

INSTRUCTION MANUAL

Type SE12
REGULATED POWER SUPPLY



RADIOMETER

ELECTRONIC MEASURING INSTRUMENTS
FOR SCIENTIFIC AND INDUSTRIAL USE

INTRODUCTION AND OPERATING MANUAL
FOR

Type SE12
REGULATED POWER SUPPLY

INTRODUCTION

The RADIOMETER type SE12 is a bench model Regulated Power Supply intended for general laboratory and industrial use.

It features a decade-selected, variable output from 0 to 60 volts (5 x 10 volts and 10 x 1 volt) with high regulation.

The current range is 0 to 2 amps independent of the voltage setting.

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SECTION 1
SPECIFICATIONS AND DESCRIPTION

1.1 SPECIFICATIONS

DC OUTPUT

VOLTAGE

0 to 60 volts. Decade-selected tens and ones (5×10 volts and 10×1 volt). A vernier control covering 0 to 1.2 volts provides for continuous voltage setting.

CURRENT

0 to 2 amps at any voltage setting.

ACCURACY OF VOLTAGE SETTING

Accuracy of decade-selected voltages better than $1\% \pm 10$ millivolts.

REPEATABILITY OF VOLTAGE SETTING

Repeatability of decade-selected voltages typically better than $0.2\% \pm 10$ millivolts.

LOAD REGULATION

Less than 0.015% or 5 millivolts (whichever is greater) change in output voltage from no-load to full-load.

LINE REGULATION

Less than 0.015% or 2 millivolts (whichever is greater) change in output voltage for a line voltage change of 10% .

OUTPUT IMPEDANCE

Less than 10 milliohms, d-c to 1 kc, and less than 100 milliohms at 10 kc. Typically 2 ohms at 1 Mc. See fig. 1.1

RIPPLE AND NOISE

Less than 0.5 millivolt rms. See fig. 1.2.

Fig.1.1. Typical output impedance.

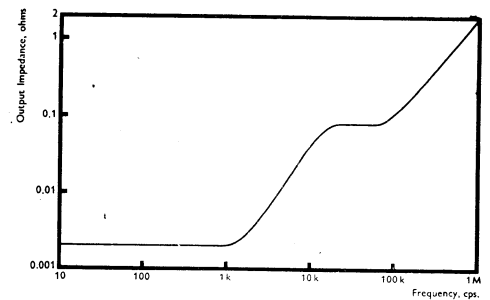


Fig.1.2. Scope view shows ripple and noise on output voltage. (1 div.=20 msec/1 mV, $V_{\text{output}} = 60$ volts, $I_{\text{load}} = 2$ amps).

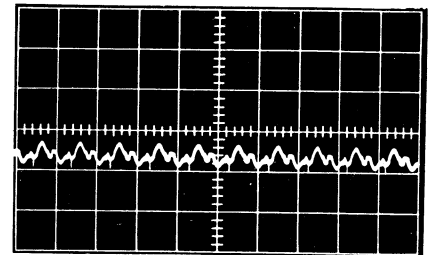


Fig.1.3. Typical effects of step load changes.

Above: 2A to 0A to 2A,
Below: 2A to 0.2A to 2A,
(1 div. = 1 msec/50 mV
 $V_{\text{output}} = 60$ V).

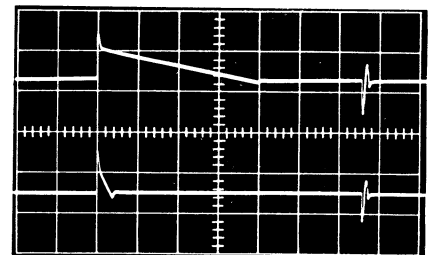
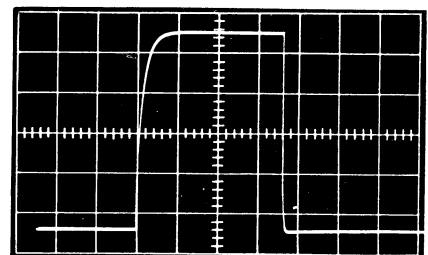


Fig.1.4. Scope view shows programming cycle. 10 volts to 60 volts to 10 volts (1 div. = 1 sec/10 volts, $I_{\text{load}} = 2$ A).



RECOVERY TIME

Typical recovery effects are shown in fig. 1.3.

POLARITY

The positive or the negative terminal may be grounded.

INSULATION VOLTAGE

Both output terminals are insulated from chassis and may be operated up to 500 volts off ground.

OVERLOAD PROTECTION

The output current can be limited automatically to 0.1, 0.2, 0.5, 1, 1.5 or 2 amps with full regulation maintained up to the limiting value. The short-circuit current will not exceed the limiting-value by more than 40 to 75%, depending on the value selected.

Continuous operation into a short-circuit will not damage the supply. The output voltage is automatically restored when the short-circuit is removed.

PROGRAMMING

Provision is made for programming by means of an external resistance control element.

Programming constant: 25 ohms per volt. A programming cycle is shown in fig. 1.4.

REMOTE SENSING

Auxiliary sensing terminals are provided to regulate the output voltage at a remote load.

CONSTANT CURRENT OPERATION

Regulated Current Output range: 50 milliamperes to 2 amps.

1.12 METERING

A built-in meter monitors the output current without affecting the low output impedance.

Current Range: 0 to 2 amps full scale.

Accuracy: 3% of full scale.

1.13 DUTY CYCLE AND AMBIENT TEMPERATURE

Continuous operation at full load up to 40°C (104°F).

Convection cooling is employed.

1.14 POWER SUPPLY

LINE VOLTAGE

103, 110, 117, 206, 220 and 234 volts $\pm 10\%$

LINE FREQUENCY

45 to 65 cps

CONSUMPTION

200 watts at full load.

1.15 OUTPUT TERMINALS

Binding posts that accept 4 mm banana plugs.

1.16 CONTROLS

Power On-Off.

Output-Voltage On-Off.

Output-Voltage Controls.

Current-Limit Switch

Sensing, Remote-Local

1.17 SEMICONDUCTORS

2-ADZ12, 2-ASZ15, 1-ASY76, 3-ASY77, 1-ASY80, 2-OC26,
4-2N1307, 8-2N1309.

2-B80C400, 2-E125C200, 1-OA5, 2-OA91, 2-OAZ203.

1.18 OVER-ALL DIMENSIONS

Height:	Width:	Depth:
260 mm	200 mm	320 mm
10 1/4 inches	8 inches	12 5/8 inches

1.19 WEIGHT

14 kilos net (31 lbs)

1.110 FINISH

Grey enamelled metal housing.

1.2 DESCRIPTION

In order to obtain extremely high regulation, three regulating systems are employed in the Regulated Power Supply, type SE12: a coarse regulating system, a pre-regulator, and a main-regulator.

A simplified block diagram is shown in fig. 1.5.

The coarse regulating system consists of two transformer tap switching relays controlled by two Schmitt triggers, which are adjusted to trigger at certain levels of the output voltage V_o . When these levels are reached, the relays are actuated and automatically select the proper transformer tap.

The pre-regulator is of the switch type, using a highly efficient transistor as the switch-element. It maintains the voltage-drop across the current limiting circuit and the main-regulator at an almost constant value independent of voltage setting as well as changes in line voltage and load current.

The power dissipation in the main-regulator is thus kept low, even at small values of the output voltage.

The main-regulator is a normal series type, employing a direct-coupled, high-gain differential amplifier and a double-stabilized reference source.

This regulator controls the output voltage.

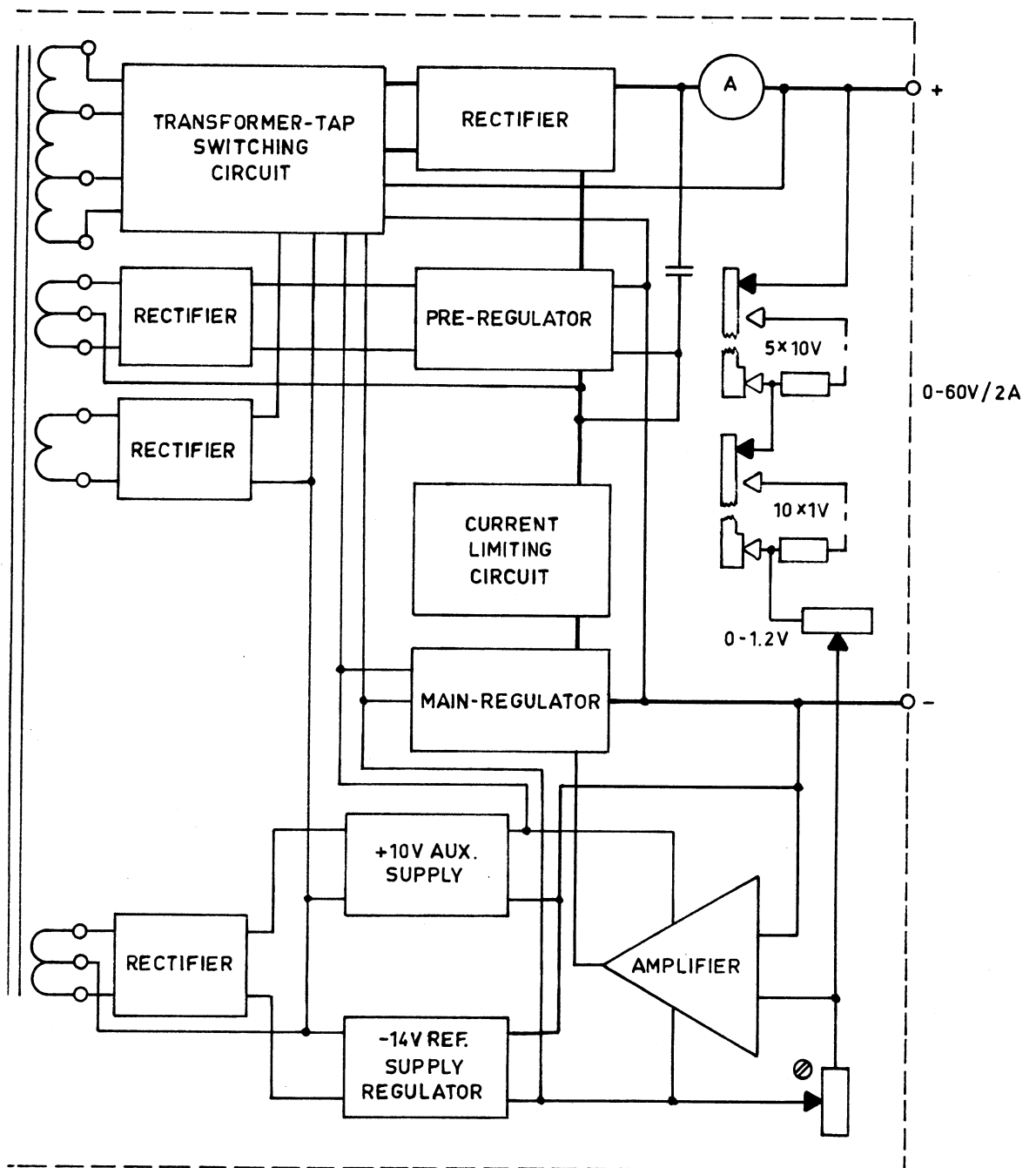


FIG. 1.5. BLOCK DIAGRAM

SECTION 2

OPERATING INSTRUCTIONS

2.1 CONTROLS AND TERMINALS

The following controls and terminals are located on the front panel of the instrument. See fig. 2.1.

2.11 Controls:

"POWER"
switch

When switched to "ON", the primary circuit is closed to line. The red pilot lamp just below lights when the power switch is turned on.

"SENSING"
switch

Local sensing of the output voltage is the normal operating mode, but the Power Supply can be switched to remote sensing at the load itself in order to maintain high d-c regulation even when a voltage drop is produced in terminals or long connecting wires.

"OUTPUT"
switch

When switched to "ON" the black "-output" terminal is connected to the internal voltage source.

"CURRENT LIMIT"
switch

The output current can be limited automatically to 0.1, 0.2, 0.5, 1, 1.5 or 2 amps with full regulation maintained up to the limiting value.

"OUTPUT VOLTAGE"
switch

Decade-selected tens and ones (5 x 10 volts and 10 x 1 volt), for adjustment of the 0 to 60 volt - voltage source.

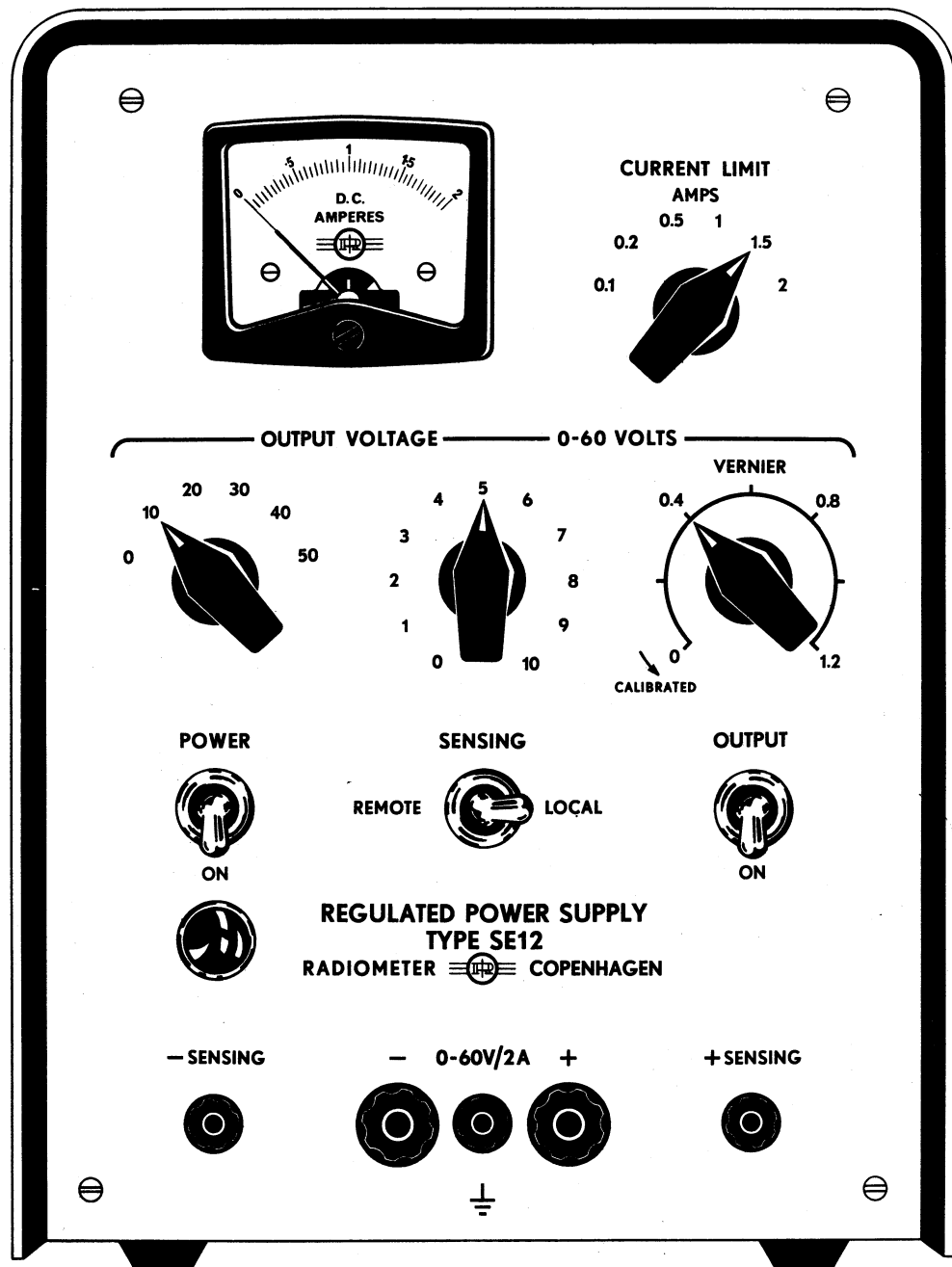


Fig.2.1 FRONT

Knob


A vernier control covering 0 to 1.2 volts provides for continuous voltage setting.

2.12 Terminals:

"0 - 60V/2 A"

One red and one black binding post. The red terminal is positive. The output is floating with respect to chassis.

"CHASSIS-GROUND"

One black binding post marked with the ground sign .

The terminal is connected to the chassis. It is recommended to ground it whenever possible.

"SENSING"

One red and one black binding post. The red terminal is positive.

The correct Remote-Sensing procedure is described in section 2.5 of this manual.

2.13 The following controls and terminals are located at the back of the instrument:

POWER FUSE

The fuse holder with fuse $6\phi \times 20$ mm.
Line voltage 103-117 volts:
Fuse 2.5 amps, slow-blow.
Line voltage 206-234 volts:
Fuse 1.25 amps, slow-blow.

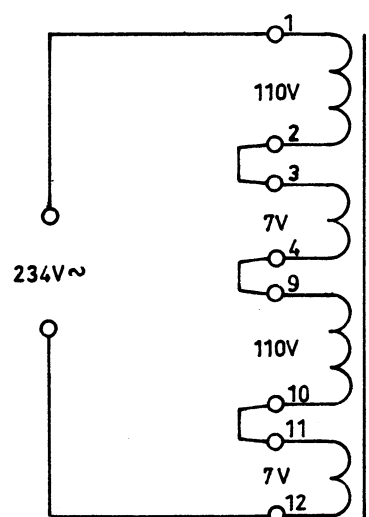
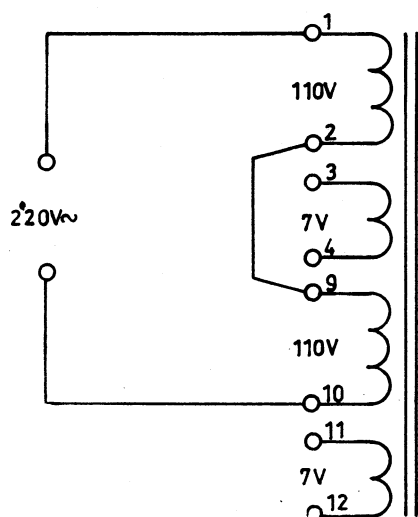
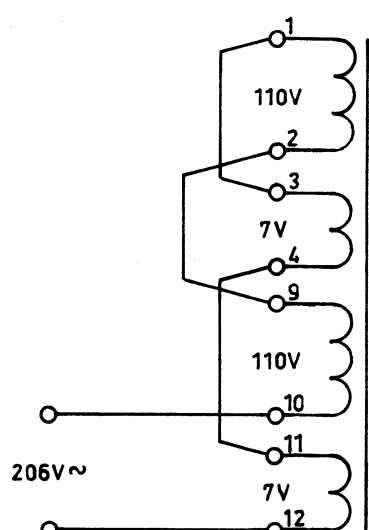
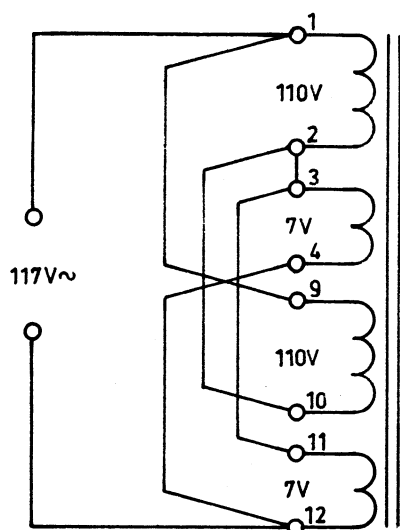
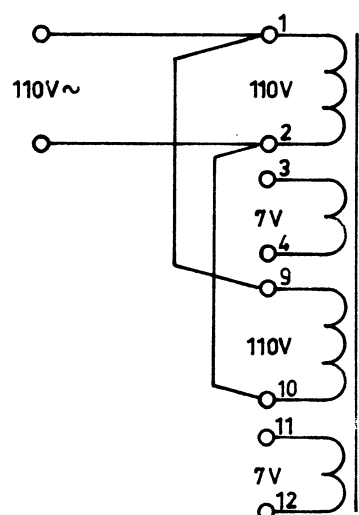
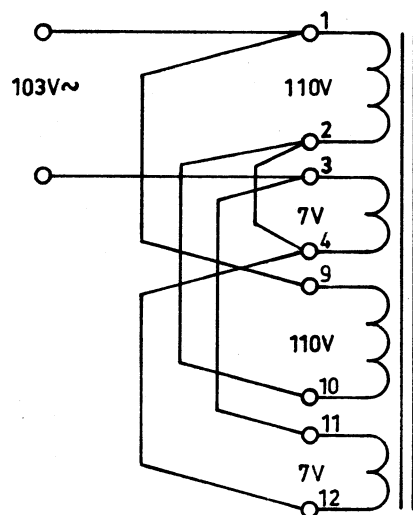
PROGRAMMING

The external programming circuit is connected to the four-way terminal block located behind the small shutter. The correct programming procedure is described in section 2.4 of this manual.

2.14 LINE VOLTAGE

SELECTION

The instrument may be set to any of the following line voltages: 103, 110, 117, 206 and 234 volts (nominal voltages).



2.2 PREPARING THE INSTRUMENT FOR OPERATION

- 2.21 When the Regulated Power Supply, type SE12, is received, inspect it for possible damage caused in transit.

The cover is easily removed by unscrewing four fixing screws at the top. The printboards marked "A" and "B" are hinged at the bottom and held in position by screws at the top.

- 2.22 Make sure that the selection of line voltage is correct and that the fuse is of the proper value.
- 2.23 Set the power switch to OFF position.
- 2.24 Set the sensing switch to LOCAL position.
- 2.25 Set the output switch to OFF position.
- 2.26 Set the OUTPUT VOLTAGE switch to 0.
- 2.27 Connect the line cord to the power line.
- 2.28 Check the zero setting of the meter and adjust, if necessary, with "POWER" switch to ON, and "OUTPUT" switch to OFF.
- 2.29 Operate the Power Supply as described in section 2.3 of this manual.

2.3 OPERATING THE SE12

- (1) Set the "OUTPUT" switch to OFF.
- (2) Set the "POWER" switch to ON.
- (3) Set the "OUTPUT VOLTAGE" switch to give the desired voltage.
- (4) Set the "CURRENT LIMIT" switch to the desired current limit.
- (5) Connect the load.
- (6) Set the "OUTPUT" switch to ON.

2.4 PROGRAMMING THE SE12

2.41 "Programming" means to control the output voltage by an externally connected resistance element, which can either be fixed or switch-selected.

The external control circuit is connected to the terminal block at the back of the instrument. The wiring is shown in figures 2.3 and 2.4.

The programming constant of the SE12 is 25 ohms per volt, i.e. the output voltage from the "0 - 60 V/2 A" - source will be 1 volt per every 25 ohms of resistance in the control loop. The lay-out of the loop may be varied widely according to the actual application, but because of the high voltage that the 0 - 60 V source is able to supply, it is RECOMMENDED TO FOLLOW THE RULES STATED BELOW.

Rule No. 1: Remove the line cord from the power line when programmed operation is to be established.

Rule No. 2: Make sure that the external loop cannot be open-circuited.

Note: Use shorting switches only (make-before-break), and avoid banana plugs and non-locking connectors.

Rule No. 3: Make sure that terminals " - sensing" and " - output" are reliable short-circuited by a strap. (See fig. 2.4).

Rule No. 4: Set the "SENSING" switch to Remote.

Rule No. 5: When reconverting to normal operation, make sure that terminals No. 1 and No. 2 in the terminal block are reliably short-circuited by a strap. (See fig. 2.3).

2.5 REMOTE SENSING

2.51 Local sensing of the output voltage is the normal operating mode, but the Power Supply can be switched to remote sensing at the load itself in order to maintain high d-c regulation even when a voltage drop is produced in terminals or long connecting wires. The SE12

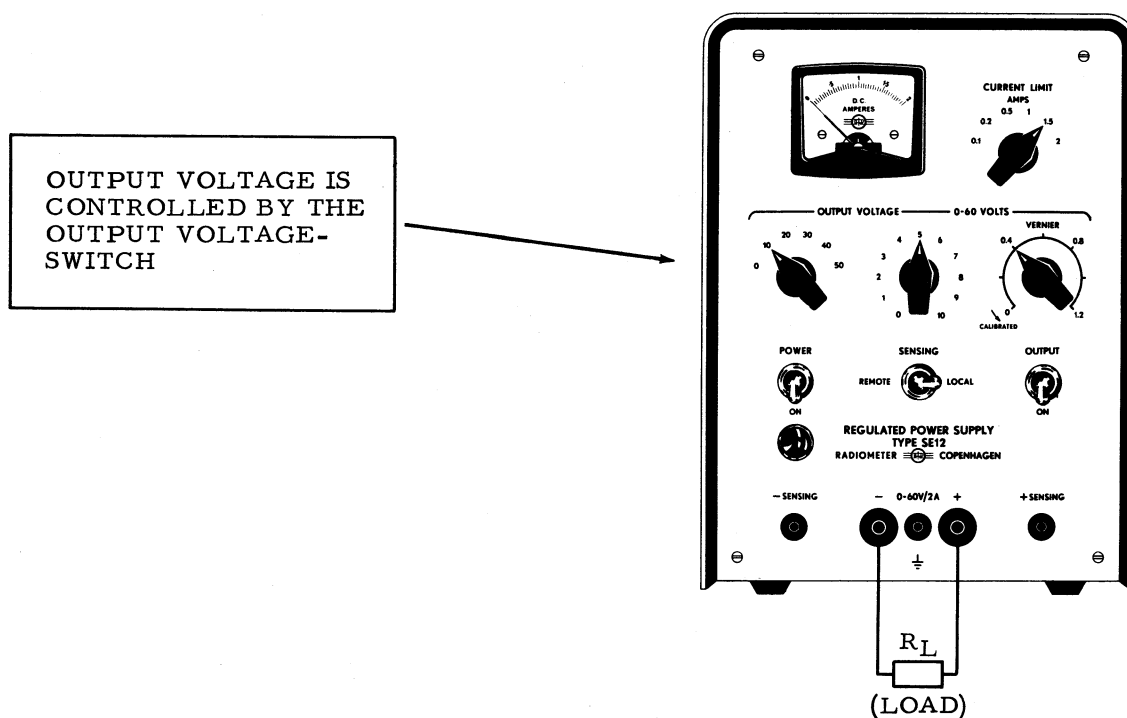
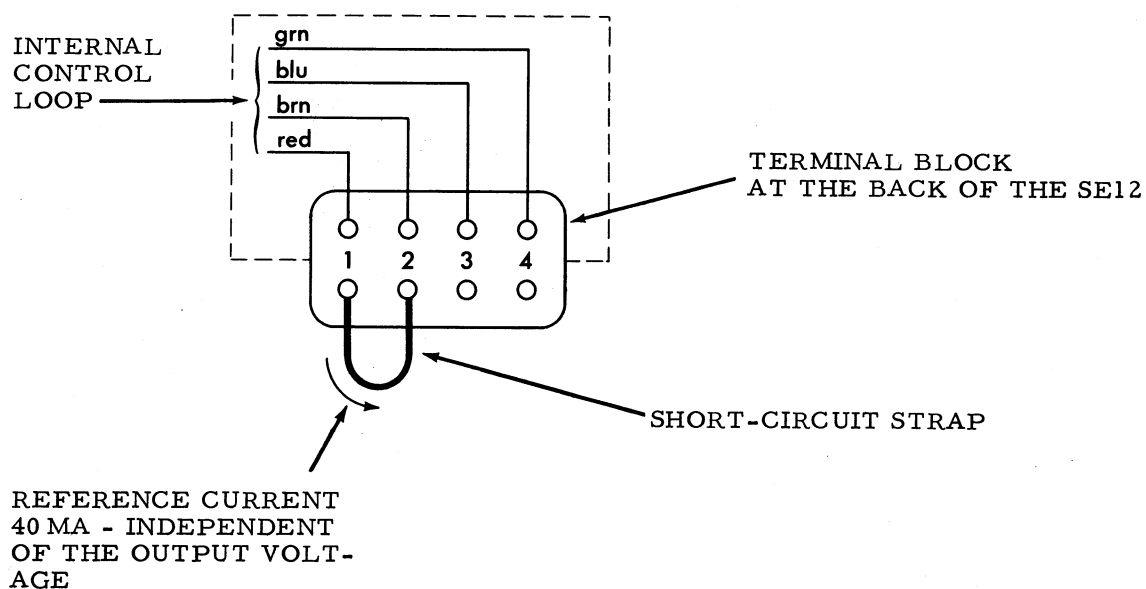
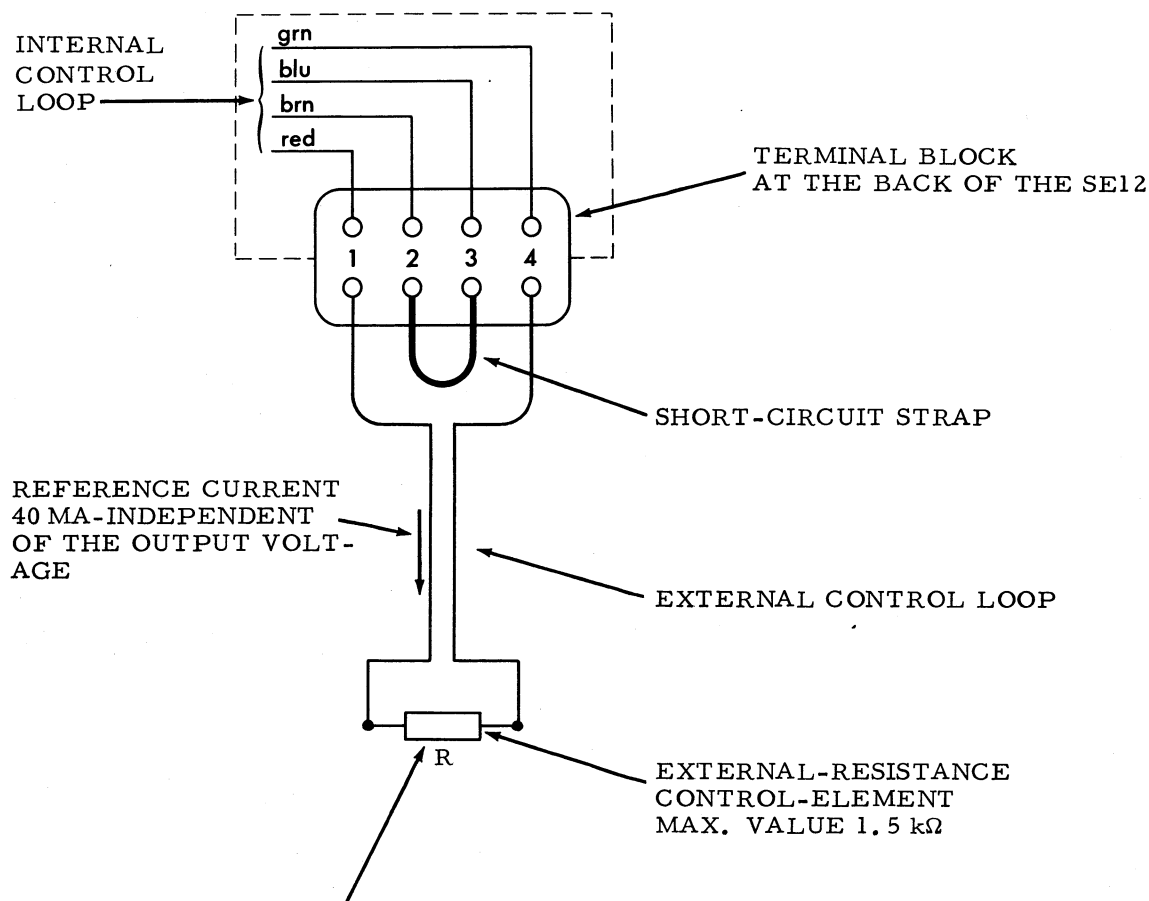


FIG. 2.3 NORMAL OPERATION



OUTPUT VOLTAGE IS
CONTROLLED BY THE
RESISTANCE IN THE
EXTERNAL CONTROL
LOOP.
OUTPUT: 1 VOLT PER 25 Ω

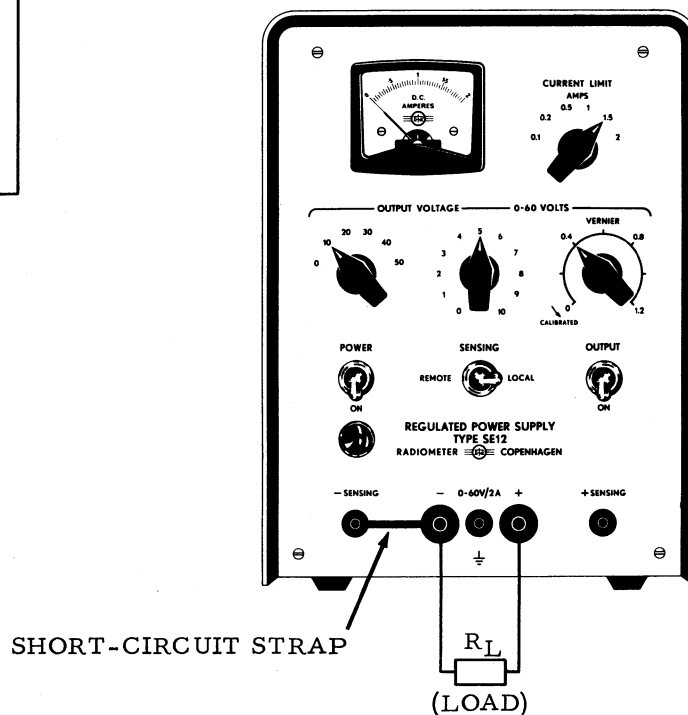


FIG. 2. 4. PROGRAMMED OPERATION

with the remote sensing feature can automatically compensate for voltage drops of up to 500 mV across each load supply lead.

Load Regulation:

Less than 0.04% or 12 millivolts (whichever is greater) change in output voltage from no-load to full load.

Output impedance:

DC: Less than 12 milliohms;

AC: A capacitor of 1000 μ F minimum is required across the remote load to maintain stability and provide low a-c impedance. (See fig. 2.5).

2.6 CONSTANT-CURRENT CONVERSION OF SE12 POWER SUPPLY

2.61 The Power Supply can be converted into a constant current supply by connecting a small resistor in series with the load, and sensing the voltage developed across this resistor.

The constant current range is from 0.05 to 2 amps.

CONVERSION PROCEDURE

- (1) Set the "POWER" switch to OFF.
- (2) Set the "OUTPUT VOLTAGE" switch (5 x 10 volts, 10 x 1 volt and vernier) to 0.
- (3) Make sure that terminals No. 2 and No. 3 in the terminal block are reliably short-circuited by a strap. (See fig. 2.6).
- (4) Set the "SENSING" switch to Remote.
- (5) Make sure that terminals "- sensing" and "- output" are reliably short-circuited by a strap (See fig. 2.6).
- (6) Select a sample resistor (R_S in figure 2.6 below) which will carry the load current minus reference current and develop a sample voltage for the control system. To determine its value, select a sample voltage. (1 to 5 volts is a good range; although the voltage may be made as high as desired, it must be remembered that the sample voltage subtracts from the available output voltage). If E_S is the sample voltage, I_L is the

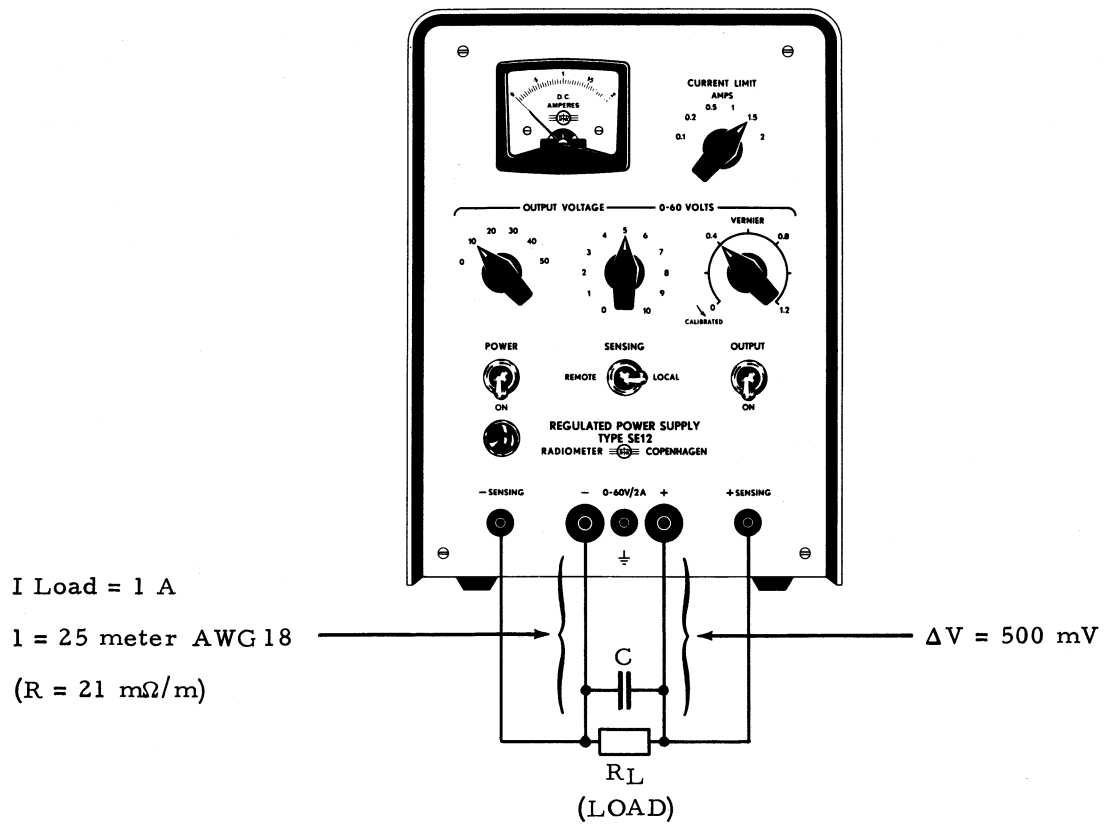


FIG.2.5. REMOTE SENSING OPERATION

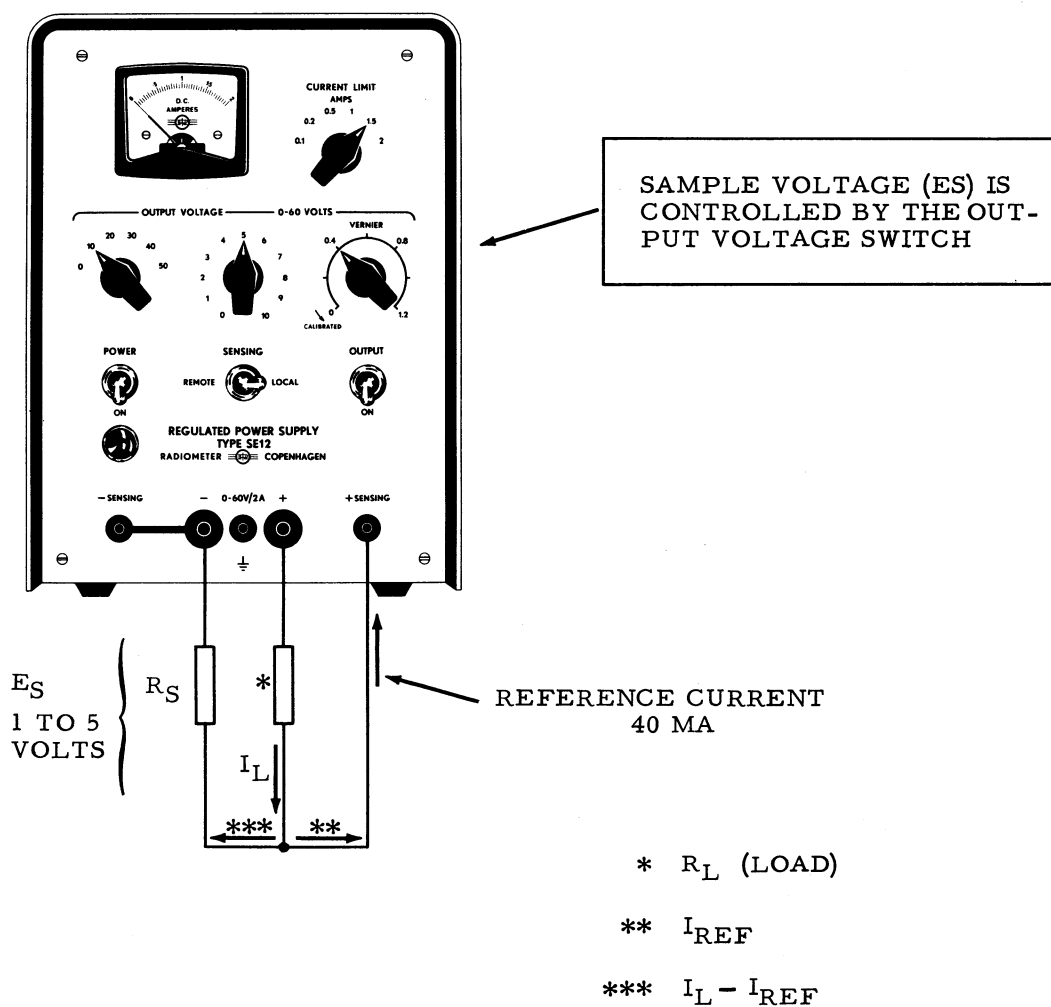
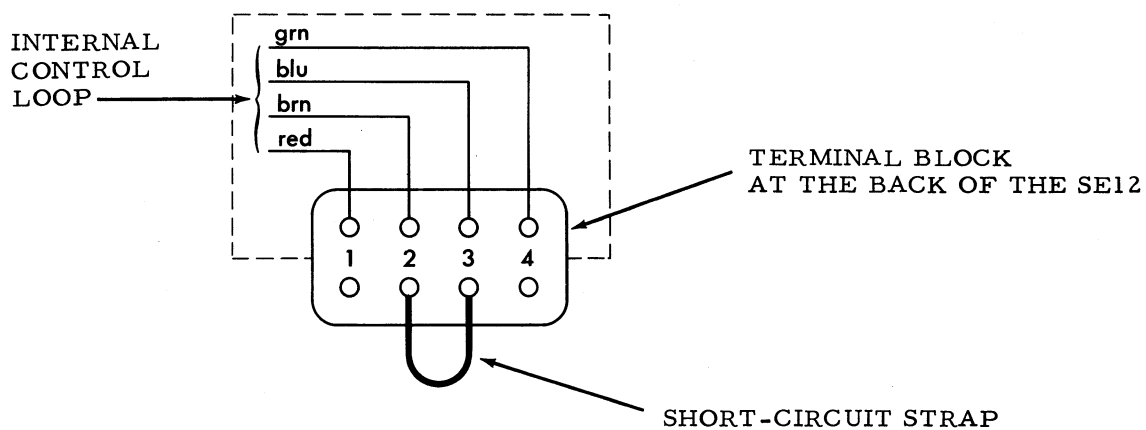


Fig. 2.6 CONSTANT-CURRENT CONVERSION

desired load current and I_{Ref} is the reference current (40 mA), then

$$R_s = \frac{E_s}{I_L - I_{\text{Ref}}} ;$$

where R_s is expressed in ohms, and I_L , I_{Ref} are expressed in amperes. The actual wattage will be $E_s \times (I_L - I_{\text{Ref}})$.

- (7) Set the "OUTPUT VOLTAGE" to E_s .
- (8) Set the "OUTPUT" switch to ON. The "output" switch should not be switched off during constant operation.
- (9) Set the "POWER" switch to ON.
- (10) When reconvertng to normal operation, make sure that terminals No.1 and No.2 in the terminal block are reliably short-circuited by a strap. (See fig.2.3).

SECTION 3

THEORY OF OPERATION

3.1 GENERAL

A complete diagram of the Power Supply is given in drawing No. 1053-A1.

A detailed description of the circuits is given below.

3.2 THE MAIN-REGULATOR

The output voltage is controlled by this regulator.

It consists of a series-transistor, Q₁₀₁, a driver, Q₁₀₂, an emitter-follower, Q₁₀₃, four amplifying transistors, Q₁₀₄, Q₁₀₅, Q₁₀₆, Q₁₀₇, and the associated components.

The two first stages of the amplifier (Q₁₀₄, Q₁₀₅, Q₁₀₆, and Q₁₀₇) are balanced in order to minimize the influence that changes in the auxiliary supply voltages may have on the output voltage.

The input that is fed to the amplifier (Q₁₀₆ - Q₁₀₇) is the difference between the output voltage and the control voltage (see fig. 3.1)

As the voltage gain of the amplifier is very high (approx. 60 dB at d-c), an input voltage of only two millivolts will cause the series transistor to go either into bottoming or into cut-off. In order to obtain regulation, the phasing of the amplifier must be chosen so that the series-transistor approximates bottoming when the Control-Voltage is higher than the Output-Voltage; and approximates cut-off when the Output-Voltage is the higher.

Under normal operating conditions, the series-transistor is in its linear region, and the input to the amplifier is then very close to Zero.

The error introduced by assuming the Output-Voltage and the Control-Voltage to be equal in sign and magnitude, is therefore negligible.

The current through R₁₀₁-R₁₁₁ is supplied by the reference supply - 14 volts. As the Control-Voltage and the Output-Voltage are equal, it will be seen from the above mentioned that the voltage drop across

the resistors $R126 + R128 + R129$ will be equal to V_{REF} , and the current I_{REF} passing through $R101-R111$ is therefore:

$$I_{REF} = \frac{V_{REF}}{R126 + R128 + R129}.$$

Increasing $R101-R111$ will increase the Control-Voltage, so that it becomes higher than the Output-Voltage. An input signal to the amplifier is then produced, which tries to drive the series-transistor into bottoming, and so the Output-Voltage rises until it has reached the new value of the Control-Voltage, and until the input signal to the amplifier again has approached Zero.

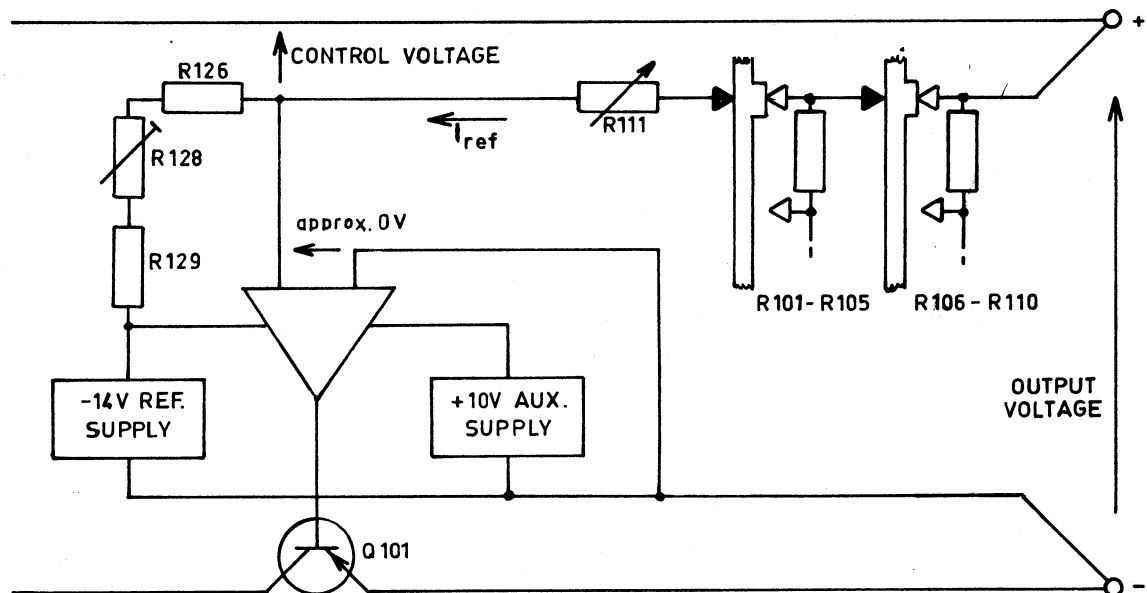


FIG. 3.1 MAIN REGULATOR SIMPLIFIED.

The current I_{REF} has the same value for any setting of the Output-Voltage. The latter is therefore a linear function of $R101-R111$, and may be varied down to Zero without any decrease in regulation performance.

By replacing R101-R111 with an externally connected resistance element, programmed operation of the OUTPUT-VOLTAGE may be obtained. In the SE12, provisions have been made for easy connection of some such external control loop to the rear of the instrument (see section 2.4).

The OUTPUT-switch (S104 in drawing No. 1053-A1) is inserted between the emitter of the series transistor and the negative OUTPUT-terminal (J104) on the front panel. When switched off, the output voltage is removed from the terminal and connections can be made with full safety for the operator. To prevent an increase in output impedance, because of contact resistance in the OUTPUT-switch, the reference sensing-point ("0 Volt" in fig. 3.1) is moved to the output terminal by an additional section in S104, when the switch is thrown on.

3.3 -14 V REFERENCE SUPPLY

The -14 V reference voltage is controlled by the series transistor, Q108, in conjunction with the reference diode, CR107, and two balanced amplifying stages (Q109, Q110, Q111 and Q112).

In order to maintain the reference voltage independent of temperature changes, a compensating diode, CR106, has been inserted in series with the reference diode, CR107.

Metal-film resistors are employed in the first balanced amplifying stage to obtain long-term stability. The stable reference voltage thus obtained provides a constant reference current and also supplies the amplifier of the series regulator.

3.4 THE PRE-REGULATOR

The circuit consists of Q7 (which operates as an electronic switch), the driver Q8, the emitter-follower Q9, and the transistor Q10, Q11, in a Schmitt-trigger coupling.

The purpose of the pre-regulator is to limit the voltage drop across the series transistor (Q101) and the limiting resistors (R42 - R48) - and consequently the collector dissipation in the series transistor - to a reasonably low value throughout the operating range.

The voltage from the power transformer is rectified by the bridge CR1 - CR4, and the rectified, unsmoothed voltage is applied to the collector of Q7 through the resistors R1 - R10.

The base of the switch transistor is controlled from the Schmitt-trigger through the driver and the emitter-follower.

Fig. 3.2 shows the pre-regulator in a somewhat simplified form.

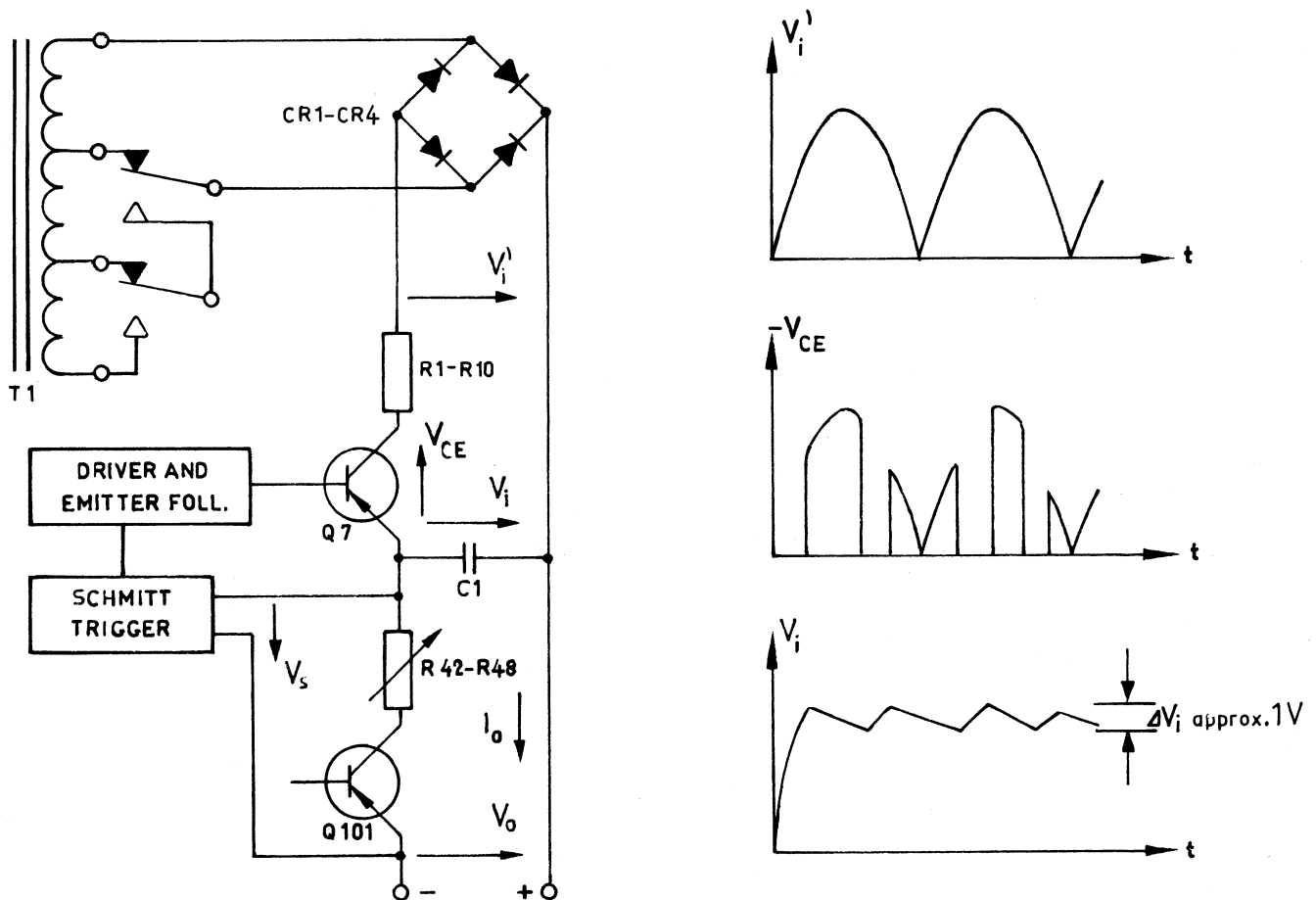


Fig. 3.2 PRE-REGULATOR (SIMPLIFIED)

V_i is the rectified, unsmoothed voltage from the rectifier bridge CR1 - CR4. C1 is the charging capacitor, V_i the voltage across C1; V_s is the voltage across R42-R48 and Q101 (the series transistor); V_o is the output voltage at the terminals on the panel.

When the line voltage is connected, there will be no charge present on C1; hence, $V_1 = 0$, and consequently: $V_s = 0$.

The Schmitt-trigger will not sense any voltage across R42-R48 and Q101; hence, Q11 will conduct, and Q10 will remain blocked. When Q10 is blocked, the base potential of Q7, as derived through the emitter-follower Q9 and the driver Q8, will be negative.

The switch transistor Q7 becomes fully conductive and commences to charge C1, so that the potential V_i is raised to a positive value.

The charging current will be limited by the resistors R1 - R10. As soon as $V_s = V_i - V_o \approx 8.7$, the Schmitt-trigger will block out the switch transistor. Because of the load, the potential of C1 will decrease. As soon as V_i has been reduced approx. 1 volt, the Schmitt-trigger again will cause the switch transistor to conduct, whereupon the charging of C1 commences.

The pre-regulator functions as a two-point regulator with hysteresis of approx. 1 volt.

3.5 TRANSFORMER TAP SWITCHING CIRCUIT

The circuit consists of the two Schmitt-triggers, the transistors Q1, Q2 and Q4, Q5, the switch transistors Q3, Q6, and the relays K1, K2.

The twofold purpose of the transformer tap switch is (1) to maintain the voltage drop across the switch transistor Q7 at a low level, and (2) to keep the collector dissipation at a minimum. Its functions can be regarded as those of a coarse-regulator.

The inputs of both Schmitt-triggers sense the V_o output voltage. When the output voltage is set to 25 V, triggering will occur in the Q1, Q2 circuit. Q3 then becomes conductive, whereupon the relay K1 will couple the rectifier CR1 - CR4 to the next tap on the transformer T1. When the output voltage is set to 45 V, the Schmitt-trigger Q4, Q5 will trigger, and the power rectifier will be transferred to the highest secondary voltage tap of the power transformer T1.

3.6 CURRENT LIMITING CIRCUIT

In a simplified schematic form (Fig. 3.3 below), the circuit is seen to contain the resistors R42 - R48, the CURRENT LIMIT switch S2, the charging capacitor C1, and the series transistor Q101.

As Fig. 3.3 clearly illustrates, the voltage present across the charging capacitor will be:

$$V_i = V_s + V_o.$$

When the output voltage V_o equals 0, V_i will equal V_s which is fixed at 8.2 volts ± 0.5 volt, and so:

$$I_o = \frac{V_i - V_{CE}}{R \dots}$$

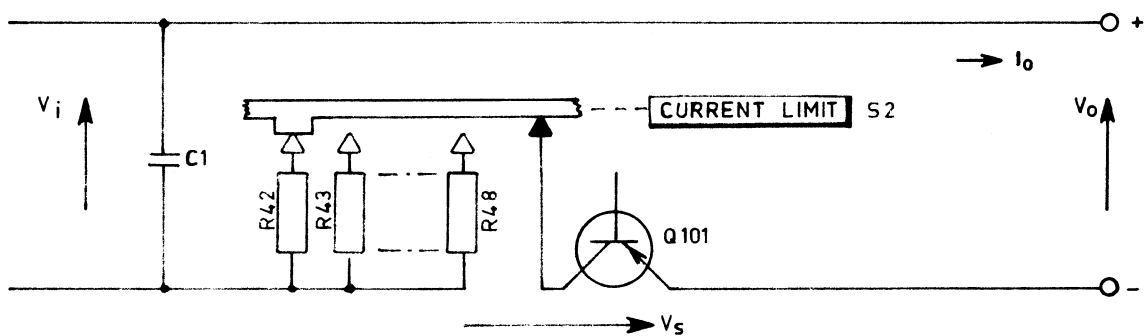


FIG 3.3 CURRENT LIMITING CIRCUIT

SECTION 4 MAINTENANCE

4.1 GENERAL

The circuitry used in the SE12 is fairly complex and fault-finding is not always simple. Four adjustments of the circuits are possible, but as a rule, the cure in case of trouble will be the replacement of defective parts.

Standard components have been used wherever possible. When ordering replacement parts, please specify model and serial number of the instrument and circuit reference; also give a short description of the parts required.

Fig. 4.1 and 4.2 show the location of the components on the printed boards A and B.

4.2 ADJUSTMENTS

Replacement of transistors and other components in the SE12 may involve a readjustment of the internal controls.

4.21 Adjustment of the Transformer Tap Switching Circuit.

- 1) Turn off the POWER switch.
- 2) Set OUTPUT VOLTAGE switches to position 0 volt.
- 3) Connect an a-c voltmeter (range 100 V) to the print terminals 5 and 22 on printboard A.
- 4) Connect the SE12 to a power line, and set the POWER switch to position ON.

The voltmeter should indicate 44 V.

- 5) Set OUTPUT VOLTAGE switches to 25 volts.
- 6) Adjust ADJ1 (R12 on printboard A) so that relay K1 is coupled to the next tap on the transformer.

The voltmeter should indicate 63 V.

- 7) Now set OUTPUT VOLTAGE switches to 45 volts.
- 8) Adjust ADJ2 (R22 on printboard A) so that relay K2 is coupled to the highest voltage tap on the transformer.

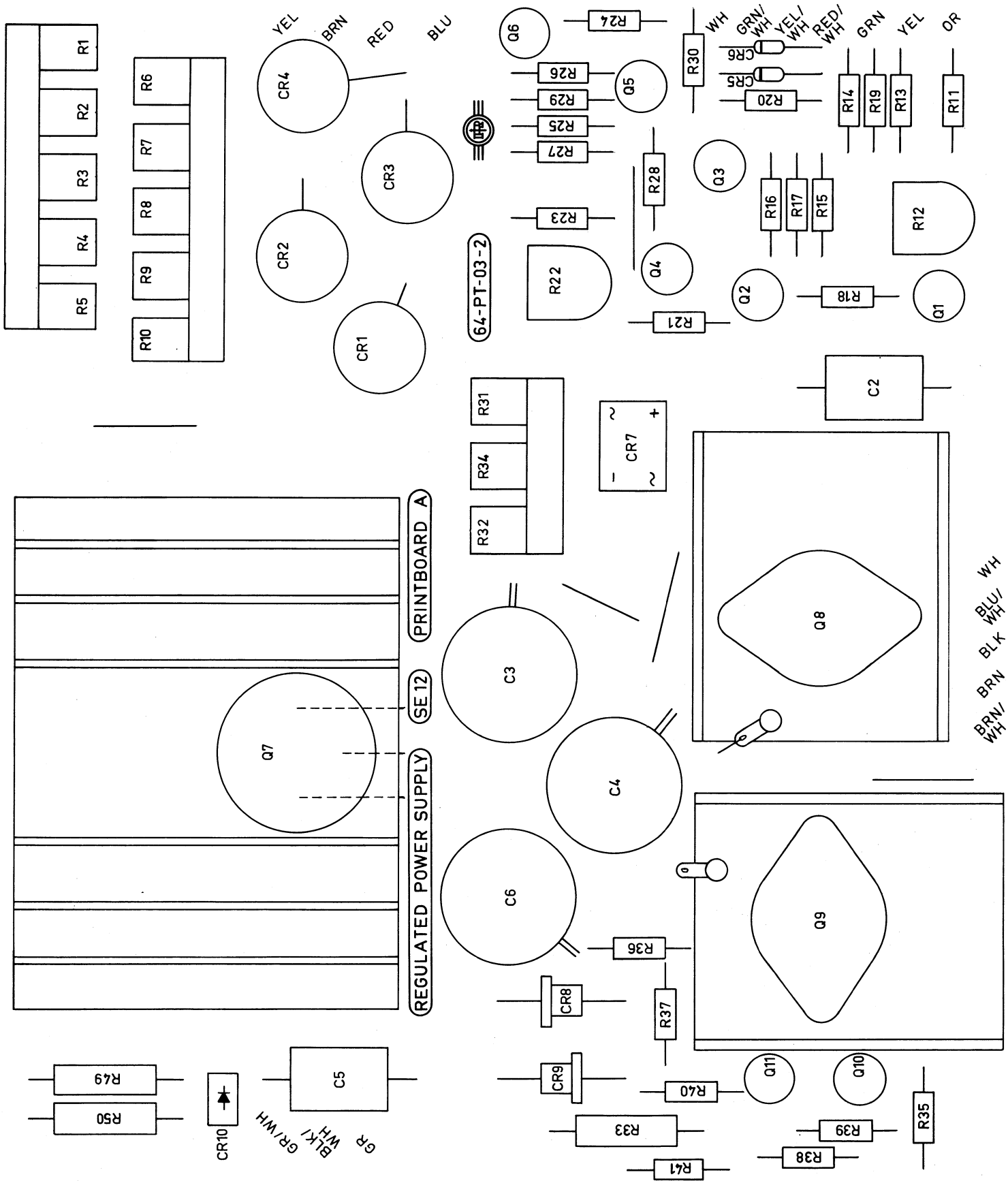


Fig 4.1

PRINT BOARD B

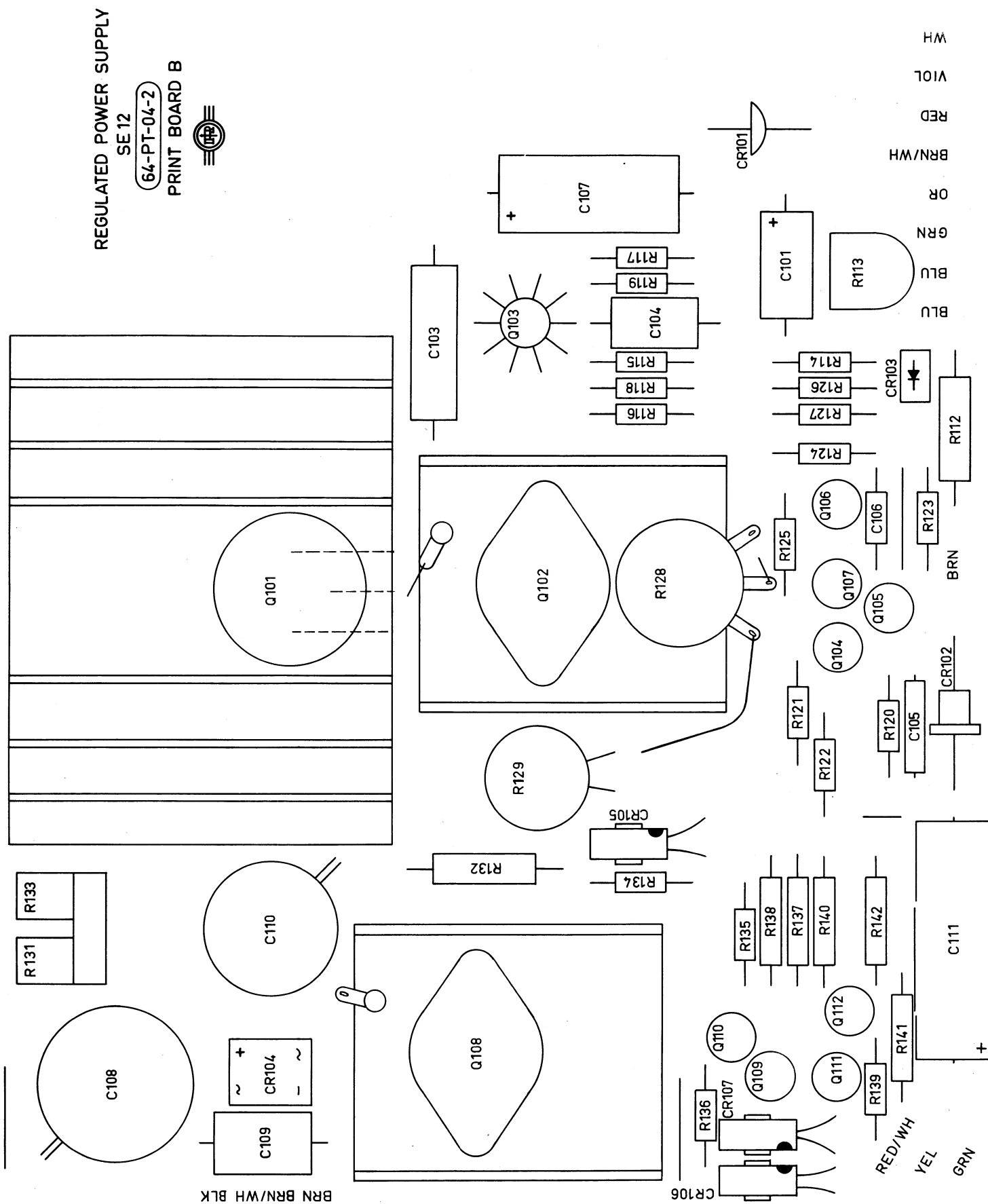


Fig 4.2

The voltmeter should indicate 76 V.

4.22 Adjustment of the Pre-Regulator

- 1) Turn off the POWER switch.
- 2) Set OUTPUT VOLTAGE switches to 0 volt.
- 3) Connect a voltmeter between the + OUTPUT terminal on the panel and the print terminal 24 on printboard A.
- 4) Turn the POWER switch to ON.
- 5) Adjust voltage reading to 8.2 V by means of ADJ3 (on printboard B).

4.23 Adjustment of the Output Voltage

Wirewound potentiometer marked R128 (ADJ4), on printboard B, placed in the resistor chain which determines the value of the current I_{REF} passing through the OUTPUT VOLTAGE control R101-R111 (See section 3.2).

The nominal value of I_{REF} is 40 mA. The permissible tolerance for this value, and consequently for the setting of the potentiometer R128, depends on how the output voltage from the OUTPUT VOLTAGE switch is controlled.

When programmed operation is to be established, I_{REF} should preferably be adjusted to 40 mA $\pm 0.2\%$. High precision d-c equipment is needed for this adjustment.

At the factory the adjustment is carried out in the following manner: The SE12 undergoing test is arranged for programmed operation as described in section 2.4 of this manual.

A high-precision, wirewound resistor (0.1%) of 25Ω is used as the external control element R. I_{REF} is passed through this resistor, and the consequential voltage drop is measured with a precision d-c millivoltmeter with very high input impedance (RADIOMETER type PHM4).

R128 is then adjusted until the voltage drop across R is 1 volt. The accuracy of the factory adjustment is better than $\pm 0.2\%$.

4.3 FAULT FINDING

In regulated power supplies as the SE12 feedback is widely used. Consequently, a defective component somewhere in the circuit will often cause nearly all potentials in the section concerned to shift from their normal values.

The easiest way to find such a defective component is to separate the circuits from each other and then test them individually.

