output current that would result from adding to the core current which allowed the core to saturate with only a small amount of input current. Current in the opposite direction through the control winding could cause output D (Figure 2.1-8C).

Driving current through the control winding in two directions as is required to obtain the output currents C and D (Figure 2.1-8C), can require complicated circuitry. To simplify circuitry it is desirable to be able to control output voltage by driving current through the control winding in only one direction. A third winding, called a bias winding, allows the desired simplification.

Figure 2.1-9 is a circuit using a bias winding. Current through the bias winding normally is in a direction such that the flux produced by it opposes the flux of the SR inductance coil. The theory of operation of the circuit with a bias winding is the same as for the other circuits previously described. The bias winding sets the static condition of the circuit which, in terms of V_L (Figure 2.1-9A), would produce a very low voltage. The control winding then carries current of sufficient value to control V_L. Figure 2.1-9B is a graphic view of the circuit operation. If the SR core is saturated, current is at its greatest value (point C). With no control winding current, the output current (I_{RL}) is at its lowest value (point A). The normal operating point would be point B, which allows the greatest amount of control.

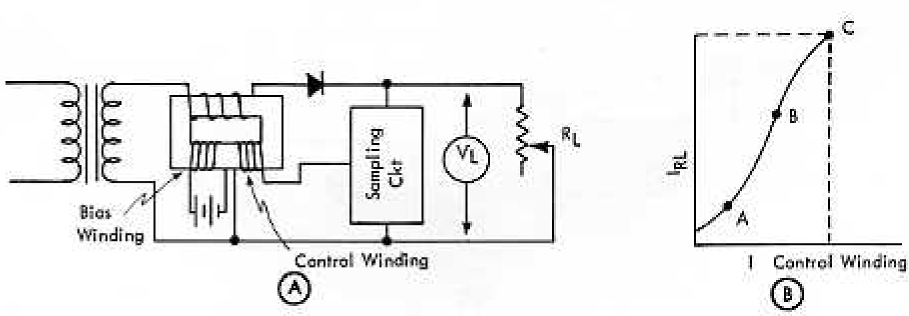
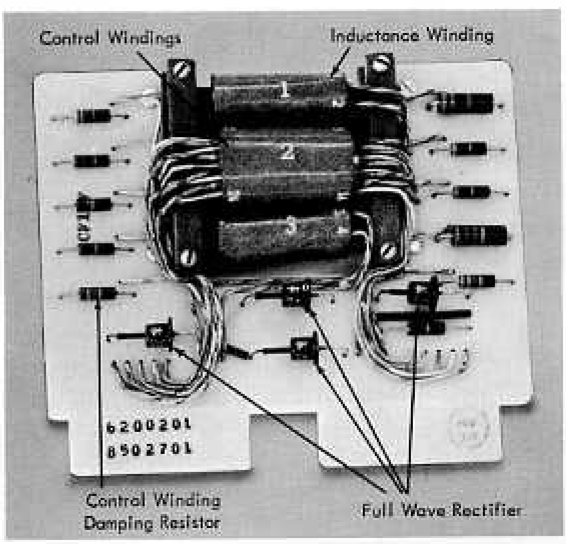


FIGURE 2.1-9. SATURABLE REACTOR WITH BIAS AND CONTROL WINDINGS

2.1.06 Self-Saturating Magnetic Amplifier

A self-saturating magnetic amplifier is a device using saturable reactors in series with a rectifier circuit. The circuit allows control of the current to an external load. A large amplification results, since a small amount of control current can cause a large change in load current. In IBM circuits, the self-saturating magnetic amplifier is normally referred to as simply a magnetic amplifier.

Figure 2.1-10 shows two saturable reactors in series with a full-wave rectifier circuit. Because of the action of the diodes in the rectifier circuit, current flows in only one coil at a time. The two reactor coils are wound to have flux in each core in the same direction.



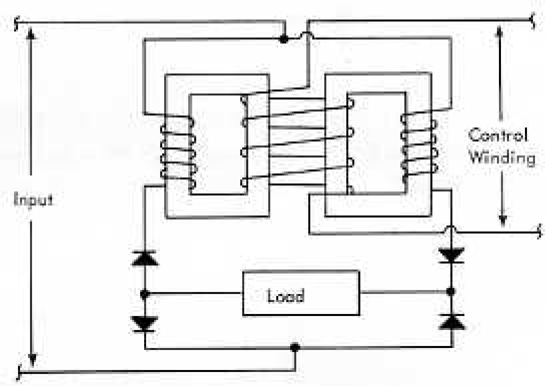


FIGURE 2.1-10. SELF-SATURATING MAGNETIC AMPLIFIER

Because the flux through each coil is in the same direction, the control winding works with each inductance coil on alternate half cycles. Figure 2.1-10 shows one control winding to the magnetic amplifier; actual circuits may use several separate control windings. Characteristic curves of magnetic amplifiers are drawn as a relationship between control winding ampere-turns and DC output current. Each line in a family of curves represents a different value of load resistance (Figure 2.1-11).

An analysis of Figure 2.1-11 shows that the curve follows the theory given for saturable reactors. As the ampere-turns of the control winding are increased, the SR reaches its saturation point earlier in the AC cycle and output current increases. A bias winding is normally used in magnetic amplifiers to allow a full output operating range. In most circuits, bias current tries to turn the amplifier off (the area where the output current is a minimum). Control winding current is then able to operate the amplifier throughout its complete output range.

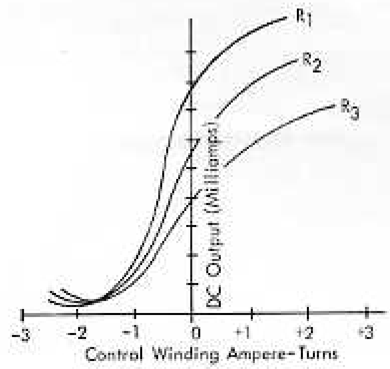


FIGURE 2.1-11. MAGNETIC AMPLIFIER CHARACTERISTICS

Figure 2.1-11 shows one factor that must be remembered when working with magnetic amplifiers; the output current never reaches 0; some voltage can always be measured across the load.

2.1.07 Open-Fuse Detection

The open-fuse detection unit is a magnetic amplifier (Figure 2.1-12A). Only one control winding is shown; in actual circuitry there may be as many as ten. Each control winding comes from a DC power supply and is shortened by a fuse; therefore, the winding has no effect on the amplifier so long as the fuse is good. The load is actually a CB trip coil, which drops DC power to the unit. Side switch interlocks on the CB itself drop power to the other half of the module when a CB trips.

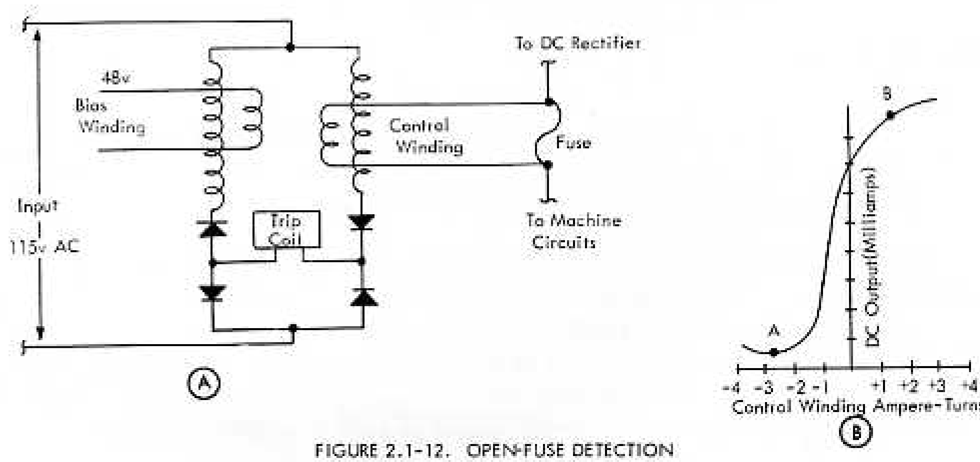


FIGURE 2.1-12. OPEN-FUSE DETECTION

A bias winding is used to establish an initial operating point. Figure 2.1-12B shows the characteristic curve for the circuit. The bias winding establishes the normal operating point (point A). If a fuse opens, the control winding is energized because the output of the rectifier must now flow through the control winding. With current in the control winding, operation is at point B of the characteristic curve. With operation at point A, current is at a minimum with a voltage drop of about 15v to 20v across the load. Operation at point B causes output current to increase and voltage across the load rises to about 60v to 70v.

The 15v to 20v which appear across the coil under normal conditions are of no consequence; it must be remembered that this is a normal condition.

2.1.08 Thermal and Air-Flow Detect Circuits

Magnetic amplifier circuits are also utilized for sensing an over-temperature condition or the failure of a blower motor in a standard modular gate. Because the opening of the -48 volt bias winding will cause the magnetic amplifier to operate the CB1 trip coil, the thermal sensing switches (two in the top of each SMS gate) have normally closed contacts in series with the bias winding supply.

Also in series with the thermal switches are the air-flow detect switches. These switches are similar to the heat-sensing thermal switches, with the addition of a half-heating device. The self-heating is composed of two resistors in parallel across the 12 volt supply, mounted in close proximity to the heat-sensing device. This unit is then located directly above the gate blower assembly. As long as the blower is running properly, the flow of air is sufficient to dissipate the heat generated by the resistors. If the blower should stop, the resistors would heat the sensing device and open the contact, thus tripping CB1.

Systems 9.02.15.1 shows a typical thermal wiring circuit in this case, CPU1. Note that with this particular circuit, either the AB supply or the CD supply may react to an open thermal sensing device in any of the four gates. The use of jumper wires makes it possible to locate any defective switch. Two types of switches are mounted on SMS cards for easy replacement.

2.2.00 7090 SPECIAL VOLTAGE POWER SUPPLY UNIT

Special voltages are needed for core storage. Figure 2.2-1 shows the power supplies mounted in the core storage frame. Load requirements in the driver circuits vary widely, especially in Z inhibit drivers. To accommodate the variation in load, core driver voltage supplies are regulated. Schematically, each supply is similar. The power supply assembly that provides core driver voltages is shown in Figure 2.2-2.

Figure 2.2-3 shows the special voltage power supply unit. The +60v, +30v, and -6v voltage supplies are fed from transformer T3. Each supply has a saturable reactor in series with a rectifier. Rectifier output is sampled by a voltage control circuit which feeds the SR for output regulation. Note that the sampling voltage for the -6v supply is taken from a point beyond the fuse. Because the -6v supply delivers relatively high current, the fuse holder contacts have a small voltage drop across them; for greatest accuracy, output is sampled on the load side of the fuse.

The -6v supply voltage control circuit differs in one other respect; a line from the +30v supply is used. The +30v line is used to establish a divider, between +30v and -6v, from which a reference voltage may be obtained. The circuit is designed this way for cost reduction because devices which can establish a reference voltage between a -6v line and ground are expensive. Also, with this circuit design the same type of reference voltage device can be used in each supply for greater standardization of parts.

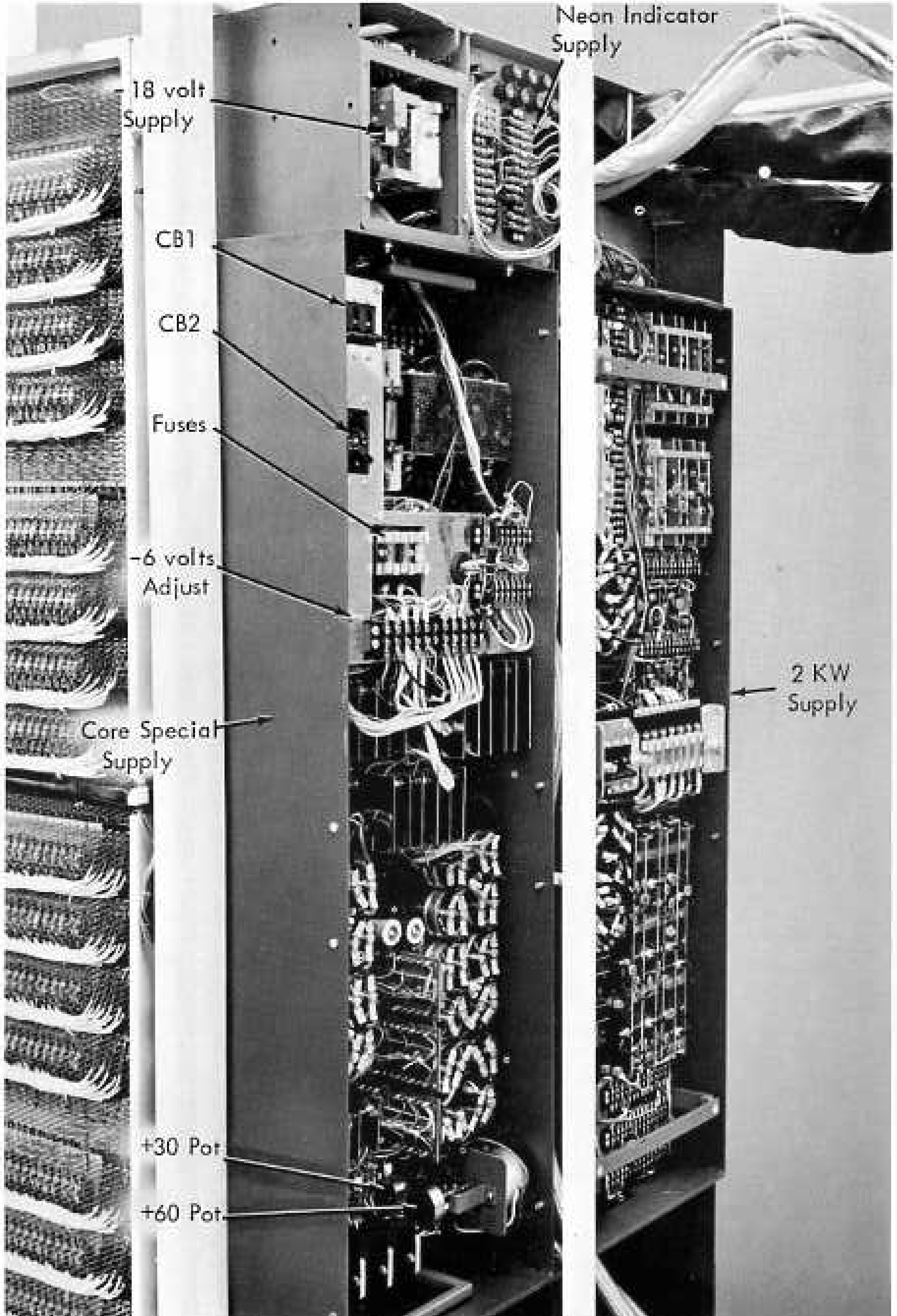


FIGURE 2.2-1. 7302 CORE STORAGE SUPPLIES - INSTALLED

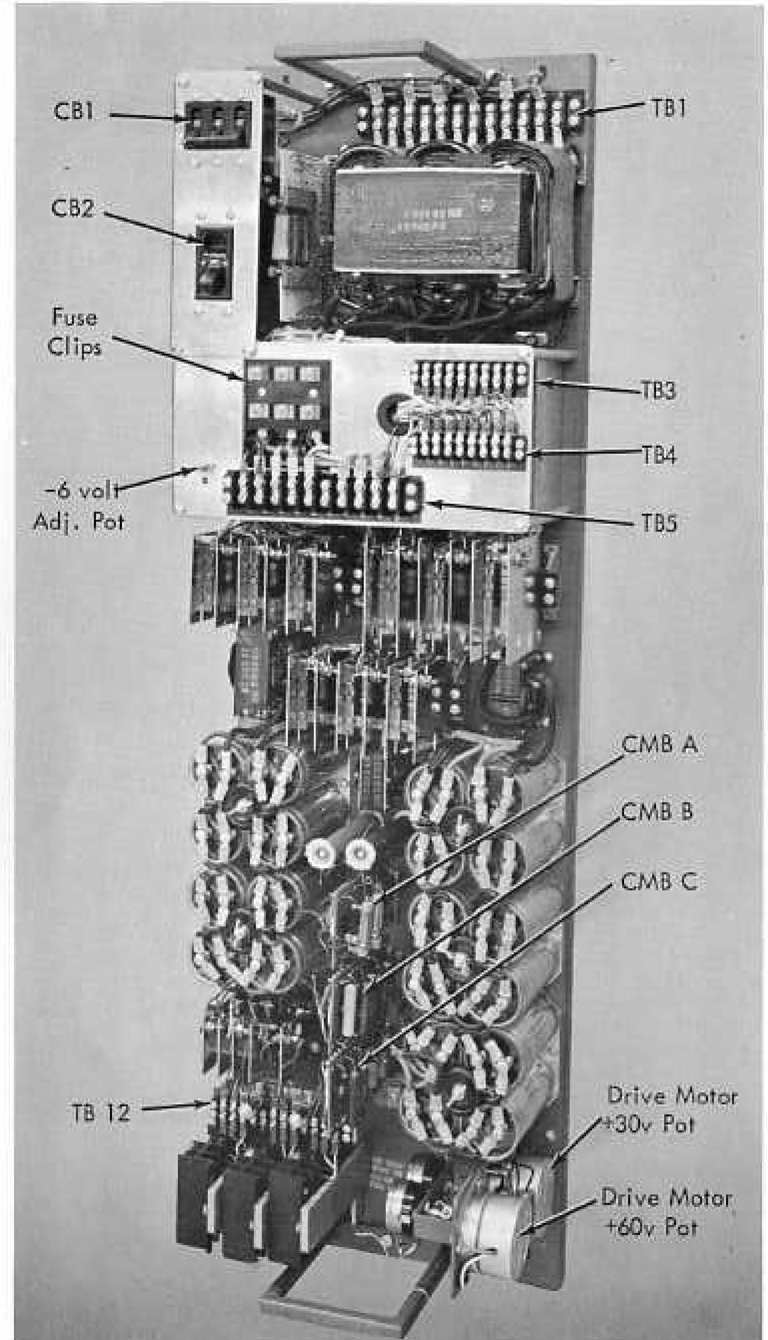


FIGURE 2.2-2. SPECIAL VOLTAGE SUPPLY - 3600 W

Both the +60 and +30v supplies can be varied for marginal testing by a motor-controlled potentiometer in the voltage control circuit. Motor controls are located at the console unit, while motors and potentiometers are located in the supply itself.

Two special purpose supplies develop voltages of +82v and -18v. The +82v supply furnishes power to neon detection circuits and is obtained by using a +22v supply whose negative side is tied to the +60v supply. The +22v supply is a standard full-wave rectifier. Input is from a tapped primary transformer T2. Output of the +22v supply can be varied from +20v to +25v in increments of 1v. Transformer T2 primary taps are brought out to a rotary switch, making it easy to vary the output. The supply is adjustable to allow for decay and variations in neon firing voltage.

The -18v supply furnishes power to CE panel indicators and is obtained by tying a -12v supply to the -6v supply. Output is not adjustable.

A transistor protection circuit is included in the power supply unit to drop power to the transistor drivers (CB2) if their bias voltage fails. Loss, or reduction, of bias voltage would allow the drivers to conduct continuously and ruin the transistors.

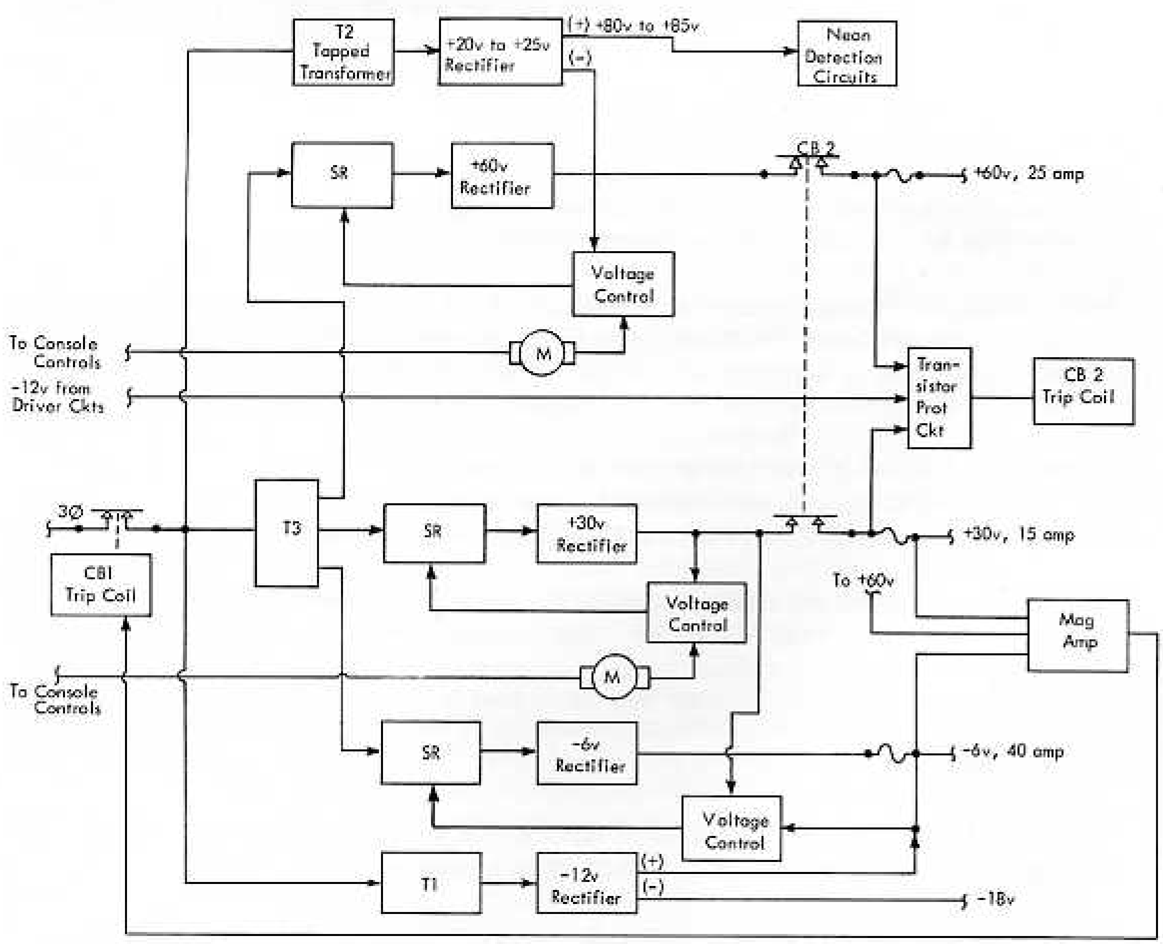


FIGURE 2.2-3. 7090 SPECIAL VOLTAGE POWER SUPPLY UNIT

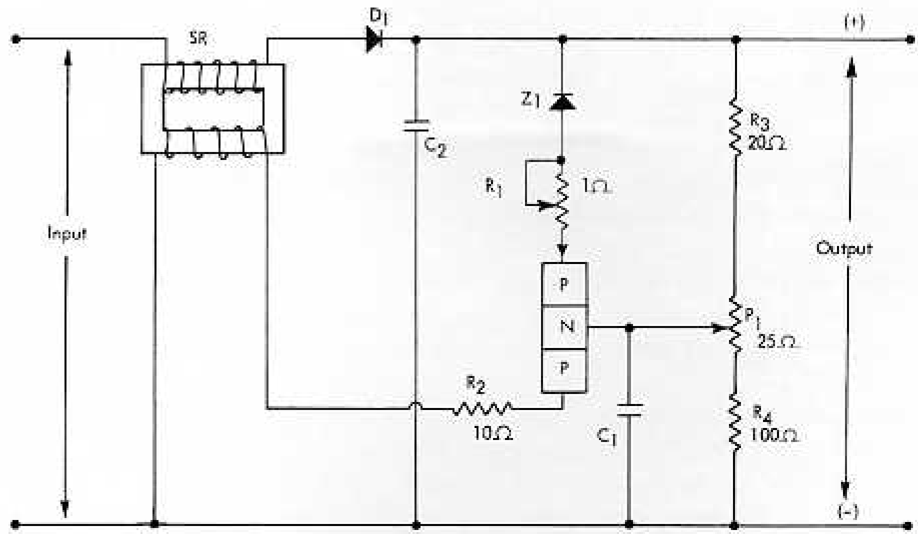


FIGURE 2.2-4. VOLTAGE CONTROL CIRCUIT USING ZENER REFERENCE DIODE

A magnetic amplifier circuit is used for open-fuse detection. If a fuse opens, the output of the magnetic amplifier energizes the trip coil of CB1 and drops power to the unit.

2.2.01 Zener Diodes as Reference Voltage Devices

A zener diode is a diode whose construction withstands zener breakdown repeatedly without harm to the diode. At zener breakdown voltage, current through the diode is limited only by the impedance of the circuit in which the diode is used.

Zener breakdown always occurs at the same voltage for a given type of zener diode. Because the voltage across the diode remains practically constant over a wide current range, it can be used as a voltage reference device.

Figure 2.2-4 shows a zener diode used as a voltage reference device. Rectifier output is controlled by a saturable reactor. The control winding to the SR is fed from a circuit which constantly checks the output voltage of the rectifier.

Reference voltage for the control circuit is a zener diode Z_1. Resistors R_3, R_4, and P_1 form a divider across the output. The voltage across Z_1, R_1 and tapped output of P_1 form the forward bias voltage for the transistor. If the output voltage increases, the bias on the transistor increases. The increased bias causes more current to flow through the transistor and the control winding of the SR, which lowers the voltage to the rectifier.

The regulated circuit shown is used in circuits where the load can vary over a wide range. The Z drivers in core storage are a typical example.

Input voltage to the circuit in Figure 2.2-4 is from the secondary winding of an input transformer. To develop special voltages, such as +60v, and +30v, it is only necessary to use different taps from the secondary winding of the input transformer.

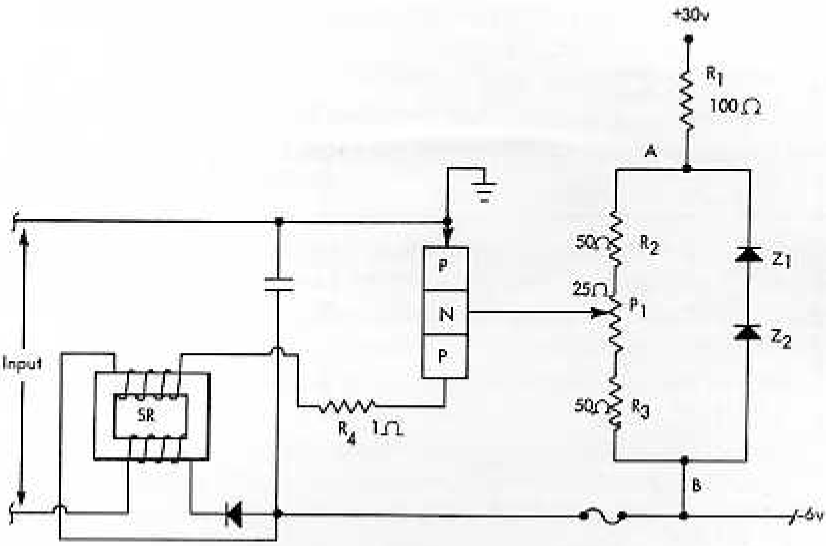


FIGURE 2.2-5. ZENER DIODES IN VOLTAGE CONTROL CIRCUITS

Figure 2.2-5 is another typical circuit using zener diodes as reference voltage devices. Diodes Z_1 and Z_2 drop approximately 10v across the load between points A and B. Because the 10v drop is in excess of the -6v supply, the circuit must be tied to some larger potential. The +30v was chosen because it is in the same power supply. The voltage drop across the zener diodes is given as approximate because the tolerances allow slight variations.

Under normal conditions, voltage across R_1 is 26v and point A is +4v with respect to ground. If the -6v supply should go to -7v, voltage at point A goes to +3v; as a result, voltage at any point along R_2 or P_1 goes slightly more negative. When point A goes in a negative direction, bias on the transistor increases, more current flows in the control winding of the SR, and output voltage is reduced. Conversely, if the -6v supply should go to -5v, point A would go in a positive direction, bias on the transistor would decrease, and output voltage would increase.

Note that the voltage with respect to ground at point A is determined solely by the voltage at point B, because the zener diodes always have about 10v drop across them. The +30v serves no function other than to obtain sufficient voltage to cause diodes Z1 and Z2, to reach their zener breakdown voltage; variations in the +30v supply have no effect on the output or regulation of the -6v supply.

Voltage control circuits in this power supply using zener diodes and transistors are designed so loss of SR control winding current causes output voltage to increase. This increase does not damage the transistors. The circuit is designed this way because the most probable failure is shorting of a transistor, which allows an increase in SR control winding current and reduces output voltage.

2.2.02 Neon Detection Circuits

Detection circuits are included in the special core storage supply to turn on an indicator light if any core driver neon ionizes (turns on). Two detection circuits are used: one checks all X and Y core drivers; the other checks all Z drivers.

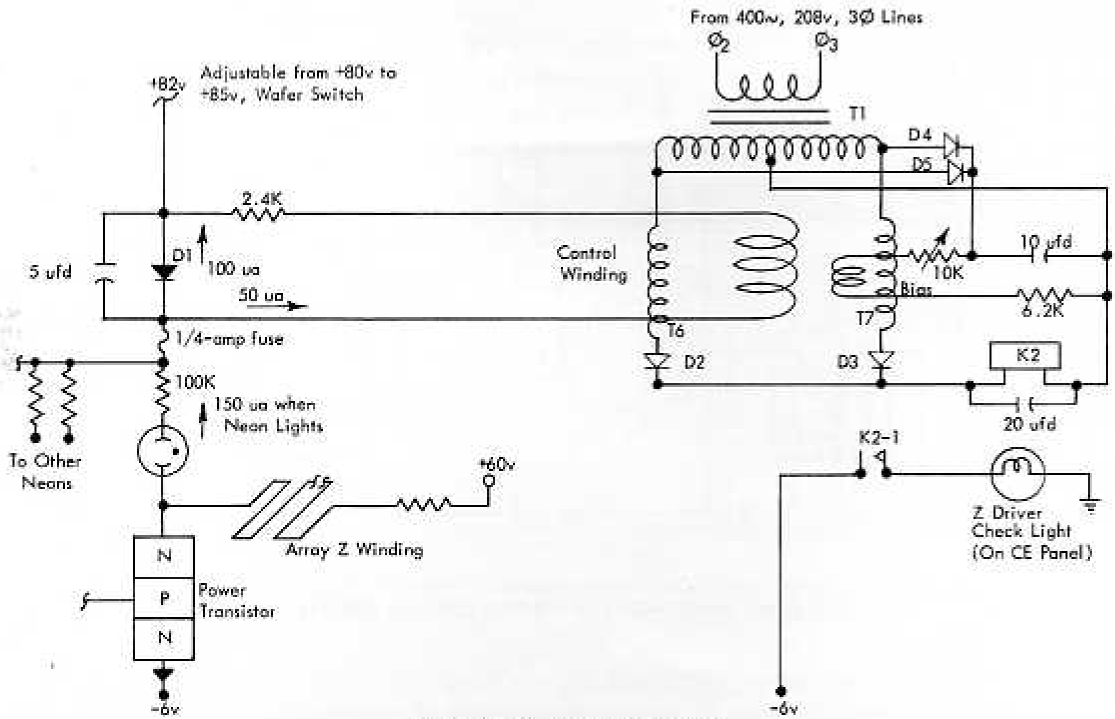


FIGURE 2.2-6. NEON DETECTION

The detection device is a magnetic amplifier which turns on with about 50 microamperes of current through its control winding (Figure 2.2-6).

One core driver power transistor is shown feeding the detection circuit. If the power transistor shorts and conducts continuously, the neon ionizes. In full conduction, the neon passes about 150 microamps (ua) of current. Diode D_1 and the magnetic amplifier control winding form a parallel circuit; the impedance of the two paths is such that 50 ua flow through the control winding and 100 ua through the diode.

Energizing the magnetic amplifier control winding with 50 ua of current saturates impedance windings T6 and T7. With T6 and T7 saturated the output is sufficient to pick relay K2 which remains energized as long as the neon is on. A K2-1 point in series with the Z driver check light turns the light on to indicate a shorted core driver.

A bias winding, energized through D4, D5, and a 10K potentiometer, is used to adjust the output of the magnetic amplifier. Because all diodes and components are identical, the bias is set to allow the relay K2 to pick when one neon is in full conduction. This is an indication only, as power is not dropped. Memory should be able to function until corrective action may be taken.

Diode D1 is a control winding protection device. If a large number of neons lock on at one time, a large current would flow through D1 and the parallel control winding. The forward characteristics of the diode are such that a large increase in current causes only a small increase in voltage drop across the diode. Because the impedance of the control winding remains constant and the voltage across it is increased only slightly, the current through the winding will not increase appreciably regardless of how many neons are on.

2.3.00 THE 2KW CORE STORAGE MODULAR SUPPLY (Figure 2.3-1)

The core storage module contains a modified SMS supply in addition to the special supply. The modified SMS supply is designed for a higher power output (2000 watts instead of the standard 750 watts). Only differences between this supply and the standard supply will be considered in detail herein.

First, the transformer arrangement is different (this was originally a 7070 supply). Buck-boost transformers are not used on the +30v and -36v sections, and the other transformers are numbered differently. Only two marginal check relays are used, one for +6v (all gates) and one for -12v (all gates). The magnetic amplifier differs in connections and in the resistors in some of the control windings, due to different loading.

The larger power output requires larger capacitors and 15 microhenry chokes for filtering the output voltage. The slow reverse recovery characteristic of the diodes generates spikes; eliminated by a de-spiking circuit using 0.1 microfarad capacitors across the diodes.

2.4.00 THYRATRON TRANSISTORS

The thyratron transistor (silicon-controlled rectifier) is a four element device with characteristics similar to those of a gas rectifier. As in a gas thyratron, there are two operating conditions. In the off (non-conducting) state, only leakage current flows. In the on state, current is limited only by the external circuit because the voltage drop across the transistor is about equal to that of one forward-biased PN rectifier. Firing is under control of a low impedance current source rather than a voltage source as in a tube thyratron.

Physical Properties

The thyratron transistor (PNPN) is constructed by diffusing two layers of P type material to a N type silicon wafer. An N type emitter is diffused on one of the layers of P material and a gate lead is attached to the same layer of P material. Figure 2.4-1A and 2.4-1B are two drawings of a PNPN thyratron transistor.

Electrical Properties

The characteristic curve of a thyratron transistor is shown in Figure 2.4-1C. Because of the shape of the characteristic curve, it is sometimes called a "hook transistor."

Consider a PNPN transistor without a gate lead attached. Applying V_c (Figure 2.4-1B) drives majority carriers toward the center PN section. With V_c of sufficient value, the center PN region becomes saturated with majority carriers and the energy of the carriers causes avalanche breakdown. Once breakdown voltage is reached, the current is limited only by the external circuit. Current flow through the transistor keeps all junctions forward-biased.

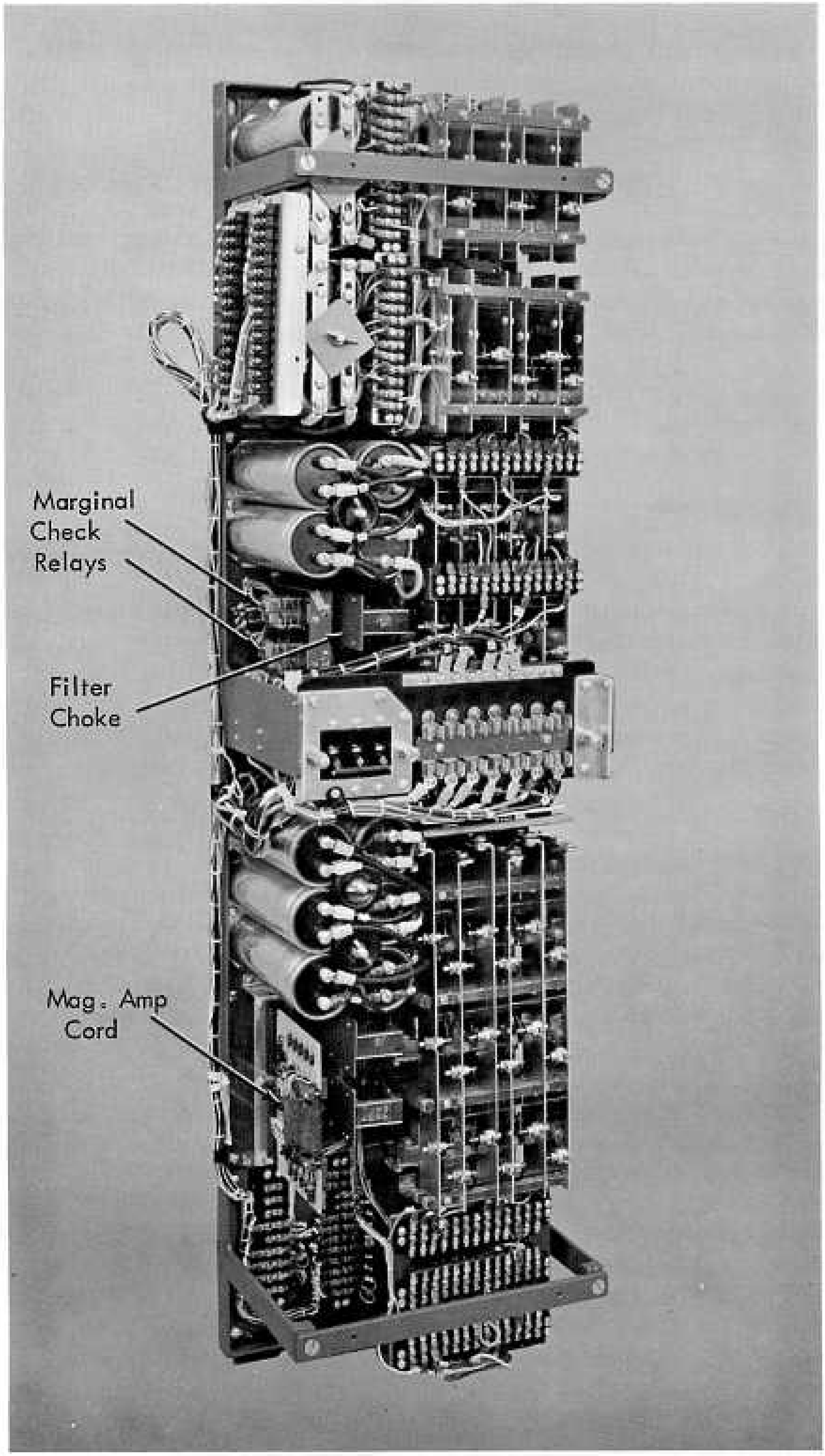


FIGURE 2.3-1. HEAVY DUTY MODULAR POWER SUPPLY - 2 KW

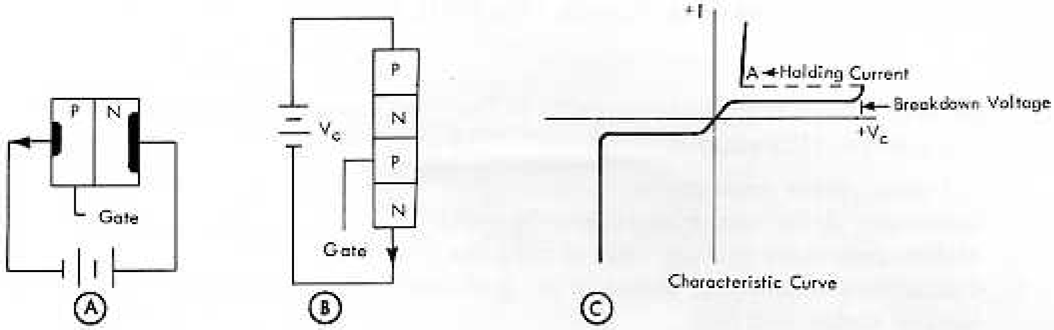


FIGURE 2.4-1. PNPN THYRATRON TRANSISTOR

Few circuits are designed so voltage across the transistor can be varied; for this reason, a control, or gate lead is normally used. Feeding current into the gate lead causes saturation of the center PN region, and avalanche breakdown occurs at a lower value of collector to emitter voltage. Once the transistor is in conduction, the gate lead loses control. The only way the transistor can be turned off is to open the circuit or cause the current to be reduced below point A of Figure 2.4-1C. Point A is called the holding current, which is the minimum current, required to keep the center PN junction forward-biased.

Figure 2.4-2 shows a thyratron transistor as used in an actual circuit to protect driver transistors. The -12v is the bias voltage to a large group of drivers. If the -12v were lost, all drivers would try to conduct and burn out the transistors. The load in the collector circuit of the transistor is a circuit breaker which drops the collector voltage to the drivers. Two zener diodes (section 2.2.01) are used to set the gate lead voltage at about -1.5v. If the -12v should drop to -10v, the gate lead goes positive and the thyratron transistor goes into conduction.

A power transistor could be used in this same circuit but the safety factor would be lost. Approximately five milliseconds (ms) are required to trip the circuit breaker. If the -12v supply drops to -10v for a period of only two or three ms, the circuit breaker does not trip and intermittant errors will occur. The thyratron transistor will turn on if the -12v supply drops for only one to three usec.

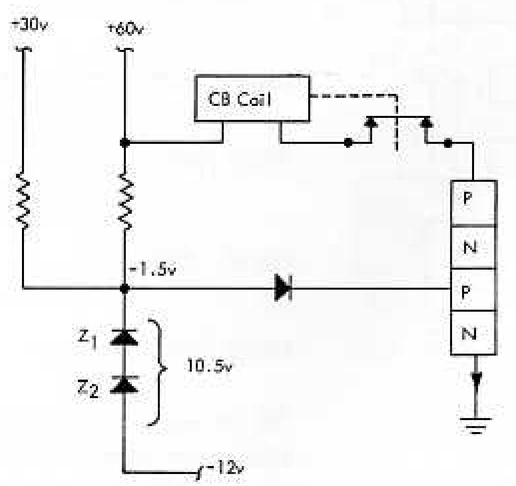


FIGURE 2.4-2. THYRATRON TRANSISTOR CIRCUIT