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AUTOMATIC RESISTANCE BRIDGE

AVS - 45

OPERATING INSTRUCTIONS

SERVICE MANUAL

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PART I OPERATING INSTRUCTIONS

CONTENTS

25.6.82

1. WARRANTY

RV-Elektroniikka Oy warrants each of its products to be free from defects in materials and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or part thereof which, within one year after shipment to the original purchaser, proves defective upon examination. This warranty does not cover defects which are due to misuse or operation in abnormal conditions, or damage which has occurred during shipment for warranty repair.

In case of any trouble, factory should be contacted and a detailed description of the misfunction should be given. RV-Elektroniikka Oy will then supply shipping information or instructions for repairing the instrument.

2. INTRODUCTION

The AVS-45 is an autoranging self-balancing resistance bridge, which has been designed to operate accurately at very low sensor dissipations. AC excitation and phase-sensitive detection make the bridge insensitive to thermal emf´s. Four-wire measurement technique permits high lead resistance/sensor resistance ratio without loss of accuracy. Other features of this versatile instrument include: Internal calibration of the scale factor, compensation of sensor lead capacitance, fast and slow response modes, display mode for deviation etc. Optional input multiplexer facilitates computer-controlled scanning of several sensors.

This operating manual contains information which helps the user to understand the operation of the bridge and to fully utilize its performance and capabilities. A separate service manual is available from us upon request. RV-Elektroniikka Oy will always be glad to answer any questions regarding the use or service of this instrument.

3. SPECIFICATIONS

RESISTANCE RANGES	0-2 ohms (100 μohm resolution)[1] 0-20, 0-200 ohms 0-2, 0-20, 0-200 kilo-ohms 0-2 Megaohms NOTE 1): Bridge operated at 20 ohms range and in ΔRx10-mode.
EXCITATION RANGES	10 μV, 30 μV, 100 μV, 300 μV, 1 mV, 3 mV (across the reference resistor).
SENSOR CONFIGURATION	4-wire measurement. One current lead can be grounded. Corresponding current and voltage leads can be externally connected together for 2-wire measurement.
EXCITATION FREQUENCY	25/30 Hz, divided from the mains frequency.
LINEARITY	Maximum error for end-point calibration:

RANGE	ERROR
20 ohms - 20 kohms	± 1 digit
200 kohms	± 2 digits 1)
2 Megaohms	± 10 digits 1)

NOTE 1): With bootstrapped cable shields.

TEMPERATURE COEFFICIENT	100 ppm/°C typical without internal calibration. 10 ppm/°C maximum if internal calibration is used to cancel all other sources of error but the reference resistors.
LONG-TERM STABILITY	35 ppm/year maximum with internal calibration.
SPEED OF BALANCE	Response time for step input from 0 to 10 000, until final accuracy is reached, is 15 sec for SLOW response mode and 2 sec for FAST response mode.
OPERATING TEMPERATURE RANGE	+10 - +35 °C.
OPERATING POSITION	Insensitive to position.

RESOLUTION

Typical resolution (both analogue and digital) at middle scale and with SLOW time constant:

RESISTANCE	EXCITATION (µV) 10	30	100	300	1000	3000
10 ohms	30mΩ	10mΩ	3mΩ	2mΩ	1mΩ	1mΩ
100 ohm	300mΩ	100mΩ	30mΩ	20mΩ	10mΩ	10mΩ
1 kohm	3Ω	1Ω	0.3Ω	0.2Ω	0.1Ω	0.1Ω
10 kohms	-	15Ω	5Ω	2Ω	1Ω	1Ω
100 kohms	-	-	150Ω	50Ω	20Ω	10Ω
1 Megohm	-	-	-	1kΩ	500Ω	200Ω

NOTE: 100 µohm resolution can be obtained in Rx10-mode at 20 ohms range.

MAINS INPUT

115/230 V ± 10%, 50/60 Hz, 10 VA.
RFI filtering.

DIMENSIONS

Height 88 mm (without feet)
Width 483 mm (for 19" rack mounting)
Depth 305 mm.

WEIGHT

5 kg.

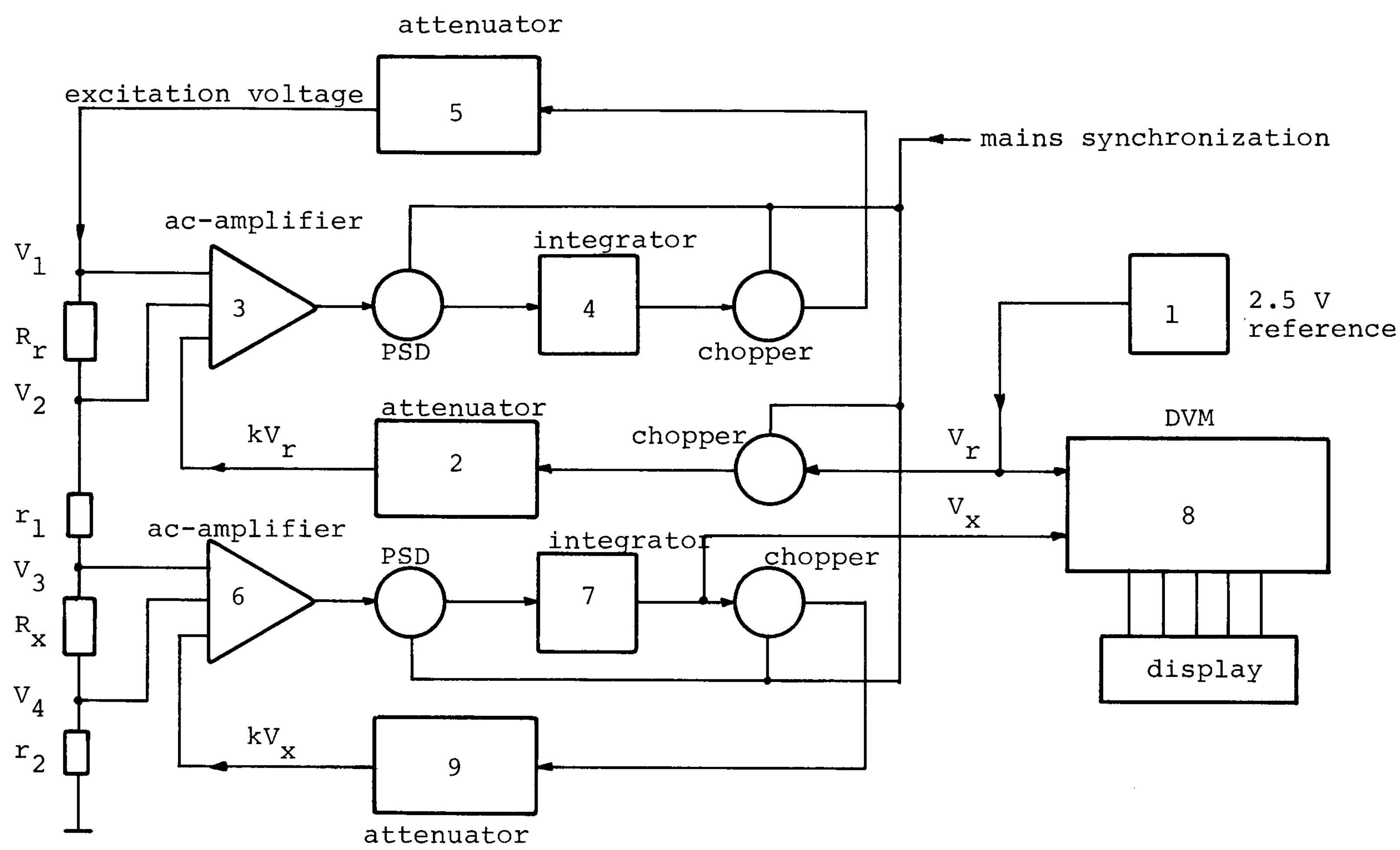

Fig. 1. Simplified block diagram of the AVS-45.

4. PRINCIPLE OF OPERATION

The operation of the AVS-45 is described with the aid of a simplified block diagram, Fig. 1.

The basic part of the bridge consists of two identical amplifier plus feedback sections, one for the reference resistor R_r and the other for the unknown resistor R_x. The purpose of these sections is to monitor the AC voltages across R_r and R_x, and to produce a DC-output voltage which is directly proportional to R_x.

A stable 2.5 Volt reference (1) is chopped at a frequency of 25/30 Hz (for 50/60 Hz mains, respectively) to form a square-wave reference signal V_r which is further attenuated to 10 μV - 3 mV level by a precision attenuator (2). This reference square-wave is applied to the reference preamplifier (3) which is constructed to amplify the difference $V_1-V_2-kV_r$, where k is the attenuation factor of (2). The output of (3) is phase-sensitively rectified at 25/30 Hz and integrated by (4). The integrator output voltage is again chopped into square-wave form and scaled down by an attenuator (5) similar to (2). The output of (5) is applied to the reference resistor and it is called the excitation voltage of the bridge.

Negative difference $V_1-V_2-kV_r$ indicates that the excitation current is too small, i.e. $I_{exc} \cdot R_r < kV_r$. The output voltage of the reference integrator (4) increases until $V_1-V_2-kV_r = 0$ (or $I_{exc} \cdot R_r = kV_r$). Similarly, positive difference results in decreasing of the integrator voltage until equilibrium is reached. This arrangement of the reference-section serves for stabilizing the excitation square-wave current to the precise value $I_{exc} = kV_r / R_r$, irrespective of what the unknown resistance R_x and the lead resistances r_1 and r_2 might be.

Suppose that the reference-section is in balance. The voltage difference across the unknown resistor R_x is then $V_3-V_4 = R_x \cdot I_{exc} = R_x \cdot kV_r/R_r$. This difference is not dependent on lead resistances. A second preamplifier (6), identical to (3), amplifies the difference $V_3-V_4-kV_x$, where the voltage kV_x has been obtained from the output of the x-integrator (7) by chopping and attenuating by factor k. In balance $V_3-V_4 = kV_x = R_x \cdot kV_r/R_r$. The output voltage of the x-integrator is then $V_x = R_x \cdot V_r/R_r$.

The x-integrator output is then measured by a dual-slope A/D-converter (8), which uses V_r as the reference voltage. Therefore, the display indicates directly the ratio R_x/R_r.

Changing the attenuation factor k simultaneously in all three attenuators by the same amount alters the excitation current and consequently the sensor dissipation power without affecting the display.

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5. CONTROLS AND FUNCTIONS

5.1 FRONT PANEL

DISPLAY

The 4 1/2-digit display is equipped with -sign for Δ R-applications. Full range 19 999 corresponds to 1.999 Volts at the RECORDER or DEVIATION output.

OVERLOAD INDICATOR

Clipping of the AC-amplifier output is indicated by red light. This clipping may result from excessive mains frequency interference in the sensor leads, especially at low excitations and high sensor resistances.

LEAD RESISTANCE INDICATOR

Excessive resistance in sensor current leads is indicated by red light. Maximum allowed total lead resistance is equal to the resistance range used. Beyond this limit, the reference integrator will saturate resulting in erroneous display.

FAST/SLOW

Switch for selecting one of the two alternative "time constants". In FAST position, the bridge settles in about 2-3 seconds and in SLOW position the settling time is about 15 seconds. The resolution, on the other hand, is three times better in SLOW position.

AUTO/MANUAL RANGE

In autorange mode, readings higher than 20 000 or lower than 1800 cause the change of range up or down, respectively. Internal 5 sec delay

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between two successive autorange operations gives the bridge time to settle before a new change can take place.

RANGE UP/DOWN

Lifting and releasing the switch lever changes the range to next higher position. Pressing and releasing changes the range downwards.

NOTE: RANGE UP/DOWN switch is always active irrespective of the position of the AUTO/MANUAL RANGE switch.

AUTO/MANUAL EXCITATION

The excitation voltage can be selected either manually or it can be changed automatically simultaneously with the resistance range.

By the simultaneous changing of range and excitation it is possible to limit the variations in sensor dissipation power to one order of magnitude.

EXC UP/DOWN

Operation is similar to RANGE UP/DOWN

R/ ΔR

Switch connects the DVM to show the sensor resistance in R position, and the deviation from the REFERENCE setting in ΔR position.

R mode is accurately scaled only with respect to changes in sensor resistance. This mode can also be used for extending the range from 20000 to 40000 (see sec. 13.2).

The lead resistance of a 2-wire sensor can be cancelled in ΔR mode.

REF	When pressed, this pushbutton switch connects the DVM to measure the deviation reference voltage, adjusted by the REFERENCE helipot. The REF switch is used for accurate setting of the helipot. It is independent of the R/ΔR switch.
CAL/MEAS	In CAL position, this switch connects the bridge to measure the voltage across its own reference resistor. The scale factor of the unit can be quickly adjusted for maximum accuracy in the CAL mode.
OFFSET	Trimmer for offset adjustment (see section 16).
SCALE	Trimmer for re-calibration of the scale factor in CALIBRATE mode.
INPUT	See section 10.1 for wiring the input connector. Plug: PREH type 71404-250.

5.2. REAR PANEL

MAINS CONNECTOR	The mains connector contains an RFI-filter. For safety reasons and correct operation of the filter, ONLY GROUNDED POWER CORD MUST BE USED.
FUSE	5x20 mm, 50 mA, slow-blow.
RECORDER OUTPUT BNC	Voltage range 0...+1.9999 Volts. Output impedance 1 kohm. See also sections 10.3 and 12.

DEVIATION OUTPUT BNC	Voltage range -1.9999 volts...+1.9999 Volts. Output impedance 1 kohm. See sec. 10.3 and 12.
DIGITAL OUTPUT AND REMOTE CONTROL INPUT	See section 15. for detailed description.
SENSOR INPUTS	Connector DC37S for 7 sensors in 4-wire configuration. This connector is assembled only if the unit is equipped with the input multiplexer option.
ΔRx10 / ΔR	In upper position this switch magnifies the deviation display by a factor of ten, so that tenfold resolution is achieved. Notice that decimal point is not shifted.

6. MAINS VOLTAGE AND FREQUENCY

The mains voltage of the unit is marked on the rear panel. If the setting does not correspond to local line voltage, rewire the power transformer primary as illustrated in Fig.2.

All 220/230 Volt units are adjusted for 50 Hz line frequency and all 110/115 Volt units are adjusted for 60 Hz at the factory. If the unit is taken from one mains frequency to another, the DVM oscillator must be adjusted as outlined in section 9.

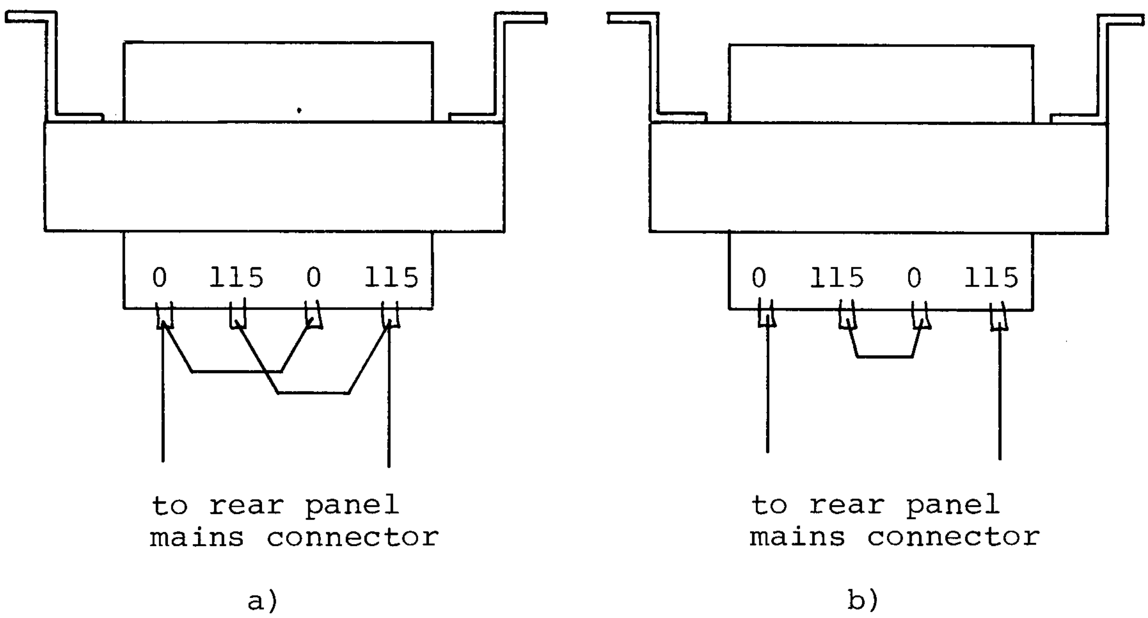

Fig. 2. Wiring of the power transformer primary. a) 115 Volts, b) 230 Volts.

7. START-UP PROCEDURE

Before connecting the unit to the mains, make sure that the voltage setting is correct.

Set the controls as follows:

CAL/MEAS	in CAL	position
FAST/SLOW	in SLOW	"
R/ΔR	in R	"
AUTO/MAN RANGE	in MAN	"
AUTO/MAN EXCITATION	in MAN	"

Switch the power on. In about one minute the AC-amplifiers will be biased and a reading of about 10 000 is displayed. It will take at least half an hour until the final accuracy is reached. When switched on, the bridge selects 2 kohm range and 3 mV excitation.

Before starting actual measurements for the first time after shipment, it is recommended that the operation of the bridge be checked as described below.

8. CHECKING THE OPERATION

Let the unit reach its normal operating temperature. This will take about 1/2 - 1 hour.

Select 3 mV excitation, 2 kohm range, CAL mode and SLOW response. The display should read 10 000 ± 1 digit. If the deviation is greater, proceed as follows:

1. Short-circuit the input. Refer to Fig. 3 on page 10-1 for the input connector wiring. If the leads are more than a few centimeters long (total resistance more than 0.1 ohm), 4-wire connection must be used.
2. Turn the bridge into MEAS mode and null the zero offset, if any, by adjusting the front panel OFFSET trimmer with a small screwdriver.
3. Switch the unit back into CAL mode. If necessary, adjust the gain by turning front panel SCALE trimmer until the reading is exactly 10 000.

Reduce the excitation step by step. The mean value of the display should be 10 000 ± 2 at all excitations. If large deviations, which cannot be attributed to random noise, are observed, the unit must be recalibrated following the simple procedure outlined in section 16.

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9. ADJUSTING THE DVM OSCILLATOR

For best possible attenuation of mains interference, the frequency of the DVM clock oscillator must be 125 and 150 kHz for 50 and 60 Hz mains frequency, respectively. This oscillator has been made adjustable.

When the unit leaves the factory, the DVM oscillator has been set for the mains frequency of the country of destination, and no further adjustment by customer should be necessary, unless the instrument is taken to another mains system. The following steps are needed to correct the oscillator frequency:

1. Let the unit warm up.
2. Remove the top cover of the instrument.
3. Connect the probe of an oscilloscope to resistor R 334. Connect the ground lead of the probe to the case of the AVS-45. Use the short-circuit plug at the input.
4. Trigger the oscilloscope from the mains.
5. Adjust trimmer P302 until the waveform stops moving.

If a frequency counter is used, then the counter input must have high impedance. A good practice is to use 10:1 oscilloscope probe for connecting the oscillator output to the counter.

1. Connect the probe to pin 3 of IC304 . Connect the ground lead to the instrument case.
2. Adjust P302 until the frequency is 125 or 150 kHz, as required.

10. CONNECTION TO THE SENSOR

10.1 INPUT CONNECTOR WIRING

The sensor connection is shown in Fig. 3.

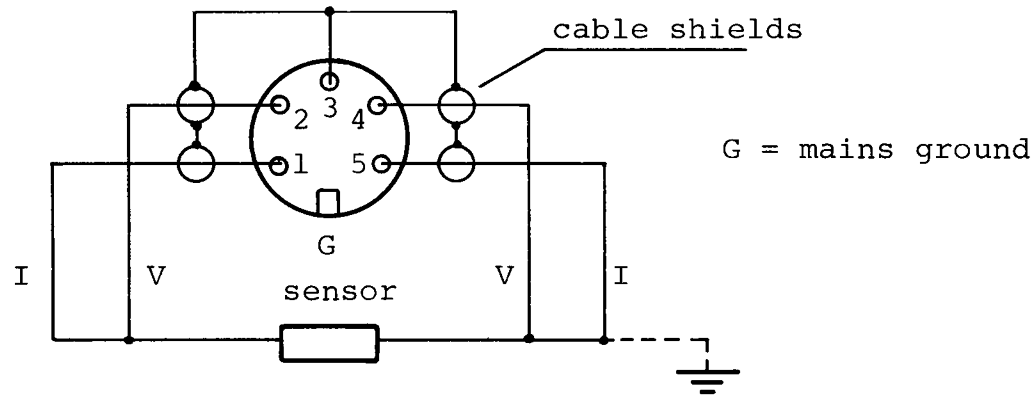

Fig.3. Input connector

NOTES:

1. Pin 5 of the input connector is instrument ground. It is not the same as the case of the unit. See sec. 10.3.
2. If one end of the sensor resistor is grounded (e.g. in the cryostat), this end must be connected to input pin 5.
3. At least the leads from pins 1 and 2 to the sensor must be shielded. It is recommended to use separate coaxial cables for each lead. It is necessary to shield the leads from pins 4 and 5 to the sensor only when the lead resistances are exceptionally high.

10.2. TWO-WIRE MEASUREMENT

The AVS-45 can also be used for 2-wire measurements by connecting pins 1 and 2 together, and pins 4 and 5 together. At least the cable from pins 1&2 should be shielded.

It is possible to use the shield of the cable as the sensor cold-lead, but care must be taken to avoid any ground loops.

The error caused by two-wire configuration cannot be observed if the lead resistances are small compared to the resistance of the sensor. If the lead resistance is high, but remains constant, two-wire measurements can still be made by using the AVS-45 in ΔR-display mode and nulling the lead resistance by the REFERENCE helipot.

10.3. GROUNDING

The mains ground is connected to the instrument case, as required by safety regulations.

THERE IS NO INTERNAL CONNECTION BETWEEN CIRCUIT GROUND AND MAINS GROUND. THEREFORE, THIS CONNECTION MUST BE MADE EXTERNALLY.

1. FLOATING SENSOR — Solder jumper from pin No.5 of the input plug to the instrument case (=metal parts of the plug). Connect pin 3 to the cable shields. Do not connect the shields to any other ground, than pin 3 of the input plug.

2. GROUNDED SENSOR — Take care that the grounded end of the sensor is connected to pin 5 of the input plug. Do not connect the cable shields to any other ground than pin 3 of the input plug.

NOTE: If the cable shields are connected to ground e.g. at the cryostat, the lead capacitance compensation will no longer be effective. The bridge will, however, operate properly at low resistance ranges without any appreciable loss of accuracy

11. SELECTING THE EXCITATION

The AVS-45 is so constructed that the voltage across the REFERENCE RESISTOR is always equal to the excitation voltage V_{exc}. Six values for V_{exc}, ranging from 10 µV to 3 mV, can be selected by the EXCITATION UP/DOWN switch. The excitation current flowing through the sensor R_x is $I_{exc} = V_{exc}/R_r$, and the power dissipated in the sensor

$$P_d = (V_{exc}^2/R_r) \cdot R_x/R_r \ .$$

In the middle of the scale, where $R_x/R_r = 1$ (display = 10 000), the dissipation (Watts) is given in the following table:

V_{exc}	RESISTANCE 10	100	1k	10k	100k	1M
10	10^{-11}	10^{-12}	10^{-13}	10^{-14}	10^{-15}	10^{-16}
30	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}	10^{-15}
100	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
300	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}
1000	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}
3000	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}

In cryogenic applications, there will always be a tradeoff between self-heating effects of the sensor and the available resolution of the measuring instrument.

11.1 AUTOMATIC CHANGE OF EXCITATION

If the AVS-45 is operated in AUTORANGE mode, and if the AUTO/MANUAL EXCITATION switch is in AUTO position, then the excitation is changed automatically simultaneously with the range upwards or downwards. The result of this arrangement is that in the middle of the scale the dissipation power is always the same independent of the range. It is thus possible to keep the variations in sensor dissipation within one order of magnitude.

An excitation memory prevents the bridge from "forgetting" its range/excitation setting, if the automatic operation should require positions below 10 μV or above 3 mV. The following example illustrates the use of this memory.

Suppose that a 100-ohm carbon resistance sensor is to be cooled down to millikelvin region, where the final resistance will be e.g. 100 kohms. If 10^{-14} Watts dissipation gives at that temperature the best resolution/self-heating compromise, the excitation voltage must be 30 μV. Determine the starting point for the excitation by first setting it to 10 μV. Then lift and release the EXC switch two times. When cooling the sensor, the excitation voltage will now remain 10 μV for ranges 100Ω , 1k and 10k, and then rise to 30 μV for 100 kohm range.

NOTE 1. The excitation memory has five positions below 10 μV and five positions above 3 mV.

NOTE 2. In case of resistances below 1.8 ohms of above 2 Megaohms, the AVS-45 will end up to continuous underrange or overrange condition. The autoexcitation operations will continue until the memory is either in its lowest or highest state, respectively.

NOTE 3. The automatic change of excitation does not occur, if the AUTO/MANUAL RANGE switch is in MANUAL position.

12. ANALOGUE OUTPUTS

The AVS-45 is equipped with two analogue outputs, RECORDER and DEVIATION.

The RECORDER output ranges from 0 to + 2.000 Volts and it is directly proportional to the sensor resistance. This output can be accurately scaled using P506. Its stability may not be as high as that of the digital display.

The DEVIATION output is the voltage difference between the RECORDER output and a voltage, determined by the setting of the REFERENCE helipot. This output also exhibits a very good stability. The scale factor can be adjusted by P403 and the scale factor in Rx10 mode is set by using P404. The DEVIATION output is useful for recording small resistance changes with a chart recorder. It can also be used as an input signal for a temperature controller.

The impedance of the both analogue outputs is 1 kohm, and they are short-circuit proof.

NOTE: The jackets of the both rear panel BNC connectors are connected to the circuit ground, NOT TO THE CASE OF THE INSTRUMENT. Be careful to avoid ground loops, as many laboratory instruments, especially oscilloscopes, use BNC connectors whose jackets are connected to the mains ground. See also sec. 10.3.

13. OPERATION IN ΔR-DISPLAY MODE

13.1. SETTING THE DEVIATION REFERENCE

The front panel REFERENCE helipot is scaled only roughly. A more precise setting of the deviation reference is made by pressing the REF switch at the front panel. The display then indicates the present reference voltage. The REF switch can be used in both R and ΔR display modes.

13.2 ΔR-MODE

The ΔR-mode is indicated by yellow light. In this mode, the display is connected to the DEVIATION output, and it shows the difference between the measured sensor resistance and the setting of the REFERENCE helipot.

This mode is especially useful in two-wire measurements, where the lead resistances can be cancelled by suitable reference setting. ΔR mode can also be used to extend the measuring range of the AVS-45 from 20000 to 40000. Using the short-circuit plug, set the REFERENCE helipot so that zero resistance gives a reading of -19999. Then, of course, you have to add 20000 to all readings.

NOTE: Autorange operations are coupled to the displayed resistance. Therefore, in ΔR mode underrange condition and consequent change of range may arise even at high sensor resistances.

13.3. ΔRx10-MODE

Tenfold sensitivity within a limited 10% range is obtained by selecting ΔRx10 mode (rear panel switch in upper position).

NOTE: The decimal point will not be shifted, so that in this mode the displayed resistance values must be divided by ten in order to get the result in proper units.

The reference is set as in ΔR mode. Accurate setting with the helipot can be difficult, but the front panel offset trimmer may be used for vernier adjustment.

13.4. 2 OHMS RANGE

An additional range from 0 to 2 ohms with 100 micro-ohm resolution is available for the measurement of very low resistances. Select 20 ohms range, ΔRx10 mode, 3 mV excitation and slow response (for best resolution). Turn the REFERENCE helipot to zero and lock the dial. Connect a short-circuit plug to the input and null the display by turning the offset trimmer with a small screwdriver.

Autoranging operates as usually. It is recommended that the unit be kept in ΔRx10 mode until the end of the measurement, as the change from ΔRx10 to ΔR or R mode would introduce errors unless the offset is adjusted again. Operation is possible up to 200 kohms.

Because the decimal point is not shifted, but corresponds to the original 20 ohms range, all readings must be divided by ten in order to obtain the results in proper units.

P404 can be used to adjust the scale factor of the ΔRx10 mode, but this adjustment requires an external reference.

13.5. OFFSET ADJUSTMENT DURING MEASUREMENT

Because of the difference formation and additional DC-amplification, ΔRx10-mode is more susceptible to offset drift than ordinary resistance ranges. Careless touching of the helipot during measurement may also shift the zero introducing errors that are difficult to realize. It is, however, relatively easy to check the offset from time to time using the short-circuit plug following the instrument.

If the AVS-45 has been modified for 10 µohm resolution (optional low-ohm version) then a short-circuit plug is no longer accurate enough for nulling the lowest 0.2 ohm range. An advantage of the 4-wire configuration is that THE VOLTAGE LEADS MAY BE INTERCHANGED. The actual resistance between the voltage leads will "change sign" whereas any offset will remain unchanged.

If the original reading is denoted by R1 and the reading after lead inversion is -R2, then the offset is R_{offs}= (R1-R2)/2 and the real sensor resistance $R_x = R1 - R_{offs}$.
After this calculation the offset can be easily zeroed using the front panel offset trimmer to change the display by the amount $-R_{offs}$.

The voltage lead inversion is best accomplished using a double-pole-double throw switch. If you deal with high impedance levels, too, the switch and all wiring should be shielded.

The method described above makes it possible to determine zero resistance (superconductive transition) to an accuracy of ± 10 µohms with the AVS-45 irrespective of lead resistances and without difficult arrangements for checking the offset. Voltage lead inversion should not be used if the display is above middle scale.

14. COMPENSATION OF THE LEAD CAPACITANCE

Square-wave excitation is used in the AVS-45 for best linearity and stability. This waveform contains high frequency components which are attenuated by capacitances in the sensor leads, resulting in a shunt effect across the sensor.

A unique feature of the AVS-45 is the bootstrapping of the input leads. This is made by connecting the cable shields to a voltage equal to that across the sensor (note that one end of the sensor is tied to the circuit ground). The output impedance of the bootstrapping supply (pin 3 of the input plug) is low, 10 ohms.

Although this compensation technique does not completely eliminate the capacitance effects, it greatly improves the linearity at 2 Megohm range, and it tolerates a capacitance of at least 10 nF with only 1% total error at 1 - 2 Megohm impedance level.

No adjustments are necessary for using the compensation for various cable lengths. The capacitance across the sensor itself should be minimized, as this cannot be automatically compensated. Also the capacitance from the sensor to the ground should be as small as possible.

The trimmer P103 (preamplifier pcb) can be used to compensate for normal small capacitances across the sensor. It is, however, necessary to know the capacitance of the sensor to make this adjustment. If the capacitance C_s is known, connect 1 Megohm, 0.01% resistor to the input, parallel with a capacitor equal to C_s , and adjust P103 until the reading is 1.0000 (2 Megohm range must be used).

15. DIGITAL OUTPUT AND REMOTE CONTROL INPUT

The digital output signals and the remote control input are all wired to a single rear panel connector, Cannon type DC 37S. This connector also has space reserved for control signals of the optional input multiplexer. All outputs are CMOS compatible (5V). For pin assignments, refer to table on page 15-3.

15.1. DESCRIPTION OF THE SIGNALS

BCD DATA

The binary coded decimal bits 2^3, 2^2, 2^1 and 2^0 are positive logic signals that go on simultaneously with the digit driver.

DIGIT DRIVERS

The digit drivers are positive going signals that each last for 200 clock pulses. 1 clock pulse = 8 µs for 50 Hz mains and 6.66 µs for 60 Hz mains. The scan sequence is D_5(MSD), D_4, D_3, D_2 and D_1(LSD). The scan is continuous unless an overrange occurs.

POLARITY

Positive for positive input signal. Zero for negative input.

BUSY

High during signal-integrate and reference-integrate periods. Low during auto-zero phase of the DVM. One cycle of BUSY corresponds to one A/D-conversion cycle.

$\overline{\text{STROBE}}$

This is a negative going pulse that aids in transferring the BCD data to external latches, UARTs or microprocessors. There are 5 negative going $\overline{\text{STROBE}}$ pulses that occur in the center of each of the digit drive pulses and occur once and only once for each measurement cycle, starting 101 pulses after the end of the full measurement

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cycle. Digit 5(MSD) goes high at the end of the measurement cycle and stays on for 201 counts. In the center of this digit pulse the first $\overline{\text{STROBE}}$ pulse goes negative for 1/2 clock pulse width. Similarly, after 200 clock pulses, digit 4 goes high and 100 pulses later the $\overline{\text{STROBE}}$ goes negative for the second time. This continues through digit 1(LSD) when the fifth and last $\overline{\text{STROBE}}$ pulse is sent. The digit drive will continue to scan, but no additional $\overline{\text{STROBE}}$ pulses will be sent until a new measurement is available.

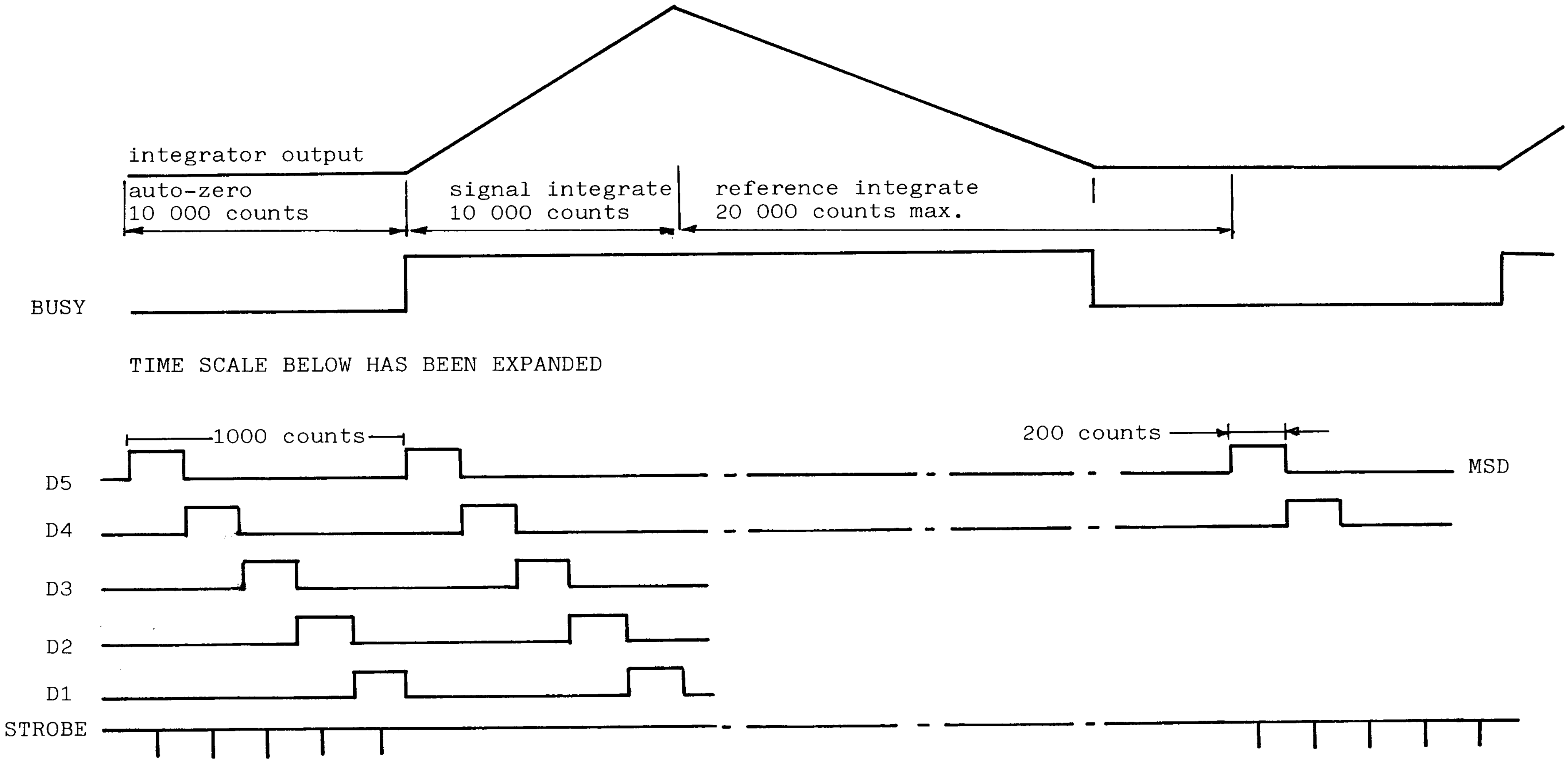
EXCITATION — Six bits indicating, which one of the six available excitation voltages is used. Only one bit can be high at a time.

RANGE — Six bits indicating the selected resistance range. Only one bit at a time is high. Only the fundamental resistance ranges are indicated, not R or Rx10 -modes.

EXCITATION UP
EXCITATION DOWN
RANGE UP
RANGE DOWN — The remote control inputs can be used to set the bridge into the desired state. These four inputs must be connected to open-collector drivers for proper operation of the manual switches and autoranging circuitry. All lines have internal 200 kohm pull-up resistors that are connected to +5 volts. Each negative going pulse applied to these inputs changes the excitation or range to the next higher or lower state. Minimum width of these pulses is 20 ms for 50 Hz mains and 17 ms for 60 Hz mains.

15.2 DIGITAL OUTPUT AND REMOTE CONTROL INPUT CONNECTOR PIN ASSIGNMENTS

Pin No	DESCRIPTION
1	+ 5 V
2	GROUND
3	N.C. (input multiplexer: 2^1)
4	N.C.
5	20 ohm range
6	2 kohm range
7	200 kohm range
8	RANGE DOWN
9	EXC DOWN
10	300 uV excitation
11	30 uV excitation
12	10 uV excitation
13	+ 5 V
14	$\overline{\text{STROBE}}$
15	10^4 (MSD)
16	10^2
17	10^0 (LSD)
18	2^2
19	2^0 (LSB)
20	GROUND
21	N.C. (input multiplexer: 2^2)
22	N.C. (input multiplexer: 2^0)
23	N.C.
24	200 ohm range
25	20 kohm range
26	2 Megaohm range
27	RANGE UP
28	EXC UP
29	3000 uV excitation
30	100 uV excitation
31	1000 uV excitation
32	POLARITY
33	BUSY
34	10^3
35	10^1
36	2^3 (MSB)
37	2^1



1 count = 8 µs for 50 Hz mains and 6.67 µs for 60 Hz mains frequency

TIMING DIAGRAM OF THE STANDARD DIGITAL OUTPUT

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16. CALIBRATION

The following simple recalibration procedure is recommended whenever the performance check described in Section 8 indicates non-satisfactory operation of the bridge. Although only a small screwdriver and a short-circuit input plug are necessary for recalibration, a chart recorder will also be useful for adjusting the scale factors of the low excitation ranges. Proceed as follows:

1. Select manual operation, R-display, 2 kohm range, 3 mV excitation voltage, MEAS-mode, SLOW time constant and connect all input pins 1-5 together with the short-circuit plug. Let the unit warm up for at least half an hour at normal operating temperature (if the bridge is to be used at some exceptional temperature, the calibration should be made at this temperature for best results).
2. Null the offset, if any, by adjusting the front panel OFFSET trimmer.
3. Switch the bridge into CAL mode.

4. Adjust the display to 10 000 by the front panel SCALE trimmer. Check other resistance ranges. The discrepancy between ranges should not exceed ± 2 digits (± 20 for 10 ohm)
5. Remove the top cover of the instrument. Reduce the excitation voltage to 1 mV. Adjust the reading to 10 000 by trimmer P501. Repeat this adjustment for all remaining excitation voltages (300 µV : P502, 100 µV : P503, 30 µV : P504 and 10 µV : P505).
6. Turn back to 3 mV excitation, MEAS mode, and select R display. Connect a short-circuit plug to the input and turn the REFERENCE helipot to zero. The offset should be within ± 10 LSD. Then switch the unit into CAL mode. The display should be 10 000 + offset. If not, adjust P403 until correct reading is obtained.

This completes the field-calibration procedure.

NOTE 1. At low excitation voltages it may be difficult to determine the true (=mean) value of the display. The adjustment can be aided by connecting a chart recorder to the deviation output. Center the pen by the REFERENCE helipot at 3 mV excitation, and make the adjustment of step 5 so that the mean value of the graph at all excitations falls to the center line.

NOTE 2. If accurate calibration of the RECORDER or DEVIATION output is required, the following step should be performed before proceeding from step 3 to step 4: Connect a high quality, at least 4 1/2-digit, DVM to RECORDER output and adjust P501 so that the external DVM reads 1.0000 Volts. The change in AVS-45 front panel display is compensated using the front panel SCALE trimmer. The adjustment of P501 does not affect the mutual alignment of the excitation ranges.

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17. INPUT MULTIPLEXER OPTION

17.1 GENERAL

The optional input multiplexer is a set of seven four-contact relays. A digital word of three bits is used to select one relay at a time. The number of the selected input channel is displayed by an extra (smaller) digit at the front panel.

The 28 sensor lines plus 7 lines for bootsrapping the shielded cables (see sec. 14.) are all wired to a common 37-pole connector at the rear panel (Cannon DC37S). The output sides of the relays are connected in parallel, and this common output (4 leads) is in turn connected in parallel with the front panel input connector.

If no digital information for selecting the sensor is applied to the control input of the multiplexer, then all relays remain open and the front panel input may be used normally. This state is indicated by blanking the sensor display. As soon as the multiplexer is used (at least one of the selector bits is high), the front panel input must be disconnected from any resistance.

17.2. CONTROL

The control data is applied to the digital output/remote control input connector at the rear panel according to table 17-1.

TABLE 17-1

pin number			
21	3	22	state
0	0	0	front panel connector active alone
0	0	1	sensor 1 connected
0	1	0	" 2 "
0	1	1	" 3 "
1	0	0	" 4 "
1	0	1	" 5 "
1	1	0	" 6 "
1	1	1	" 7 "

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NOTE 1. Logic levels: 0 = ground, 1 = +5 Volts
Ground is available at pin 2. +5 Volts is connected to pin 1.

NOTE 2. +5 Volts provided by the data output connector is intended as a supply for simple interface circuits only. Current drawn from this supply should be limited to 10-20 mA.

The multiplexer has been implemented using CMOS logic, and the control input is shown in Fig. 17-1.

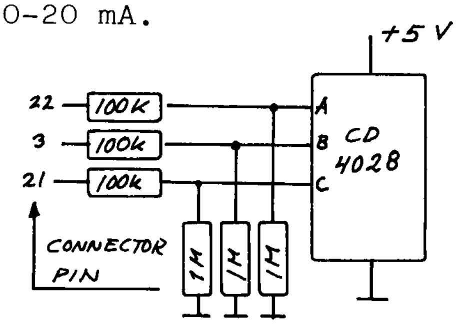

FIG. 17-1

17-3. SENSOR CONNECTION

Four separate leads, I_1, V_1, V_2 and I_2 are provided for each sensor. I_2 is circuit ground, and if a grounded sensor is used, the grounded end must be connected to I_2-lead. Because the ground leads for each sensor are separate, the sensors may be grounded to different points without causing ground loops.

NOTE If a floating sensor is used, then I_2 -lead must be externally connected to the case of the instrument (= mains ground).

Table 17-2 shows the pin configuration of the rear panel sensor connector.

TABLE 17-2

sensor No.	I_1	V_1	V_2	I_2	shield
1	1	20	2	21	3
2	22	4	23	5	24
3	6	25	7	26	8
4	27	9	28	10	29
5	11	30	12	31	13
6	32	14	33	15	34
7	16	35	17	36	18

18. PARALLEL TTL OUTPUT OPTION

18.1. GENERAL

The parallel TTL output option is built in a separate box, which is connected to the digital output/remote control input connector of the AVS-45. The power for the output unit is supplied by the resistance bridge.

Because our standard 37-pole connector is used on the output side of the unit, all information present at the AVS-45 output connector cannot be transferred to the parallel output. This is due to the need of 17 parallel BCD lines compared with the 9 lines of the serial output. The omitted signals are those for remotely controlling the range and excitation. However, the lines for controlling the input multiplexer are wired to the parallel output connector.

18.2. DESCRIPTION OF THE OUTPUT SIGNALS

BCD DATA

BCD data consists of 4 x 4 bits + 1 bit (MSD). The data is updated simultaneously every 0.32 seconds (50Hz) or every 0.266 seconds (60Hz). The updating of the data is effected by the rising edge of the BUSY signal.

Data is valid typ. 20 ns after the positive transition of BUSY, and it is valid always during the negative transition of BUSY.

BUSY

BUSY is high during signal-integrate and reference-integrate periods of the A/D-converter, and low during auto-zero phase. The duty cycle of BUSY is dependent on the input voltage of the A/D-converter.

UPDATE II

The digit scan of the serial output from D5 to D1 (LSD) is continuous. After each completed A/D-conversion five negative-going strobe pulses, occurring in the middle of each digit select pulse, are provided by

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the A/D-converter. These pulses clock the new data into latches IC7, 8, 9, 10 and 11. The last strobe pulse sets a flip-flop so that UPDATE II goes high.

Although the digit scan goes on, no more strobe pulses are sent until a new conversion cycle has been completed.

UPDATE I

UPDATE I is an input signal used to reset UPDATE II into low state. Reset action is static and takes place when UPDATE I goes low. Minimum reset pulse width is 0.5 µs. UPDATE I must be kept high always except during the reset pulse.

The purpose of the UPDATE I/II signals is to provide means for the computer to know, whether or not the data present at the output has been updated since last reading.

POLARITY

POLARITY is high for positive readings and low for negative readings.

RANGE

The six range bits determine the fundamental range. The output contains no information indicating whether the bridge is in R-mode, Rx10-mode or in the basic R-mode.

EXCITATION

The six excitation bits determine the excitation range. See also page 15-1.

MULTIPLEXER CONTROL

Can be used only if the multiplexer option has been installed. Refer to section 17.

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PART II SERVICE

CONTENTS

1. INTRODUCTION

Basically, the AVS-45 is an AC-ohmmeter which has been designed to operate at ultralow sensor dissipation power. In addition to the the AC-operation with six selectable excitation ranges, much of the complexity of the instrument is due to the real four-wire measurement technique. It is for this reason that two identical amplifier-feedback sections are needed: one for stabilizing the excitation current and the other for measuring the voltage across the sensor resistance. The bridge also incorporates a 4 1/2-digit A/D-converter and an autoranging circuitry.

The operating principle of the AVS-45 has been briefly discussed in Part I (Operating Instructions). This second part of the manual provides information for servicing or repairing the instrument. Whenever the data given turns out insufficient, please contact RV-Elektroniikka Oy, and we will be glad to give all possible assistance for solving your service problem.

2. CIRCUIT-BOARD ORGANIZATION

The following symbols have been used in the wiring diagrams:

R	resistor
C	capacitor
D	diode
TR	transistor (also darlington and FET)
IC	integrated circuit
P	potentiometer (also trimmer)
J	connector
W	wire or wire terminal
RL	relay
LED	light-emitting diode
DY	display (7-segment LED display)
N	internal junction node

Although the instrument consists of only two printed circuit boards, the main board and the display, the serviceability of the unit has been greatly improved by dividing the whole circuit into six separate sections, which are later referred as "printed circuit boards". The PCB:s are:

1. Preamplifier — The Preamplifier PCB contains the two preamplifiers, +8 V regulator and the six precision reference resistors with reed relays selecting the range.
   All component numbers on the preamplifier PCB begin with number "1", e.g. R101, IC102 etc.

2. Logic — The Logic PCB contains circuitry necessary for selecting the range and excitation. It also drives the range relays and range and excitation LEDs.
   Component numbers begin with 2 (C206, D222...)

3. DVM — In addition to the 4 1/2-digit A/D-converter, this PCB also takes care of the autoranging function and drives the 7-segment display. The 2.5 Volt precision reference voltage is also generated on this PCB.

4. Amplifiers — Here the signals from the two pre-amplifiers are further processed by two variable-gain stages followed by phase-sensitive detectors and integrators. The deviation output signal is formed on this PCB, and this section also activates the indicator LEDs for amplifier overload and high lead resistance.

5. Choppers and attenuators — This PCB contains identical choppers for the reference, excitation and signal. Each chopped waveform is attenuated in 1:3:3:3:3:3 sequence. The desired signal level, which quadratically correlates with the desired excitation power, is selected via three analog multiplexers followed by buffers. Only one of the three attenuators is adjustable, and it is the one for signal channel.

6. Power supply — The power supply PCB also incorporates the 25/30 Hz sychronizing circuit.

3. WIRING BETWEEN THE PCBs

Each "printed circuit board" corresponds to one of the six wiring diagrams. The internal inputs and outputs for each diagram are called "nodes" in distinction from real circuit inputs or outputs. The nodes are designated by N (e.g. N101, N226 etc., where the first number identifies the PCB in question). Each node has its physical equivalence as an empty plated-thru circle by the side of the "circuit board", and is therefore easily accessible for measuring or monitoring (see the component layout figure).

The internal connections between the printed circuit boards are connections between two or several nodes. Notation N226/106/316 tells that node 26 of PCB number 2 is connected to node 6 of PCB number 1 and also to node 16 of PCB number 3. Looking at the DVM schematic, we find only N316/226. Note that now N106 is not mentioned, because both N316 and N106 are considered as inputs whereas N226 is considered as output driving these two inputs (generally: in case of an output, all loading inputs are mentioned, but in case of an input, only the driving output is mentioned).

The connections from the PCBs to external switches, connectors and potentiometers, or other components external to the PCB, are called "wires" (e.g. W603, W405...). The terminations of the wires are marked on the component layout figure and they are numbered according to the nearest PCB .

4. TROUBLE SHOOTING

4.1. GENERAL REMARKS

Always start the trouble shooting in CAL mode with the input disconnected. Problems associated with mains interference are hereby eliminated. Having first verified correct operation in CAL mode, you can turn your attention to the measuring arrangement, which may cause the misfunction in several ways: wrong lead grounded, ground loop, poor shielding, excessive capacitance across the sensor etc.

Some conclusions can be made from the nature of the misfunction (see also the block diagram):

- If the fault appears in the digital display, but the RECORDER and DEVIATION outputs are correct, check the DVM.
- If the RECORDER output is correct, but the DEVIATION is not, check the differential amplifier IC412.
- If the misfunction (in CAL mode) depends on the resistance range, check the range relays and the range selector signals.
- If the misfunction depends on the excitation, check the excitation selector signals, attenuators and variable gain amplifiers.
- If the fault is seen only in FAST response mode, check the FETs TR403, 404, 407 and 408.

4.2. TROUBLE SHOOTING PROCEDURE

It rather straightforward to decide whether the fault lies in the analogue section, in the DVM or in the range and excitation logic. The recommended step-by-step procedure is limited to the analogue section only, whereas a functional description is given about the logic circuits.

Before starting the trouble shooting,

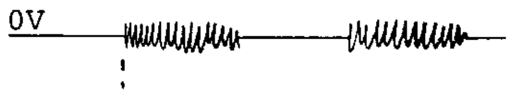
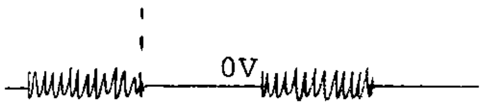
- let the unit warm up for at least five minutes
- switch the unit into MANUAL, SLOW, CAL mode, select R display, 3mV excitation and 2 kohm range.

NOTE 1) Ground is available for the oscilloscope probe or for the DVM at the minus-pole of C608.

NOTE 2) When checking the higher resistance ranges, the circuit ground and the mains ground (chassis) must be interconnected.

NOTE 3) Use a 10 kohm resistor as the probe when you measure the preamplifier bias voltages. This will prevent oscillations due to the long DVM leads and large input capacitance.

CHECK	COMMENTS
1. Internal voltages: N604: +15V ± 5% DC 605: 0V 606: -15V ± 5% DC 607: + 8V -"- DC 608: 0V 609: + 5V ± 5% DC 610: 0V	Mains fuse blown Defective regulator Defective transformer Short-circuit loading the supply
2. Synchronization: N601: Square-wave -10V to +15V 25/30Hz N602: Same as above but opposite phase N603: Square-wave 0V to +5V 25/30 Hz	Short-circuit in choppers or PSD´s. Defective TR603 or 604 Schmitt-trigger (TR601-602) or flip-flop (÷2) IC601 not operating Short-circuit on pcb 2 (logic) or pcb 3 (DVM)
3. Precision DC-reference: N302: +2.5V ± 1% DC	Defective IC 303 Short-circuit on pcb 3, 4 or 5.
4. Reference chopper: Tp 1 (R501): -2.5V DC Tp 2 (R506): Square-wave -2.5V to +2.5V 25/30Hz (2.5Vrms)	Defective IC501 or IC502 " D501 or D502 " TR501 or TR502 NOTE: TR501/502 gate is connected to case and shall swing from -10V to +2.5V (TR501) or from -10V to -2.5V (TR502).
5. Reference attenuator: N506: Square-wave -2.5V to +2.5V (2.5Vrms)	3mV excitation not selected Incorrect excitation selector signals: pins 9, 10 and 11 of IC503 must be high, high and low, respectively. Buffer IC504 defective
6. Reference preamplifier: N108: Bias +4 to +6.5V DC. Noise and mains interference below 20mVpp AC	Incorrect biasing due to changes in component values. Refer to circuit schematic for other test points. Regulator IC101 (+8V) defective. Broken input lead or defective CAL/MEAS switch Defective relay RL101...RL106 Range selector signal N101-106 missing. Check the range logic.
7. Variable gain amplifier (reference section): Tp 3 (R407): DC level same as that of N108. AC level 1.7 times that of N108.	Defective amplifier IC401 or analog multiplexer IC402.

CHECK	COMMENTS
8. Phase-sensitive detector (reference section): Tp 4 (R408) waveform:  Tp 5 (R409) waveform:  	Defective TR401 or TR402 NOTE: TR401/402 gates are connected to transistor case and shall swing from -10V to appr. 0V. (25/30Hz)
9. Reference integrator:	Defective IC403
Tp 6 (R413): +1V DC (NOTE: +2V at 20 ohm range)	Leak in capacitors C403 or 404
N406: same as Tp 6	Defective IC409
10. Excitation chopper:	Defective IC509
Tp 7 (R556): -1V DC (-2V at 20 ohm range)	Defective D505,506, TR505 or 506
Tp 8 (R561): square-wave -1V to to +1V (-2V to +2V at 20 ohm range)	NOTE: TR501/502 gates are connected to transistor case and shall swing from -10V to +1V (to +2V at 20 ohm range) Defective IC 510
11. Excitation attenuator	
N508: square-wave -1V to +1V (-2V to +2V at 20 ohm range)	Defective IC511 Defective IC512

POSITIVE RESULTS FROM ALL THE ABOVE CHECKS INDICATE THAT THE REFERENCE AND EXCITATION SECTIONS ARE WORKING PROPERLY IN CAL MODE AND THAT AN EXCITATION SIGNAL OF CORRECT MAGNITUDE IS GENERATED. THE PURPOSE OF THE REMAINING STEPS IS TO VERIFY THE OPERATION OF THE SIGNAL SECTION.

CHECK	COMMENTS
12. Signal preamplifier N110: +4 to +6.5V DC. Noise and mains interference below 20mVpp AC	Incorrect DC-biasing. Refer to circuit schematic for test points and voltages.
13. Variable gain amplifier (signal section)	
Tp 9 (R427): DC-level same as that of N110. Noise level and mains interference 1.7 times that of N110.	Defective IC404 or IC405

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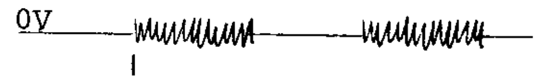
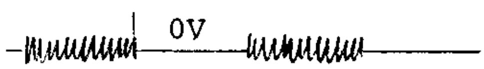
CHECK	COMMENTS
14. Phase-sensitive detector (signal section): Tp 10 (R428) waveform:  Tp 11 (R429) waveform: 	Defective FET TR405 or 406 NOTE: TR405/406 gates are connected to transistor case and shall swing from -10V to 0V. If the DC-level of the non-grounded portion of the signal deviates from zero, then - there is no signal feedback - C412 is leaking - integrating capacitors are leaking - IC 406 is defective (large offset)
15. Signal integrator N409: +1V DC	Defective IC406 or leaking capacitor C413 or C414 Short-circuit loading the IC406 output Defective IC407 input
16. Signal chopper Tp 12 (R528): -1V DC Tp 13 (R534): square-wave -1 to +1V	Defective IC505 Defective D503, 504, TR503 or 504 Defective IC506
17. Signal attenuator N508: square-wave -1V to +1V	Defective IC507 or 508

If the bridge works correctly at 3mV excitation, but at other excitation(s) it shows remarkable deviations from 10 000, which cannot be calibrated by trimmers P501-505, proceed as follows: Reduce the excitation step by step, performing checks 5, 7, 11, 13 and 17 every time until the faulty amplifier or attenuator is found.

4.3. THE DVM AND THE AUTORANGING CIRCUITRY

The DVM pcb contains the 125/150 kHz oscillator, an analogue-to-digital converter, decoder and display drive, 4 1/2-digit display (separate vertical printed circuit board) and autoranging circuitry.

The clock frequency of the oscillator IC304 is set by trimmer P302 to 125 kHz for 50Hz mains and to 150 kHz for 60Hz mains. The signal integrating period of the A/D-converter will then be 80 ms or 66.6 ms for 50 and 60 Hz mains, respectively. This arrangement results in the best rejection of both 50/60 Hz mains interference and 25/30 Hz chopper frequency.

The A/D-converter is implemented with IC305 and IC306, and for closer description of these LSI circuits we refer to Intersil data sheet (ICL 71C03 / 8052 Pair).

The multiplexed BCD data from the A/D-converter is applied to BCD-to 7-segment decoder IC307. Diodes D315-321 and resistors R320-326 are used to change the high state voltage level of the segment outputs appr. 0.7V upwards making the display brighter. IC308 performs the gating needed for leading zero suppression.

The autoranging circuitry has two tasks: to produce separate down-going pulses for changing the range and/or excitation, which are initiated by OR and UR signals from the A/D-converter IC305, and to provide a 5 sec delay between two adjacent autoranging operations. Autoranging can be inhibited by S301 and autoexcitation by S302.

An up-going edge of the underrange or overrange pulse (UR or OR) triggers the second half of IC309, which in turn triggers the first half of the said dual flip-flop. A down-going edge is now formed by either the first or the second quarter of IC301, depending on UR or OR condition, respectively.

Corresponding pulses for changing the excitation are formed by the two remaining gates of IC301, if the autoexcitation is not inhibited by opening switch S302.

As the second half of IC309 goes to high state, the reset input of IC310 goes low. IC310 now starts to count the 25Hz frequency supplied by the mains sychronization circuitry. The fourth 25Hz cycle (Q2) resets the first half of IC309, thereby ending the autorange/autoexcitation pulses. The 128th cycle (Q8) finally resets the first half of IC309, making the circuit ready for a new autorange operation. This 5 sec delay has been included to allow the bridge settle before changing the range again.

4.4. THE RANGE AND EXCITATION LOGIC

The range is selected by one of the six range selectors N226-231 which drive the range relays and range indicator LEDs.

The range counter IC207 is incremented by lifting the RANGE UP/DOWN switch S201. This enables the 25 Hz sychronizing signal to trigger IC204 (first half) into low state. After S201 has been released, the next 25 Hz cycle brings IC204 back to high state. This positive-going transition is the clock signal for the up-count input of IC207. The conter´s binary output is decoded into six decimal states by decoder IC208. The inverting transistor stages TR201-206 provide the power amplification necessary to drive the range relays and LEDs.

In a similar manner, the range counter is decremented by pressing and releasing the RANGE UP/DOWN switch.

What was said about the incrementing and decrementing of the range counter applies also to the excitation counter IC205 (lift/press and release S202), but now the decoding of the binary output is made in another way.

IC209 performs the binary-to-decimal decoding of the eight lowest states from "0" to "7". All outputs of IC206 remain low, because the 2^3-output of IC205 has been inverted by IC202, and therefore a high state is applied to the 2^3-input of IC206. From "8" to "15", the 2^3-output of IC205 is high, inhibiting the decoding action of IC209 but enabling the operation of IC206. States from "0" to "5" are further reduced into one single state (10 uV excitation) by diodes D217-222 and states from "10" to "15" also into a single state (3 mV excitation) by diodes D211-216. This arrangement provides a simple "excitation memory".

The reduced six excitation selector signals are then decoded back to binary form suitable for controlling the attenuators (pcb no 5) and variable gain amplifiers (pcb no 4).

PARTS LIST

PART No.	DESCRIPTION			MFR
R101	100k	metal-film resistor	1%	
R102	30k1	"	0.25%	HOL
R103	30k1	"	0.25%	"
R104	100R	"	0.25%	"
R105	100R	"	0.25%	"
R106	1k	"	1%	
R107	15k	"	"	
R108	15k	"	"	
R109	1k5	"	"	
R110	1k0	"	"	
R111	47k	"	"	
R112	10k	"	"	
R113	10k	"	"	
R114	33k	"	"	
R115	3k3	"	"	
R116	33k	"	"	
R117	100R	"	"	
R118	4k7	"	"	
R119	33k	"	"	
R120	200k	"	"	
R121	200k	"	"	
R122	75k	"	0.25%	HOL
R123	75k	"	0.25%	"
R124	100R	"	0.25%	"
R125	100R	"	0.25%	"
R126	100k	"	1%	
R127	15k	"	"	
R128	15k	"	"	
R129	1k5	"	"	
R130	1k0	"	"	
R131	47k	"	"	
R132	10k	"	"	
R133	10k	"	"	
R134	33k	"	"	
R135	3k3	"	"	
R136	33k	"	"	
R137	3k01	"	"	
R138	4k7	"	"	
R139	33k	"	"	
R140	200k	"	"	
R141	200k	"	"	
R142	10R	"	"	
R143	10R	Wirewound resistor	0.01%	GEN RES
R144	100R	"	0.01%	"
R145	1k	"	0.01%	"
R146	10k	"	0.01%	"
R147	100k	"	0.01%	"
R148	1M	"	0.01%	"
R149	680R	metal-film resistor	1%	
R150	3k01	"	"	
R151	10R	"	"	
R152	20k	"	"	

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PART No.	DESCRIPTION	MFR
P101	50k trimpot 63X	SPECTROL
P102	100R " "	"
P103	20k " 63P	"
P104	500R " 63P	"
D101	BAY 73 low-leakage diode	FAIRCHILD
D102	" "	"
D103	" "	"
D104	" "	"
D105	" "	"
D106	" "	"
D107	" "	"
D108	" "	"
C101	33p ceramic capacitor	ITT
C102	3p9 "	"
C103	1nF polystyrene capacitor	PHILIPS
C104	1000uF/16V electrolytic capacitor	ITT
C105	1000uF/16V "	"
C106	2u2 solid tantalum cap.	"
C107	2u2 "	"
C108	33pF ceramic capacitor	"
C109	1nF polystyrene capacitor	PHILIPS
C110	1000uF/16V electrolytic cap.	ITT
TR101	IMF 6485 dual-FET	INTERSIL
TR102	2N 3904 transistor npn	NATIONAL
TR103	2N 5087 " pnp	FAIRCHILD
TR104	2N 5087 " "	"
TR105	2N 5087 " "	"
TR106	2N 5087 " "	"
TR107	MPS-A14 transistor darl. npn	MOTOROLA
TR108	IMF 6485 dual-FET	INTERSIL
TR109	2N 3904 transistor npn	NATIONAL
TR110	2N 5087 " pnp	FAIRCHILD
TR111	2N 5087 " "	"
TR112	2N 5087 " "	"
TR113	2N 5087 " "	"
TR114	MPS-A14 transistor darl. npn	MOTOROLA
RL101	PRMA 2A12 reed relay	CLARE
RL102	" "	"
RL103	" "	"
RL104	" "	"
RL105	" "	"
RL106	" "	"
LED101	CQV23-4 light emitting diode	SIEMENS
IC101	uA7808UC 8V regulator	FAIRCHILD

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PART No.	DESCRIPTION	MFR
R201	200k metal-film resistor 1%	
R202	200k " "	
R203	200k " "	
R204	200k " "	
R205	200k " "	
R206	33k " "	
R207	33k " "	
R208	33k " "	
R209	33k " "	
R210	33k " "	
R211	33k " "	
R212	470R " "	
R213	470R " "	
R214	470R " "	
R215	470R " "	
R216	470R " "	
R217	470R " "	
R218	200k " "	
R219	200k " "	
R220	33k " "	
R221	33k " "	
R222	33k " "	
R223	33k " "	
R224	33k " "	
R225	33k " "	
R226	470R " "	
R227	470R " "	
R228	470R " "	
R229	470R " "	
R230	470R " "	
R231	470R " "	
D201	1N 4148 switching diode	TEXAS INSTR.
D202	1N 4148 "	"
D203	1N 4148 "	"
D204	1N 4148 "	"
D205	1N 4148 "	"
D206	1N 4148 "	"
D207	1N 4148 "	"
D208	1N 4148 "	"
D209	1N 4148 "	"
D210	1N 4148 "	"
D211	1N 4148 "	"
D212	1N 4148 "	"
D213	1N 4148 "	"
D214	1N 4148 "	"
D215	1N 4148 "	"
D216	1N 4148 "	"
D217	1N 4148 "	"
D218	1N 4148 "	"
D219	1N 4148 "	"
D220	1N 4148 "	"
D221	1N 4148 "	"
D222	1N 4148 "	"

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PART No.	DESCRIPTION	MFR
C201	0.1uF/100V polyest. capacitor	EVOX
TR201	MPS-A14 transistor, darl., npn	MOTOROLA
TR202	MPS-A14 "	"
TR203	MPS-A14 "	"
TR204	MPS-A14 "	"
TR205	MPS-A14 "	"
TR206	MPS-A14 "	"
TR207	MPS-A14 "	"
TR208	MPS-A14 "	"
TR209	MPS-A14 "	"
TR210	MPS-A14 "	"
TR211	MPS-A14 "	"
TR212	MPS-A14 "	"
IC201	CD4013 CMOS dual D-flip-flop	NATIONAL
IC202	CD4011 CMOS quad nand-gate	"
IC203	CD4025 CMOS triple nor-gate	"
IC204	CD4013 CMOS dual D-flip-flop	"
IC205	MM74C193 CMOS up/down counter	"
IC206	CD4028 CMOS BCD-to-Decim. decoder	"
IC207	MM74C193 CMOS up/down counter	"
IC208	CD4028 CMOS BCD-to-Decim. decoder	"
IC209	CD4028 "	"
LED201	CQV25-3 light-emitting diode, green	SIEMENS
LED202	CQV25-3 "	"
LED203	CQV25-3 "	"
LED204	CQV25-3 "	"
LED205	CQV25-3 "	"
LED206	CQV25-3 "	"
LED207	CQV25-3 "	"
LED208	CQV25-3 "	"
LED209	CQV25-3 "	"
LED210	CQV25-3 "	"
LED211	CQV25-3 "	"
LED212	CQV25-3 "	"

3.7.84

PART No.	DESCRIPTION			MFR
R301	200k	metal-film resistor	1%	
R302	200k	"	"	
R303	3k32	metal-film resistor	0.25%	HOLCO
R304	2k21	"	"	"
R305	100R	metal-film resistor	1%	
R306	2k21	"	"	
R307	33k	"	"	
R308	300k	"	"	
R309	680R	"	"	
R310	300k	"	"	
R311	10k	"	"	
R312	10k	"	"	
R313	10k	"	"	
R314	10k	"	"	
R315	10k	"	"	
R316	10k	"	"	
R317	10k	"	"	
R318	10k	"	"	
R319	220R	resistor 0.5W , 5%		
R320	10k	metal-film resistor	1%	
R321	10k	"	"	
R322	10k	"	"	
R323	10k	"	"	
R324	10k	"	"	
R325	10k	"	"	
R326	10k	"	"	
R327	10k	"	"	
R328	47R	"	"	
R329	47R	"	"	
R330	47R	"	"	
R331	47R	"	"	
R332	47R	"	"	
R333	47R	"	"	
R334	47R	"	"	
R335 x	100R	"	"	
R336 x	100R	"	"	
R337 x	100R	"	"	
	x) located on the display pcb			
C301	2u2	solid tantalum capacitor		ITT
C302	2u2	"		"
C303	2u2	"		"
C304	3u3/100V	polyester capacitor		EVOX
C305	2nF	polystyrene capacitor		PHILIPS
C306	0.1uF/100V	polyester capacitor		EVOX
C307	1uF/100V	"		"
C308	0.1uF	polypropylene capacitor		ROEDERSTEIN
C309	220uF/16V	electrolytic capacitor		ITT

3.4.84

PART No.	DESCRIPTION	MFR
D301	1N 4148 switching diode	TEXAS
D302	1N 4148 "	"
D303	1N 4148 "	"
D304	1N 4148 "	"
D305	1N 4148 "	"
D306	1N 4148 "	"
D307	1N 4148 "	"
D308	1N 4148 "	"
D309	1N 751A zener diode 5.1V	FAIRCHILD
D310	1N 751A "	"
D311	1N 751A "	"
D312	1N 751A "	"
D313	1N 751A "	"
D314	1N 751A "	"
D315	1N 4148 switching diode	TEXAS
D316	1N 4148 "	"
D317	1N 4148 "	"
D318	1N 4148 "	"
D319	1N 4148 "	"
D320	1N 4148 "	"
D321	1N 4148 "	"
P301	500R trimmer resistor 63P	SPECTROL
P302	500R "	"
TR301	2N3906 transistor pnp	NATIONAL
TR302	2N3906 "	"
TR303	2N3906 "	"
TR304	MPS-A14 transistor darl. npn	MOTOROLA
TR305	MPS-A14 "	"
TR306	MPS-A14 "	"
TR307	MPS-A14 "	"
TR308	MPS-A14 "	"
TR309	2N3904 transistor npn	NATIONAL
TR310	2N3904 "	"
TR311	2N3904 "	"
TR312	2N3904 "	"
TR313	2N3904 "	"
TR314	2N3904 "	"
TR315	2N3904 "	"
TR316	2N3904 "	"

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PART No.	DESCRIPTION	MFR
IC301	CD4011 CMOS quad nand-gate	NATIONAL
IC302	CD4001 CMOS quad nor-gate	"
IC303	MC1403 2.5 Volt reference	MOTOROLA
IC304	LM555 timer	NATIONAL
IC305	ICL71C03 A/D-conv. subsystem. dig.	INTERSIL
IC306	ICL8052 A/D-conv. subsystem. ana.	"
IC307	CD4511 CMOS 7-segment decoder	NATIONAL
IC308	CD4011 CMOS quad nand-gate	"
IC309	CD4013 CMOS dual D-type flip-flop	"
IC310	CD4040 CMOS 12-stage bin. counter	"
DY301	MAN6980 7-segment LED display	GEN. INSTRUMENT
DY302	MAN6980 "	"
DY303	MAN6980 "	"
DY304	MAN6980 "	"
DY305	MAN6980 "	"

3.7.84

PART No.	DESCRIPTION			MFR
R401	10k	metal-film resistor	1%	
R402	1k0	"	"	
R403	3k3	"	"	
R404	100k	"	"	
R405	300k	"	"	
R406	33k	"	"	
R407	200k	"	"	
R408	100k	"	"	
R409	100k	"	"	
R410	15k	"	"	
R411	100k	"	"	
R412	100k	"	"	
R413	47k	"	"	
R414	10k	"	"	
R415	680R	"	"	
R416	15k	"	0.25%	HOLCO
R417	1k0	"	1%	
R418	15k	"	0.25%	HOLCO
R419	15k	"	"	"
R420	1M	"	1%	
R421	10k	"	"	
R422	1k0	"	"	
R423	3k3	"	"	
R424	100k	"	"	
R425	300k	"	"	
R426	33k	"	"	
R427	200k	"	"	
R428	100k	"	"	
R429	100k	"	"	
R430	15k	"	"	
R431	100k	"	"	
R432	100k	"	"	
R433	200k	"	"	
R434	200k	"	"	
R435	15k	"	"	
R436	680R	"	"	
R437	15k	"	"	
R438	10k	"	"	
R439	15k	"	"	
R440	15k	"	"	
R441	15k	"	"	
R442	15k	"	"	
R443	1k0	"	"	
R444	15k	"	0.25%	HOLCO
R445	4k75	"	"	"
R446	15k0	"	1%	
R447	150k	"	"	
R448	150k	"	"	
R449	15k0	"	"	
R450	2k21	"	"	

3.4.84

PART No.	DESCRIPTION	MFR
C401	1000uF/16V electrolytic capacitor	ITT
C402	220uF/16V "	"
C403	3u3/100V polyester capacitor	EVOX
C404	3u3/100V "	"
C405	0.33uF/100V polyester capacitor	"
C406	0.33uF/100V "	"
C407	33pF ceramic capacitor	ITT
C408	2u2/35V solid tantalum capacitor	"
C409	2u2/35V "	"
C410	220uF/16V electrolytic capacitor	"
C411	1000uF/16V "	"
C412	220uF/16V "	"
C413	3u3/100V polyester capacitor	EVOX
C414	3u3/100V "	"
C415	0.33uF/100V "	"
C416	0.33uF/100V "	"
C417	100pF ceramic capacitor	ITT
C418	33pF "	"
C419	1uF/100V polyester capacitor	EVOX
C420	220uF/16V electrolytic capacitor	ITT
P401	20k trimmer resistor 63P	SPECTROL
P402	20k "	"
P403	500R "	"
P404	500R "	"
D401	BAY73 low-leakage diode	FAIRCHILD
D402	BAY73 "	"
D403	1N4148 switching diode	TEXAS
D404	1N4148 "	"
D405	BAY73 low-leakage diode	FAIRCHILD
D406	BAY73 "	"
TR401	2N4392 JFET n-channel	NATIONAL
TR402	2N4392 "	"
TR403	2N4392 "	"
TR404	2N4392 "	"
TR405	2N4392 "	"
TR406	2N4392 "	"
TR407	2N4392 "	"
TR408	2N4392 "	"
TR409	2N3904 transistor npn	"
TR410	2N3904 "	"

3.7.84

PART No.	DESCRIPTION	MFR
IC401	LF13741 JFET-input op.ampl.	NATIONAL
IC402	CD4051 CMOS analog multiplexer	"
IC403	LM308A op.ampl.	"
IC404	LF13741 JFET-input op.ampl.	"
IC405	CD4051 CMOS analog multiplexer	"
IC406	LM308A op. ampl.	"
IC407	OP-07 low-offset op. ampl.	PMI
IC408	LF13741 JFET-input op.ampl.	NATIONAL
IC409	LF13741 "	"
IC410	LF13741 "	"
IC411	LM308A op.ampl.	"
IC412	OP-07 low-offset op. ampl.	"
LED401	CQV21-5 light emitting diode, red	SIEMENS
LED402	CQV21-5 "	"

3.4.84

PART No.	DESCRIPTION		MFR
R501	15k metal-film resistor	0.25%	HOLCO
R502	15k "	"	"
R503	200k "	1%	
R504	200k "	"	
R505	15k "	"	
R506	20k "	0.25%	HOLCO
R507	100R "	1%	
R508	100R "	"	
R509	15k "	0.25%	HOLCO
R510	20k "	"	"
R511	100R "	1%	
R512	100R "	"	
R513	15k "	0.25%	HOLCO
R514	20k "	"	"
R515	100R "	1%	
R516	100R "	"	
R517	15k "	0.25%	HOLCO
R518	20k "	"	"
R519	100R "	1%	
R520	100R "	"	
R521	15k "	0.25%	HOLCO
R522	20k "	"	"
R523	100R "	1%	
R524	100R "	"	
R525	20k "	0.25%	HOLCO
R526	20k "	"	"
R527	15k "	1%	
R528	15k "	0.25%	HOLCO
R529	15k "	"	"
R530	100R "	1%	
R531	1M "	"	
R532	200k "	"	
R533	200k "	"	
R534	20k "	0.25%	HOLCO
R535	100R "	1%	
R536	100R "	"	
R537	15k "	0.25%	HOLCO
R538	20k "	"	"
R539	100R "	1%	
R540	100R "	"	
R541	15k "	0.25%	HOLCO
R542	20k "	"	"
R543	100R "	1%	
R544	100R "	"	
R545	15k "	0.25%	HOLCO
R546	20k "	"	"
R547	100R "	1%	
R548	100R "	"	
R549	15k "	0.25%	HOLCO
R550	20k "	"	"

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PART No.	DESCRIPTION		MFR
R551	100R metal-film resistor	1%	
R552	100R "	"	
R553	20k "	0.25%	HOLCO
R554	20k "	"	"
R555	15k "	1%	
R556	15k "	"	
R557	15k "	"	
R558	15k "	"	
R559	200k "	"	
R560	200k "	"	
R561	20k "	"	
R562	15k "	"	
R563	20k "	"	
R564	15k "	"	
R565	20k "	"	
R566	15k "	"	
R567	20k "	"	
R568	15k "	"	
R569	20k "	"	
R570	20k "	"	
R571	20k "	"	
R572	15k "	"	
R573	2k2 "	"	
R574	2k2 "	"	
P501	20k trimmer resistor 63P		SPECTROL
P502	20k "		"
P503	20k "		"
P504	20k "		"
P505	20k "		"
D501	1N4148 switching diode		TEXAS
D502	1N4148 "		"
D503	1N4148 "		"
D504	1N4148 "		"
D505	1N4148 "		"
D506	1N4148 "		"
D507	1N751A zener diode 5.1V		FAIRCHILD
D508	1N751A "		"
TR501	2N4392 JFET n-channel		NATIONAL
TR502	2N4392 "		"
TR503	2N4392 "		"
TR504	2N4392 "		"
TR505	2N4392 "		"
TR506	2N4392 "		"

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PART No.	DESCRIPTION	MFR
IC501	LF13741 JFET-input op.amp.	NATIONAL
IC502	LF13741 "	"
IC503	CD4051 CMOS analog multiplexer	"
IC504	LF13741 JFET-input op. amp.	"
IC505	OP-07 low-offset op. amp.	PMI
IC506	LF13741 JFET-input op. amp.	NATIONAL
IC507	CD4051 CMOS analog multiplexer	"
IC508	LF13741 JFET-input op. amp.	"
IC509	LF13741 "	"
IC510	LF13741 "	"
IC511	CD4051 CMOS analog multiplexer	"
IC512	LF13741 JFET-input op. amp.	"

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PART No.	DESCRIPTION	MFR
R601	4k7 metal-film resistor 1%	
R602	20k " "	
R603	20k " "	
R604	20k " "	
R605	470R " "	
R606	10k " "	
R607	4k7 " "	
R608	10k " "	
R609	20k " "	
R610	20k " "	
R611	33k " "	
R612	33k " "	
C601	0.1uF/100V polyester capacitor	EVOX
C602	0.1uF/100V "	"
C603	2u2/35V solid tantalum capacitor	ITT
C604	2u2/35V "	"
C605	2u2/35V "	"
C606	2u2/35V "	"
C607	2200uF/40V electrolytic capacitor	"
C608	2200uF/40V "	"
C609	2u2/35V solid tantalum capacitor	"
C610	2u2/35V "	"
C611	2u2/35V "	"
C612	2200uF/40V electrolytic capacitor	"
C613	1uF/100V polyester capacitor	EVOX
D601	1N4148 switching diode	TEXAS
D602	1N4148 "	"
D603	1N4148 "	"
D604	1N4148 "	"
D605	1N4148 "	"
D606	1N4148 "	"
D607	1N4001 rectifier diode	FAIRCHILD
D608	1N4001 "	"
D609	1N4001 "	"
D610	1N4001 "	"
D611	1N4001 "	"
D612	1N4001 "	"
D613	1N4001 "	"
D614	1N4001 "	"
D615	1N4001 "	"
D616	1N4001 "	"
D617	1N4001 "	"
D618	1N4001 "	"

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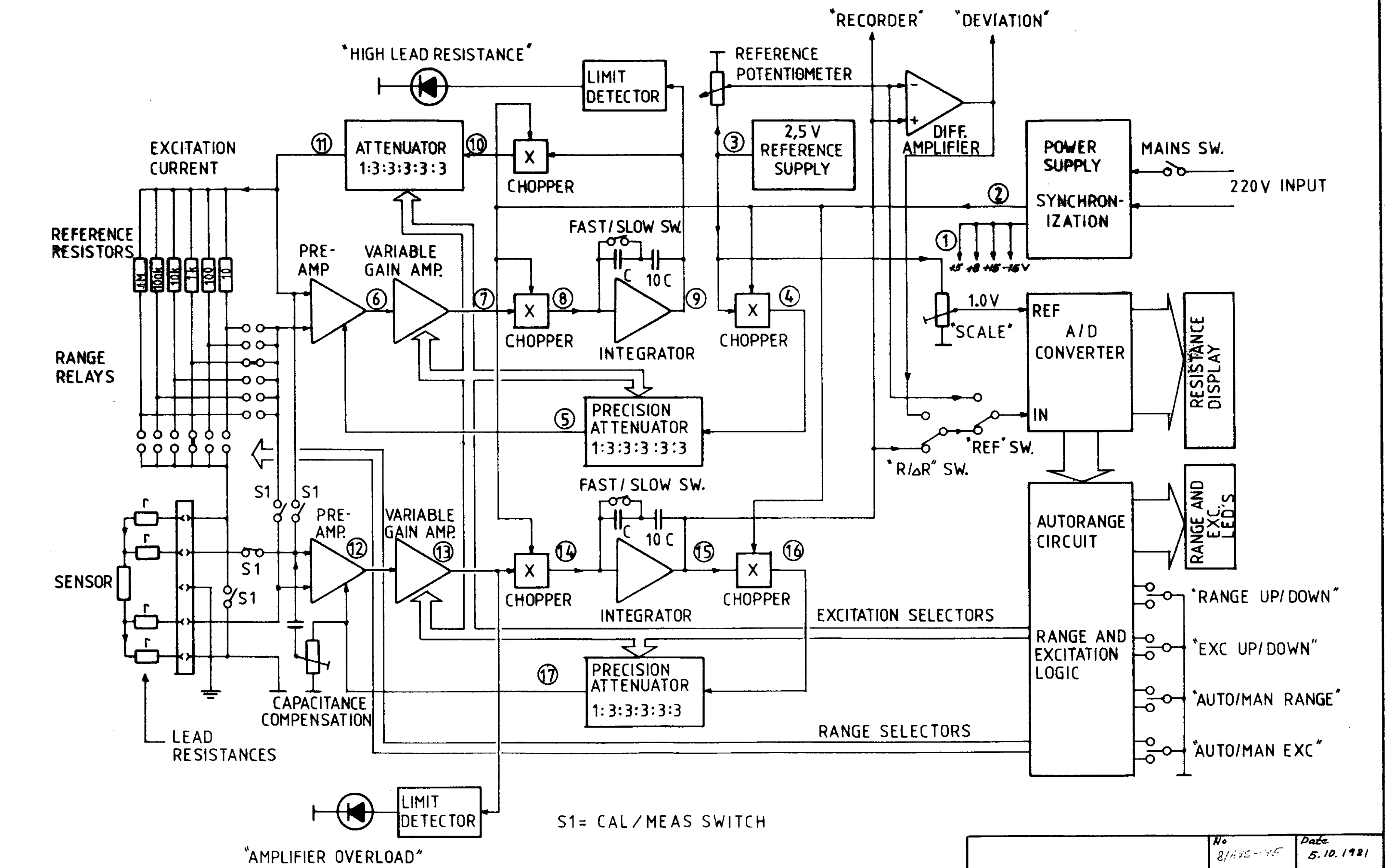
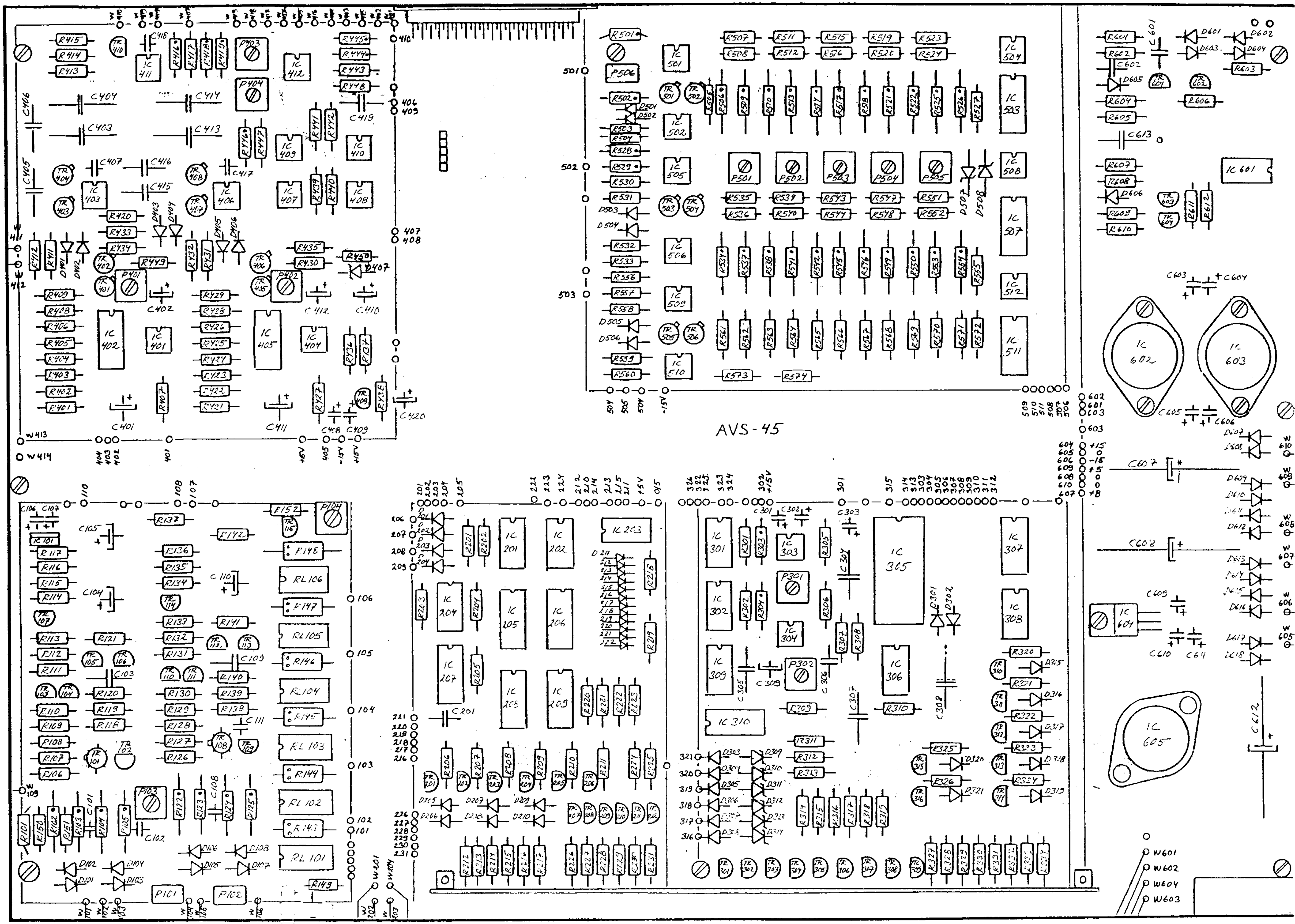
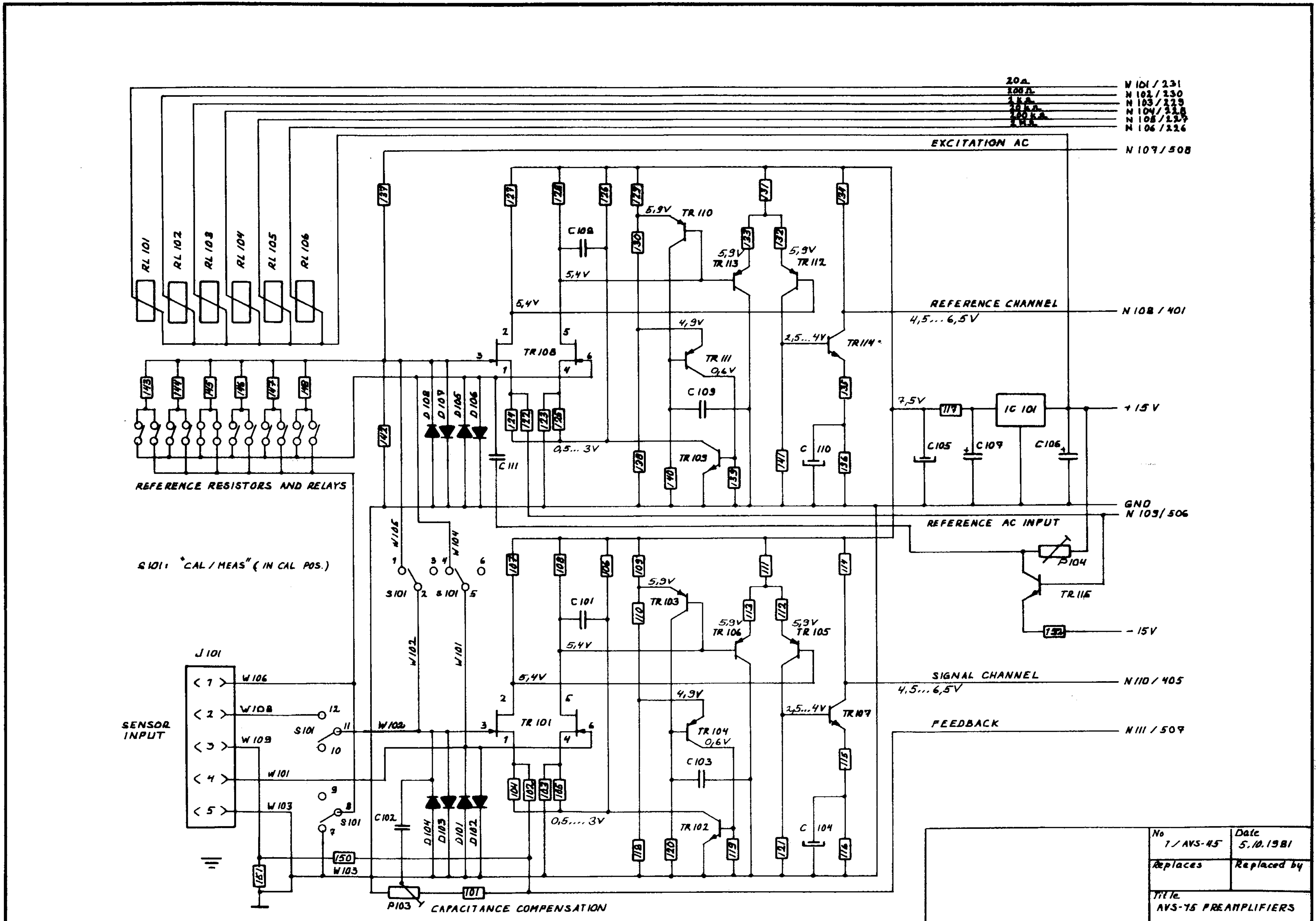
PART No.	DESCRIPTION	MFR
TR601	2N3904 transistor npn	NATIONAL
TR602	2N3904 "	"
TR603	2N3906 "	"
TR604	2N3906 "	"
IC601	CD4013 CMOS dual D-type flip-flop	NATIONAL
IC602	uA7815KC 15 Volt regulator	FAIRCHILD
IC603	uA7815KC "	"
IC604	uA7805UC 5 Volt regulator	"
IC605	uA7807KC 8 Volt regulator	"

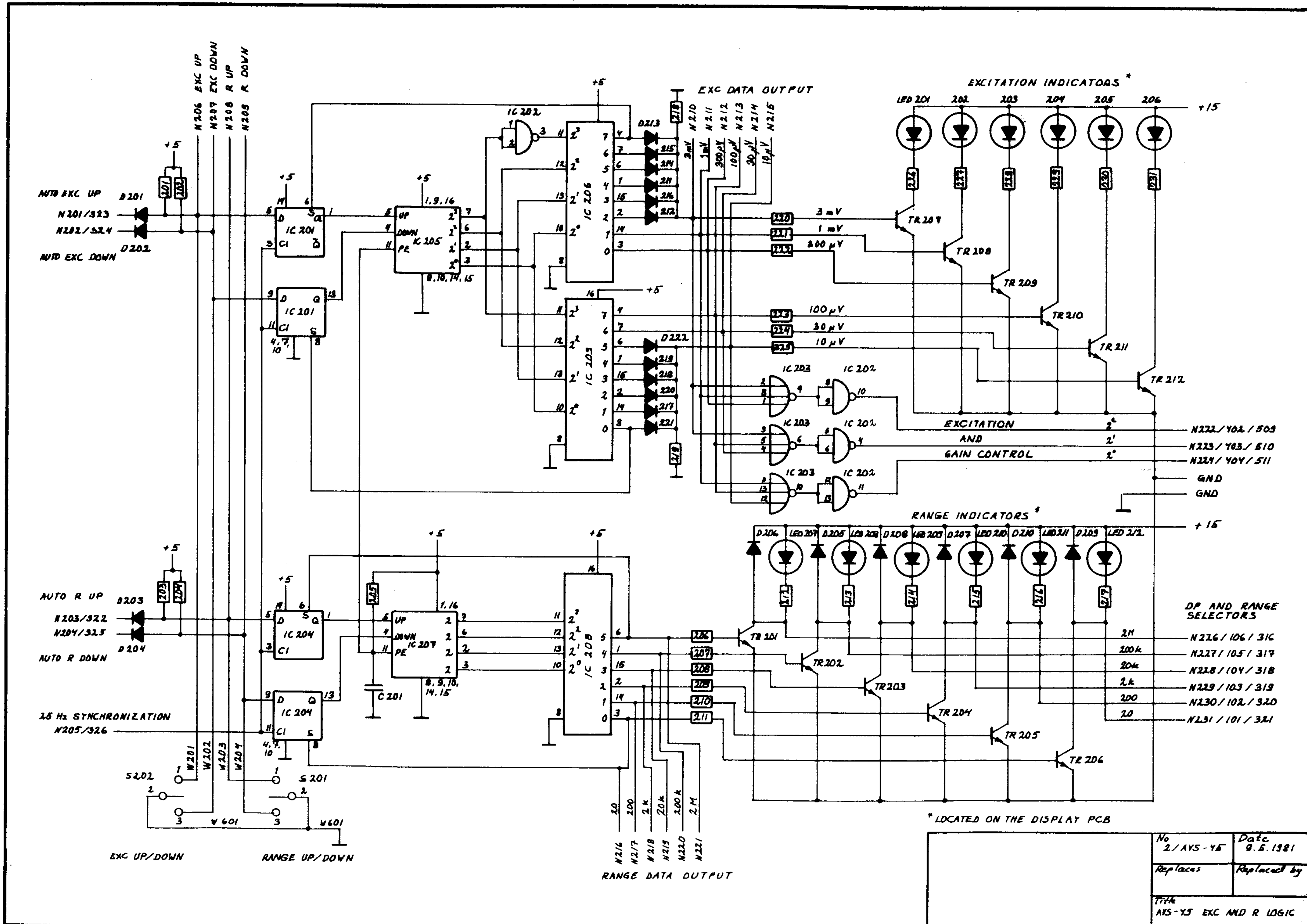
17.10.81



No 8/AVS-45	Date 5.10.1981
Replaces	Replaced by
Title AVS-45 BLOCK DIAGRAM	

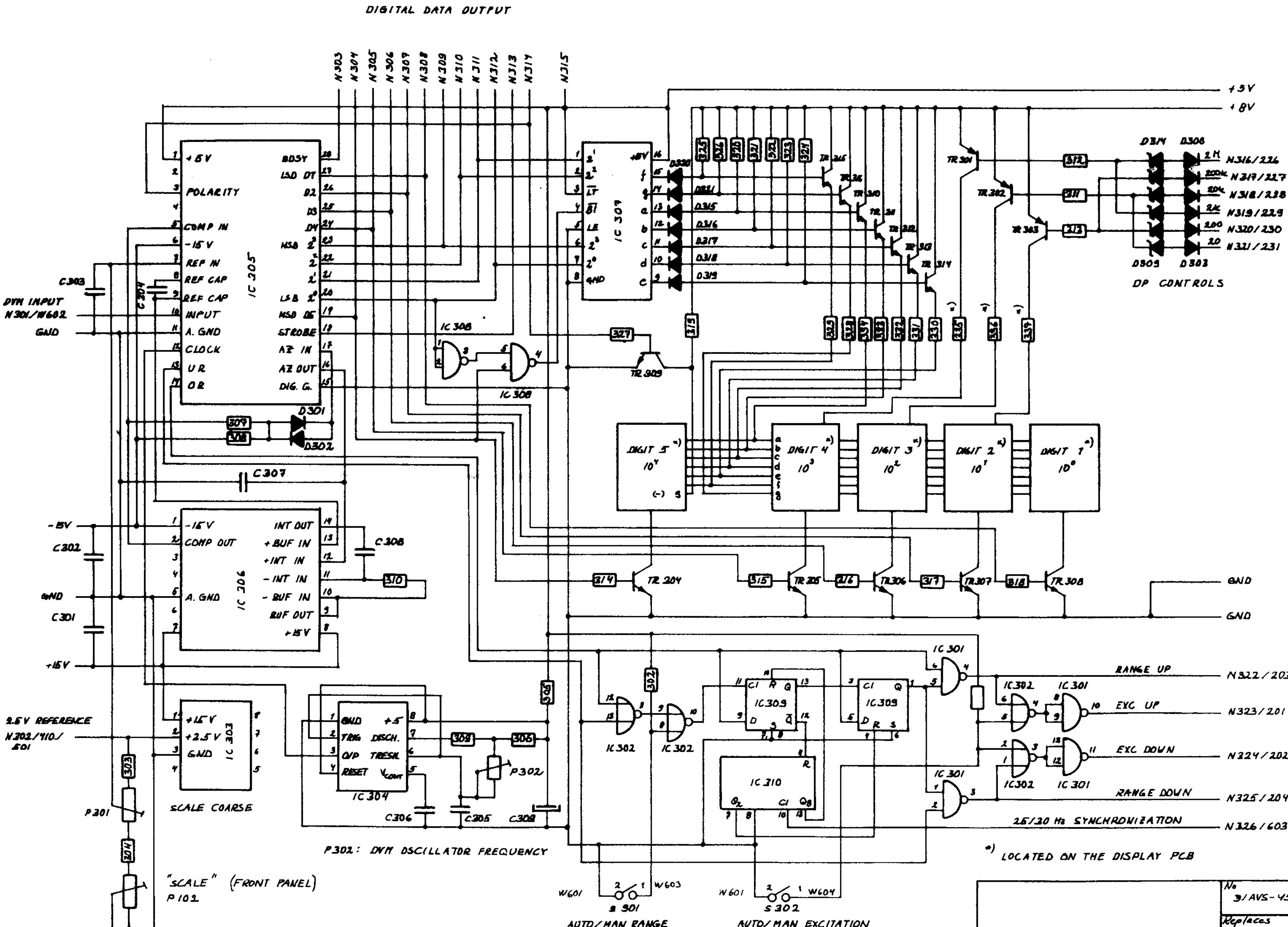

AVS-45


EXCITATION AC
REFERENCE CHANNEL
REFERENCE AC INPUT
SIGNAL CHANNEL
FEEDBACK
REFERENCE RESISTORS AND RELAYS
S101: "CAL / MEAS" (IN CAL POS.)
SENSOR INPUT
CAPACITANCE COMPENSATION
N 101 / 231
N 102 / 230
N 103 / 229
N 104 / 228
N 105 / 227
N 106 / 226
N 107 / 508
N 108 / 401
GND
N 109 / 506
N 110 / 405
N 111 / 507
+ 15 V
- 15 V
No 7 / AVS-45
Date 5.10.1981
Replaces
Replaced by
Title AVS-75 PREAMPLIFIERS

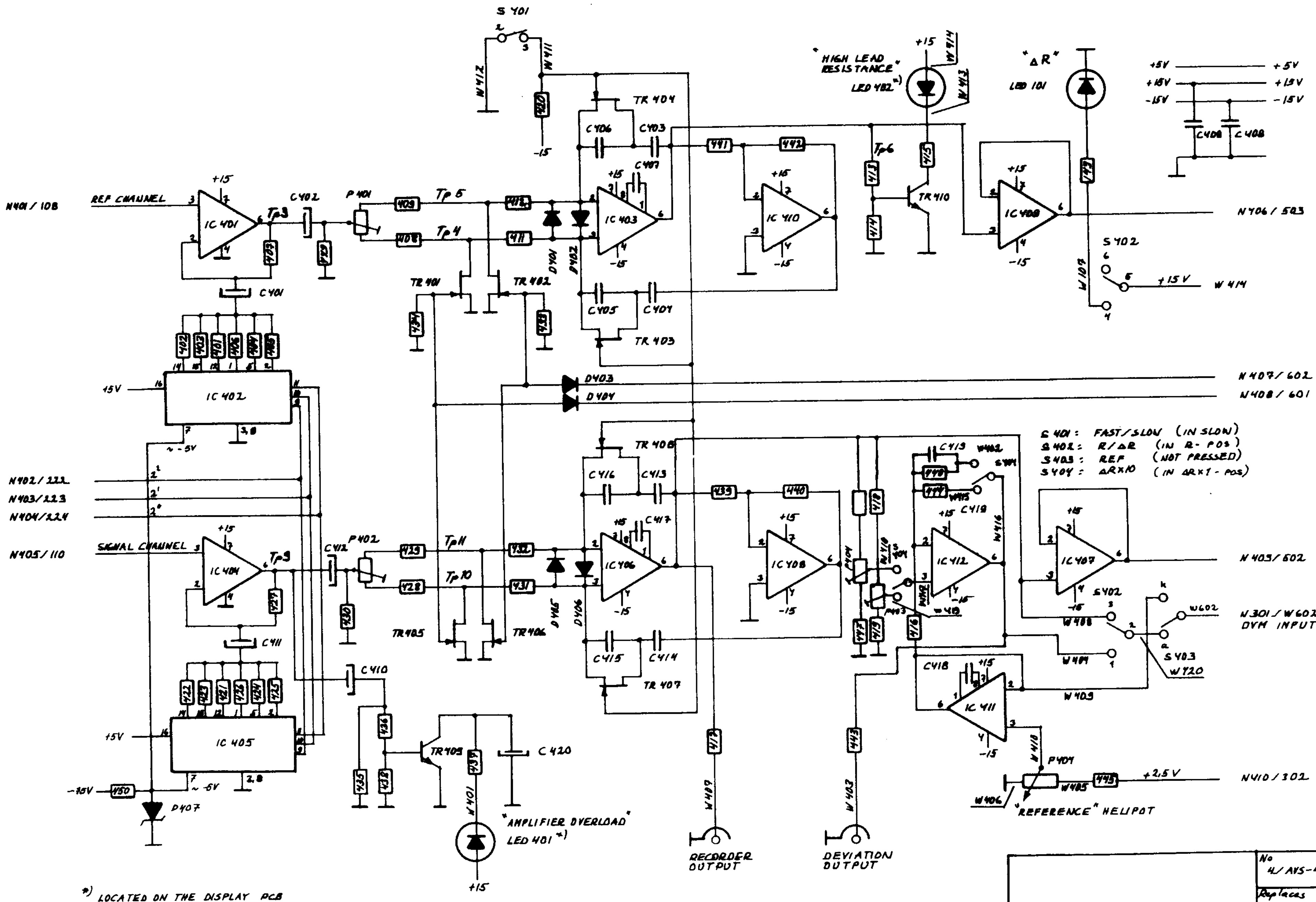


No	Date
2/AVS-45	9.5.1981
Replaces	Replaced by

Title: AVS-45 EXC AND R LOGIC

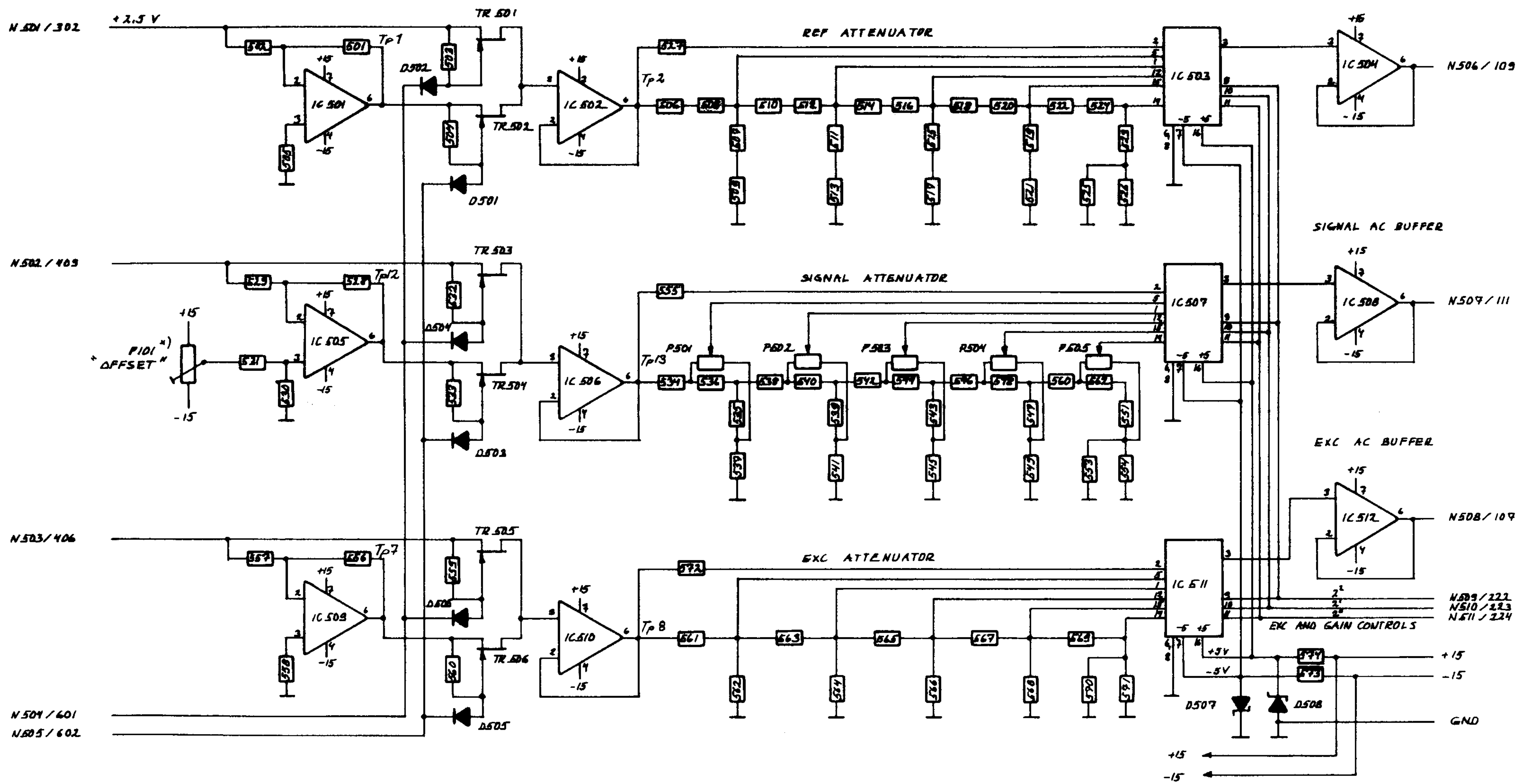


No	Date
3/AVS-45	5.10.1981
Replaces	Replaced by
Title AVS-45 DVM & AUTORANGE	



No	Date
4/AVS-45	4.4.84
Replaces	Replaced by
Title AVS-45 AMPLIFIERS	

*) LOCATED ON THE DISPLAY PCB



x) LOCATED ON THE PREAMPLIFIER PCB

No 5/ AVS-45	Date 9.5.1981
Replaces	Replaced by
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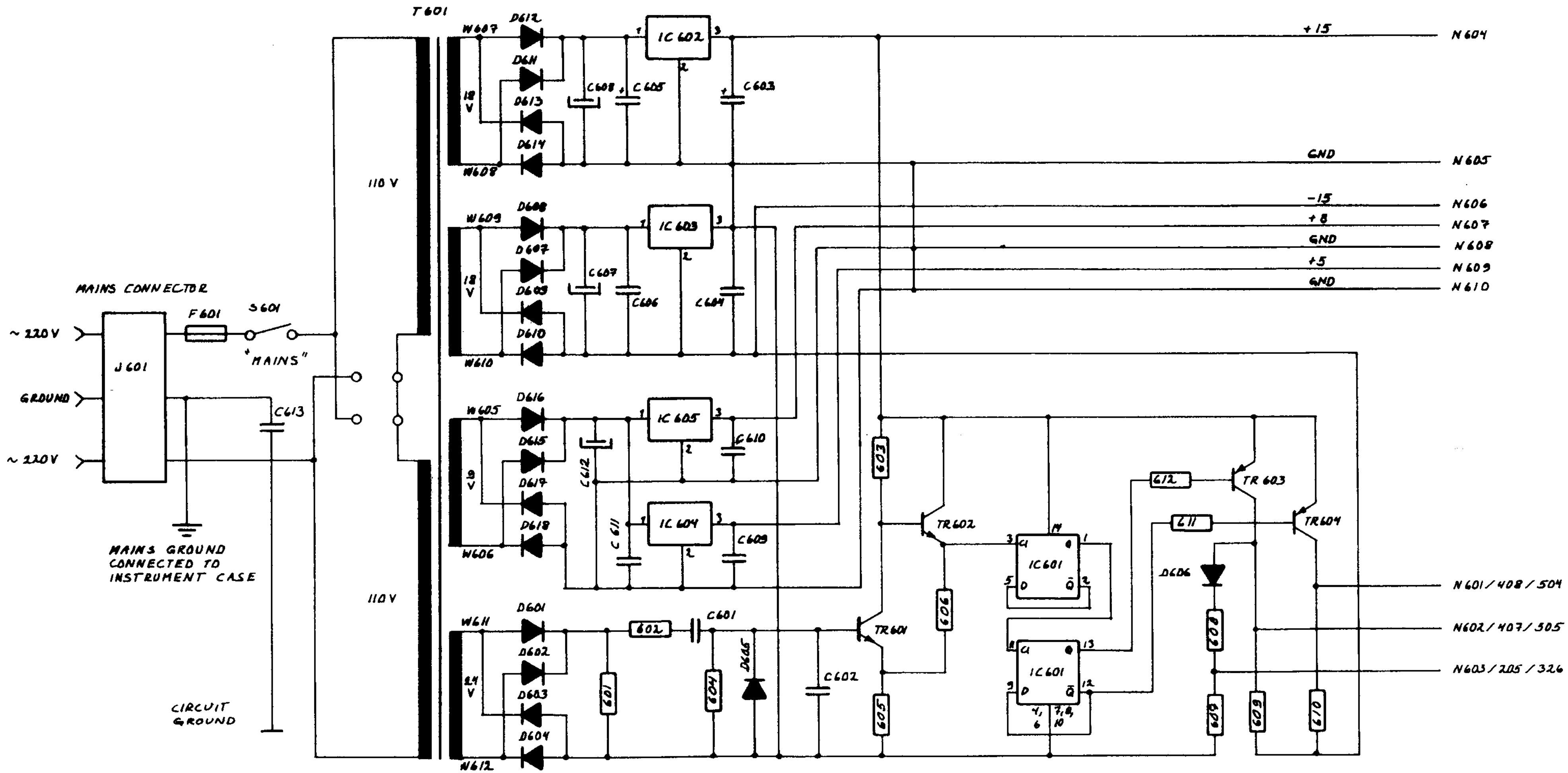

NOTE: TRANSFORMER PRIMARY WIRED FOR 220V MAINS.

	No 6/ AVS-45	Date 4.4.84
	Replaces	Replaced by
	Title AVS-45 POWER SUPPLY	