

INSTRUCTION MANUAL

Type SE21
REGULATED POWER SUPPLY



RADIOMETER

**ELECTRONIC MEASURING INSTRUMENTS
FOR SCIENTIFIC AND INDUSTRIAL USE**

INSTRUCTION AND OPERATING MANUAL
FOR

Type SE21
REGULATED POWER SUPPLY

INTRODUCTION

The RADIOMETER type SE21 is a bench model Regulated Power Supply intended for general laboratory use.

It features a continuously variable output from 0 to 500 volts with ultrahigh regulation. The current range is 0 to 200 mA independent of the voltage setting.

In addition to the High-Voltage output, a regulated d-c BIAS-Supply with a fixed output of -150 volts and a variable one of 0 to -50 volts are available.

Filament current is supplied from two separate a-c outputs, each supplying 6.3 volts, 5A. The two outputs can be connected in series or in parallel.

The High-Voltage output and the variable 0 to -50 volts BIAS-output are monitored by a built-in voltmeter/milliammeter.

SECTION 1
SPECIFICATIONS AND DESCRIPTION

1.1 SPECIFICATIONS

1.11 DC HIGH-VOLTAGE OUTPUT

VOLTAGE

0 to 500 volts, continuously variable in one range by a 10-turn potentiometer.

CURRENT

0 to 200 mA at any voltage setting. When short-circuited, the output current is limited to approx. 270 mA.

LOAD REGULATION

Less than 0.005% or 5 millivolts (whichever is greater) change in output voltage from no-load to full-load.

LINE REGULATION

Less than 0.005% or 5 millivolts (whichever is greater) change in output voltage for a line voltage change of 10% within operating range.

OUTPUT IMPEDANCE

Less than 0.1 ohm, d-c to 10 kc, and typically 1 ohm at 1 Mc. See fig. 1.1.

RECOVERY TIME

Less than 10 μ sec when switching from no-load to full-load, and less than 50 μ sec when switching from full-load to no-load. See fig. 1.2.

Less than 10 μ sec when switching from 10% load to full-load or vice versa. See fig. 1.3.

(Recovery time is the time needed for the output voltage to return to a value within the regulation specifications).

Fig. 1.1 Typical output impedance.

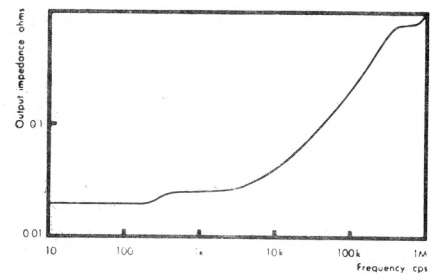


Figure 1.2. Scope view shows effect of step load changes. 200 mA to 0 mA to 200 mA. (1 div. = 40 μ sec/10 mV, $V_{\text{output}} = 300$ volts.)

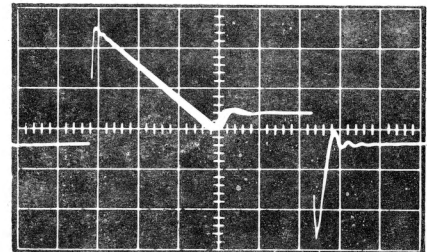


Fig. 1.3. Scope view shows effect of step load changes. 200 mA to 20 mA to 200 mA. (1 div. = 40 μ sec/10 mV, $V_{\text{output}} = 300$ volts).

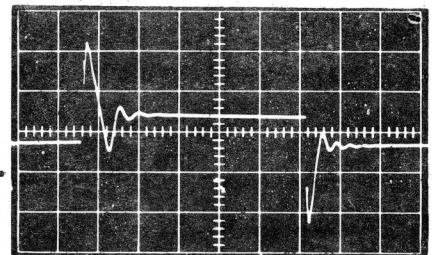


Figure 1.4. Scope view shows ripple and noise on output voltage. (1 div. = 20 msec/1mV, $V_{\text{output}} = 300$ volts, $I_{\text{Load}} = 200$ mA).

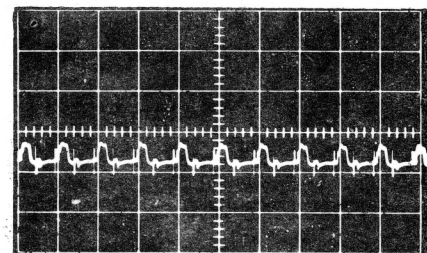
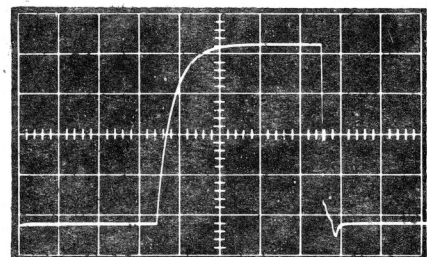


Figure 1.5. Scope view shows programming cycle. 50 volts to 500 volts to 50 volts (1 div. = 1 sec/100 volts, $I_{\text{Load}} = 200$ mA).



TRANSIENT VOLTAGE

Less than 200 millivolts for a load step of 200 mA.

Less than 1 millivolt for a 10% line step.

RIPPLE AND NOISE

Less than 0.2 millivolt rms or 1 millivolt peak-to-peak.

See fig. 1.4.

STABILITY

Typically less than ± 250 ppm ± 50 millivolts change in output voltage over an 8-hour period.

(After 4 hours of warm-up and with line voltage, load and ambient temperature kept constant).

TEMPERATURE COEFFICIENT

Typically less than ± 50 ppm change in output voltage per 1°C change in ambient temperature.

POLARITY

Either the positive or the negative terminal may be grounded, or both can be kept floating. The leakage current from the line is less than $10\text{ }\mu\text{A}$.

SERIES CONNECTION

Two type SE21's may be connected in series to obtain an output voltage of 1000 volts.

PROGRAMMING

Provisions for programming by means of an external resistance control element.

Programming constant: 250 ohms per volt.

(A typical programming cycle is shown in fig. 1.5).

1.12 FIXED BIAS OUTPUT

VOLTAGE	CURRENT
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-150 volts	0 to 25 mA.
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LOAD REGULATION

Less than 0.02% change in output voltage from no-load to full-load.

LINE REGULATION

Less than 0.07% change in output voltage for a line voltage change of 10% within operating range.

RIPPLE AND NOISE

Less than 0.5 millivolt rms.

OUTPUT IMPEDANCE

Less than 1.5 ohm.

POLARITY

See Variable BIAS Output

1.13 VARIABLE BIAS OUTPUT

VOLTAGE

0 to -50 volts, controlled by a semi-logarithmic potentiometer.

CURRENT

0 to 1 mA.

LINE REGULATION

See Fixed BIAS Output.

RIPPLE AND NOISE

Less than 0.2 millivolt rms.

OUTPUT IMPEDANCE

0 to 15 kilohms in parallel with 4 μ F.
(Resistance depends on voltage setting).

POLARITY

The fixed and variable bias supplies have a common positive terminal, and are isolated from the high-voltage supply and from ground. They may be used separately or connected in series with the high-voltage output.

1.14 AC OUTPUT

Two unregulated, isolated and ungrounded filament supplies of 6.3 volts at 5 amps each. May be used separately, in series, or in parallel. A d-c potential of max. 250 volts between each output and chassis-ground is permissible.

1.15 METERING

The milliammeter/voltmeter monitors:

DC HIGH-VOLTAGE OUTPUT

Current: 200 mA full scale.

Voltage: 50, 200, and 500 volts full scale.

VARIABLE BIAS OUTPUT

Voltage: 5, 20 and 50 volts full scale (no loading effect).

ACCURACY

Voltage: $\pm 2\%$ of full scale.

Current: $\pm 3\%$ of full scale.

1.16 DUTY CYCLE AND AMBIENT TEMPERATURE

Continuous operation at full load up to 45°C (113°F).

1.17 POWER SUPPLY

LINE VOLTAGE

110, 115, 127, 200, 220, and 240 volts $\pm 10\%$.

LINE FREQUENCY

45 to 65 cps.

CONSUMPTION

300 watts at full load.

1.18 OUTPUT TERMINALS

Binding posts that accept 4 - mm banana plugs.

1.19 CONTROLS

Power On-Off.

High-Voltage On-Off.

High-Voltage Control.

Variable Bias Control.

Meter Range Switch.

1.110 TUBES

1 PL6574 (6574), 1 E235L (7751), 2 ECL82 (6BM8), 3 E80CF (7643), 2 E188CC (7308), 1 85A2 (5651), 1 83A1 & 1 0A2.

1.111 SEMICONDUCTORS

1 ASZ16, 1 OC72, 9 BY100 & 2 OAZ203.

1.112 OVER-ALL DIMENSIONS

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

1.113 WEIGHT

14.5 kilos net (26 1/2 lbs).

1.114 FINISH

Grey enamelled metal housing.

1.2 SPECIFICATIONS FOR THE SE21/DVS1 COMBINATION

When externally controlled by the Decade Voltage Selector, type DVS1, the specifications of the Regulated Power Supply, type SE21, are changed in the following respects:

1.21 DC HIGH-VOLTAGE OUTPUT

VOLTAGE

0 to 500 volts, adjustable in steps of 1 volt with 3 decades giving in-line read-out.

ACCURACY OF VOLTAGE SETTING

Better than $1\% \pm 25$ millivolts.

(After 2 hours of warm-up of the SE21 and with line voltage, load and ambient temperature kept constant).

STABILITY

Typically less than ± 250 ppm ± 25 millivolts change in output voltage over an 8-hour period.

(After 4 hours of warm-up of the SE21 and with line voltage, load and ambient temperature kept constant).

The following specifications apply to the Decade Voltage Selector, type DVS1, alone:

1.22 CONTROLS

3 decades giving in-line read-out. 4 x 100 volts, 9 x 10 volts, and 10 x 1 volt. Mode switch for switch-over from external control to normal control of SE21.

1.23 OVER-ALL DIMENSIONS

Height:	Width:	Depth:
94 mm	200 mm	320 mm
3 3/4 inches	8 inches	12 5/8 inches

1.24 WEIGHT

2.7 kilos net (6 lbs).

1.25 FINISH

Grey enamelled metal housing.

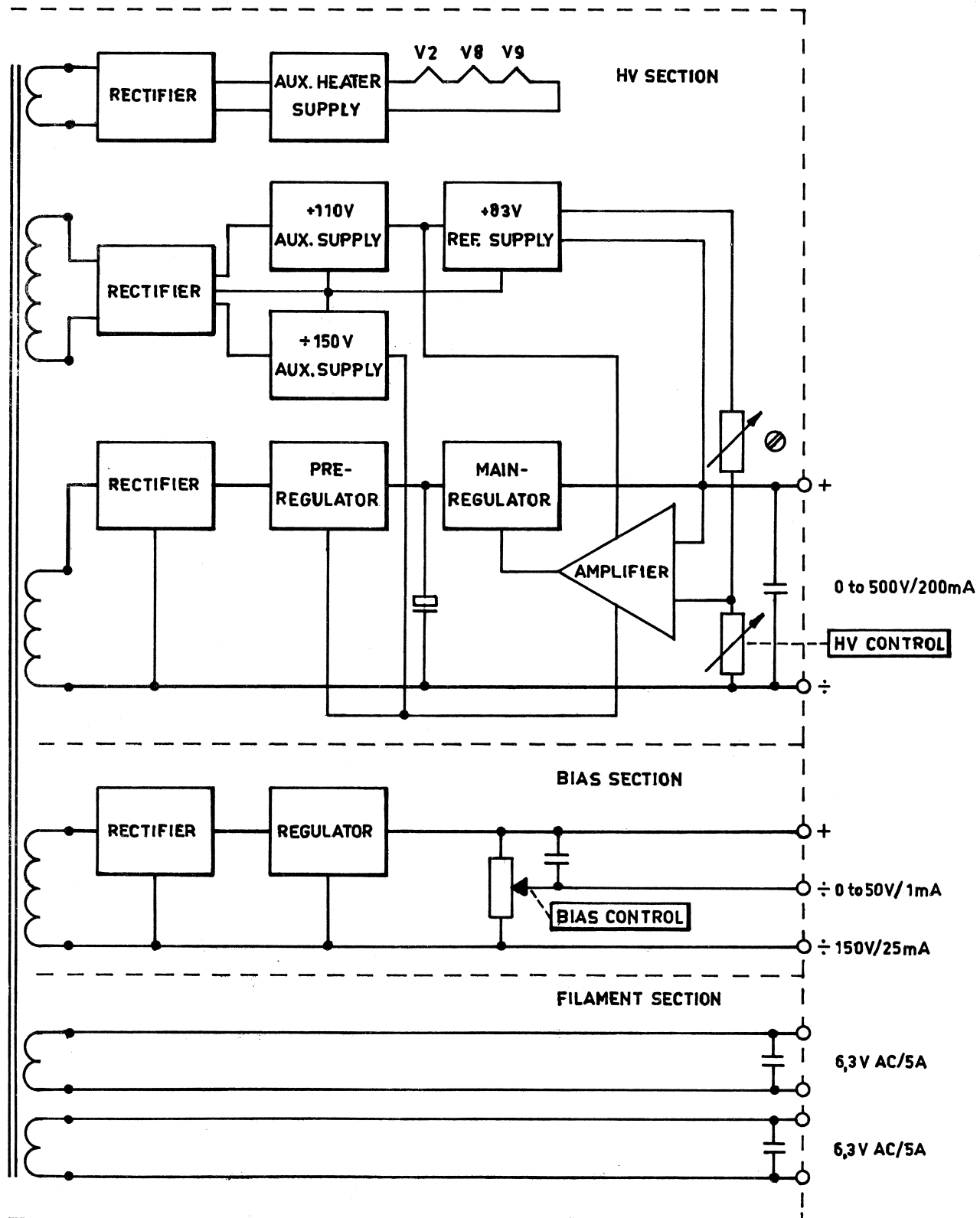


FIG. 1.6 BLOCK DIAGRAM

1.3 BRIEF DESCRIPTION

1.31 BLOCK DIAGRAM

As mentioned in the introduction, the SE21 contains three independent main units - in the following referred to as HV-, BIAS- and FILAMENT-Sections.

Each of these main units is in turn built up of a number of sub-units as shown in the block-diagram, fig. 1.6.

1.32 HV-SECTION

Two cascaded regulators are used in the HV-section:

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.

The Pre-Regulator is of the switch type, using a thyatron as the series-element. It maintains the voltage-drop across 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.

Due to the high efficiency of the thyatron circuit itself, the total amount of heat to be dispersed from the cabinet is so low, that natural convection cooling is sufficient even at 45°C ambient temperature.

The supply voltages required to put the amplifier and the Pre-Regulator to work are taken from two auxiliary regulators, delivering +110 volts and -150 volts respectively. The +110 volts auxiliary supply also feeds the reference source.

Finally, the heaters of the most sensitive tubes in the amplifier and in the +110 volts regulator are fed from a third auxiliary supply.

The output from the HV-section is truly floating, and two type

SE21's may be connected in series to obtain an output voltage of 1000 volts.

1.33 BIAS-SECTION

The regulator used in the BIAS-section is a conventional series regulator, giving moderate regulation data.

It supplies a fixed voltage of 150 volts, and 25 mA may be drawn from this output.

The variable BIAS-output is derived from the fixed output of 150 volts by means of a simple voltage divider. The two outputs from the BIAS have thus their positive terminal in common.

The BIAS-section as a whole is truly floating and may be connected in series with the HV-section.

1.34 FILAMENT-SECTION

This section simply consists of two separate windings on the power transformer. Each winding is truly floating.

A d-c potential of max 250 volts is permissible between a FILAMENT output and chassis-ground.

The two outputs may be operated separately, in series, or in parallel.

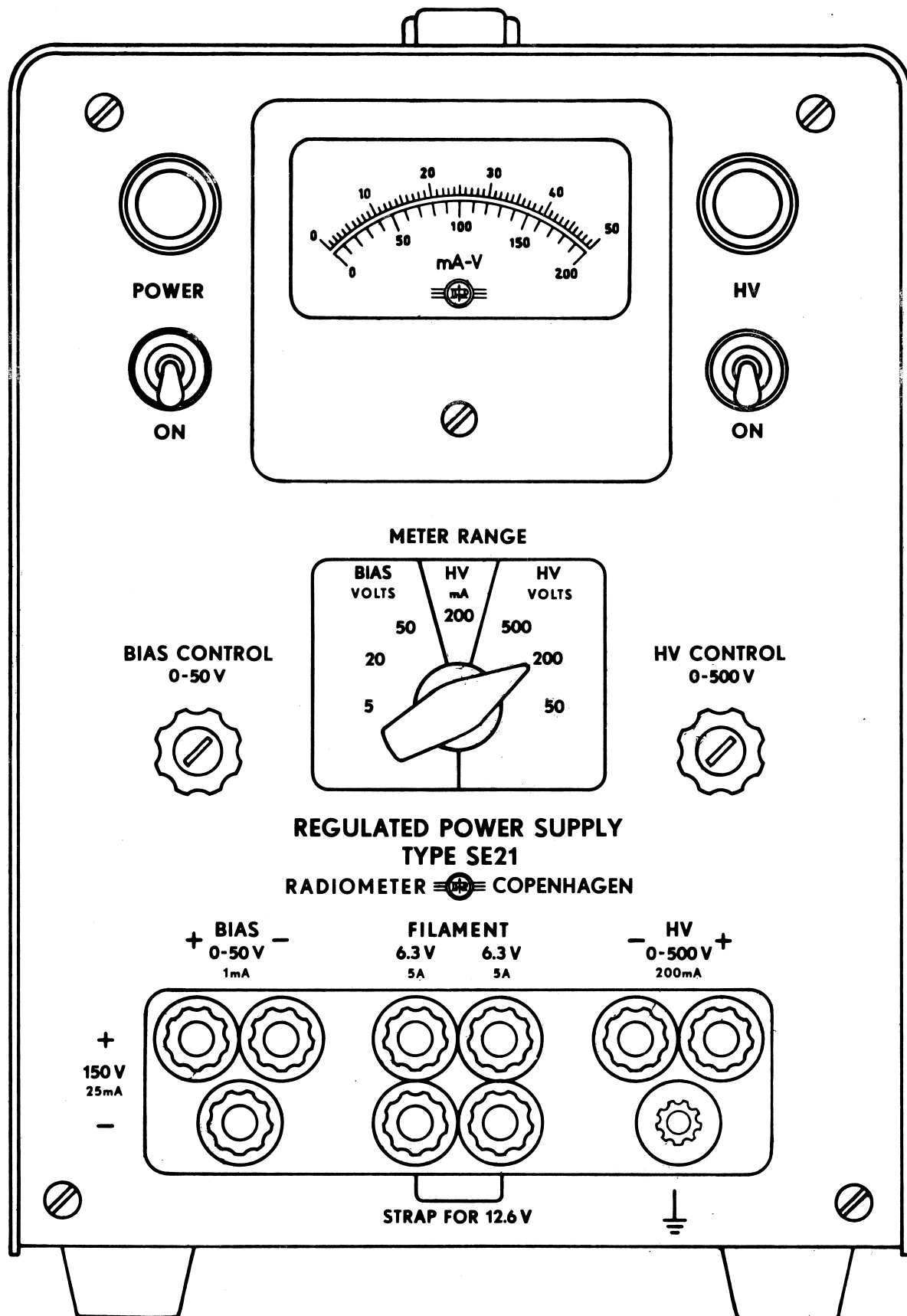


FIG.2.1 FRONT

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 and voltage is present across the terminals marked "FILAMENT" and, after a few minutes of warm-up, across the three terminals marked "BIAS".

The green pilot lamp just above lights when the power switch is turned on.

"HV"
switch

When switched to "ON", the red +HV-terminal is connected to the internal High-Voltage source.

The red pilot lamp just above lights when the HV-switch is turned on.

"BIAS CONTROL" knob Semi-logarithmic potentiometer for adjustment of the 0 to -50 volt BIAS source.

"METER RANGE" switch 7-position rotary switch that connects the built-in meter circuit either to the 0-50 volt BIAS source where it monitors the output voltage (three ranges), or to the HV source where the meter monitors the output current (one range) and output voltage (three ranges). When the HV-switch is turned off, the meter monitors the voltage just behind the disconnected +HV-terminal.

"HV CONTROL" knob 10-turn potentiometer for adjustment of the 0 to 500 volt High-Voltage source.

2.12 Terminals:

"BIAS"

"0-50 V, 1 mA"

"150 V, 25 mA"

One white and two black binding posts. The white one is positive and common to both the variable and the fixed BIAS. The bias sources are floating with respect to chassis.


"FILAMENT"

Two pairs of black binding posts. Each pair is vertically mounted and marked 6.3 V/5A, 12.6 V/5A may be obtained by means of a strap, as indicated on the front panel. The filament sources are floating with respect to chassis.

"HV"

"0-500 V, 200 mA"

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.

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

LINE VOLTAGE
SELECTOR

The instrument may be set to any of the following line voltages: 110, 115, 127, 200, 220, and 240 volts (nominal voltages).

POWER FUSE

The fuse holder is combined with the line voltage selector. Accepts fuse 6 ϕ x 20 mm.

Line voltage 110-127 volts: Fuse 3.15 amps, slow-blow.

Line voltage 200-240 volts: Fuse 1.6 amps, slow-blow.

PROGRAMMING

The external programming circuit is connected to the three-way terminal block located behind the small shutter.

The correct programming procedure is described in section 2.4 of this manual.

2.2 PREPARING THE INSTRUMENT FOR OPERATION

- 2.21 When the Regulated Power Supply, type SE21, is received, inspect it for possible damage caused in transit.

The cover is easily removed by unscrewing four fixing screws at the top. The large 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 line voltage selector is set correctly, and that the fuse is of the proper value. See section 2, item 1.3.
- 2.23 Check the zero setting of the meter and adjust, if necessary.
- 2.24 Set the HV switch to OFF position.
- 2.25 Set the meter range switch to 500 volts.
- 2.26 Turn the potentiometers "HV CONTROL" and "BIAS CONTROL" fully counter-clockwise.
- 2.27 Set the power switch to OFF position.
- 2.28 Connect the line cord to the power line.
- 2.29 Set the power switch to ON, and allow the instrument to warm up for about half an hour. This will expel all moisture condensed within the instrument during storage and transit.
- 2.210 Operate the power supply as described in section 2.3 of this manual.

2.3 OPERATING THE SE21

2.31 The HV source:

CAUTION - The high tension behind the terminals of the SE21 may prove fatal!

For YOUR safety we have provided the instrument with the HV switch - please use it!

Whenever you want to connect a load to the HV source, follow this procedure:

- (1) Set the "HV" switch to OFF.
- (2) Detach all unnecessary connections from the terminals.
- (3) Connect the load.
- (4) Turn the "HV CONTROL" to give the desired voltage which can be read from the built-in meter.
- (5) Turn the "METER RANGE" switch to the current range.
- (6) Set the "HV" switch to ON and make sure that the current drawn is within the operating range: 0 to 200 mA.

2.32 The BIAS sources:

The BIAS is a separate, regulated supply producing a fixed voltage of -150 volts. The variable bias is derived from the fixed voltage by means of a simple voltage divider.

When the meter range-switch is set to one of the three positions marked "BIAS VOLTS", the built-in meter monitors the voltage between the terminals marked "BIAS, 0-50 V", and no loading effect occurs.

The BIAS voltage is present at the terminals soon after the power switch has been thrown on.

2.33 General recommendations:

When the SE21 is in operation and power is not required for a short time, it is recommended to leave it in a stand-by condi-

tion: "POWER" switched on, and "HV" switched off.

In this way the high degree of stability is not affected by temperature changes inside the instrument.

It is also recommended to wait a few minutes before reapplying power to the instrument once it has been switched off. The cathode of the thyatron (V5) is then spared, and the life of the tube prolonged.

2.4 PROGRAMMING THE HV-SOURCE OF THE SE21

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 2.2 and 2.3.

The programming constant of the SE21 is 250 ohms per volt, i.e. the output voltage from the HV-source will be 1 volt per every 250 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 HV-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: Components used in the external loop should preferably be rated for a test voltage of twice the output voltage plus 1000 volts.

Rule No. 4: 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. 2.2).

2.5 THE SE21/DVS1 COMBINATION

The type DVS1 is a control box used in connection with the programming circuit of the SE21 to provide stepwise adjustment of the output voltage from the HV source.

The range of the DVS1 is 0-500 volts in steps of 1 volt by means of three decades giving in-line read-out.

The "MODE" switch on the front panel of the DVS1 makes possible quick change-over from stepwise to normal control of the HV source. The data for the SE21/DVS1 combination are given on pages 1-5 and 1-6 of this manual.

2.51 The DVS1 and the SE21 are electrically and mechanically coupled.

The assembling is simple and may be carried out quickly - simply proceed as shown in figures 2.4 and 2.5.

OUTPUT VOLTAGE FROM HV-SOURCE IS
CONTROLLED BY THE "HV-CONTROL"

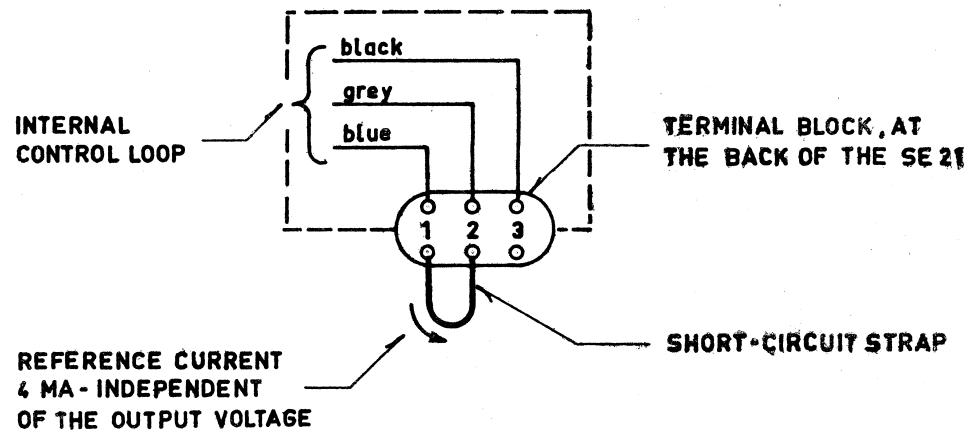


FIG.2.2 NORMAL OPERATION

OUTPUT VOLTAGE FROM HV-SOURCE
IS CONTROLLED BY THE RESISTANCE
IN THE EXTERNAL CONTROL LOOP.
OUTPUT: 1 VOLT PER 250 Ω

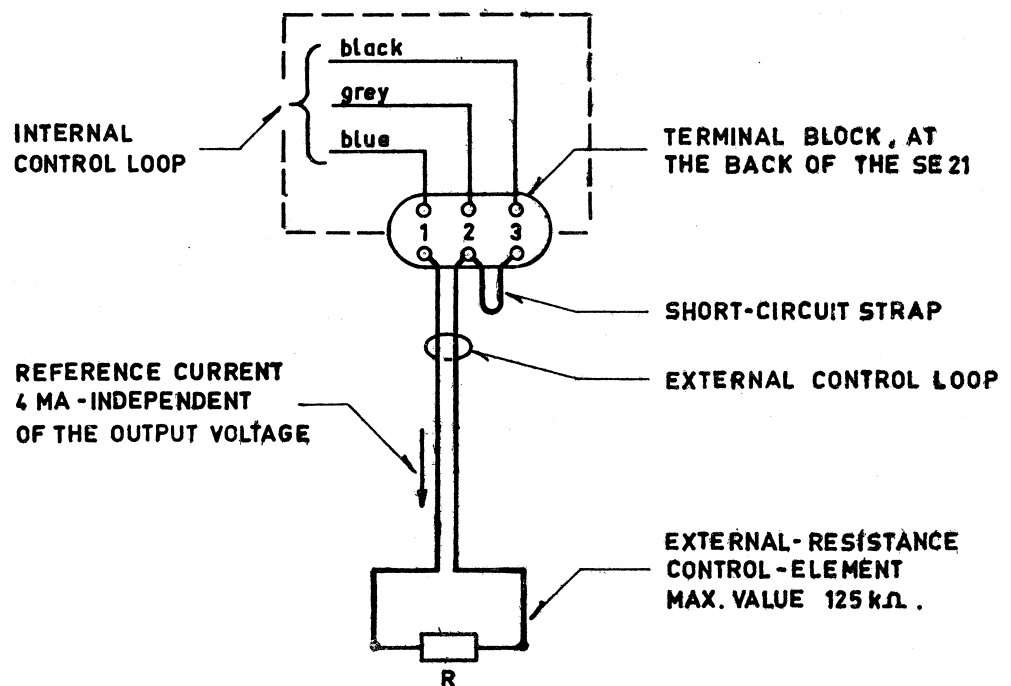


FIG.2.3 PROGRAMMED OPERATION

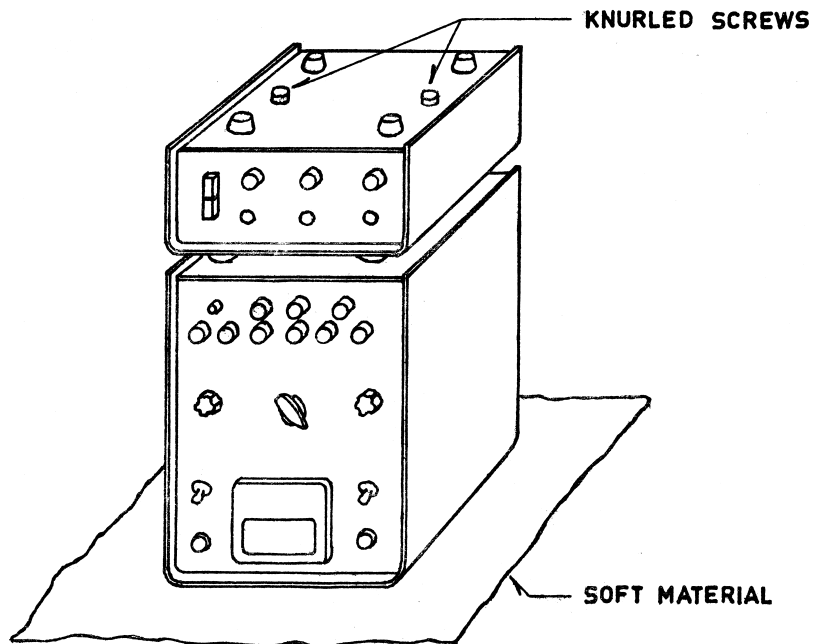


FIG.2.4 MECHANICAL ASSEMBLY OF THE SE21/DVS1

OUTPUT VOLTAGE IS CONTROLLED
IN STEPS OF 1VOLT BY THE DE-
CADES OF THE DVS1.

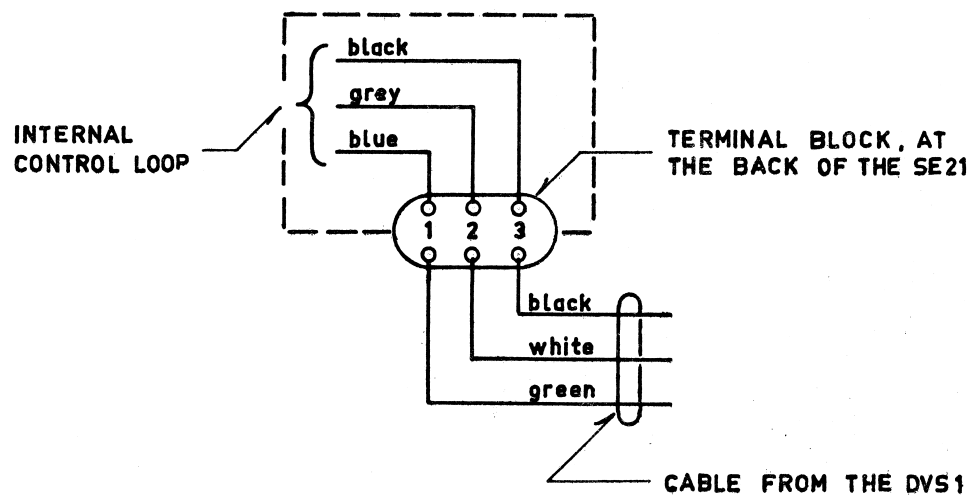


FIG.2.5 ELECTRICAL ASSEMBLY OF THE SE21/DVS1

SECTION 3

THEORY OF OPERATION

3.1 GENERAL

A complete diagram of the HV-section is given in drawing No.1011-A1. The BIAS-section, the auxiliary heater supply, and the FILAMENT-section are shown in drawing No.1375-A2. Finally, the meter circuit is shown separately in drawing No.1376-A2.

A detailed description of the circuits is given below.

3.2 THE HV-SECTION

This section of the SE21 is built up from a number of sub-units as shown in the block diagram fig.1.6.

3.21 THE MAIN-REGULATOR

The output voltage from the HV-section is controlled by this re-regulator. It consists of a pass tube, V_6 , three amplifying tubes, V_7 , V_8 , V_9 , a reference tube, V_3 and the associated components (see drawing No.1011-A1).

The two first stages of the amplifier (V_8 and V_9) are balanced in order to minimize the influence on the output voltage of changes in the auxiliary supply voltages. In the third stage, V_{7B} acts as an impedance converter for one side of the balanced output from V_8 in order to obtain single-ended drive of the last amplifying tube, V_{7A} .

The input that is fed to the amplifier (V_9) 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. 90 dB at d-c), an input voltage of only a few millivolts will cause the pass tube 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 pass tube 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 pass tube 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 R_{50} is supplied by the reference supply V_3 . 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 $R_{17} + R_{18} + R_{19}$ will be equal to V_{REF} , and the current I_{REF} passing through R_{50} is therefore:

$$I_{REF} = \frac{V_{REF}}{R_{17} + R_{18} + R_{19}} .$$

Increasing R_{50} 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 pass tube into bottoming, and so the Output-Voltage rises until it has reached the new value of the Control-Voltage and the input signal to the amplifier again has approached zero.

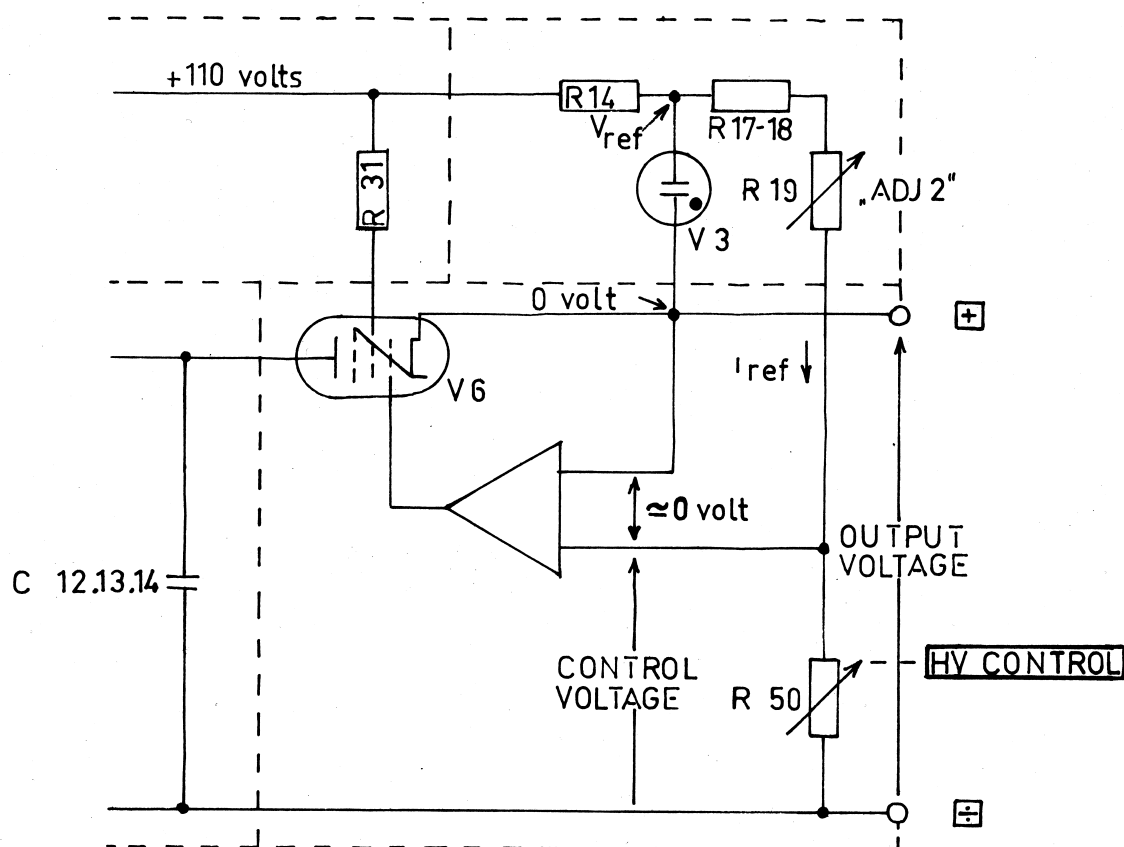


FIG. 3.1 MAIN REGULATOR SIMPLIFIED

The current I_{REF} has the same value for any setting of the Output-Voltage. The latter is therefore a linear function of R_{50} , and may be varied down to zero without any decrease in regulation performance.

By substituting R_{50} with an externally connected resistance element, programmed operation of the HV-section may be obtained. In the SE21, provisions have been made for easy connection of some such external control loop to the rear of the instrument (see sect. 2.4)

The HV-switch (S_3 in drawing No. 1011-A1) is inserted between the cathode of the pass tube and the positive HV-terminal (J_1) 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. The meter-circuit is not affected by the switch, and the output voltage can be set to the desired value independent of the position of the HV-switch.

To prevent an increase in output impedance, because of contact resistance in the HV-switch, the reference sensing-point ("0 Volt" in fig. 3.1) is moved to the output terminal by an additional section in S_3 when the switch is thrown on.

A red pilot lamp indicates when S_3 is in on-position.

3.22 AUXILIARY +110 VOLTS SUPPLY

The output from this supply is referred to the positive HV-terminal J_1 . The circuit is shown in drawing No. 1011-A1. It consists of the pass tube V_{1A} , a cascode-coupled amplifier V_{1B} and V_{2A} , a cathode follower V_{2B} , and the associated components.

The reference-voltage is derived from V_3 by means of the voltage divider R_{15} , R_{16} .

To ensure low ripple voltage and good long-term stability, the heaters of $V_{2A} + B$ are fed with regulated d-c from the auxiliary heater supply.

The output voltage of +110 volts is present at TP2 and may be adjusted slightly by means of the potentiometer "ADJ" (R_{12}).

The auxiliary +110 volts regulator supplies the reference tube V_3 , the plates of the amplifying tubes V_7 , V_8 & V_9 in the Main-Regulator, the screen grid of the pass tube V_6 and, finally, the control voltage for the Pre-Regulator.

3.23 AUXILIARY -150 VOLTS SUPPLY

The output is referred to the cathode of the pass tube, V_6 . The circuit is shown in drawing No. 1011-A1 and consists of the filter R_{20} , R_{21} , C_7 , C_8 , C_9 , and the voltage stabilizer V_4 .

The output voltage of -150 volts (nominal value) supplies the cathode voltages of the amplifying tubes V_7 , V_8 & V_9 , in the Main-Regulator. Besides this, the -150 volts provide start delay for the Pre-Regulator and act as reference voltage for the auxiliary heater supply.

3.24 THE REFERENCE SOURCE

The circuit is shown in drawing No. 1011-A1. It is made up of the reference tube V_3 , the resistor R_{14} , R_{17} , R_{18} , R_{19} , and the capacitor C_6 . The reference source is fed from the regulated +110 volts auxiliary supply through the series resistor R_{14} . The output from the reference source is the current I_{REF} passing through the resistor chain R_{17} , R_{18} , R_{19} . As previously described (see fig. 3.1), the voltage drop across this chain is constant and equal to V_{REF} , the voltage across V_3 . The "reference voltage" sensed by the amplifier in the Main-Regulator is the voltage across R_{50} . To keep the HV-output independent of temperature changes, I_{REF} must have a TC which counteracts the inevitable TC of the HV-CONTROL-potentiometer R_{50} . This is achieved by using a combination of high-stability carbon film (R_{17}), metal film (R_{18}) and wire-wound (R_{19}) resistors in the chain.

3.25 THE AUXILIARY HEATER SUPPLY

The circuit is shown in drawing No. 1375-A2. It consists of a separate rectifier $CR_{102-103}$ with a storage capacitor C_{108} two transistors Q_{101} , Q_{102} , and the associated parts.

The plus-lead from the rectifier is connected to the cathode of the pass tube V_6 in the Main-Regulator.

The two transistors are compound-connected and function as a single transistor with very high beta. The load made up of the heaters in V_2 , V_8 and V_9 , is inserted between the emitter of Q_{101} and the cathode of V_6 .

To maintain the voltage across the load constant when the line changes, the base of Q_{102} is kept at a constant potential by means of the voltage divider R_{119} , R_{120} , R_{121} , which is fed from the auxiliary -150 volts supply. The resistor R_{122} is fed from an unregulated positive potential and provides compensation for the finite collector impedance of the compound transistor.

3.26 THE PRE-REGULATOR

The complete circuit is shown in drawing No. 1011-A1. It consists of the thyatron V_5 , the storage capacitors C_{12-14} , the a-c bias generator T_2 and the associated components. The Pre-Regulator is shown slightly simplified in fig. 3.2.

The purpose of the Pre-Regulator is to keep the voltage drop across the pass tube V_6 , and consequently the power dissipation in this tube, at a reasonably low value throughout the operating range.

The voltage from the power transformer is rectified by the bridge CR_9 - CR_{12} . The unsmoothed, rectified voltage is applied to the plate of V_5 .

The thyatron is vertically controlled by means of a d-c voltage superimposed on a shaped a-c bias voltage, which is derived from the mains voltage. The waveform (see fig. 3.3) is produced in the following manner: First the mains voltage is clipped by means of the zener diodes CR_2 and CR_3 ; then the signal is passed through the network R_2 , T_2 . Being nearly unloaded, the transformer T_2 acts as an inductance. During its passage of R_2 - T_2 , the signal is therefore partially differentiated. Finally, the signal is rectified in the bridge CR_4 - CR_7 . R_{26} provides suitable loading of the transformer.

The d-c bias on the control grid of V_5 is taken from the voltage divider $R_{29} - R_{30}$. The grid is therefore kept at a constant d-c potential with respect to the cathode of the pass tube V_6 .

As previously stated, the a-c and the d-c biasing voltages to the control grid of V_5 are connected in series.

Fig. 3.4 shows the Pre-Regulator in a greatly simplified form.

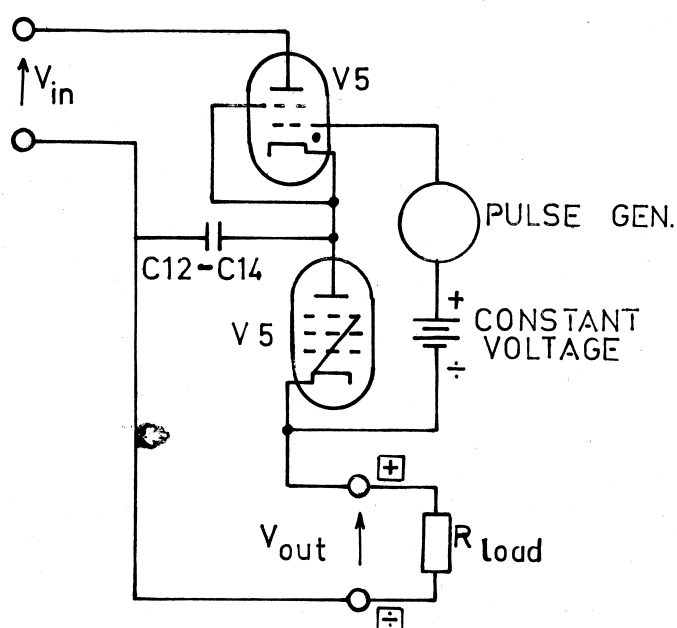


FIG. 3.4 PRINCIPLE OF PRE-REGULATION

V_{IN} is the rectified, unsmoothed voltage from the rectifier bridge CR_{9-12} ; C_{12-14} is the storage capacitor, and V_{OUT} is the output from the HV-terminals on the front panel.

When the circuit begins to operate there will be no charge present on C_{12-14} . The cathode potential of V_5 is therefore zero. As the grid potential of V_5 is positive, the thyatron will fire and start charging C_{12-14} , thus raising the potential of V_5 to a positive value.

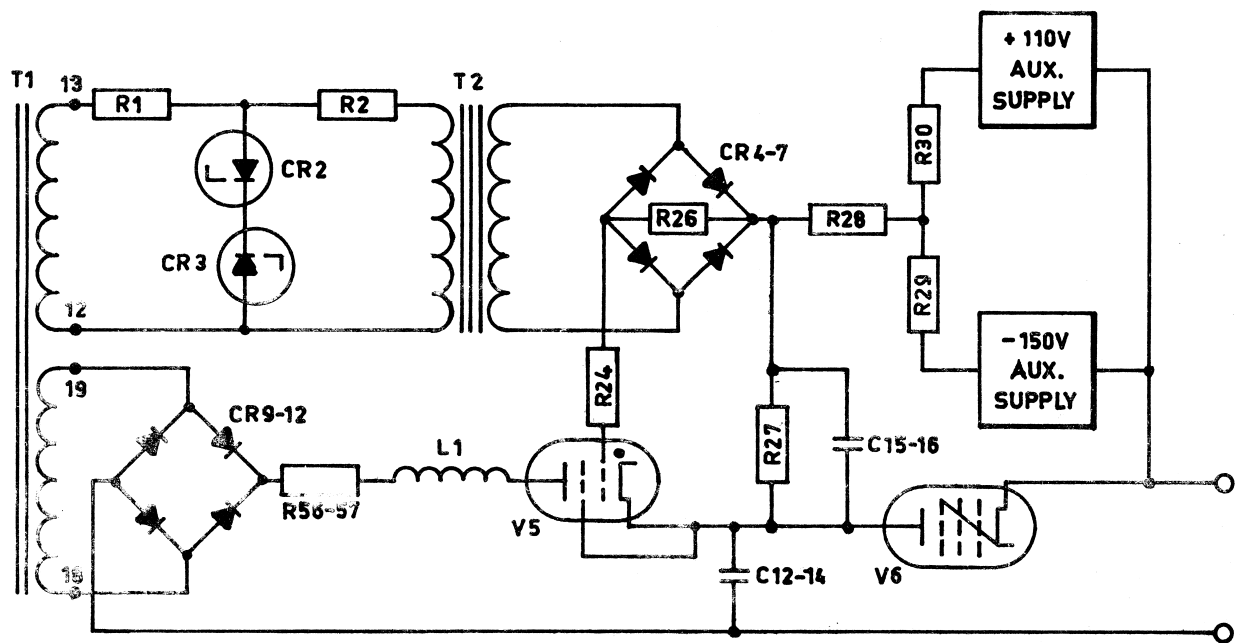


FIG. 3.2 PRE-REGULATOR SIMPLIFIED

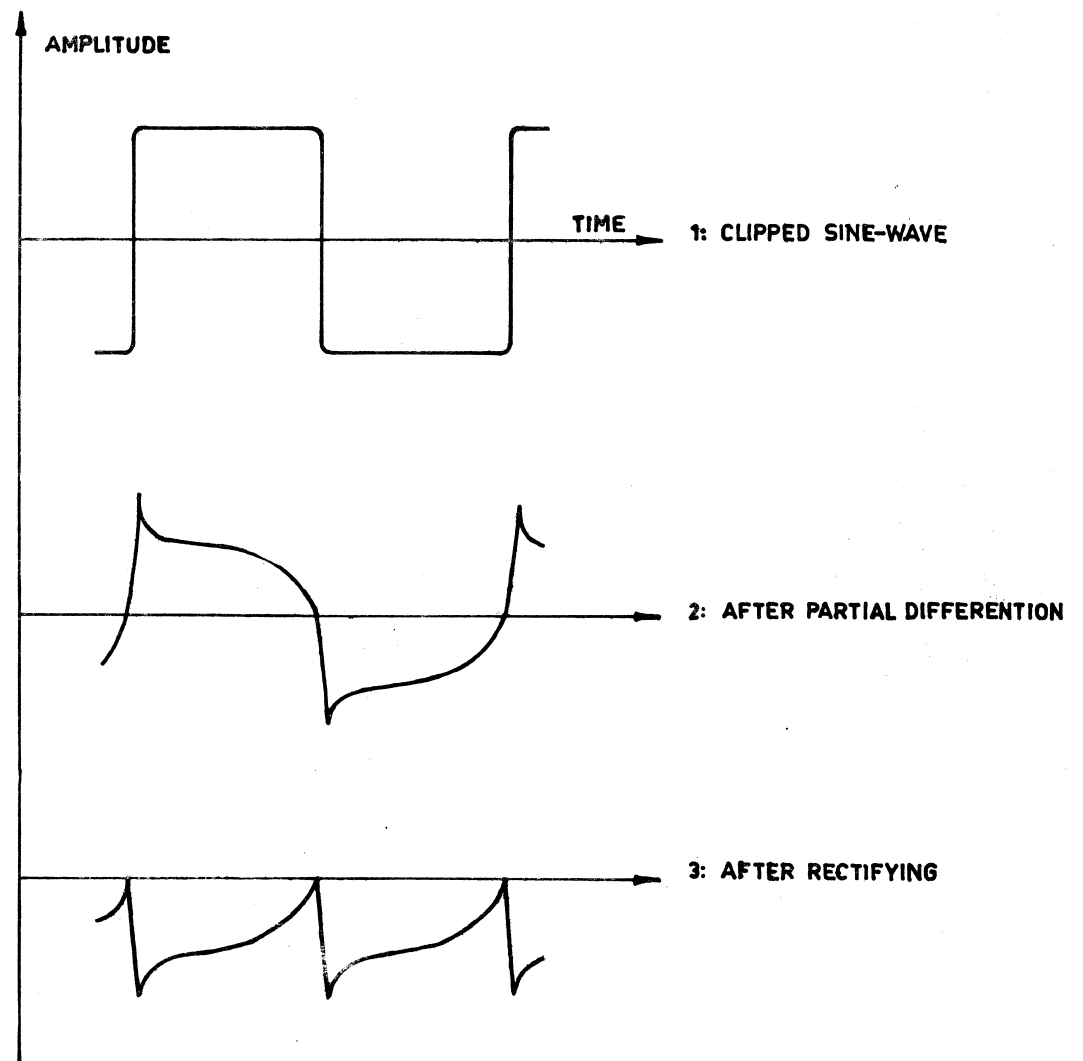


FIG. 3.3 AC BIAS VOLTAGE

Once fired, a thyatron will burn until the plate voltage has decreased to a value below the arc-voltage. With the unsmoothed plate voltage used, V_5 will switch off automatically at the end of each half-wave period.

If the cathode potential of V_5 after the first firing is raised to a value higher than the grid potential, the thyatron is negatively biased, and when the plate voltage in the next half-wave period again becomes positive, no firing will occur until the load current (through V_6) has discharged C_{12-14} sufficiently for the potentials of the cathode and the control grid to approximate each other. If d-c alone was used as grid voltage for V_5 , the firing angle could not be less than 90° , because of the shape of the critical grid voltage characteristic; but due to the superimposed a-c biasing voltage, firing angles down to 0° are obtained. After a few half-wave periods from start, the circuit automatically reaches the state of balance where the charge supplied to C_{12-14} by V_5 within one half-wave period is equal to the charge abstracted by the load in the time passing from V_5 switches off at the end of the period, and until it is fired again in the next half-wave period. The integrating network, C_{15-16} , $R_{28} + R_{29}/R_{30}$ ensures that the firing angle is nearly constant from one half-wave period to the next, as it prevents the ripple voltage across V_5 from reaching the control grid of the thyatron.

For small values of the load current only small firing angles are needed, and the d-c voltage across the pass tube will have a value close to the d-c biasing voltage. For higher load currents greater firing angles are needed. Hereby the d-c voltage across the pass tube decreases a little, causing the a-c biasing signal to hit the critical grid voltage characteristic a little earlier. When the output-voltage from the Main-Regulator is increased, the d-c voltage across the series tube tends to decrease. This, however, means that the control grid of the thyatron becomes positive with respect to the cathode, and that V_5 therefore will fire earlier in each halfwave period until the voltage across C_{12-14} has been raised according to the increment of the output voltage.

When the output voltage is decreased, the voltage across V_6 will

increase, and the cathode of the thyatron will be more positive than the control grid. No firing of V₅ will therefore occur until C₁₂₋₁₄ has been discharged and until the voltage drop across V₆ has resumed its normal value.

3.3 THE BIAS SECTION

The BIAS-section is a separate unit in the SE21. It is independent of the HV-section as well as the FILAMENT-section and may be used alone or in connection with one of these sections.

3.31 THE BIAS REGULATOR

The complete circuit is shown in drawing No. 1375-A2. The regulator is made up of the pass tube V_{101A}, a cascode-coupled amplifier V_{101B} and V_{102A}, a cathode follower V_{102B}, and a reference tube V₁₀₃.

The regulator provides a fixed voltage of 150 volts. The output voltage can be adjusted slightly by means of the potentiometer "AD3101" (R₁₁₀). The fixed BIAS-voltage is available from the terminals J₁₀₁ and J₁₀₃ on the front panel.

The variable BIAS-voltage is derived from the output of the regulator by means of the voltage divider R₁₁₄₋₁₁₅. The variable BIAS-voltage is available between the terminals J₁₀₁ and J₁₀₂ on the front panel. The positive terminal J₁₀₁ is common to the fixed and the variable BIAS-voltage.

3.4 METERING

The built-in meter may be coupled either to the HV-output or to the variable BIAS-output by means of the METER RANGE switch on the front panel. The meter circuit is shown separately in drawing No. 1376-A2.

3.41 THE HV-OUTPUT

Three voltage ranges and one current range are available. The current is measured as the voltage drop across R₄₆ (drawing No. 1011-A1). As R₄₆ is placed within the regulation loop, it does not contribute to the output impedance.

3.42 THE VARIABLE BIAS OUTPUT

Three voltage ranges are available. In order to avoid that the output from the variable BIAS source changes with the setting of the METER RANGE switch, the loading of the meter circuit is constant and equal to $25\text{ k}\Omega$ for any setting of the switch. Constant loading is achieved by means of the resistors R_{206} , R_{212} and R_{213} .

SECTION 4 MAINTENANCE

CAUTION!

The voltages present in the SE21 are highly dangerous! When components have to be replaced, pull out the line plug and wait a few minutes until all capacitors have discharged.

4.1 GENERAL

The circuitry used in the SE21 is fairly complex and fault-finding is not always simple. A few 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 whenever 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.

Fig. 4.1 - 4.3 show the location of the components on the printed boards A, B and C.

4.2 ADJUSTMENTS

Replacement of tubes and other components in the SE21 may involve a re-adjustment of the internal controls.

Before making any adjustments, allow the SE21 to warm up for at least two hours at normal room temperature (25°C).

Only insulated screwdrivers should be used as the shafts of the internal controls are not separated from the circuits!

4.21 THE HV-SECTION

Proper functioning of the HV-section is dependent on correct setting of four internal controls:

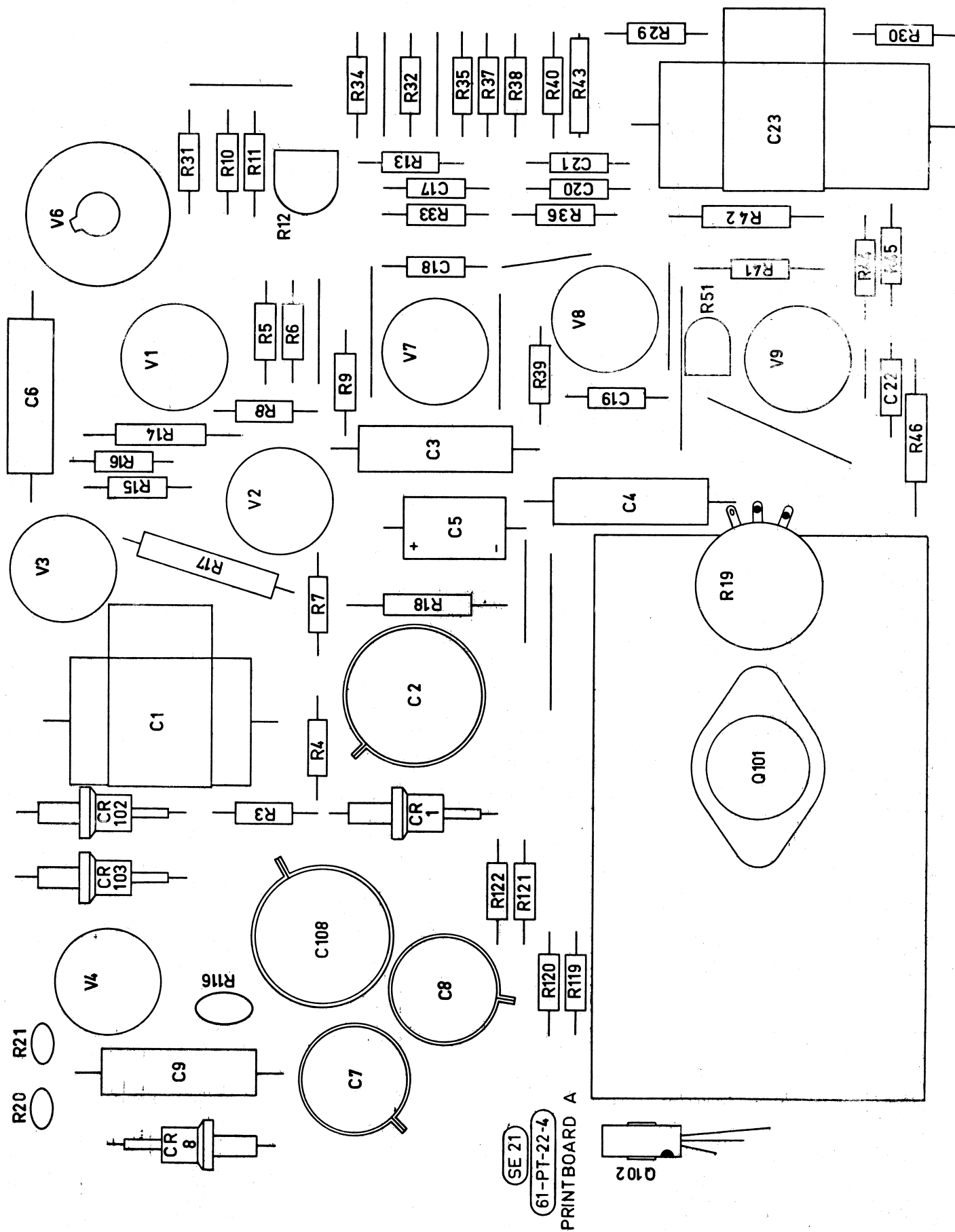


FIG. 4.1. PRINTBOARD A - COMPONENTS

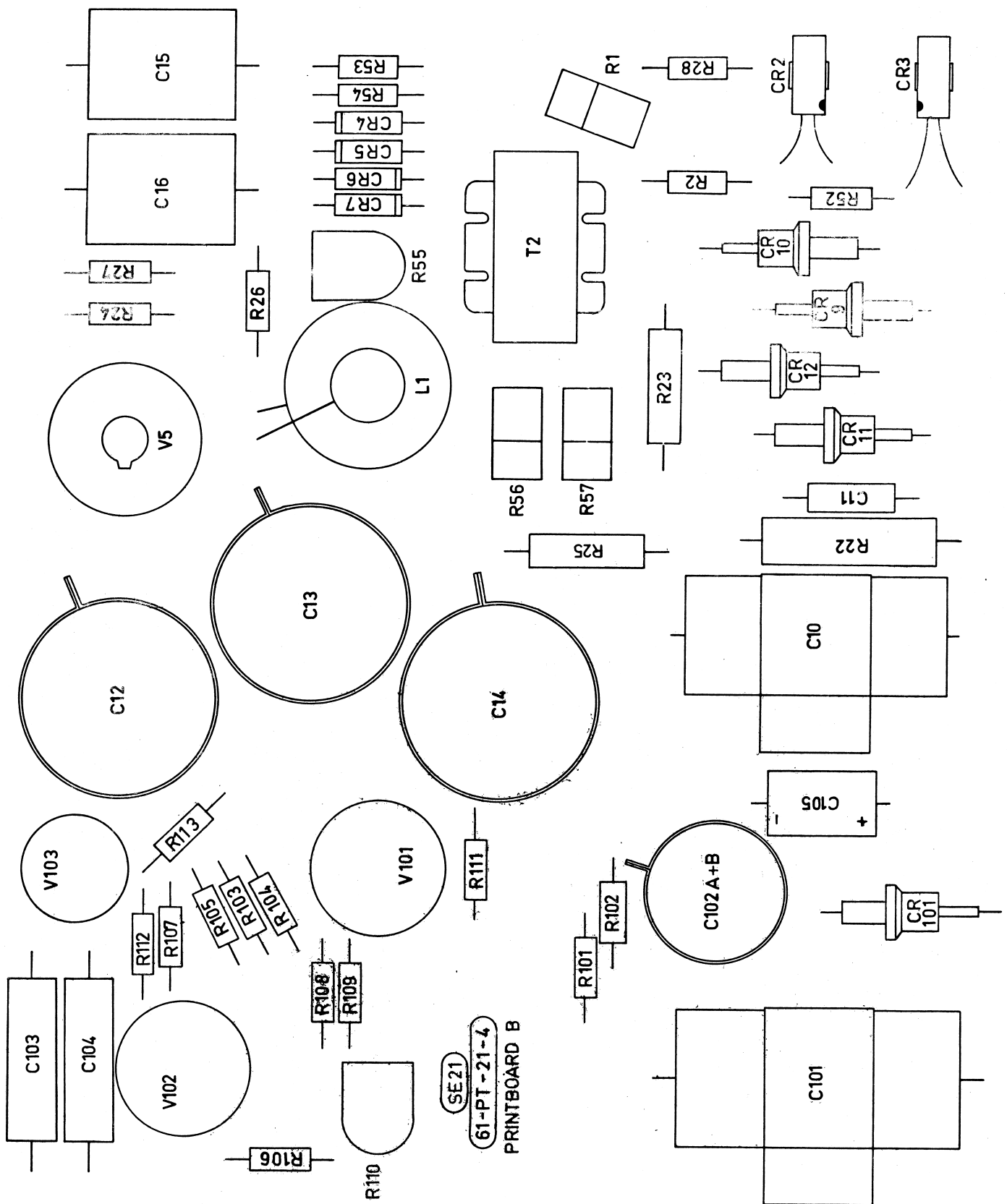


FIG. 4. 2.

PRINTBOARD B - COMPONENTS

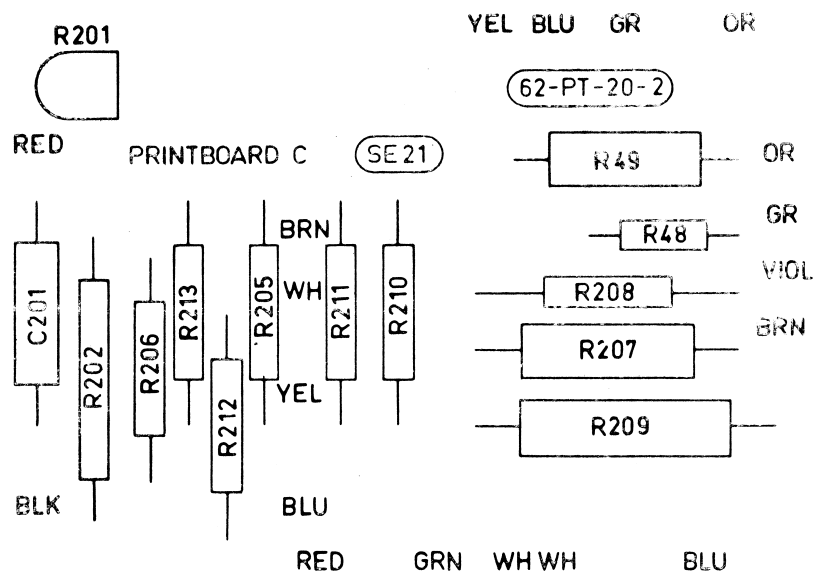


FIG. 4. 3. PRINTBOARD C - COMPONENTS

ADJ1

Carbon film potentiometer marked R_{12} . The setting of this control determines the output voltage from the +110 volts auxiliary regulator.

Check the +110 volts after replacement of components in the HV-section. The voltage is measured between TP_2 and the positive (red) HV-terminal on the panel with HV-switch thrown on. Adjust R_{12} to +110 volts $\pm 1\%$ at TP_2 .

The positive HV-terminal should preferably be grounded, and the HV CONTROL set to minimum output voltage (fully counter-clockwise) during this procedure.

ADJ2

Wirewound potentiometer marked R_{19} , placed in the resistor chain, which determines the value of the current I_{REF} which passes through the HV CONTROL potentiometer R_{50} (see sect. 3.21).

Readjustment of R_{19} may become necessary after replacement of the reference tube V_3 .

The nominal value of I_{REF} is 4 mA. The permissible tolerance for this value and consequently for the setting of the potentiometer R_{19} depends on how the output voltage from the HV-section is controlled.

If only the built-in HV CONTROL potentiometer is used, the setting of R_{19} should be so that the output voltage is slightly higher than 500 volts, when HV CONTROL is set to maximum (fully clockwise).

When programmed operation or output control by means of the decade voltage selector type DVSl (see sect. 2.5) is to be established, I_{REF} should preferably be adjusted to 4 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 SE21 undergoing test is arranged for programmed operation as described in sect. 2.4 of this manual. A high-precision, wirewound resistor (0.01%) of 250 Ω is used as the ex-

ternal 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). R_{19} is then adjusted until the voltage drop across R is 1 volt. The accuracy of the factory adjustment is better than $\pm 0.2\%$.

Before making any connections to programming circuit read section 2.4 in this manual very carefully.

ADJ3

A carbon film potentiometer marked R_{51} , placed between the cathodes of V_9 . Perfect balance is of importance only in those cases where the output voltage from the HV-section has to be exactly zero when the HV CONTROL is set to minimum (fully counter-clockwise).

As the d-c balance between the two triode systems will change during their lifetime, it is recommended to check this point whenever it is of importance to be able to reach exact zero voltage at the output. In any case, the balance should be checked after replacement of V_9 .

The following procedure is recommended: Allow the SE21 to warm up for about two hours. Turn HV CONTROL fully counter-clockwise. Connect a voltmeter to the HV-terminals (10 k Ω per volt and 100 mV full deflection will suffice), and set the HV-switch in ON-position. Then adjust R_{51} until the meter reads zero.

The positive HV-terminal should preferably be grounded during the procedure.

ADJ4

A carbon film potentiometer marked R_{55} . The rectifying bridge CR4-7 in the Pre-Regulator circuit is balanced by means of R_{55} .

Readjustment may be necessary after replacement of one or more of the diodes CR2-7 or the resistors R_{53-54} .

An oscilloscope with a sensitivity of 5 volts/cm is necessary for this adjustment.

Proceed in this way: Connect the positive HV-terminal to ground and set the HV-switch in ON-position. Set the HV CONTROL to some low output voltage (1 or 2 volts). Load the HV-output until 200 mA are drawn. Then connect the scope-ground to the positive HV-terminal, and the scope-input to TP₆ (the cathode of V₅). The scope now shows the ripple voltage existing across the pass-tube V₆.

For correct setting of R₅₅ the ripple should be as shown in fig. 4. 4. If the rectifier bridge R₄₋₇ is out of balance, the firing angle of the thyatron will vary from one half-wave period to the next, and the ripple voltage will be like the one shown in fig. 4. 5.

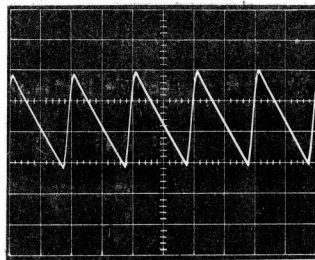


Fig. 4. 4: Scope view shows ripple voltage across V₆ for correct setting of AD34: (1 div. = 5 volts/5mSec. I load = 200 mA)

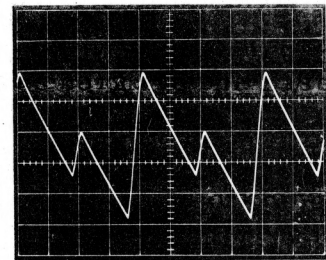


Fig. 4. 5: Scope view shows ripple voltage across V₆ when the rect. bridge is out of balance. (1 div. = 5 volts/5mSec. I load = 200mA)

The procedure should be repeated at an output voltage close to 500 volts to ensure correct operation of the pre-regulator throughout the operating range.

It may happen that the optimal setting of R₅₅ at high output voltages differs from the one found at the low output voltage. A compromise must then be accepted, allowing for a "ripple" on the ripple of about 2 volts.

4.22 THE BIAS-SECTION

Only one internal control is present in this section of the SE21:

ADJ101

A carbon film potentiometer, marked R₁₁₀ and placed in the 150 volts BIAS-regulator.

The output voltage from the regulator is set by means of R₁₀₆.

Readjustment may be necessary after replacement of tubes V₁₀₂₋₁₀₃. The output voltage should preferably be adjusted to 150 volts $\pm 1\%$.

4.23 THE METER CIRCUIT

Only one internal control is found in the meter circuit:

ADJ201

A carbon film potentiometer R₂₀₁, placed in series with the built-in meter M₂₀₁.

The purpose of R₂₀₁ is to compensate for the normally occurring differences in the meter coil-resistance.

The correct setting of R₂₀₁ is achieved in this way: Set the METER RANGE switch to HV - 200 mA and connect a load in series with a precision mA-meter to the HV output-terminals. Increase the output voltage until 200 mA are drawn (read on the external meter). Adjust R₂₀₁ until the built-in meter reads 200 mA. Adjustments of R₂₀₁ should only be made after replacement of R₂₀₂, M₂₀₁ or R₄₆.

4.3 FAULT FINDING

In regulated power supplies as the SE21 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.

It is recommended to follow the procedure described below.

4.31 TESTING THE HV-SECTION

A defective circuit in the HV-section may give rise to high voltages being present at points normally not dangerous to touch. For your own sake, pull out the line plug when making preparations for the test.

When testing the HV-section, the positive (red) HV-terminal on the front panel should be grounded, the HV CONTROL turned fully counter-clockwise, and the HV switch thrown on.

In order to separate the different sub-units which make up the HV-section, remove the thyatron V_5 and the pass tube V_6 .

Make sure that the printboards A and B are securely fastened in a vertical position.

A d-c VTVM, covering the range 1 volt to 1000 volts and with an input resistance of at least 50 Megohms, should be used for the voltage measurements. The RADIOMETER type RV23 with a 2 Megohms probe is well-suited for the purpose.

During the test of the HV-section, the ground side of the VTVM input should be connected to the grounded, positive HV-terminal on the front panel.

As the function of one circuit may depend on the proper operation of another, the tests should be carried out in the same order as they are described.

THE +110 VOLTS AUXILIARY SUPPLY

Apply line power to the SE21 and allow the tubes to warm up for a minute or so. While waiting, control that the heaters in V_1 and V_2 light normally. The heater light can be seen either by looking into the SE21 from above, or by peering through the small holes in the printboards where the tube sockets are soldered.

If no light can be seen in V_1 , check the tube for an opencircuited heater, and the SE21 for broken leads.

If no light can be seen in V_2 , check the heaters of V_2 , V_8 and

V₉. The three tubes are fed in series from the auxiliary heater supply, which also may be the source of trouble. After a minute of warming up, the reference tube V₃ should light.

In drawing No. 1011-A1 the potentials at different points are given with respect to the positive HV-terminal. The values stated are typical and appear for guidance only. The location of the components in the +110 volts auxiliary supply is shown in fig. 4.1.

Under normal operating conditions the screen grid of the pass tube V₅ draws a current of about 20 mA from the +110 volts auxiliary supply. The same loading of the regulator is obtained by connecting a resistor of 5.5 kohms, 3 watts, between the positive HV-terminal and TP2.

After replacement of the components the setting of ADJ1 (R₉) should be checked as described in section 4.2.

THE -150 VOLTS AUXILIARY SUPPLY

As soon as line power is applied to the SE21, the voltage stabilizer V₄ should light. The maintaining voltage of V₄ is 150 volts nominal value.

To ensure proper functioning of the Pre-Regulator, the actual output voltage from the -150 volts auxiliary supply should not be less than -145 volts and not more than -160 volts.

If the voltage is outside this range, replace V₄ and check the setting of ADJ4 (R₅₅) as described in sect. 4.2.

THE MAIN AMPLIFIER

Before applying line power to the SE21, connect the negative HV-terminal to the grounded positive HV-terminal (both on the front panel), and check that the HV CONTROL is turned fully counter-clockwise.

Now apply line power to the instrument and wait a few minutes, allowing the tubes to warm up. While waiting, control that heaters of V₇, V₈ and V₉ light normally (compare with the testing procedure for the +110 volts auxiliary supply).

When the amplifier is in proper working order, the potential at TP₇ will vary widely with the setting of ADJ3 (R₅₁).

Set the potential at TP₇ to -10 volts by means of ADJ3, and then turn the HV CONTROL a few degrees clockwise. The potential of TP₇ should then surge towards +110 volts.

When set to -10 volts, the potential at TP₇ will be rather unstable and tend to move around. This is due to small changes in the line voltage which cannot be compensated, because the regulation loop is open-circuited. For the same reason, the potentials stated in drawing No. 1011-A1 for the tubes V₇, V₈ and V₉ are valid only under normal operating conditions.

A positive response from the amplifier to the above mentioned tests means that the d-c signal-path through the amplifier is free from defective tubes and components.

Finally, remove the short-circuit strap between the positive and the negative HV-terminals.

THE AUXILIARY HEATER SUPPLY

Before checking this unit make sure that the heaters of V₂, V₈ and V₉ are in order. Then apply line power to the SE21 and allow the tubes to warm up.

The output voltage from the auxiliary heater supply can be measured at TP102. Typical values of the potentials at different points of the circuit are stated in drawing No. 1375-A2.

THE PRE-REGULATOR

As the thyatron V₅ and the pass-tube V₆ both are removed from their sockets during this test programme, only the grid biasvoltage of V₅ can be checked.

Apply line power to the SE21 and allow the auxiliary supplies to warm up for a few minutes.

As previously mentioned, the bias voltage on the control grid of V₅ is the sum of a d-c voltage and a shaped a-c signal. The composite bias signal is present at TP₄. The d-c value at this point should be +52 ±5 volts.

For checking voltages and waveforms in the Pre-Regulator under normal operating conditions: see section 4.33 of this manual.

When the testing of the HV-section is completed, the ground connection should be removed from the positive HV-terminal, and V_5 and V_6 mounted in their sockets again.

CAUTION: When mounting a "cold" thyatron in a circuit where the rest of the tubes are "warm", line power must not be applied until all tubes have cooled down for at least ten minutes. The "warm" tubes will try to put the thyatron to work before its cathode has reached the working temperature and thereby damage it.

4.32 TESTING THE BIAS-SECTION

Although the BIAS-section is electrically separated from the HV-section, the components which make up the former are mounted on the printboard also carrying the Pre-Regulator. High-voltage is therefore present close to the circuits of the BIAS-section. To minimize the risk for the serviceman, the HV-output should be floating when the BIAS-section is being tested. The location of the components in the BIAS-section is shown in fig. 4.2.

The 150 VOLTS BIAS REGULATOR

When testing the BIAS-regulator, the -150 volts terminal on the front panel should be grounded, as should the ground-side of the VTVM input.

Typical values of the potentials at various points of the circuit are stated in drawing No. 1375-A2.

Replacement of tubes or other components may necessitate readjustment of ADJ101 (R_{110}). The adjustment procedure is described in section 4.22.

4.33 TYPICAL WAVEFORMS IN THE PRE-REGULATOR

The four pictures in figure 4.6 show typical waveforms at anode and control grid of the thyatron V_5 under different load conditions. In both cases with the cathode of V_5 (TP6) as the reference point.

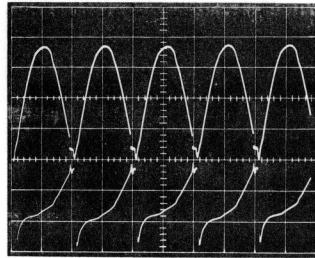
When checking the waveforms, it is recommended to keep the HV-output, and consequently the load, floating, and instead ground the cathode of V_5 (TP6) and the scope chassis.

A dual beam oscilloscope was used for the pictures shown to illustrate clearly the relation in time between the voltages present at the two electrodes of V_5 .

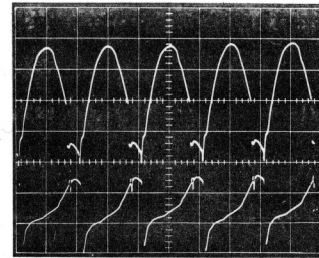
Upper beam: Anode voltage measured at TP5
Vertical scale: 1 div = 200 volts

Lower beam: Grid voltage measured at TP4
Vertical scale: 1 div = 20 volts

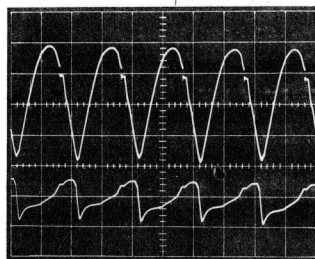
Sweep (both beams): 1 div = 5 msec.



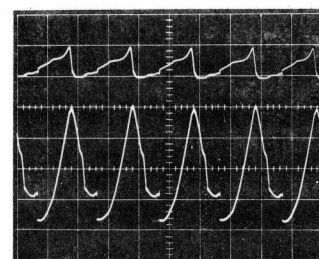
a. $V_{\text{output}} = 1.5$ Volts;
 $I_{\text{load}} = 5$ mA



b. $V_{\text{output}} = 1.5$ Volts;
 $I_{\text{load}} = 200$ mA

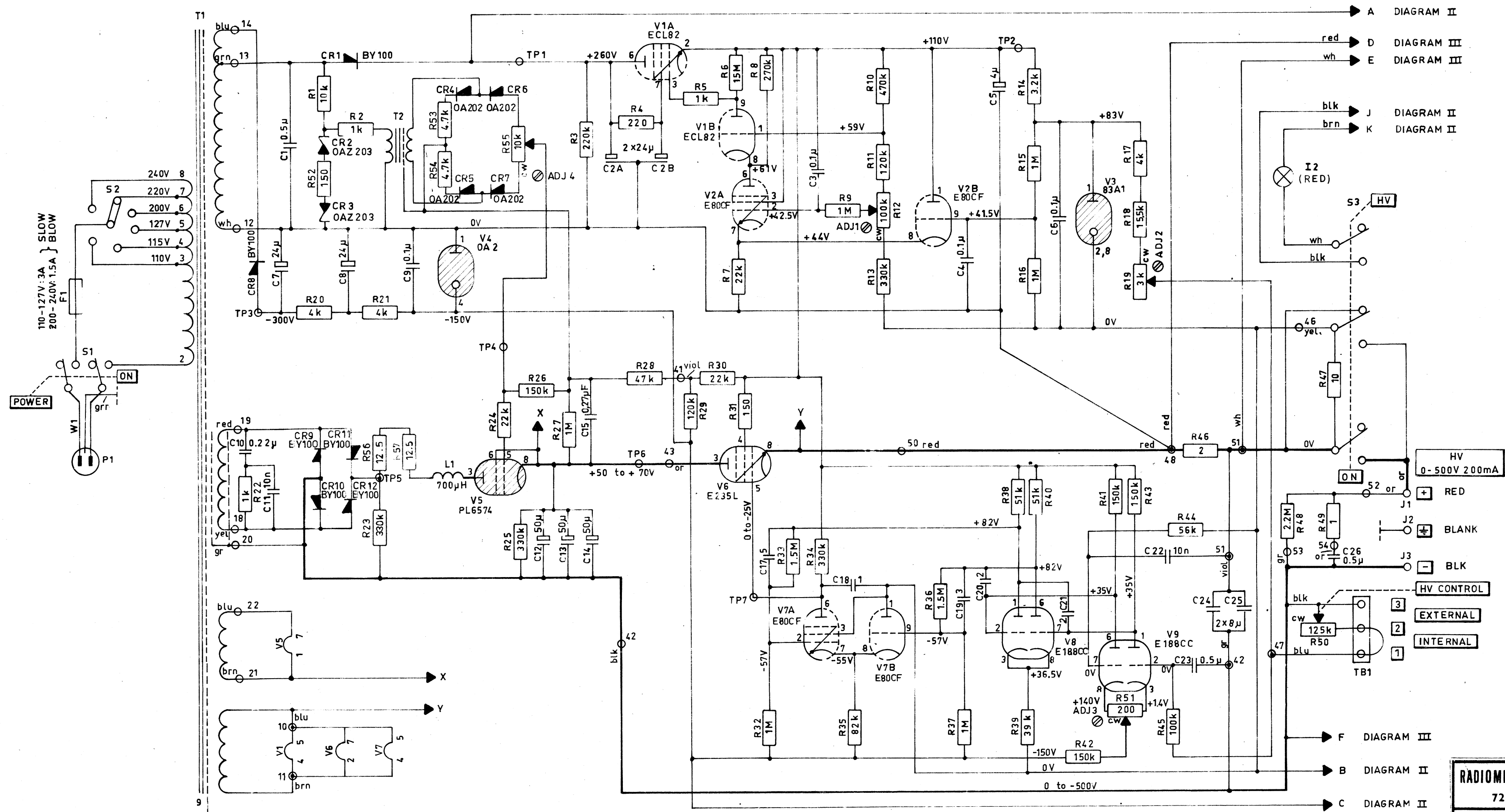


c. $V_{\text{output}} = 500$ Volts;
 $I_{\text{load}} = 5$ mA



d. $V_{\text{output}} = 500$ Volts;
 $I_{\text{load}} = 200$ mA

Fig. 4.6: Typical waveforms in the Pre-Regulator.



2		24/10-63	EA	KR.	
1		4/3-63	EA	KR.	
Rt.Nr.	Fra Fab. Nr.	Dato	Rt. af	Konf.	Norm.

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ALL d-c POTENTIALS MEASURED WITH RESPECT TO + HV TERMINAL, J1

MEASURING CONDITIONS:
NOMINAL LINE VOLTAGE
VTVM INPUT RESISTANCE > 60M
HV-SWITCH IN POSITION ON

ALL VALUES IN Ω OR pF (μ F) UNLESS OTHERWISE SPECIFIED
cw: CLOCKWISE POSITION
HEAVY SOLID LINE: MAIN HV CIRCUIT
TP: INTERNAL TEST POINT
PRINT TERMINAL

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

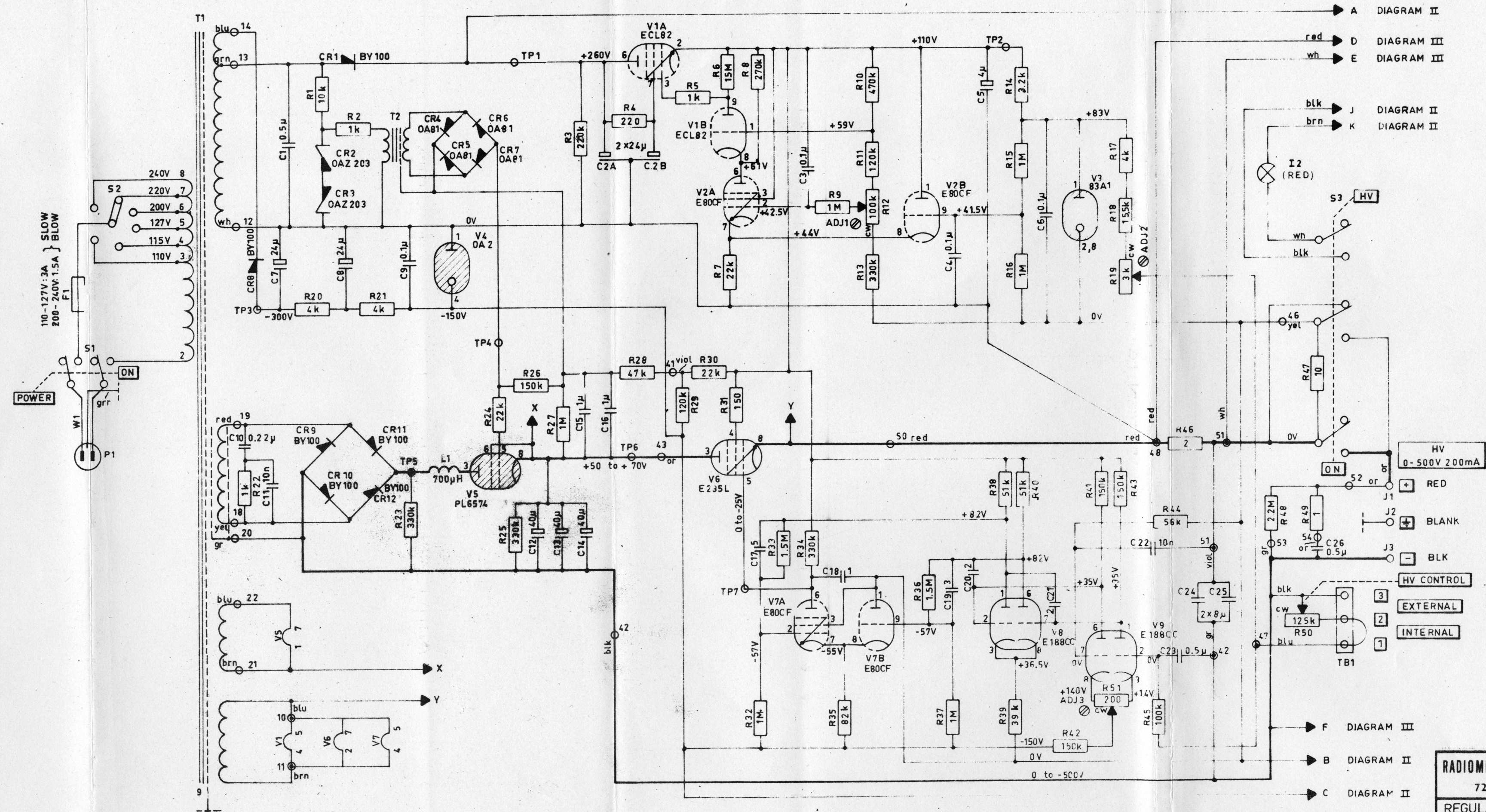
REGULATED POWER SUPPLY
DIAGRAM I HV-SECTION
TYPE SE 21a

From no. to no.

MAJESTOK
Tegn. E.A. 27/12-62
Konf. KR. 17/1-63
Norm.

Erstatter
1011-A1
Erstattes af

- A DIAGRAM II
- D DIAGRAM III
- E DIAGRAM III
- J DIAGRAM II
- K DIAGRAM II
- F DIAGRAM III
- B DIAGRAM II
- C DIAGRAM II

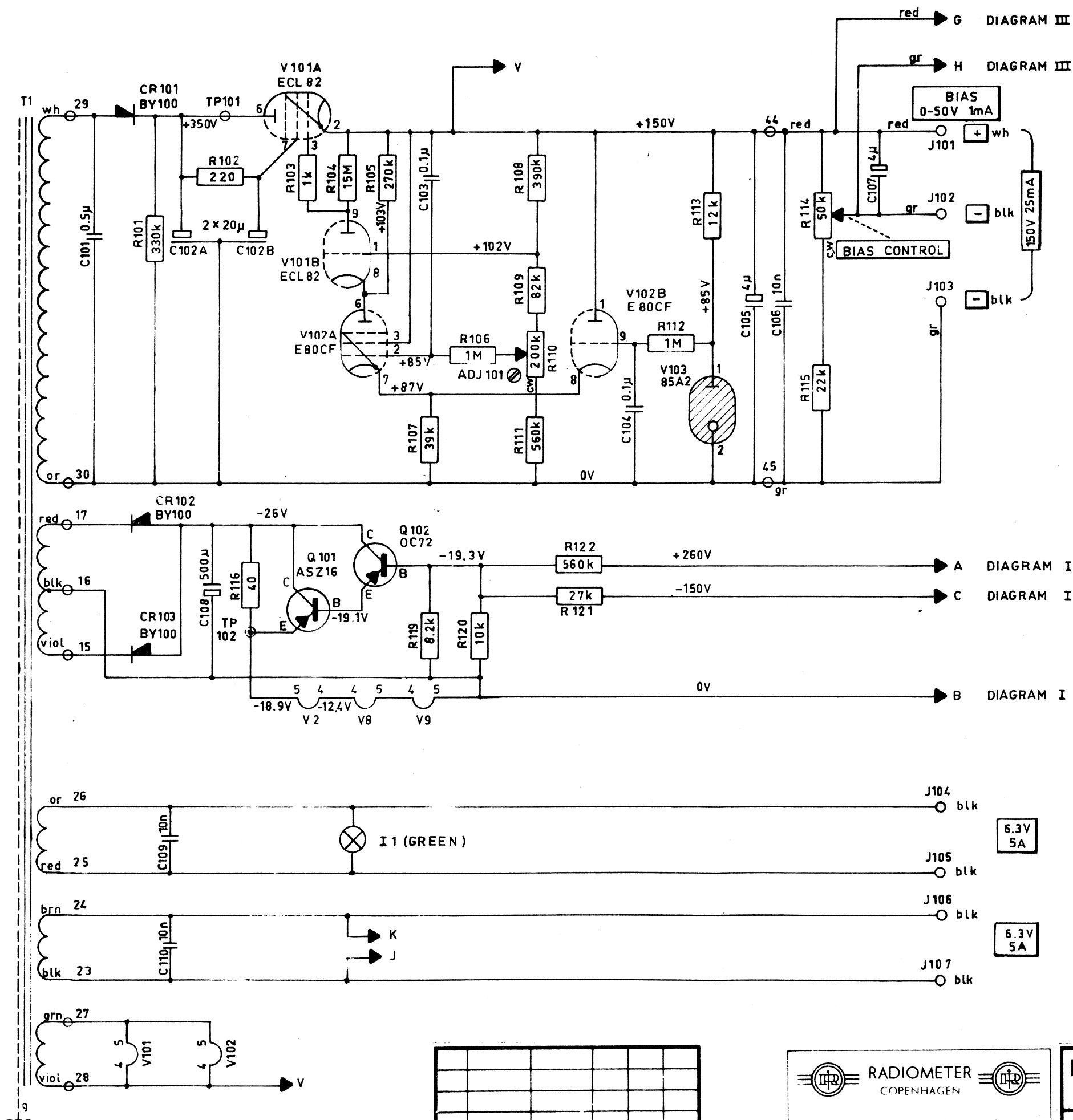


1	43-63	EA	HR
Rt. Nr.	Fra. Fab. Nr.	Dato	Rt. af. Kont. Norm.

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ALL d-c POTENTIALS MEASURED WITH RESPECT TO +HV TERMINAL, J1
MEASURING CONDITIONS:
NOMINAL LINE VOLTAGE
VTVM INPUT RESISTANCE > 60M
HV-SWITCH IN POSITION ON
ALL VALUES IN Ω OR pF (μ F)
UNLESS OTHERWISE SPECIFIED
cw: COUNTERCLOCKWISE POSITION
HEAVY SOLIDLINE: MAIN HV CIRCUIT
TP: INTERNAL TEST POINT
⊕: PRINT TERMINAL

RADIOMETER COPENHAGEN		Maestrosk	Tegn.	EA 27/12-62
72 EMDRUPVEJ NV		Kont.	HR	17/1-63
REGULATED POWER SUPPLY DIAGRAM I HV-SECTION TYPE SE 21a		Erstatter	1011-A1	
From no.		Erstattes af		



BIAS SUPPLY:
ALL d-c POTENTIALS ARE MEASURED
WITH RESPECT TO -150V
BIAS TERMINAL, J103

HEATER SUPPLY:
ALL d-c POTENTIALS ARE MEASURED
WITH RESPECT TO +HV TERMINAL, J1

MEASURING CONDITIONS:
NOMINAL LINE VOLTAGE
VTVM INPUT RESISTANCE >60M
HV SWITCH IN POSITION **ON**

ALL VALUES IN Ω OR pF ($\mu\mu\text{F}$)
UNLESS OTHERWISE SPECIFIED
cw: CLOCKWISE POSITION
TP: INTERNAL TEST POINT
⊕ PRINT TERMINAL
48

1	4/3-63	EA	NR		
Rt. Nr.	Fra Fab. Nr.	Dato	Rt. af	Kont.	Norm.

RADIOMETER COPENHAGEN

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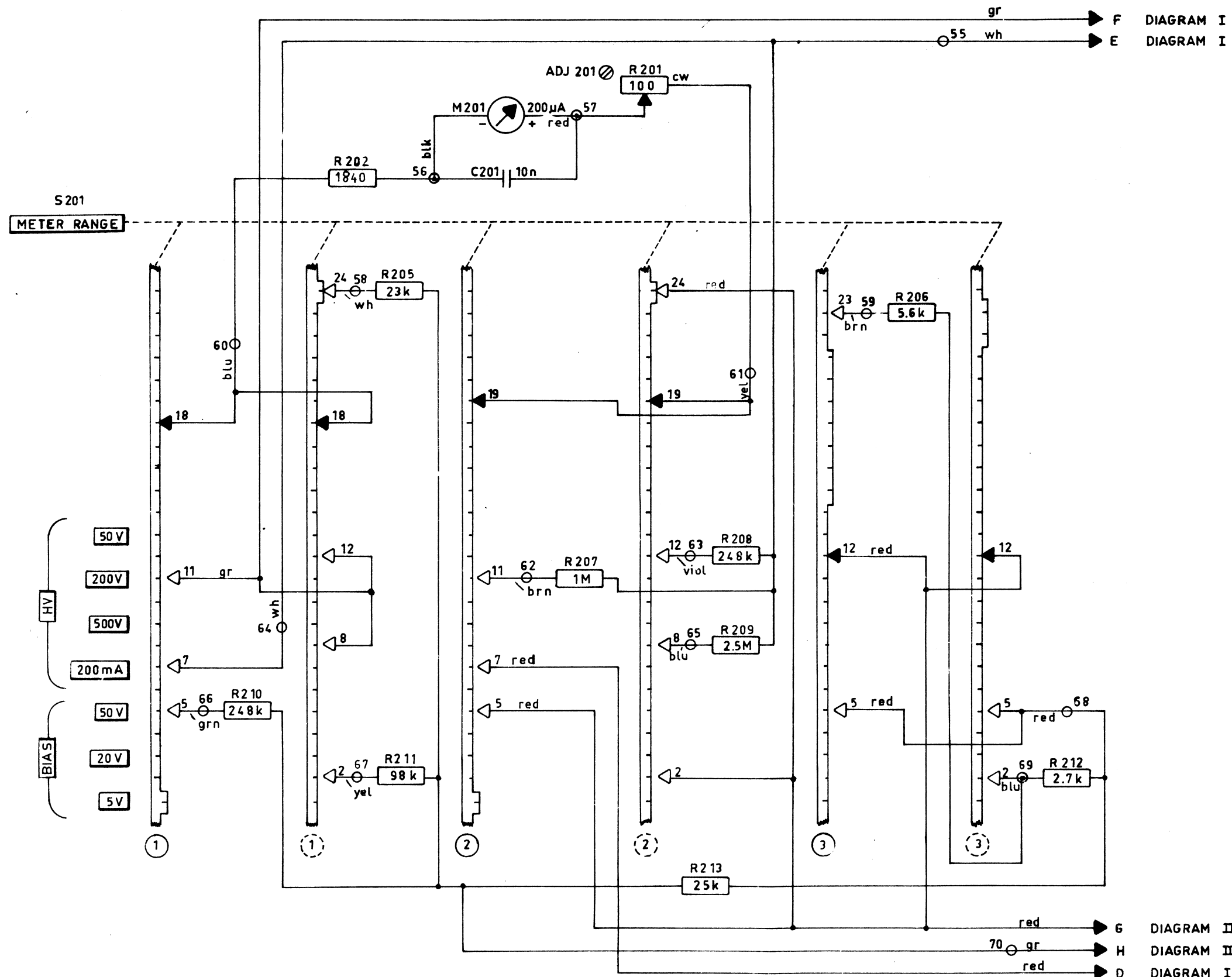
RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

REGULATED POWER SUPPLY
DIAGRAM II BIAS SECTION
TYPE SE 21a

From no. to no.

Malestok	Tegn.	EA	20/12-62
Kont.	NR	17/1-63	
Norm.			

Erstatter
1375-A2
Erstatter af



ALL VALUES IN Ω OR μF (pF)
UNLESS OTHERWISE SPECIFIED
cw: CLOCKWISE POSITION
THE SWITCH IS SHOWN IN
COUNTER CLOCKWISE POSITION
⊖ PRINT TERMINAL
48

1	7-8-63	WP	KR		
Rt. Nr.	Fra. Fab. Nr.	Dato	Rt. af	Kont.	Norm.

RADIOMETER COPENHAGEN

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RADIOMETER COPENHAGEN		Maestok	Tegn. <i>FA 28/12-64</i>
72 EMDRUPVEJ NV		Kont. <i>42 71-63</i>	Norm.
REGULATED POWER SUPPLY DIAGRAM III METER SECTION TYPE SE 21a		Erstatter	
From no.		to no.	
		Erstatter af	
		1376-A2	