IBM Customer Engineering Manual of Instruction

60-Cycle SMS Power Supply

IBM® Customer Engineering Manual of Instruction

Issued to: L. E. Hudson

Branch Office: __________

Department: __________

Address: __________

If this manual is mislaid, please return it to the above address.

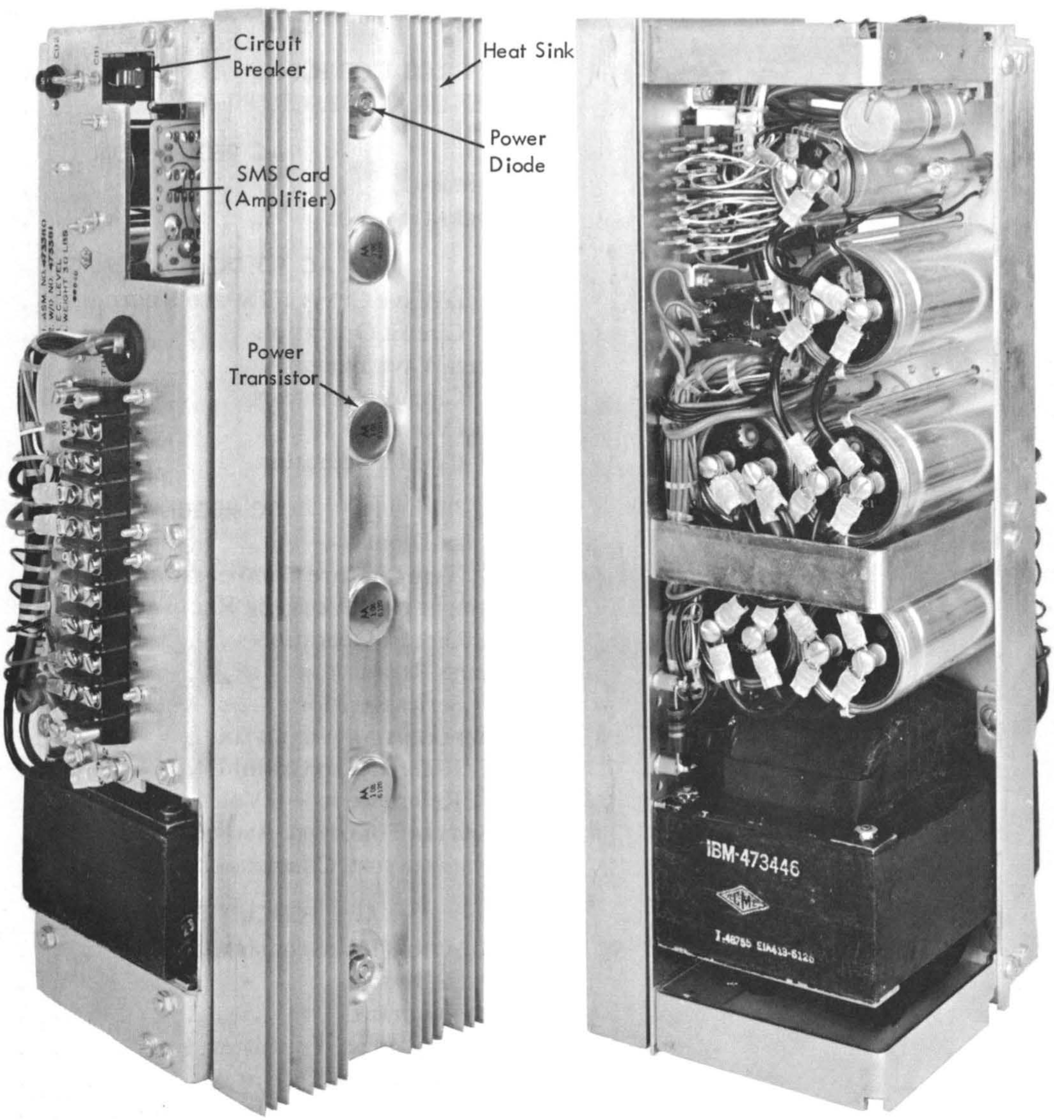
60-Cycle SMS Power Supply

MAJOR REVISION (June 1962)

This edition, 225-6478-1, supersedes but does not obsolete, 225-6478-0. Major changes are:

PAGE	SUBJECT
8	AC Regulation (Operation)
21	Portable Unit

Contents



SMS POWER SUPPLY MODULE

60-Cycle SMS Power Supply

This manual contains information on the 60 cycle SMS power supplies which were designed to provide all the dc voltages required in a solid-state computer. Because these power supplies are used in many different systems and applications, they may be modified to meet an individual need. These variations, not included in this manual, are contained in the manual of instruction on the individual system or machine along with the power-on sequence.

The power supply components are packaged in standard building-block modules. These modules (opposite page) can be mounted in both the Module I (swinging gate) and Module II (sliding gate) type of packaging. At present there are 25 different power-supply modules which satisfy the requirements of most machines. Power-supply systems of different sizes and ratings can be easily designed by using various combinations of the standard power-supply modules available. This eliminates the need of a separate "custom-made" power supply for each system or machine type.

The 1400, 1200, and 1600 series systems use this standard SMS power-supply system. The requirements of most machines in the development stages will also be satisfied by these power supplies. (Certain systems, such as the 7070 and 7090, have a 400-cycle power-supply system which will not be discussed in this manual.)

General Description

Figure 1 shows a power-supply system utilizing these modular units in block form. Each block represents a standard module. The system is described as follows:

The line ac voltage is fed into one or more ferroresonant regulators where it is changed to a regulated ac voltage. This regulated ac voltage is distributed to the dc power-supply modules where it is converted into a regulated dc voltage. The dc voltage is then distributed to the various machine or system circuits requiring it.

The ferroresonant regulators, sometimes referred to as constant-voltage transformers, consist of special transformers and capacitors. The capacitors and the transformers are packaged into separate modules to provide flexibility in mounting. They are located close to each other on the machine.

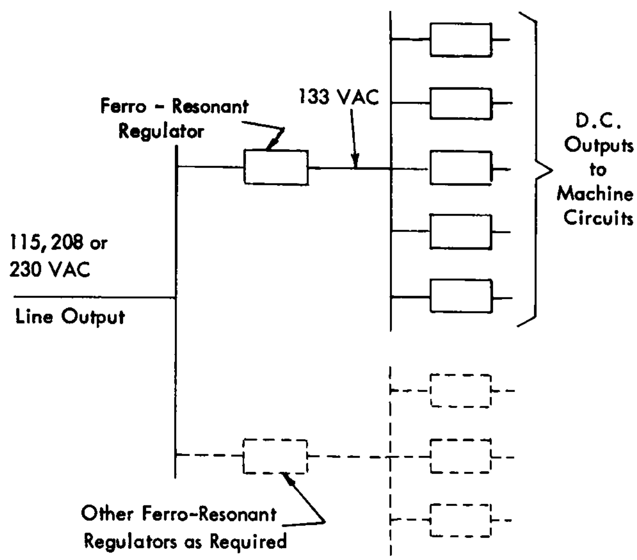


FIGURE 1. TYPICAL SYSTEM DIAGRAM

The dc power-supply module (Figure 2A) consists of an isolation transformer, solid-state rectifiers, associated filter networks, and a magnetic-type circuit breaker for overcurrent protection. The regulation from such a dc power supply is ±8%, which is sufficient for some applications.

When closer regulation is required, as in most of IBM's transistor circuitry, a dc power-supply module incorporating a series regulator is used. This provides a dc voltage with ±2% regulaton. The series regulator consists of an SMS pluggable amplifier card, power transistors, and an additional filter. Overvoltage protection circuits are also provided as required.

Figures 2A and 2B are block diagrams of the standard power supplies.

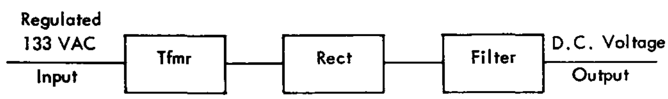


FIGURE 2A. STANDARD POWER SUPPLY

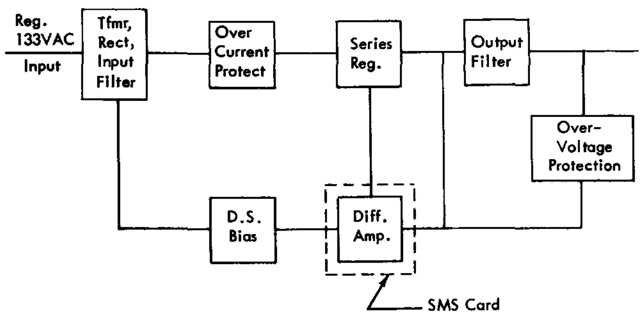


FIGURE 2B. STANDARD SERIES — REGULATED POWER SUPPLY

AC Regulation

AC regulation for the dc power-supply modules is provided by one or more ferroresonant regulators. The ac regulator in the standard SMS power-supply system changes the line voltage to a regulated voltage of about 133 volts ac. Two important characteristics of the ferroresonant regulator as it applies to SMS power supplies are these:

1. It has the ability to regulate for input-line variations.
2. Its output voltage collapses when a short circuit occurs across the secondary winding.

Figure 3 shows a typical ferroresonant regulator transformer that is used in standard SMS power-supply systems. The electrical circuit consists of two windings: a primary winding, and a secondary winding that is connected in parallel with a capacitor to form a ferroresonant circuit.

The magnetic circuit is a closed shell-type core equipped with magnetic shunts between the input and output sections. These shunts have air gaps in the flux path as shown.

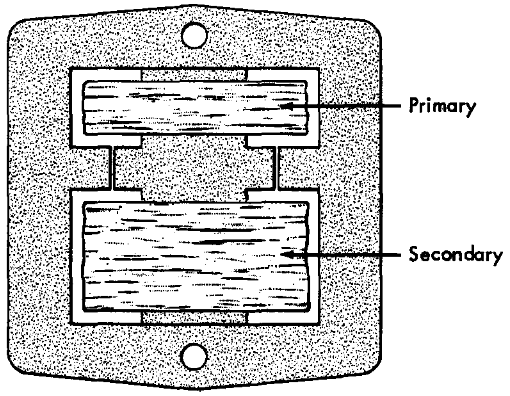


FIGURE 3. FERRORESONANT REGULATOR TRANSFORMER

Operation

A ferroresonant regulator relies entirely on the saturation characteristic of a magnetic material for its voltage stabilizing property. To take advantage of this property the input voltage must be sufficiently large to saturate at least part of the magnetic structure.

Figure 4 represents a standard, ferroresonant, regulator structure. It is so designed that the leg on which the output winding is placed saturates at the end of each half cycle, when the input voltage is its minimum value and the line frequency is fixed. Higher input voltages can't appreciably increase the flux through the output winding because of this saturation phenomena. Hence, the output voltage is almost constant if the input frequency is fixed.

For line variations of 10% dynamic and ±10% static, the output voltage remains constant to within ±1%. Because of the relatively large output impedance due to rectifiers, copper loss, etc., this circuit is not much of a load regulator.

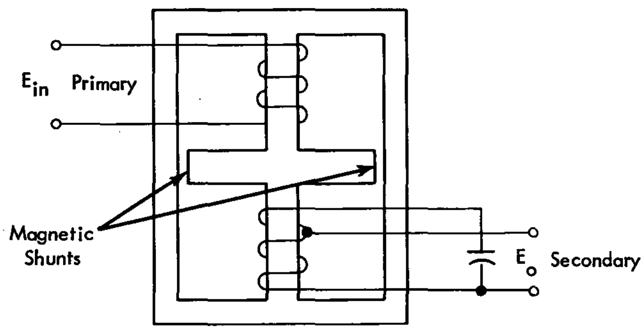


FIGURE 4. FERRORESONANT REGULATOR

Figure 5 depicts the input-output voltage characteristic of a ferroresonant circuit with the output power as a parameter. Each curve has two parts, each of which represents an entirely different mode of operation. In the steep region which starts at the origin, the circuit behaves as a transformer. The output voltage under this condition is simply the inverse turns ratio times the input voltage.

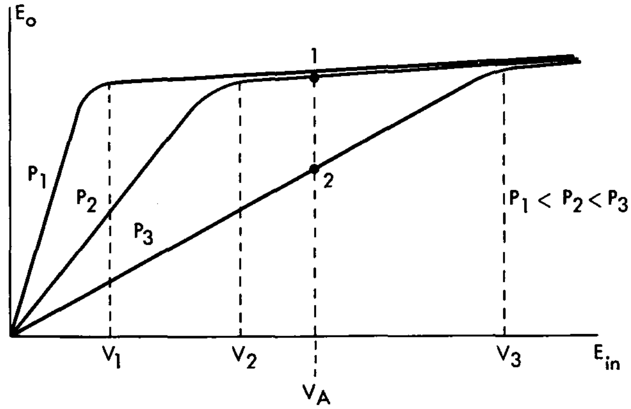


FIGURE 5. FERRORESONANT REGULATOR INPUT VOLTAGE VS. OUTPUT VOLTAGE

The second region of the curve represents the circuit when it is operating as a regulator. In this region, the output voltage is approximately constant. The voltages V_1, V_2, V_3 on Figure 5 are the minimum voltages which will saturate the magnetic structure for loads P1, P2, and P3, respectively. These curves illustrate a characteristic of the regulator to collapse under heavy loading. Imagine a given circuit operating with an input voltage V_A and an output power P_2. This corresponds to point 1 on Figure 5. If the load requirements increase to P_3, the operating point "jumps" from point 1 to point 2. The output voltage is now much lower, and the circuit is essentially a transformer with no regulating properties.

When the circuit experiences its maximum load (a short on the secondary winding) the output voltage goes to zero. Refer again to Figure 4. The input voltage can still drive flux through the shunt path. The primary has not been short-circuited as would occur when the secondary of an ideal transformer is shorted. The proper design of these shunts can limit the input current to any "safe" value.

AC to DC Conversion

The regulated ac voltage from the ferroresonant regulator is transformed by an isolation transformer to the correct voltage magnitude and then converted to dc voltage by solid-state rectifiers. Some of the advantages of using an isolation transformer in each module are:

1. One main distribution line (133-volt) from the ferro to each dc power supply.
2. Isolate noise from one dc module to another.
3. A dc power supply may be used for either a negative or a positive voltage.

The SMS standard power supplies use two basic rectifier circuits:

1. Full-wave center-tapped
2. Full-wave bridge

Full-Wave Center-Tapped Rectifier

Figure 6 shows a full-wave center-tapped rectifier circuit similar to those used in SMS power supplies rated for less than 20 volts. It is also used in all series regulated SMS power supplies, described in this manual, to develop the bias voltage required to operate the regulator transistor circuitry.

Circuit Operation

Regulated ac voltage is applied to the primary of T1. The secondary of T1 provides the correct ac voltage to the anodes (arrow heads) of the D1 and D2 silicon diodes.

The e1 and e2 voltages are developed across the two halves of the secondary, with respect to the center tap, as noted in Figure 6. The e1 and e2 voltages are of equal magnitude and 180° out of phase with each other.

Electron flow from the center tap (point B) through R1 and D1, and the upper half of T1 results in a positive voltage pulse across R1.

The anode of D1 is positive with respect to the center tap at time 1 (t1) of the first cycle shown. (Note that the anode of D2 is negative at this time.)

During the following half cycle (t2), the polarity of the voltages developed across the two halves of T1 is reversed. The anode of D2 is now positive, while the anode of D1 is negative with respect to the center tap. Electron flow from the center tap through R1, D2 and the lower half of T1 also results in a positive pulse being developed across R1. Alternate conduction through D1 and D2 results in a pulsating dc output voltage being developed across R1.

If added to the circuit, capacitor C1 would serve as a filter and smooth out the pulsating dc voltage waveform as illustrated in Figure 6.

D1 and D2 are silicon diodes about the size of a sewing thimble known for their ability to pass large currents.

Full-wave rectification utilizes the full cycle of the input voltage; therefore, the output pulsations (ripple) are twice the frequency of the input voltage.

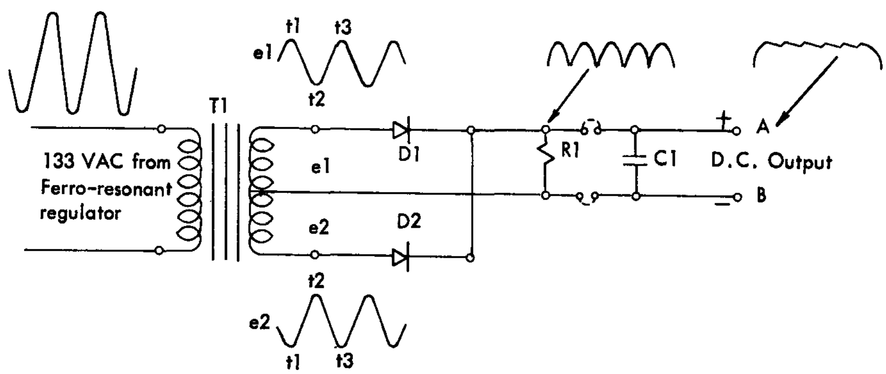


FIGURE 6. FULL-WAVE CENTER-TAPPED RECTIFIER CIRCUIT

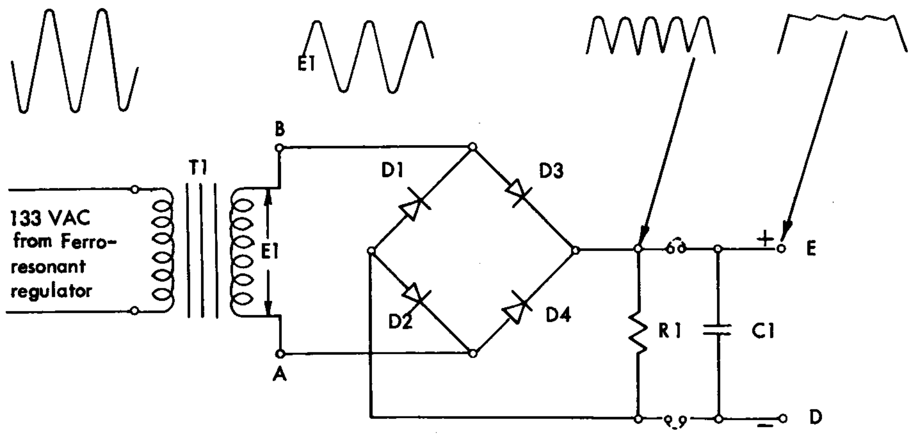


FIGURE 7. BRIDGE-TYPE FULL-WAVE RECTIFIER CIRCUIT

Full-Wave Bridge

The full-wave bridge-type rectifier circuit is used in most standard SMS power supplies rated at 20 volts dc or more. The 20-volt, 6-amp power supply, which uses a center-tapped full-wave rectifier circuit, is an exception.

Figure 7 shows a typical bridge-type rectifier circuit. The two major differences between this type rectifier circuit and the center-tapped rectifier circuit previously described are:

1. Four silicon diodes are used instead of two.
2. The entire secondary voltage, rather than one half of it, is utilized on each half cycle.

Circuit Operation

With a regulated ac input to the primary of T1, a stepped-down ac voltage of correct magnitude is developed across the secondary. When the top of the secondary is positive with respect to the bottom of the secondary winding, the electron flow starts with the negative output terminal, point D, through R1, D3, the secondary winding of T1, through D2, back to point D. On the alternate half cycle, when the bottom of the secondary is positive with respect to the top half of the secondary winding, the electron flow starts at point D, through R1, D4, the secondary winding of T1, through D1, back to point D.

The electron flow was through R1 from the negative terminal to the positive terminal in each case. This develops a pulsating dc voltage across R1 as shown by the waveform in Figure 7.

The capacitor action is the same as in the full-wave rectifier circuit previously described. It tends to smooth out the pulsations as shown in Figure 7, when connected to the circuit.

Bridge-type rectifier circuits utilize the full cycle of the input voltage; therefore, the ripple frequency is twice that of the input voltage frequency. The full voltage existing across the entire secondary winding is rectified with a bridge-type rectifier; therefore, the output voltage is twice that of a center-tapped full-wave rectifier which rectifies one half of the secondary voltage at a time.

Bias Voltage

Each dc power supply module incorporating a series regulator has two rectifier circuits:

1. the main rectifier circuit which is used to develop the output voltage,
2. another rectifier circuit in the bias supply which develops the voltage required by the series regulator circuitry.

The bias supply consists of two solid-state diodes and filter capacitance. The diodes are connected, as a full-wave center-tapped rectifier circuit, across an additional secondary winding of the isolation transformer. It develops approximately 30 volts dc.

Circuit Operation

See *Circuit Operation, Full-Wave Center-Tapped Rectifier.*

Regulation for ac input voltage variations is primarily provided by the ferroresonant regulator. Additional regulation for input voltage variations and regulation for load variations are provided by a series regulator.

The series regulator incorporates the following units:

1. A zener diode for reference voltage.
2. Series regulator transistors.
3. A differential amplifier.
4. A two-stage emitter-follower amplifier.
5. A separate dc voltage supply to bias the transistor circuitry.

The zener diode, differential amplifier, and two-stage emitter-follower amplifier are mounted on an SMS card. The series regulator transistors are mounted on a large piece of metal, called a *heat sink,* which forms one side of the dc power-supply module as shown in the frontispiece.

One type of differential amplifier card is used for all dc power-supply modules referenced to ground. Power supplies referenced to −6, such as certain −12 volt supplies, require a different pluggable amplifier card.

Zener Diode

The zener diode is a solid-state device constructed with a constant reverse bias breakdown voltage. At this breakdown voltage, called zener breakdown voltage, the current through the diode is limited only by the impedance of the circuit in which it is used.

Zener breakdown always occurs at the same voltage for a given type of zener diode. Because the voltage drop across a zener diode is practically constant (zener breakdown) over a wide current range, this component can be used as a voltage reference device. Circuit-wise, it may be compared to a gas type voltage regulator tube (Figure 8A).

Notice that when the applied voltage drops (Figure 8B), the entire change is reflected across the resistor and the voltage across the zener diode remains constant at 10 volts.

The zener diode used in the SMS power supply described in this manual develops a constant voltage of 10 volts which is used by a differential amplifier as a standard voltage. A sample of the rectified output voltage is also fed to the differential amplifier where it is compared against the standard 10 volts. The output of the differential amplifier is used to maintain the correct output voltage.

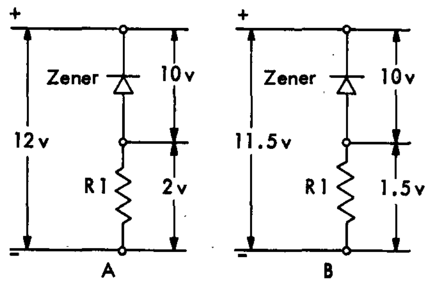


FIGURE 8. CONSTANT VOLTAGE ACTION, ZENER DIODE

Temperature Compensation

The zener breakdown voltage increases as the temperature rises. This is an undesirable characteristic because the zener breakdown voltage is used as a standard for comparison as previously mentioned. A forward-biased conventional diode, which reacts to temperature changes in the opposite manner, is used in series with the zener diode (Figure 9) to form a temperature-compensated device.

Assume that a temperature increase raises the zener voltage drop across the zener diode to 9.7 volts. Simultaneously, the increased temperature decreases the voltage across the conventional diode to .3 volt. The reference voltage remains unchanged at 10 volts.

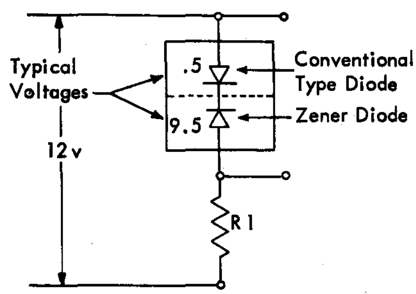


FIGURE 9. TEMPERATURE-COMPENSATED ZENER

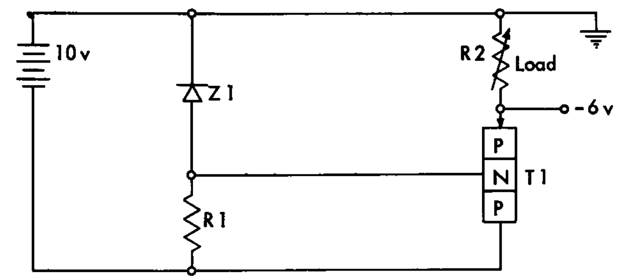


FIGURE 10. THEORETICAL VOLTAGE REGULATOR CIRCUIT

Theoretical Voltage Regulator

Figure 10 shows a circuit in which a 6.2 volt zener diode is used as a voltage reference device. The variable resistor R2 represents the load resistance. The battery represents a rectifier.

The zener diode (Z1) provides a fixed voltage of −6.2 volts on the base of the regulator transistor (T1). The load (R2) is in the emitter circuit of T1, and together they form a simple emitter follower circuit. Any change in the R2 load which tends to change the voltage drop across it, causes T1 to conduct more or less to keep its emitter potential at −6 volts. The emitter potential in an emitter follower circuit tends to follow the base potential.

Circuit Operation

Let a decrease in the load resistance (R2) lower the voltage drop across it. This changes the base to emitter potential and causes increased current to flow through the transistor. The increased current flow through R2 raises the voltage across it.

Any change in the emitter voltage, because of changes in the load resistance, is countered by a change in the emitter – base potential. It is this action that causes Z1 and T1 to act as a voltage regulator.

Voltage regulation in the standard SMS power supplies is accomplished in a similar manner.

Series Regulator

The series regulator controls the output voltage of the power supply. It is controlled by the output of an amplifier and consists of one or more paralleled power transistors in series with the negative terminal of the rectifier section and the negative output terminal of the power supply.

The simplified diagram in Figure 11 shows a series regulator and its relationship to the power supply. The number of power transistors in parallel depends upon the current and voltage rating of the power supply. (For example, four transistors are used for 8 amps on a 12 volt power supply, while only three are required for 8 amps in the 6 volt power supply.)

To have conduction in the transistor, there must be a difference of potential across it; therefore, the rectifier circuit must develop a voltage higher than that required at the output terminals of the power supply. This is usually about 3 volts greater than the rated output voltage of the power supply.

The rate of conduction through the power transistor is dependent upon its base to emitter potential. If the base swings positive with respect to the emitter, the current flow decreases. If the base voltage swings negative with respect to the emitter, the current through the transistor increases. By regulating the current flow through the load, we maintain the rated output voltage. In E = IR, *R* is the load.

Series Resistor

The two resistors in series with the emitters of the power transistors in Figure 11 balance the current through the transistors when more than one transistor is used. They are .2 ohm 5-watt precision resistors and are called series resistors.

Consider the power transistor a variable resistor. Its resistance changes as the base to emitter voltage changes. In other words, if the base goes positive with respect to the emitter, the resistance increases. Saying the same thing another way, if the emitter becomes negative with respect to the base, the resistance of the power transistor increases.

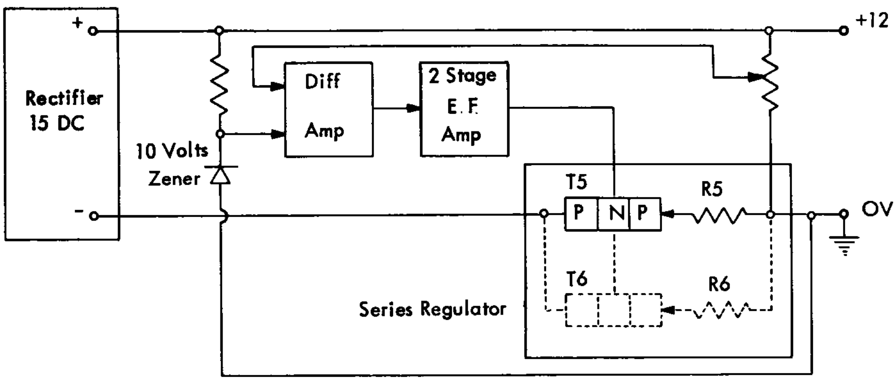


FIGURE 11. SERIES REGULATOR TRANSISTORS

The bases of both power transistors are tied together in Figure 11. If T5 started to conduct more than T6, the increased voltage drop across R5 would make the emitter of T5 slightly more negative than the emitter of T6. This action increases the effective resistance of T5. If the effective resistance of T6 remains constant and the resistance of T5 becomes greater, T6 will conduct more. This action continues until the current flow is evenly balanced between the two transistors.

Differential Amplifiers

Referenced to Ground

As stated previously, there are two types of differential amplifier pluggable cards (SMS cards):

1. the card that is used for dc power-supply regulators referenced to ground
2. the card that is used with regulators in the dc power-supply modules referenced to −6 volts.

A dc power-supply module referenced to ground is one that has its regulation tolerance specified in relation to ground potential. For example, a 12-volt power supply referenced to ground with a regulation tolerance of ±2% should maintain an output voltage of between 11.76 and 12.24 volts.

Although the same SMS card is used in all dc power-supply modules that are referenced to ground, that part of the regulator circuitry not mounted on the SMS card may vary from one dc power-supply module to another. The differential amplifier circuitry for power-supply modules referenced to ground can be broken into two basic circuits:

1. the circuit used in 6-volt power-supply modules
2. the circuit used in all other series-regulated power-supply modules.

6-Volt Power Supplies

Figure 12 is a simplified diagram of the differential amplifier used in 6-volt power supplies. The −30-volt bias is developed by a separate rectifier circuit within this power-supply module. The 10-volt zener diode keeps the voltage across R1 constant at 10 volts. The potentiometer is set to about −6 volts with respect to ground which is the positive terminal in this example. Because T1, together with R3, forms an emitter follower circuit, its emitter is fixed to a definite potential in reference to ground (about −6 volts). The emitter of T2, which is common to the emitter of T1, has a fixed voltage in reference to ground (about −6 volts). The base of T2 is connected to the negative output line of the power supply.

Circuit Operation – The objective is to recognize any change in the output voltage level and signal, through an amplifier, the series regulator so that it can maintain the specified voltage output level. This signal comes from the collector of T2.

Normally, with −6 volts output, the base potential of both T1 and T2 is the same. Both T1 and T2 share the current flow through R3 to maintain a 6-volt drop across R3. This provides a certain potential at the collector of T2, which, through an amplifier, signals the series regulator to maintain its present rate of conduction.

If the external load on the power supply should suddenly change and cause the output voltage to decrease, the base of T2 tends to change in a positive direction, in reference to its emitter which is clamped −6 volts. This action turns T2 off (decrease the current flow) which causes the collector of T2 to become more negative. The negative swing in collector voltage at T2 causes an increase in the rate of conduction through the series regulator transistors which raises the output voltage level.

If the output voltage should increase (go more negative), T2 would turn on more and cause the collector voltage of T2 to change in a positive direction. The positive swing causes the series regulator transistors to turn off (conduct less), which lowers the output voltage.

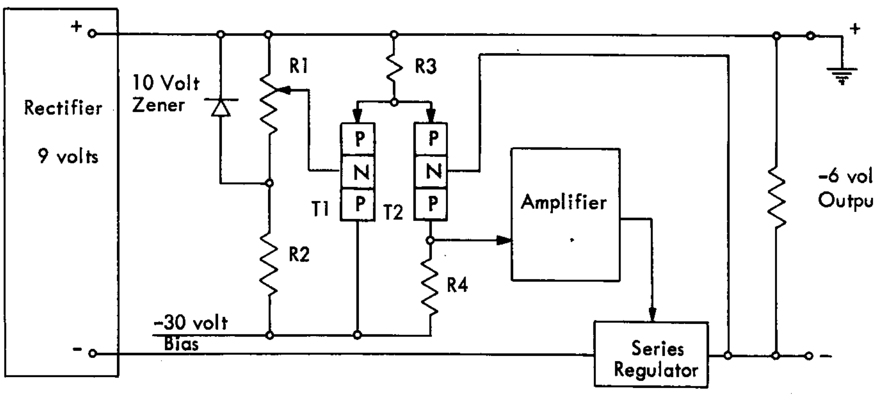


FIGURE 12. DIFFERENTIAL AMPLIFIER FOR 6-VOLT POWER SUPPLIES

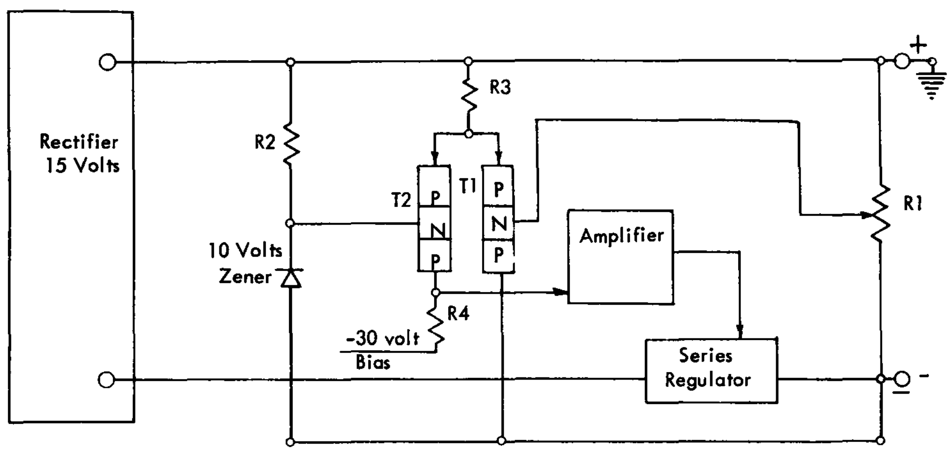


FIGURE 13. DIFFERENTIAL AMPLIFIER FOR 12-VOLT OR MORE POWER SUPPLIES

12-VOLT OR MORE POWER SUPPLIES

The differential amplifier circuit in Figure 13 is used in the standard SMS power supplies that are referenced to ground and rated for 12 volts or more. It is similar to the differential amplifier previously discussed for 6-volt power supplies and incorporates the same SMS card.

Assume that the positive output terminal of the supply is connected to ground. The base of T1, which is an emitter follower, is set to about −2 volts with respect to ground. This clamps the emitter of T2 to about −2 volts. Notice that this voltage will vary simultaneously with a change in the output voltage. The base of T2 is connected to a zener developed voltage which is ten volts more positive than the negative output voltage (−2 volts under no load conditions). Any variation in the output voltage changes the base to emitter voltage of T2. This action varies the collector potential of T2 which controls the conduction through the series regulators to maintain the specified output voltage.

Circuit Operation — If the output voltage should increase to −12.2 volts, for example, the base potential of T2 will go more negative (from −2 volts to −2.2 volts). This action causes T2 to turn on more, which results in its collector potential becoming more positive. The series regulator transistors, sensing this change, tends to turn off, lowering the output voltage.

Notice that when the output voltage increased, the entire amount of change was reflected on the base of T2, while only a portion of the change was reflected onto the base of T1 because of the voltage divider action of R1.

If the output voltage drops from −12 volts to −11.8 volts, for example, the base potential of T2 becomes more positive with respect to ground which causes T2 to turn off. This action makes the collector voltage of T2 more negative, which causes the series regulator to turn on more. The increased current flow raises the output voltage.

Referenced to −6 Volts

Certain transistor applications require a tighter tolerance between −12 volts and −6 volts than is provided for with the normal differential amplifier circuit. To satisfy this requirement, a scheme using −6 volts as the regulating voltage is incorporated. Minus twelve-volt power supplies that might require this type regulation may be referenced to either −6 volts or ground by using the proper SMS differential amplifier card.

Normal regulation of ±2% in reference to ground results in the following permissible voltages:

For − 6 volt supplies: between − 5.88 and − 6.12 volts

For −12 volt supplies: between −11.76 and −12.24 volts

Notice that if the −6-volt supply is at −5.88 volts and the −12-volt supply is at −12.24 volts, a difference of 6.36 volts between the two supplies exists. In other words, while the two supplies are regulated to a tolerance of ±2%, the difference between the two voltages can vary up to ±6%. This variation would cause erratic operation in some transistor applications.

By using the −6-volt supply as a reference voltage, and regulating the −12-volt power supply against it instead of ground, a tolerance of ±2% of the difference voltage can be maintained between these two voltages.

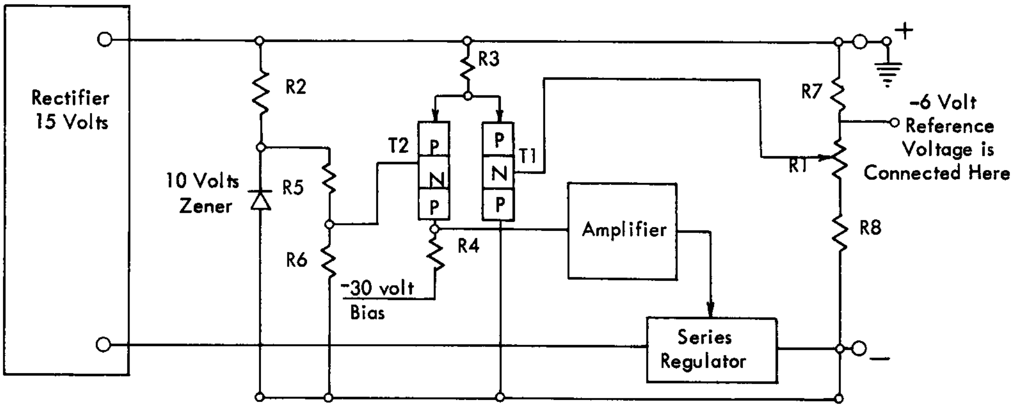


FIGURE 14. DIFFERENTIAL AMPLIFIER FOR POWER SUPPLIES REFERENCED TO −6 VOLTS

Figure 14 shows a simplified circuit diagram of the differential amplifier used in power supplies referenced to −6 volts. Notice that the output from the −6-volt supply is connected between potentiometer R1 and ground (the positive terminal in the example). This takes R7 out of the circuit and causes the base potential of T1 to vary in step with the −6-volt supply instead of ground. The zener diode develops a constant 10-volt drop across R5 and R6. Any change in the voltage across R1 and R8 will change the rate of conduction in T2 which controls the series regulator transistors. Therefore, the −12-volt output will regulate to a tolerance of ±2% of the 6-volt difference with respect to the −6-volt power supply.

Circuit Operation — The circuit operation is the same as that previously described for differential amplifiers in the power supplies referenced to ground.

Emitter Follower Amplifier

The simplified circuit diagram in Figure 15 shows the two stages of amplification following the output of T2 in the differential amplifier circuit. It is an emitter-follower circuit and provides sufficient current to drive the power transistor (s) in the series regulator.

An emitter follower is a current-amplifying device, not a voltage amplifier; therefore, approximately the same voltage change appears at the emitter of T4 as on the collector of T2. This current had to be amplified because the series regulator transistors require much more current to control the output than is available from T2. The current gain for each stage of amplification is between 20 and 100.

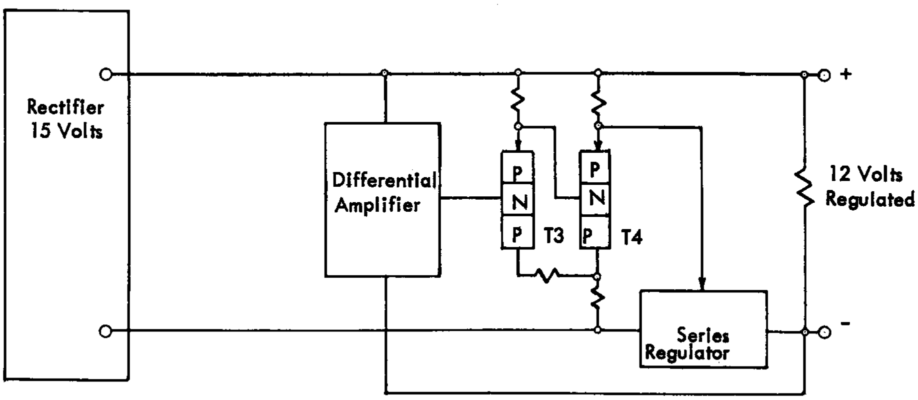


FIGURE 15. TWO-STAGE EMITTER FOLLOWER AMPLIFIER

Temperature Compensation

The two-transistor-differential amplifier compensates for the increased conduction in a transistor caused by heat.

As the temperature increases, T1, which forms a simple emitter-follower circuit as shown in Figure 16, conducts heavier. The increased conduction, which is through R1, causes a larger voltage to be developed across the emitter resistor. The increased voltage drop across R1 decreases the base to emitter potential of T2. This action tends to turn off T2, opposing the turn-on effect of the increased temperature.

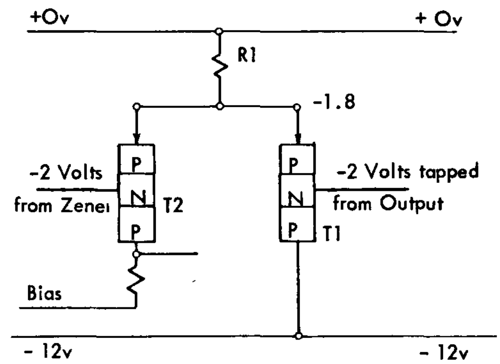


FIGURE 16. TEMPERATURE COMPENSATION

Circuit Protection

Isolation Transformer

Protection to the isolation transformer, in the event of a power supply component failure, is provided by means of a circuit breaker in series with the primary winding of the isolation transformer. It is physically located near the overcurrent circuit breaker. This is a thermal-type circuit breaker incorporating a bi-metallic element. It operates two sets of contacts:

1. a normally closed contact in series with the primary winding of the isolation transformer and,
2. a normally open set of contacts which may be used for external purposes.

The contacts may be manually operated by means of the reset plunger, which resets the circuit breaker. The plunger has a white ring around its base which is exposed when the circuit breaker is operated. This indicates to the customer engineer that the circuit breaker is open.

Overcurrent

Overcurrent protection up to and including a short circuit is provided, by means of a circuit breaker, to protect power-supply components on most SMS power supplies. Figure 17 shows a circuit breaker connected in a power-supply module. It is in series with the negative ouput terminal of the rectifier section and the series regulator transistors. In addition to controlling normally closed contacts which are in series with the negative output line, the circuit breaker controls another set of points used for external functions, such as stopping the machine and indicating the trouble.

The circuit breaker is designed to trip in approximately 40 ms at 150% overload. Once tripped, it must be manually reset by a customer engineer. The frontispiece shows where it is located on the dc power-supply module.

Overvoltage

Overvoltage protection is provided, when necessary, for protection of the machine circuitry. Whenever the voltage rises more than 10% above its rated value, the overvoltage protection circuit overloads the power supply, causing the overcurrent circuit breaker to trip.

The overvoltage protection unit includes a zener (for reference voltage), a differential amplifier, and a gate-controlled solid-state rectifier, sometimes called a *thyratron transistor*. It takes about 10 microseconds to react to an overvoltage condition.

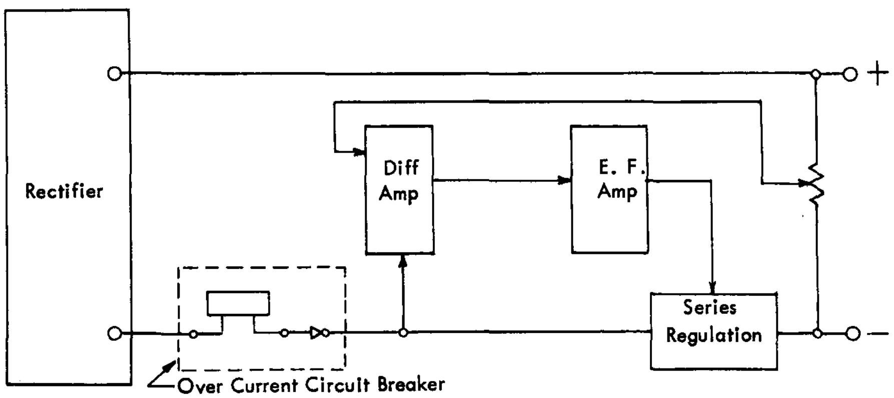


FIGURE 17. OVERCURRENT CIRCUIT PROTECTION

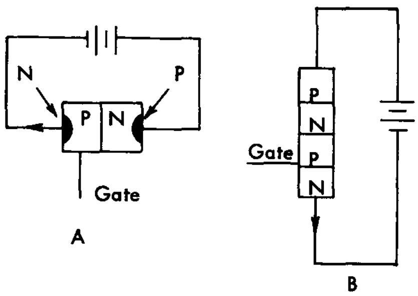


FIGURE 18. THYRATRON TRANSISTOR

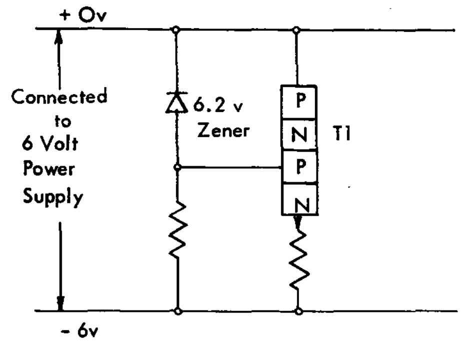


FIGURE 19. THEORETICAL OVERVOLTAGE PROTECTION CIRCUIT

Thyratron Transistor

The thyratron transistor (gate-controlled solid-state rectifier) is a four-element device with characteristics similar to those of a gas rectifier. As in the gas rectifier, there are two operating conditions:

1. in the OFF (nonconducting) state, only leakage current flows.
2. in the ON state, current is limited only by the external circuit impedance. The voltage drop across the transistor in the ON state is about equal to that of one forward-biased PN type rectifier.

The thyratron transistor (PNPN) is constructed by diffusing two layers of P-type material to an 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. Figures 18A and 18B illustrate a PNPN thyratron transistor.

Because of its electrical properties, the thyratron transistor stays in its ON state once it is turned on. The collector voltage necessary to turn it on depends upon the potential applied to the gate lead. If the gate lead is positive with respect to the emitter, the thyratron transistor turns on with a relatively small collector voltage.

Theoretical Circuit

The theoretical circuit (Figure 19) uses a zener diode and a thyratron transistor. The gate of the thyratron transistor (T1) becomes positive, with respect to its emitter, when the output voltage exceeds −6.2 volts. This is due to the clamping action of the zener diode. When T1 turns on, it acts as a short circuit across the output of the power supply, which trips the overcurrent circuit breaker previously described.

Once the transistor is in conduction, the gate lead loses control. The only way the transistor can be turned off is to open the emitter circuit, which is done by a set of normally closed points on the overcurrent circuit breaker.

Overvoltage Protection Circuit

Figure 20 is a typical circuit diagram of the overvoltage protection unit used with a 12-volt power supply. The voltages shown are approximate values.

The overvoltage circuit has two conditions:

1. the condition for normal power supply output;
2. the state it is in to cause the thyratron transistor to turn on.

The circuit description for each will be discussed separately.

NORMAL CONDITION

The zener diode (Z1) clamps the emitter of T2 to −6 volts because of the emitter follower action of T1. The collector potential of T2 is set at −15 volts by the potentiometer (R1). Because its base is more negative than its emitter (NPN), T3, which is turned off, acts as an open circuit and keeps the gate potential of T4, the same as its emitter (−12 volts). This keeps T4 in its OFF state.

OVERVOLTAGE CONDITION

An increase in the power-supply output raises the voltage across the R1, R2 voltage-divider circuit. This increases the base potential of T2 (becomes more negative) and causes the transistor to turn on more. The base voltage of T3 drops (goes from −15 to less than −12 volts), and T3 turns on. The path of current flow is through R3, R4, T3 to the zero-volt line. This action causes a voltage drop across R3 which makes the gate of T4 positive with respect to its emitter. T4 turns on and acts as an overload to the power supply causing the overcurrent circuit breaker in the power supply to trip.

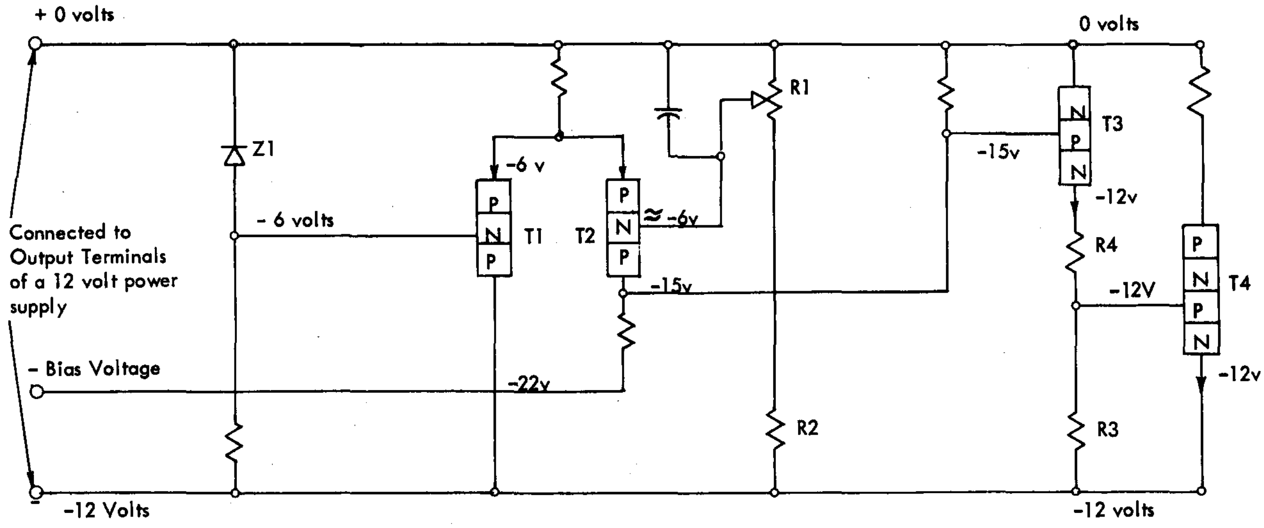


FIGURE 20. OVERVOLTAGE PROTECTION UNIT CIRCUIT

Marginal-Check Unit

A marginal-check system will be furnished for most systems or machines incorporating solid-state circuitry.

The system consists of a special power supply with a variable output voltage which, when placed in series with one of the standard system or machine power supplies, assists the customer engineer in locating marginal or intermittent failures.

The marginal-check power-supply system covered in this manual has two basic designs: 1. The modular unit that provides ±25% regulation and does not contain a ferroresonant regulator. It must, therefore, obtain its ac regulation from the ferroresonant regulator in the machine on which it is mounted. 2. The design that provides ±2% regulation and contains its own ferroresonant regulator. It may be either machine-mounted or used as a portable unit, when placed in a portable mounting box.

Both supplies vary the voltages furnished to transistor base circuits. They supply a variable ±3 volts at 5 amps. This permits the customer engineer to change a particular voltage by ±3 volts, if necessary. For example, a −12 volt line can be varied from −9 volts to −15 volts. The scheme used in connecting the marginal-check supply voltage to a system or machine power-supply voltage will be discussed in a manual of instruction for that particular system or machine.

Modular Unit (Fixed)

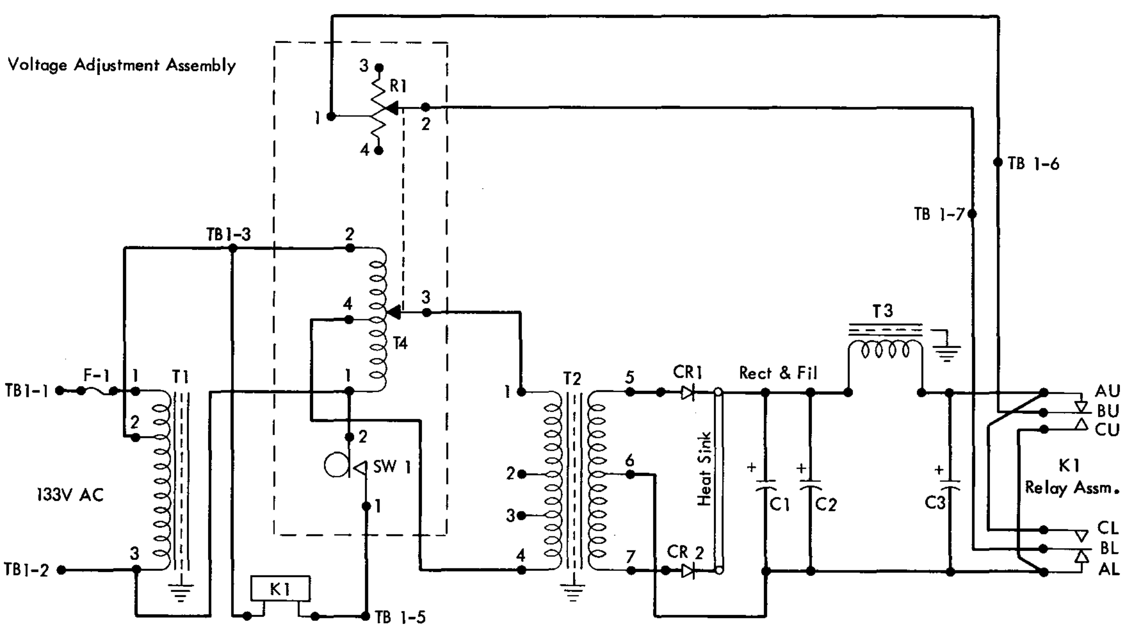
The marginal-check unit designed to fit in an SMS gate is used on machines or systems that have available space and are of sufficient size to justify the costs of the unit.

The output voltage is controlled by a rheostat and switch assembly. With the adjustable terminal on the rheostat in its center position, the output voltage is zero. The output voltage increases from zero to a maximum of 3 volts, either plus or minus, depending upon the direction of rotation as the adjustable terminal is rotated from its central or neutral position.

Figure 21 is the wiring diagram for the modular marginal-check power supply composed of the following components:

T4	An autotransformer
T2	An isolation transformer
Rectifier and Filter	A full-wave rectifier with a capacitor-inductance filter
Relay Assembly	A polarity reversing relay assembly
R1	A rheostat assembly

The rheostat and autotransformer are ganged together and have a switch-actuating cam on the end of the operating shaft. This cam controls the polarity reversing relay K1.



Note: Sw 1 actuated by cam on shaft of T4.
T4 and R1 have common operating shaft.

FIGURE 21. MARGINAL-CHECK POWER SUPPLY (MODULAR UNIT)

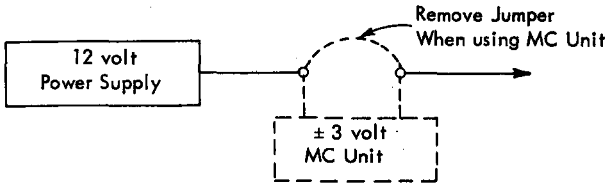


FIGURE 22. MARGINAL-CHECK UNIT IN SERIES WITH SMS POWER SULLPY

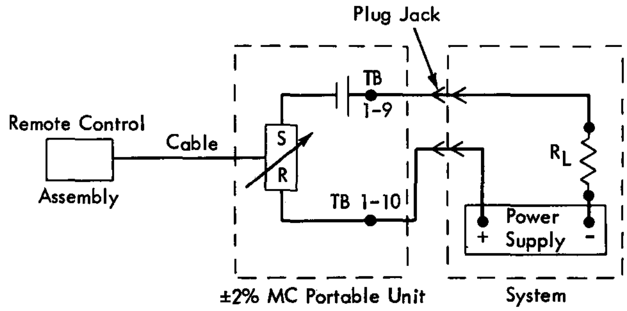


FIGURE 23. PORTABLE MARGINAL-CHECKING UNIT AND CABLE CONNECTIONS

Circuit Operation

With the rheostat-autotransformer shaft in its neutral position (Figure 21) the voltage across the isolation transformer T2 is zero. If the unit is connected in series with a system power supply as shown in Figure 22, the rheostat acts as a short circuit and the marginal-check unit has no effect on the machine power supply.

As the rheostat-autotransformer shaft is rotated, a voltage is induced in transformer T2 and is rectified. The rectified dc voltage across R1 acts like a battery in series with a power supply and either adds to or subtracts from the voltage with which it is in series. The amount of voltage across R1 depends upon the amount of voltage supplied to the rectifier by the autotransformer.

Switch SW1 is actuated by a cam connected to the rheostat-autotransformer shaft, as previously mentioned, and is operated when the rheostat is operated from its neutral position in a counterclockwise direction. When closed, the switch operates relay K1, which reverses the polarity of the output voltage. For a circuit description of the rectifier section, refer to *Full-Wave Center-Tapped Rectifier.*

Portable Unit

Earlier portable units are the same as the modular unit shown in Figure 21, with the exception that they have their own ferroresonant regulators. The circuit operation is therefore identical to that previously described for the modular unit. Unlike the earlier unit, the newer portable unit explained here is also machine mountable for special system application, and its output-voltage regulation is ±2%.

Figure 23 shows the portable MC unit connected in series with a system power supply. The remote control assembly is connected to the MC unit by a long cable, as illustrated, so that the control can be carried around the machine while marginal checking is taking place. The output of the MC portable unit is connected by cable to the machine through a plug-jack receptacle on the console of the machine.

Figure 24 shows the actual wiring diagram of the ±2% MC portable unit. The parts comprising the unit are listed and described as follows:

1. ferroresonant regulator
2. full-wave rectifiers and output-voltage filter
3. overcurrent protection: CB1 opens if a current exceeding 6 amps is drawn
4. series regulator
5. differential amplifier T1, T2; emitter-follower amplifier T3, T5.
6. rectified voltage for biasing T1 in differential amplifier, variable at R20 in remote control assembly.
7. rectified voltages for transistor circuitry: +10v and −10v.
8. remove control unit containing these components:
   - L1 Shunt-open indicator. It lights when K1 is picked and S2 is transferrerd.
   - S2 DPST (N/O—N/C) switch ganged with potentiometer control. This switch allows K1 to pick when positioned as shown, and when transferred it allows the shunt-open indicator to light.
   - Potentiometer R20 provides the control of the series regulator bias.
   - S1 Provides the selection of marginal-checking polarity.
9. Shunt-control relay K1. When K1 is not energized, normally-closed points K1B shunt the marginal-check output terminals TB1-9 and TB1-10. K1 is picked through SW2 and held through its own points K1A. To protect the transistor circuitry from surge currents, the relay K1 cannot be picked unless the potentiometer is reset to zero.

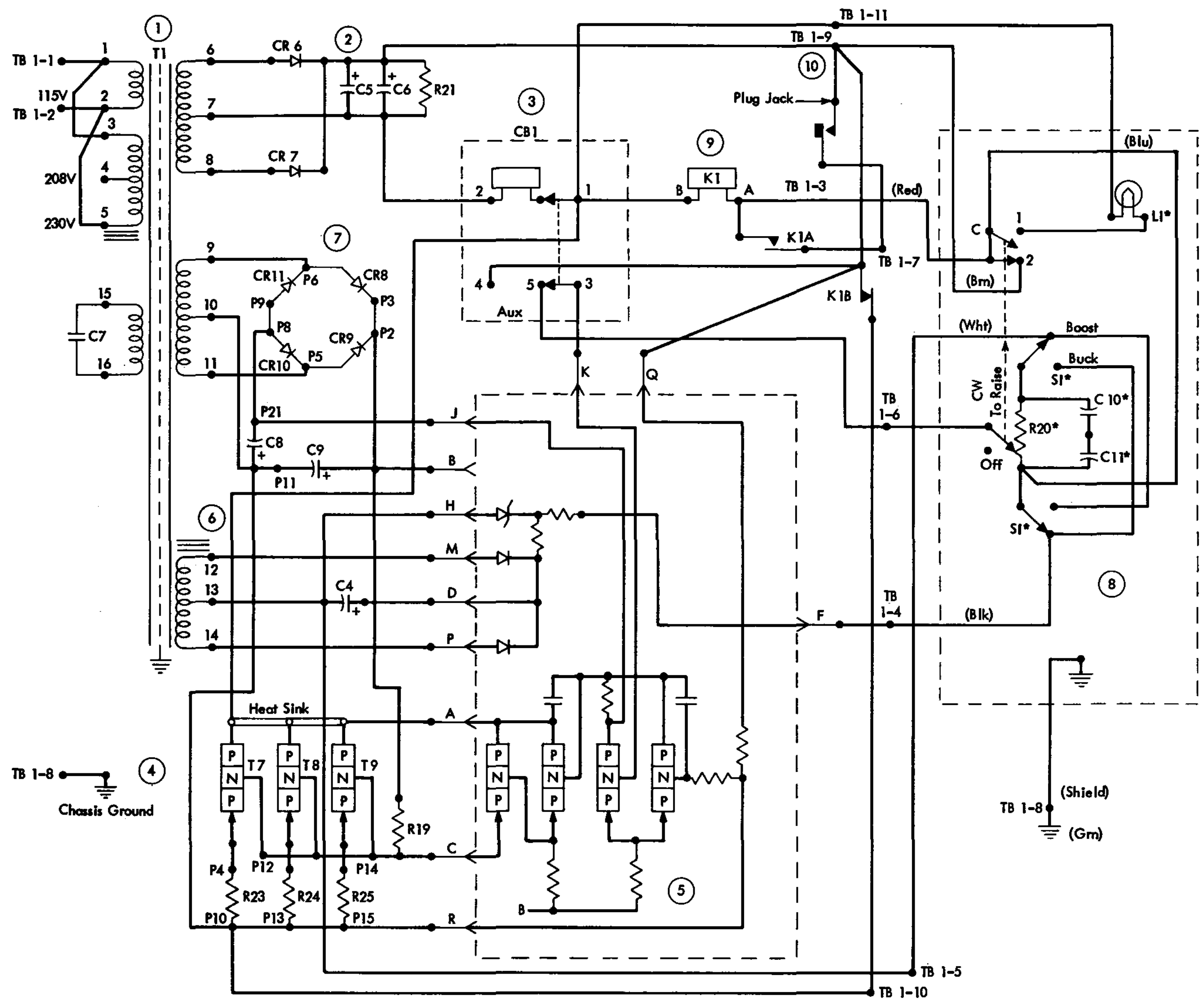


Figure 24. ±2% Portable Marginal-Checking Unit Wiring Diagram

10. Plug-jack normally-open points. These points are forced together if the cable from the MC unit to the receptacle on the machine console is in place. Should the cable be pulled out of its receptacle before marginal-check voltage is returned to zero, the points open and drop out relay K1. Consequently, points K1B close, shunt the MC output voltage, and cause the circuit-breaker to open.

Of the preceding components, the ferroresonant regulator, rectifiers and filters, the circuit-breaker, the series regulator, the differential amplifier, and the emitter-follower amplier have been explained in this manual.

Circuit Operation

Figure 25 is a simplified diagram of Figure 24. Corresponding voltage supplies in the two figures are identified by the same encircled number. Voltage approximations are given at several locations in Figure 25 to aid in explaining the circuit operation.

With SW1 set to BOOST, the polarity across R20 is as shown in Figure 25. As the potentiometer shaft is rotated from 0 v toward 3 v (indicated on the remote control unit), the base of T1 swings in a negative direction. Because T1 is an emitter follower, its emitter also becomes more negative. And because T1 and T2 share a common emitter resistor R28, the emitter of T2 becomes more negative. T2, connected in a grounded base configuration, conducts less and its collector swings in a negative direction through R11.

Through the cascaded-emitter followers T3 and T5, the negative swing appears at the base of the series regulator. The series regulator, consequently, presents less impedance to the circuit allowing the voltage between TB1-9 and TB1-10 to rise.

As more current flows through the series regulator, its emitter becomes more positive through resistor R23. When the voltage between the terminals has risen by the amount selected at R20, the emitter potential of T2 returns to its original level. The collector of T2 returns to its original voltage level, and the series regulator is signaled to maintain its present rate of conduction.

With SW1 set to BUCK, the polarity from 0 v to 3 v is negative to positive. As the potentiometer shaft is rotated from 0 v toward 3 v, the base of T1 swings in a positive direction. The T2 emitter also swings positive and T2 conducts heavily. The T2 collector, therefore, swings positive and, through the cascaded-emitter followers T3 and T5, the base of the series regulator becomes more positive. The current of the series regulator, therefore, decreases, and the emitter of the series regulator becomes more negative through T23.

As its impedance increases, the series regulator causes less voltage to appear between the output terminals. At the 3 v (BUCK condition) setting of R20, the impedance of the series regulator becomes sufficiently large to drop across it the marginal-check power-supply voltage and three volts of the load voltage.

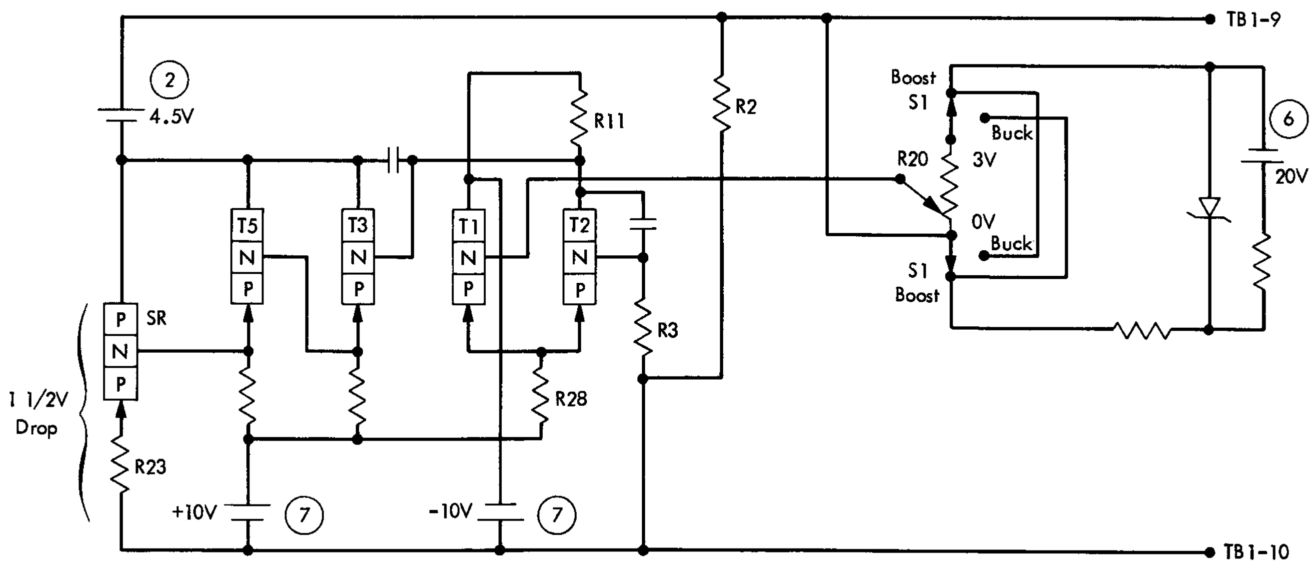


FIGURE 25. PORTABLE MARGINAL-CHECKING UNIT (±2% REG.)—SIMPLIFIED WIRING DIAGRAM

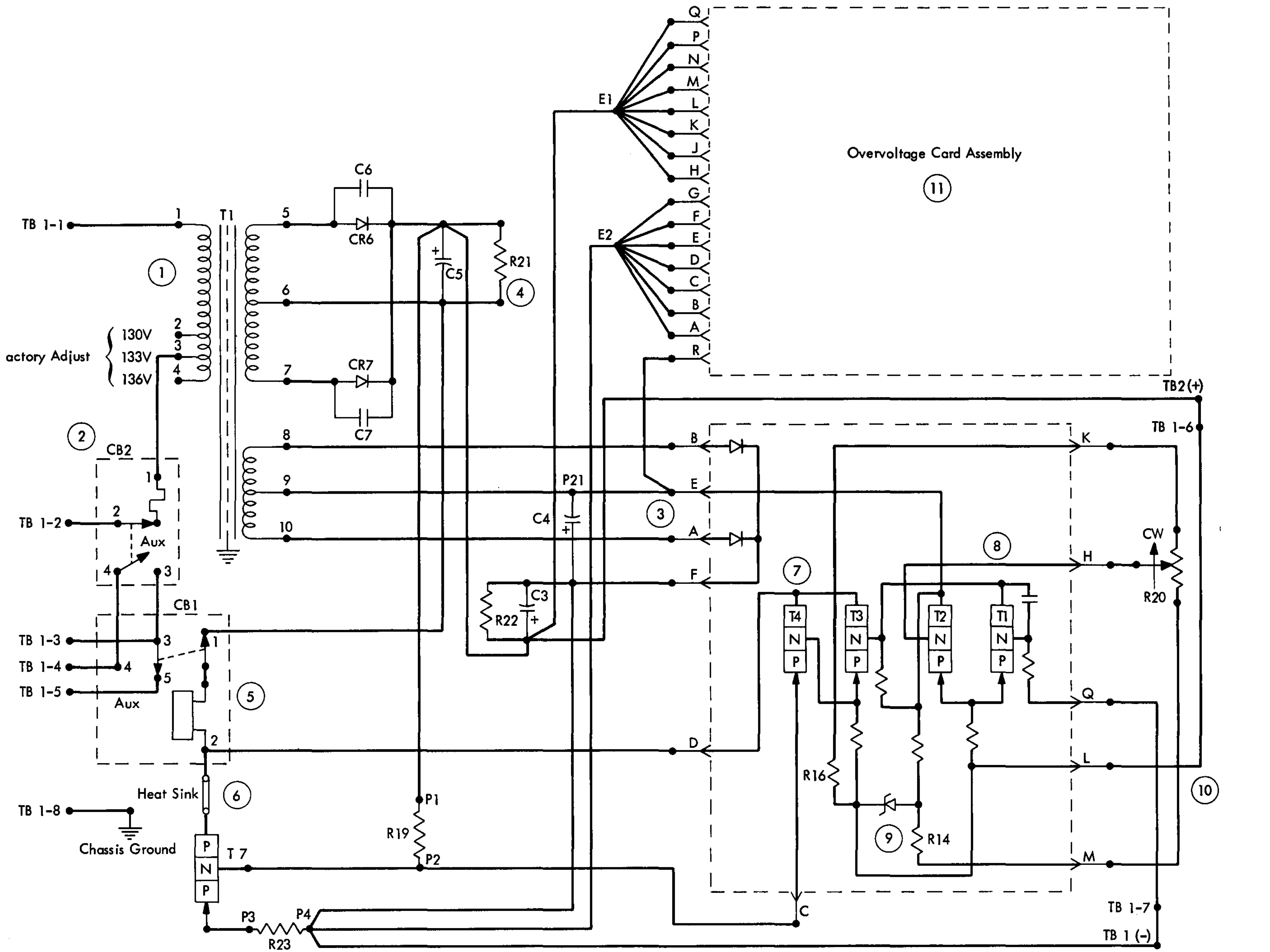


Figure 26. Typical Series—Regulated SMS Power Supply

Figure 26

(1) Isolation transformer.

(2) Isolation transformer protection circuit breaker with an extra set of points (CB2 AUX) used externally.

(3) Bias voltage rectifiers and filter. Furnishes bias voltage for regulator circuitry and overvoltage circuitry.

(4) Output voltage rectifiers and filter. The dc output voltage developed is approximately 3 volts higher than the rated output voltage of unit.

(5) Overcurrent circuit breaker. It protects the power-supply from overload. It is in series with the negative output line.

(6) Series regulator transistor. It is in series with negative output line.

(7) Two-stage emitter-follower amplifier (output taken from emitter of T4 and connected directly to base of T7).

(8) Differential amplifier. The output from T1 connects to base of T3.

(9) Zener diode and voltage divider network. The zener diode keeps voltage drop across R14, R20, R16 combination constant.

(10) Output terminals (TB1-7 and TB1-6) and an additional filter (C3 and R22).

(11) Overvoltage protection unit receptacle. If overvoltage protection is specified, the protection unit will be plugged into this receptacle; otherwise, these terminals remain dead-ends.

TABLE OF AVAILABLE 60-CYCLE SMS POWER SUPPLIES

Voltage	*Current*	*Reg. To:*	*Comment*
± 3v	5a	±25%	Marginal Check Power Supply
± 3v	5a	± 2%	Marginal Check Power Supply
± 6v	2a	± 2%	
± 6v	4a	± 2%	
± 6v	8a	± 2%	
± 6v	12a	± 2%	
± 6v	16a	± 2%	
± 6v	20a	± 2%	
±12v	8a	± 8%	No-Series Regulator
±12v	2a	± 2%	Can be referenced to either ground or −6 volts depending on which differential amplifier card is used.
±12v	4a	± 2%	
±12v	8a	± 2%	
±12v	12a	± 2%	
±12v	16a	± 2%	
±12v	20a	± 2%	
−20v	6a	± 8%	
−20v	15a	± 8%	
+30v	2a	± 2%	
+30v	4a	± 2%	
+30v	7a	± 2%	
+30v	4a (S*)	± 2%	Special supply for core storage has external voltage adjustment control
−36v	2a	± 2%	
−36v	4a	± 2%	
+48v	6a	±10%	Non-standard voltage provided for existing 48-volt relay circuits
+60v	6a (S*)	± 2%	Has external voltage adjustment control
Power Supplies not suitable for SMS Mounting			
+60v	10a	± 2%	

* (S) — Storage

225-6478-1

IBM 60-Cycle SMS Power Supply Printed in U.S.A. 225-6478-1

IBM
International Business Machines Corporation
Data Processing Division
112 East Post Road, White Plains, New York

620705MFW