

PHILIPS



DIGITAL MULTIMETER

PM 2421

9447 024 21011

9499 470 04311

1/769/1/01



PHILIPS

Manual

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CONTENTS

GENERAL

I. INTRODUCTION	5
II. TECHNICAL DATA	6
III. ACCESSORIES	10
IV. DESCRIPTION OF THE WORKING	12
A. Block diagram	12
B. Functional diagram	13

INSTRUCTIONS FOR USE	27
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V. INSTALLATION	27
VI. OPERATION	31

SERVICE DATA	37
--------------	----

VII. CIRCUIT DESCRIPTION	37
A. Chopper-stabilised DC amplifier	37
B. AC-to-DC converter	46
C. 300 kHz-Oscillator, control circuit	54
DC current generator and	
automatic controlled voltage divider	
D. Digital section	60
E. Supply	84
VIII. GAINING ACCESS TO THE PARTS	90
IX. MAINTENANCE AND SERVICE	92
X. FAULT FINDING	93
XI. SURVEY OF ADJUSTING ELEMENTS	105
XII. CHECKING AND ADJUSTING	106
XIII. LIST OF PARTS	113
XIV. HF PROBE PM 9203 AND HF T-PIECE PM 9253	126
XV. DIGITAL OUTPUT UNIT PM 9221	129
XVI. INFORMATION ON INTEGRATED CIRCUITS	138

IMPORTANT

In correspondence concerning this instrument, please quote the type number and serial number as given on the type plate at the rear of the instrument.

LIST OF FIGURES

1. Accessories	10
2. HT probe GM 6070	10
3. Plug in cabinet PM 9706	11
4. Block diagram	15
5. Functional diagram	17
6. D.C. measuring circuit	18
7. A.C. measuring circuit	18
8. Circuit for H.F. measurements	18
9. Resistance measuring circuit in the Ω -range	20
10. Resistance measuring circuit in the $k\Omega$ and $M\Omega$ range	20
11. Integration process	20
12. Display section	23
13. Resoldering the jumpers on the mains transformer	27
14. Rear view	29
15. Front view	29
16. D.C. amplifier	36
17. Collector voltages in the chopper circuit	39
18. Printed circuit board U1	41
19. Circuit diagram of the chopper-stabilised D.C. amplifier	43
20. Printed circuit board U2	47
21. Circuit diagram of the a.c. - to - d.c. converter	50
22. Printed circuit board U3	55
23. Circuit diagram of H.F. section	57
24. Sequence diagram	60
25. Integration process	61
26. Integration circuit	61
27. Schmitt trigger	63
28. Switch drivers	63
29. Zero passage	65
30. Table representing the programm steps	65
31. Zero signal	66
32. The "Z" signal (< 100)	68
33. The "Y" signal (> 1400)	69
34. Truth table of automatic range selector	70
35. Astable multivibrator	71
36. Circuit diagram indication tube driver, clock oscillator, delay circuit and relay driver	72
37. Input circuit of the digital part	76
38. Printed circuit board U4	74
39. Logic circuit diagram of the digital section	81
40. Printed circuit board U5	85
41. Circuit diagram supply section	87
42. Pulling the instrument chassis out of the cabinet	90
43. Emitter signals of TS121 and TS122	93
44. Signals of TS109... TS112	94
45. Collector signal of TS113	94
46. Fault tracing survey	99
47. Applying an external signal to the Schmitt trigger	102

48. Combined measuring arrangement set-up	106
49. Principle diagram of the measuring arrangement	107
50. Checking the range selection	110
51. Front view with item numbers	114
52. Rear view with item numbers	114
53. Bottom view (chassis removed)	124
54. Top view (chassis removed)	125
55. Push button assembly SK2	125
56. HF-probe PM 9203 and T-piece PM 9253	126
57. Accuracy-curve of PM 9203 with PM 9253	127
58. Standing wave ratio of PM 9253	127
59. Circuit diagram of probe PM 9203	128
60. Digital output unit PM 9221 fitted on digital unit U4	131
61. Printed circuit board PM 9221 (U6)	132
62. Circuit diagram PM 9221	135
63. Circuit diagram PM 2421	

I. INTRODUCTION

GENERAL

The PHILIPS Digital multimeter PM 2421 is a universal instrument with digital display for the accurate measurement of electrical quantities.

The instrument permits of measuring direct and alternating voltages in a level range of more than $1:10^7$. The frequency range in the case of alternating voltage measurements extends from 10 Hz to 1 MHz.

In conjunction with a measuring probe (optional) it is possible to carry out HF voltage measurements at frequencies up to 700 MHz.

Current and resistance measurements are possible with the PM 2421 in a range greater than $1:10^{10}$.

Range and mode selection is effected with the aid of simple and conveniently arranged push-buttons. An automatically controlled measuring range selector switches a voltage divider within 3 decades so that the most favourable display value is obtained. If desired, the range selector can also be operated manually.

The measuring data (polarity of the direct voltage, automatically selected range and the digital measuring quantity) are available from the memory in encoded digital form.

With the aid of an additional printed circuit board which can be plugged into the digital section, the digital information is converted into standard levels, thus enabling the connection of a printer or recorder.

Apart from the digital output signal a conventional analogue output signal is also available for continuous recording of the measuring quantity.

The circuit zero is isolated from the housing and from the mains by means of a double screening so that floating measurements are also possible.

The instrument is provided with integrated circuits and silicon semi-conductors.

On account of its high sensitivity, its great accuracy and its rugged construction, the PM 2421 is suitable for research and development as well as for educational purposes, repair service, testing, general industrial applications etc.

II. TECHNICAL DATA

Properties expressed in numerical values with tolerances are guaranteed by the factory.

Numerical values without tolerances serve only for information and represent the properties of an average instrument.

A. GAMMES DE MESURE

1. Direct voltages

a. mV-ranges

Full-scale values	13.99 mV, 139.9 mV, 1399 mV
Resolution	10 μ V at the most sensitive range
Input resistance	1 M Ω
Overload protection	max. 500 V d.c.

b. V-ranges

Full-scale values	13.99 V, 139.9 V, 1000 V
Input resistance	10 M Ω
Overload protection	max. 1000 V d.c.

Accuracy

Relative to full-scale value	$\pm 0.1 \%$
Relative to reading	$\pm 0.1 \%$

<u>A.C. rejection for frequencies > 50 Hz</u>	min. 80 dB
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2. Direct currents

a. nA-ranges

Full-scale values	13.99 nA, 139.9 nA, 1399 nA
Resolution	10 pA at the most sensitive range
Voltage drop	1 mV/nA

b. μ A-ranges

Full-scale values	13.99 μ A, 139.9 μ A, 1399 μ A
Voltage drop	1 mV/ μ A

c. mA-ranges

Full-scale values	13.99 mA, 139.9 mA, 1399 mA
Voltage drop	1 mV/mA

Accuracy

Relative to full-scale value	$\pm 0.3 \%$
Relative to reading	$\pm 0.2 \%$

3. Alternating voltages

a. mV-ranges

Full-scale values	13.99 mV _{rms} , 139.9 mV _{rms} , 1399 mV _{rms}
Resolution	10 μ V at the most sensitive range
Preliminary indication with short-circuited input	max. 20 μ V
Input impedance	1 M Ω // 40 pF
Overload protection	at frequencies ≤ 50 Hz max. 300 V _{rms} at all other frequencies max. 30 V _{rms}

b. V-ranges

Full-scale values	13.99 V _{rms} 139.9 V _{rms} 500 V _{rms}
Input impedance	10 MΩ // 25 pF
Overload protection	max. 500 V _{rms} or 750 V _p

Accuracy

20 Hz - 300 kHz : Relative to full-scale	+ 0.3 %
Relative to reading	+ 0.2 %
10 Hz - 20 kHz and 300 kHz - 1 MHz:	
Relative to full-scale	+ 1 %
Frequency response	10 Hz ... 1 MHz

Measuring method

By means of full wave rectifier (for sinewave input voltages, calibrated in rms values).

4. Alternating currentsa. nA-ranges

Full-scale values	13.99 nA, 139.9 nA, 1399 nA
Resolution	10 pA at the most sensitive range
<u>Accuracy</u>	
10 Hz - 50 Hz	+ 0.5 %, relative to full-scale value
	+ 0.5 %, relative to reading
50 Hz - 100 Hz	+ 1 %, relative to full-scale value
	+ 0.5 %, relative to reading
Voltage drop	1 mV/nA

b. μA-ranges

Full-scale values	13.99 μA, 139.9 μA, 1399 μA
Accuracy 10 Hz ... 10 kHz	0.5 %, relative to full-scale value
	0.5 %, relative to reading
10 kHz - 20 kHz	+ 1 %, relative to full-scale value
	+ 1 %, relative to reading
Voltage drop	1 mV/μA

c. mA-ranges

Full-scale values	13.99 mA, 139.9 mA, 1399 mA
Accuracy 10 Hz ... 100 kHz	+ 0.5 %, relative to full-scale value
	+ 0.5 %, relative to reading
100 kHz - 200 kHz	+ 1 %, relative to full-scale value
	+ 1 %, relative to reading
Voltage drop	1 mV/mA

5. H. F. voltages

To be measured with probe PM 9203	
Frequency range	300 kHz ... 700 MHz
Full-scale values	13.99 mV _{rms} 139.9 mV _{rms} 1399 mV _{rms}
Minimum measurable H. F. voltage	2 mV
Deviation of frequency response	≤ 0.5 dB, 300 kHz ... 300 MHz
	≤ 1.5 dB, 300 MHz ... 700 MHz

Accuracy at voltages > 5 mV	≤ 1 dB, between 300 kHz and 300 MHz
	≤ 2 dB, between 300 MHz and 700 MHz
Input capacitance	≤ 2 pF
Parallel damping resistance	Dependent on voltage and frequency, between 10 k Ω and 200 k Ω
Measurements with probe PM 9203 and T-connector PM 9253.	
Frequency range	300 kHz...1200 MHz
Accuracy	700 kHz...1200 MHz < + 5 dB - 0 dB

6. Resistances

a. Ω -range

Full-scale values	13.99 Ω ; 139.9 Ω ; 1399 Ω
Resolution	0.01 Ω in range 13.99 Ω
Accuracy	± 0.2 %, relative to full-scale value ± 0.2 %, relative to reading
Measuring current	1 mA
Measuring voltage	1.4 V max.

b. k Ω range

Full-scale values	13.99 k Ω ; 139.9 k Ω ; 1399 k Ω
Accuracy	± 0.2 %, relative to full-scale value ± 0.2 %, relative to reading
Measuring current	5 μ A
Measuring voltage	7 V max.

c. M Ω range

Full-scale values	13.99 M Ω ; 139.9 M Ω ; 1399 M Ω
Accuracy	± 0.3 %, relative to full-scale value } up to ± 0.2 %, relative to reading } 100 M Ω ± 2 %, above 100 M Ω
Measuring current	5 nA
Measuring voltage	7 V

B. GENERAL DATA

- Range selection

Range group with push-buttons, manually.

Three ranges within each group, chosen by means of automatic range selector; also manually adjustable.

- Temperature range

For the stated accuracy $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$

Temperatur coefficient (except for H. F. measurements) between -10°C ... 45°C

Typical value

≤ 200 ppm/ $^{\circ}\text{C}$

≤ 100 ppm/ $^{\circ}\text{C}$

- Power supply

Mains voltage	115 V and 230 V \pm 15 %
Mains frequency	50...60 Hz
Power consumption	22 VA
Capacitance between mains and circuit zero	< 50 pF
Capacitance between "LO" and chassis	1.5 nF
Permissible direct voltage between chassis and circuit zero	max. 500 V

- Common mode rejection

120 dB

- Timing

Integration time	100 ms
Integration time without range selection	for d. c. approx 750 ms for a. c. approx 2 s
Range selection	approx. 100 ms

- Analogue output

Voltage per digit	5 mV
Max. output voltage	7 V
Source resistance	5 k Ω \pm 0.25 %

- Digital output

With additional printed circuit board PM 9221.

C. MECHANICAL DATA

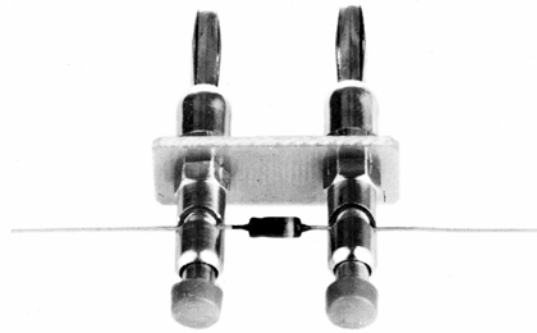
Dimensions	Width	305 mm
	Height	145 mm
	Depth	270 mm
Weight		7 kg.

III. ACCESSORIES

- Mains lead
- Fuse indication plate for mains voltage
- Measuring cable, complete with one measuring probe holder, two measuring clips and measuring probe tip. (Fig. 1A)
- Measuring terminal (Fig. 1B)
- 2.5 mm Allen key
- Manual



Fig. 1. Accessories



OPTIONALLY AVAILABLE

- HT probe GM 6070

This probe is suitable for measuring direct voltages up to 30 kV.

Maximum measuring error: 5 % (in conjunction with PM 2421).

Input resistance: 1000 M Ω

Further information concerning GM 6070 see separate manual.



Fig. 2. HT probe GM 6070

- HF probe PM 9203 (see chapter XIV)
- HF-T-piece PM 9253 (see chapter XIV)
- Digital output unit PM 9221 (see chapter XV)
- Plug-in cabinet PM 9706

PM 9706 is a universal 3E-cabinet, with a width of 6 modules. It is provided with side panels including handles, feet, tilting bracket, top and bottom plate, guiding strips and a grey, plastic cable cover, in which two brackets are located for 19" rack mounting.

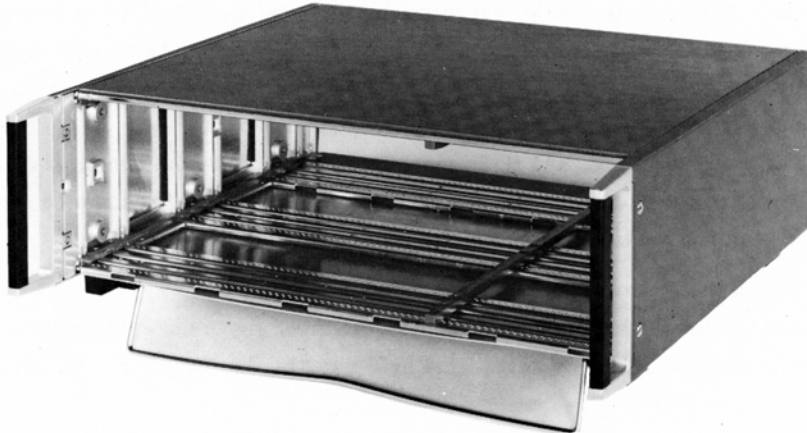


Fig. 3. Plug in cabinet PM 9706

- Blank panel PM 9722

PM 9722 is a blank panel for a 3E cabinet, having a width of 2 modules, to fill the blank space when the PM 2421 is mounted in cabinet PM 9706.

- Blank panel PM 9721

PM 9721 is a blank panel for a 3E cabinet, having a width of 1 module. Two panels PM 9721 can be used instead of one PM 9722.

IV. DESCRIPTION OF THE WORKING

A. BLOCK DIAGRAM (Fig. 4)

Both the modes and the ranges are selected by means of push-buttons.

Dependent on this selection, the functional units are arranged so that an optimum measuring result is obtained. In this respect the following functions can be distinguished:

a. Arrangement of the functional units

The AC or DC amplifier, the direct current generator and the 300 kHz oscillator are connected to the appropriate input dependent on the mode of operation and are then connected to the analogue to digital converter.

Various combinations are then possible (see under point B).

Moreover, in the case of a.c. and H.F. measurements, a low-ohmic voltage divider is included between the two a.c. amplifiers and in the case of d.c. and resistance measurements this divider is connected to the output of the d.c. amplifier.

b. Pre-selection of the measuring ranges

In the case of voltage or current measurements the input signals are matched to the inputs in accordance with the selected range. This pre-selection is effected in 10^3 steps, such as e.g. for nA, μ A and mA.

c. Auxiliary functions

The push-button switch performs various auxiliary functions such as short-circuiting the current terminals in the case of voltage and resistance measurements.

In the case of d.c. measurements it provides the polarity indication, and in the case of a.c. and h.f. measurements the sine symbol and it eliminates these signs in the case of resistance measurements.

1. D.C. amplifier

This amplifier serves for measuring direct voltages, direct currents and resistance values.

In the case of H.F. measurements it operates as a very sensitive control amplifier.

This amplifier is chopper-stabilised and has a d.c. gain of more than 5×10^7 .

The chopper operates in series-parallel arrangement at 190 Hz and is equipped with cadmium-sulphide photo-conductors.

2. A.C. amplifier and a.c. - to - d.c. converter

The a.c. amplifier and the a.c. - to - d.c. converter are operative in the case of alternating current, alternating voltage and H.F. measurements.

The first a.c. amplifier section is an impedance matching stage supplying the low-ohmic voltage divider.

The second voltage amplifier is followed by the a.c. to d.c. converter, which supplies an output voltage which is symmetrical with respect to earth. This direct voltage which is exactly proportional to the input a.c. signal, is converted in a d.c. difference amplifier into an output voltage, which is asymmetrical with respect to the circuit zero.

3. Current generator

The current generator supplies a constant direct current of 1 mA, which is employed for resistance measurements. To avoid long measuring times, the output voltage is limited.

4. H. F. section

The H. F. section comprises an L-C oscillator operating at 300 kHz.

The 300 kHz output voltage is controlled by a regulator until it is equal to the H. F. voltage to be measured.

The principle of H. F. measurements is further described under point B.3 of this chapter.

5. Voltage divider

Within the pre-selected coarse range voltage division is effected in three decades. The low-ohmic voltage divider consisting of precision resistors, is automatically controlled by a reed relay.

The switching pulses for the relay are obtained from the digital section.

Changing over to the relevant measuring range is effected automatically but manual operation is also possible.

6. Digital section

The analogue to digital converter converts the analogue input signal into a digital signal. The digital information is first stored and then transferred to the display section. As long as the measuring value remains the same, the same value will be displayed. When the measuring value changes, the new value is displayed and is retained until the value changes again. When the measuring value is equal to or greater than 1400, the pilot lamp "OVERLOAD" indicates that the end-of-range value is exceeded.

7. Power supply

The stabilised supply circuits provide the voltages required for the various sections. The + 15 V and - 15 V direct voltages serve also as reference for the analogue to digital conversion.

All supply circuits are protected against short-circuiting and brief overloads.

B. FUNCTIONAL DIAGRAM

Fig. 5 shows the functional diagram. Dependent on the measuring mode the individual units are combined by means of the push-button switch.

A survey of the circuit arrangements for the various modes of operation is given below.

1. D.C. measurements (Fig. 6)

The 1:1000 input attenuator divides the voltage in the measuring range "V" so that the output signal corresponds to that in the "mV" range and can be processed by the instrument. In the case of current measurements the voltage across the shunt is measured.

The direct voltage measurement is based on the gain of a chopper-stabilised d.c. amplifier, which depends on the degree of feedback. The resulting analogue output signal is converted into a digital signal by means of an analogue to digital converter. A.C. interference superimposed on the measuring signal is suppressed by a low-pass filter. The signal on the input of the d.c. amplifier is inverted by this amplifier. The voltage amplification of the circuit depends practically only on the voltage divider and the resistors in the feedback circuit, the internal amplification being very high.

At the "mV" ranges when the input signal is applied directly, the voltage gain is 5-times (upper relay contact closed), in the case of a 10:1 division (centre contact closed) it is 50 times, and in the case of 100:1 division (lower contact closed) it is 500 times.

An input voltage of 10 mV causes an analogue output voltage of 5 V at the highest sensitivity (gain factor of 500). This voltage corresponds to an indication of 10.00 in the digital section (button "mV" depressed).

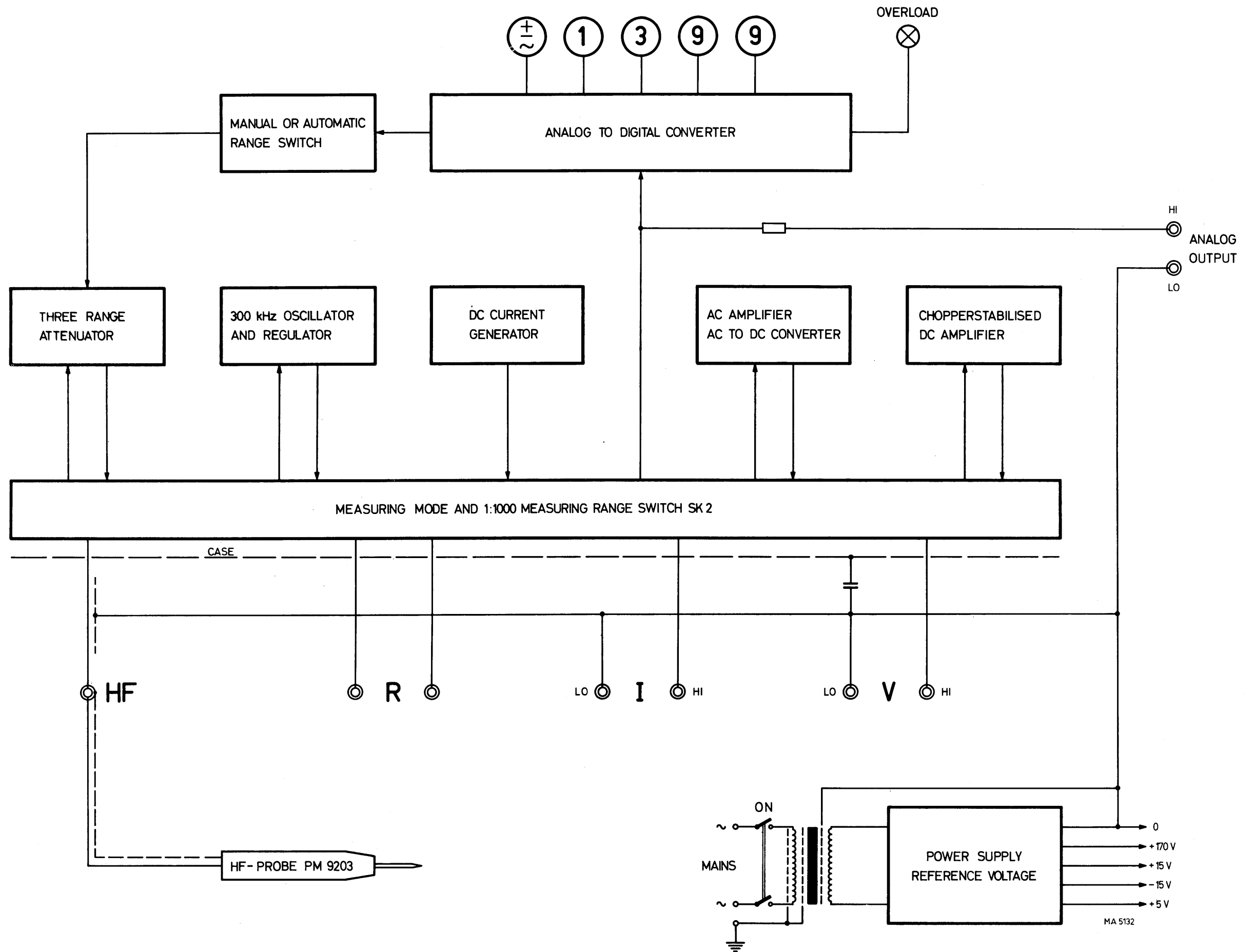


Fig. 4. Block diagram

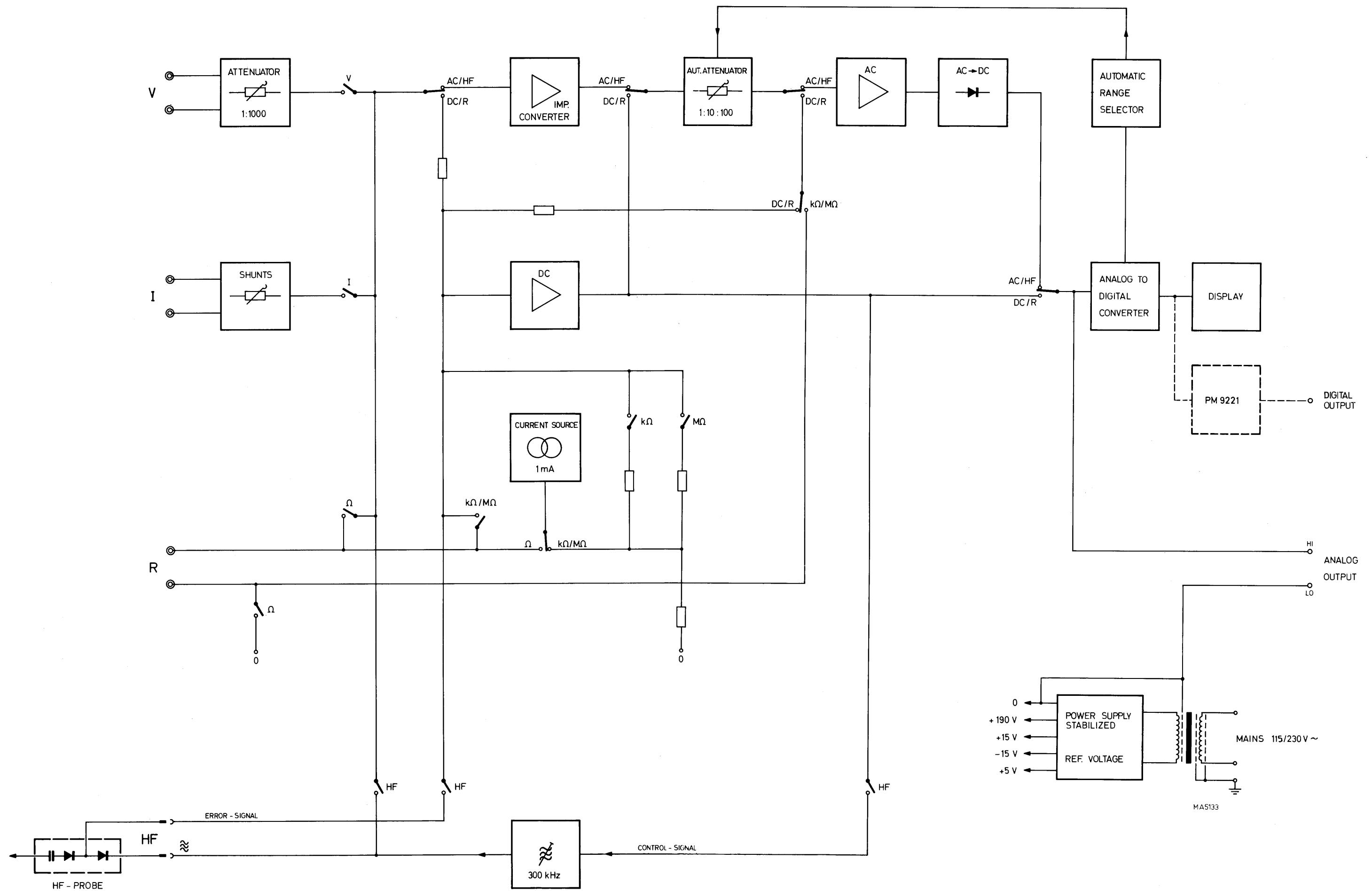


Fig. 5. Functional diagram

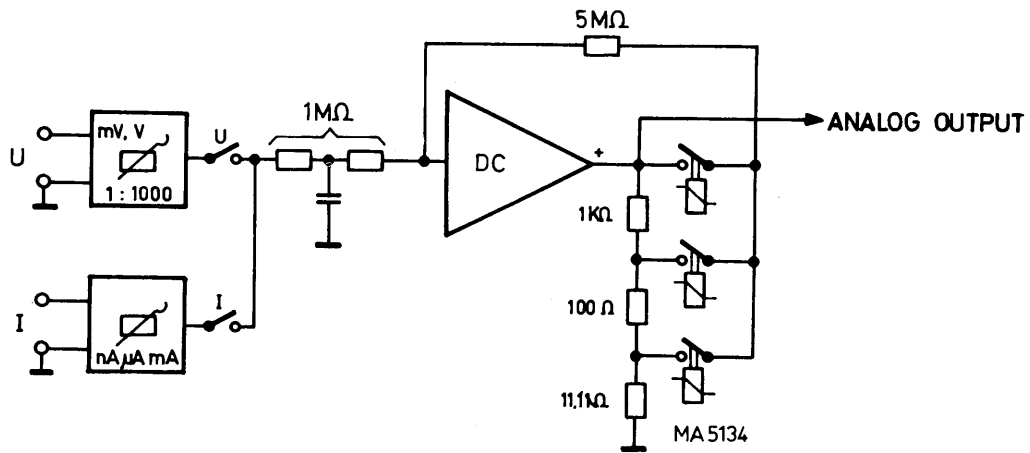


Fig. 6. D.C. measuring circuit

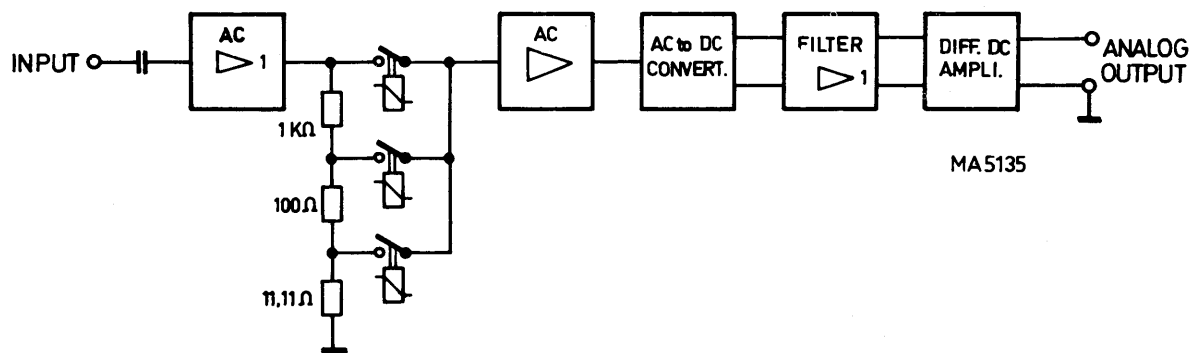


Fig. 7. A.C. measuring circuit

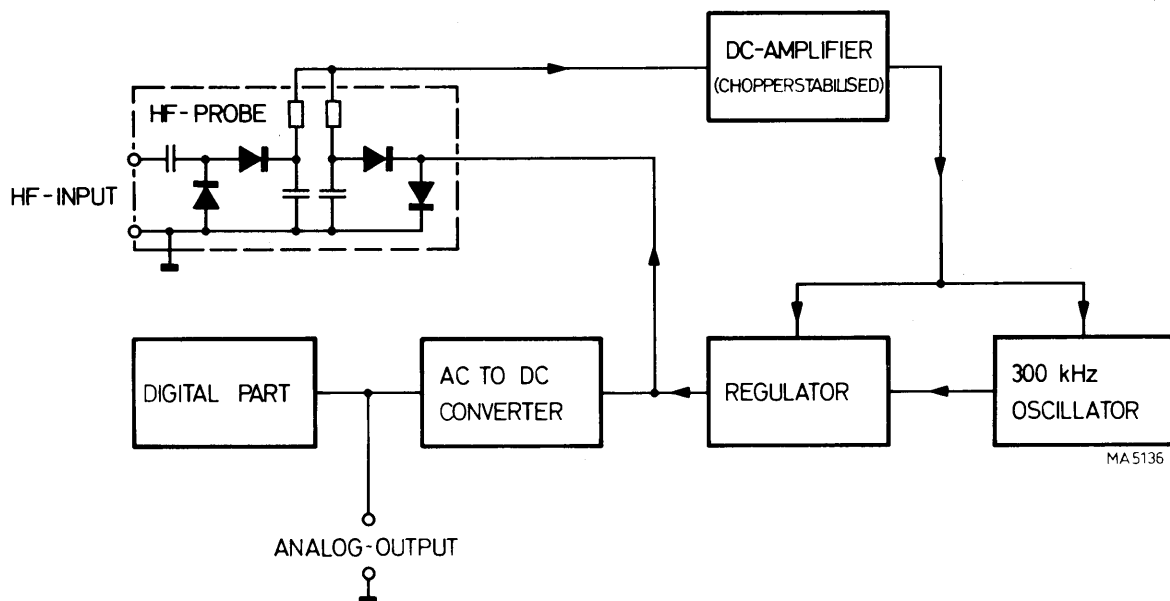


Fig. 8. Circuit for H.F. measurements

2. A.C. measurements (Fig. 7)

The a.c. signal to be measured is applied to the input of the impedance matching stage in the mV ranges. In the V ranges and in the current ranges the same voltage divider elements and shunts are employed as in the corresponding d.c. ranges. This means that in fact all a.c. measurements are reduced to voltage measurements at the mV ranges.

The d.c. components are blocked by a capacitor at the input of the impedance matching stage. Alternating voltages are matched to a low output impedance in the impedance matching stage which has unity gain.

The voltage divider connected to the impedance stage is also employed for d.c. and resistance measurements, but in the case of a.c. measurements the sensitivity steps are reversed. As a result, the output voltage on the analogue output is 5 V d.c. when the upper contact is closed, if a sinusoidal input voltage of 10 mV r.m.s. is applied.

The voltage divider of the automatic range selector is followed by an a.c. amplifier with a high input impedance. The a.c. to d.c. converter comprises a wideband amplifier with a high no-load gain and a full-wave rectifier network included in the negative feedback circuit. This results in average value rectification of high linearity. The output voltage of the a.c. to d.c. converter is symmetrical with respect to the circuit zero and will contain a.c. components.

Therefore, the signal is filtered and applied to an impedance matching stage. The following difference amplifier makes the signal asymmetrical with respect to the circuit zero, after which the value is determined by the digital section and the analogue output circuit.

3. H.F. voltage measurements (Fig. 8)

The H.F. voltage measurements are based on the compensation principle.

For this purpose the amplitude of the voltage required for compensation is controlled so that the input and the compensation voltage have the same value. The measuring probe contains two pairs of diodes, one pair in the H.F. input circuit and the other pair in the compensation circuit.

The direct current supplied by the diodes controls the d.c. amplifier which has a very high gain if there is no negative feedback. The output voltage of the d.c. amplifier controls the oscillator and the control amplifier of the latter so that the oscillator voltage which is used as compensation voltage becomes equal to the H.F. input voltage. The polarity of the rectified H.F. voltage is opposite to that of the rectified compensation voltage.

When the two voltages have the same value, the resulting d.c. output voltage will be zero.

On the input of the a.c. to d.c. converter a 300 kHz signal arises, whose amplitude has the same value as that of the H.F. signal to be measured. This 300 kHz compensation voltage is measured by the digital section via the a.c. - to - d.c. converter in the same way as with a.c. voltages in the mV ranges.

Errors arising on account of the spread in tolerances of the rectifier diodes in the input circuit are practically eliminated by employing diodes with the same properties in the compensation circuit.

4. Resistance measurements

Resistance measurements at the Ω -ranges are effected by measuring the voltage drop across an unknown resistance. (Fig. 9). A current generator supplies a constant current of 1 mA flowing through the resistance to be measured. The voltage drop across the resistor is proportional to the resistance value and is measured by the direct voltage measuring circuit after which it is displayed.

At the k Ω and M Ω ranges the current from the current generator flows through a 10 Ω resistor (Fig. 10).

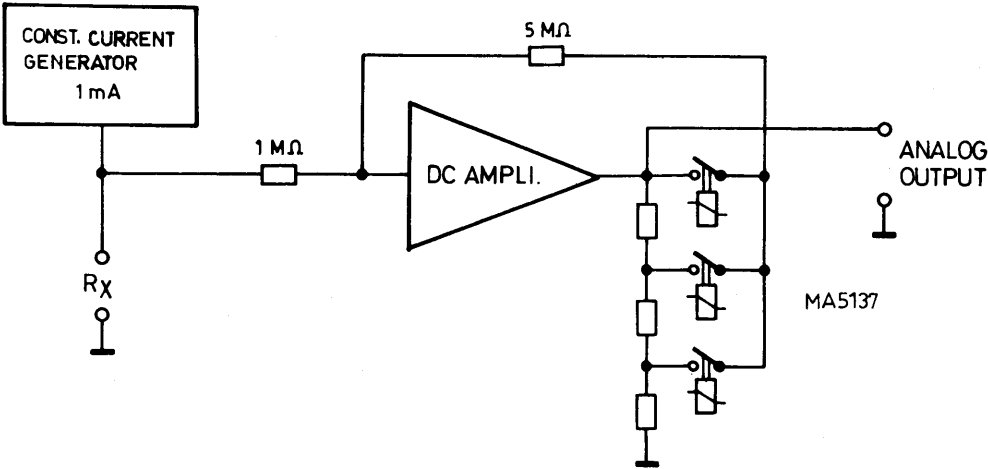


Fig. 9. Resistance measuring circuit in the Ω -range

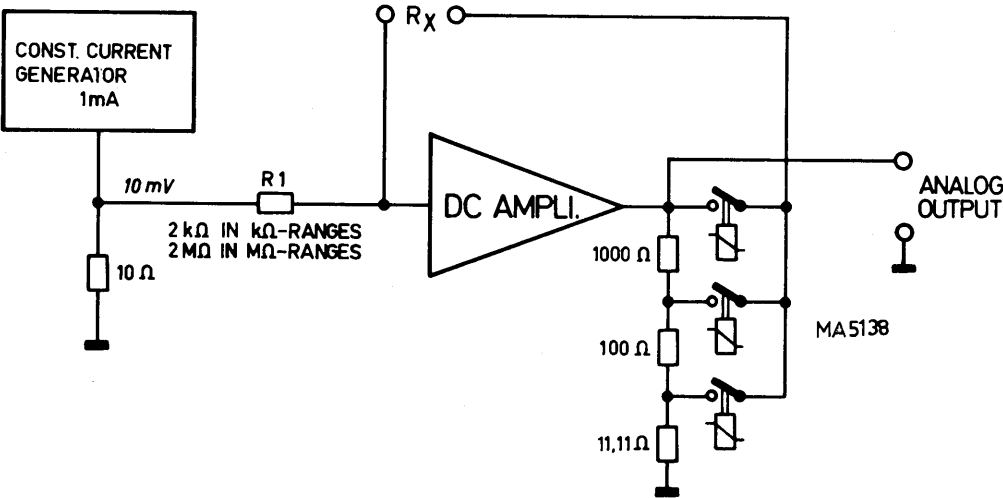


Fig. 10. Resistance measuring circuit in the $\text{k}\Omega$ and $\text{M}\Omega$ range

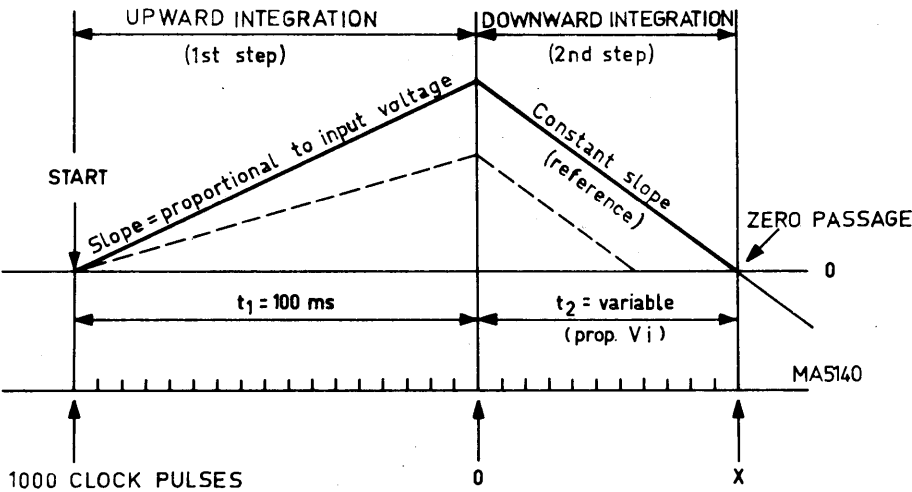


Fig. 11. Integration process

As a result a 10 mV voltage source is obtained and the resistance to be measured which is included in the feedback circuit then changes the gain of the d. c. amplifier.

The voltage on the analogue output depends on the position of the voltage divider and is exactly proportional to the value of R_x . The drive circuit of the d. c. amplifier comprises resistor R1. The value of this resistor defines the k Ω and M Ω ranges, because the current through R_x in the feedback circuit assumes the value determined by R1. The voltage on the output of the amplifier is measured by the analogue to digital converter and displayed.

5. Display section (Fig. 12)

Conversion of the analogue signals into digital form is based on the dual slope principle in PM 2421.

The analogue input signal is applied to the integrator via series resistors and switching transistors.

The integrator supplies an output pulse whose width is proportional to the measuring value. The working principle of the integrator is described in more detail in the following chapter. Fig. 11 shows a graphical representation of the voltage as a function of time during the charging and discharging cycle.

During the integration process two main conditions should be distinguished which will be called upward integration (first step) and downward integration (second step).

During the first step (start) a current is applied to the integrator, which is proportional to the input voltage (S1 open, S2 and S3 closed).

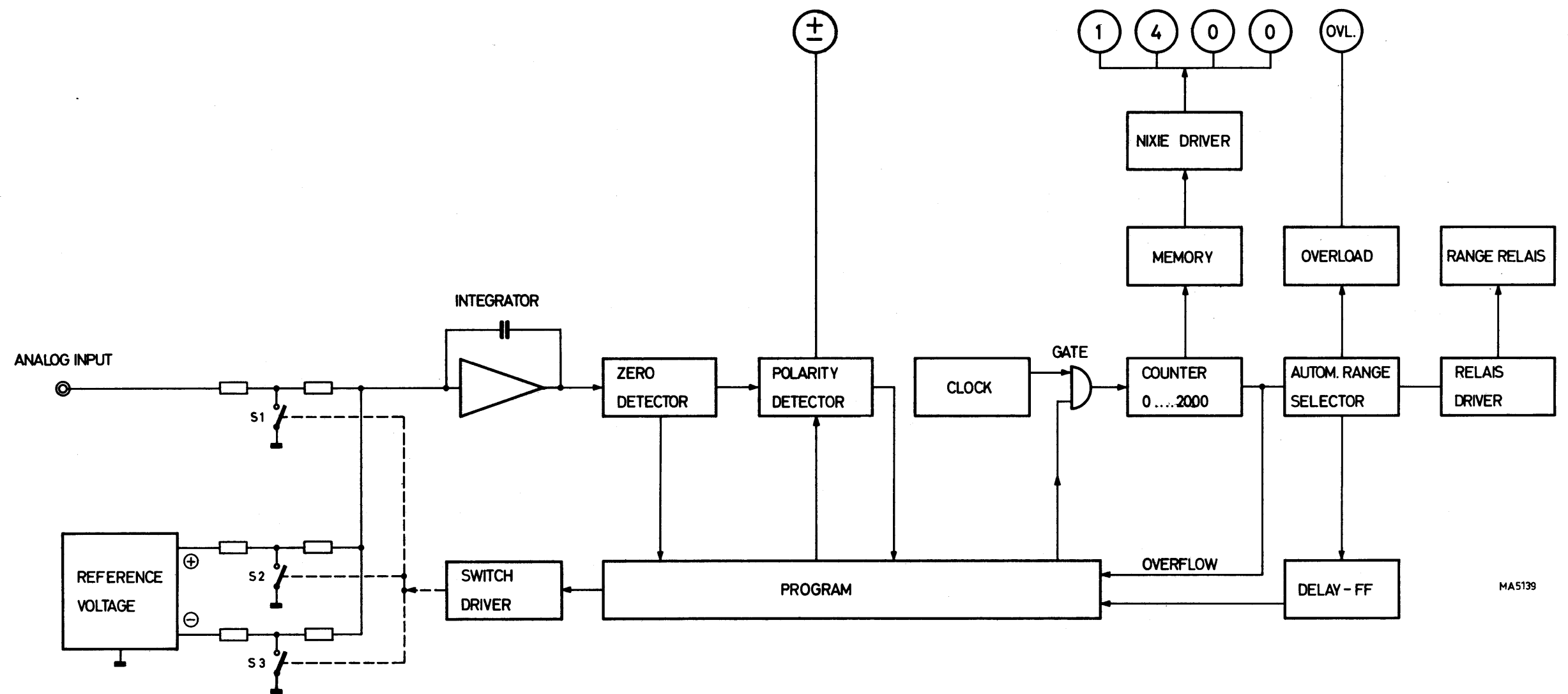
The output voltage of the integrator increases linearly as a function of time; its direction depends on the polarity, and its steepness on the value of the input voltage. The integration time is determined by the duration of 1000 clock pulses. During this interval upward integration is effected and capacitor C402 is charged.

At the end of the first step the polarity of the integration voltage is determined and indicated. At this moment the counter supplies the transfer pulse, which initiates the downward integration and at the same time sets the counter to zero.

During the second step the integrator is discharged to zero by a constant current (S1 closed, S2 or S3 open, dependent on the polarity determined during the first step). The discharge rate is determined by the discharge current and, consequently, by the reference voltage, so that it will be constant. The time is measured by counting the number of clock pulses; it is directly proportional to the unknown input voltage applied during the first step.

As the same integration elements and clock generator are employed for both steps, temperature variations, long-term drift and absolute values will not affect the measuring accuracy. The measuring accuracy in the first place depends on the accuracy of the reference voltage. Even without filters, this type of circuit is not sensitive to superimposed alternating voltages, because these are also integrated, i. e. the average value is determined.

As soon as the voltage on integrating capacitor C402 passes through zero during the discharge process, the gate is closed and the contents of the counter is transferred to the memory and displayed. The counter also controls the automatic range selector, which has three different ranges. At a measuring value of more than 1400 units the next range is selected. When in the upper range the measuring value is again equal or more than 1400, pilot lamp "OVERLOAD" lights up and indicates that the measuring voltage has exceeded the permissible value and that the displayed result is no longer reliable. If an indication of 100 units is not obtained, the automatic range selector changes over to a more sensitive range. The selected range can be derived from the position of the decimal point. At each step of the automatic range selector the starting moment for the next measurement is delayed by 100 msec by the delay flip-flop. The pre-amplifiers of the a. c., d. c. and H. F. ranges are then adapted to the new measuring value during this delay.



MA5139

Fig. 12. Display section

V. INSTALLATION

INSTRUCTIONS FOR USE

1. Adjustment to the local mains voltage

Before the instrument is put into operation, check that the instrument is adapted to the local mains voltage. The voltage to which the instrument is set in the factory, can be read on an indication plate at the rear of the instrument (220 V or 115 V). At these voltage values deviations of $\pm 15\%$ are permissible; fuse VL1 should have the following rating:

Nominal value	Voltage range	Fuse VL1
230 V	200...264 V	160 mA delayed action
115 V	100...132 V	250 mA delayed action

Adjustment to a different voltage range is effected by resoldering the two jumpers on the mains transformer. For this purpose the chassis should be pulled out of the cabinet (caution, the instrument should not be connected to the mains) with the two locking devices (see chapter VIII. 1).

For the two voltage ranges the jumper should be connected as indicated in Fig. 13.

When the instrument has been adapted to a new voltage value, the indication plate at the rear of the instrument should be changed accordingly.

Connection to the mains:

The instrument should be connected to a socket with rim earthing contacts by means of the three-core mains lead supplied with the instrument.

2. Earthing

When the instrument is connected to the mains via the three-core mains lead the housing is connected to safety earth.

If for safety reasons separate earthing of the instrument housing is desired (e.g. when measuring high voltages) the instrument may be earthed by means of a separate lead which should be connected to the earthing screw (\perp) at the rear (Fig. 14).

The instrument is equipped with a special mains transformer whose primary winding is enclosed by a screening on both sides. These screenings are connected to safety earth so that capacitive earthing currents from the primary winding are drained to safety earth via the screening.

The maximum permissible voltage between measuring input "LO" and the cabinet is 500 V d.c. Furthermore, earthing should be effected in accordance with local safety regulations.

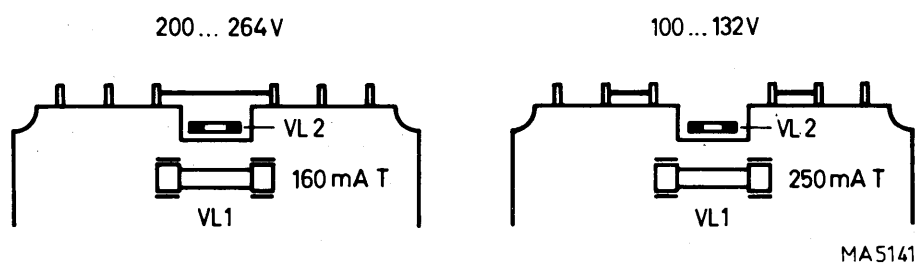
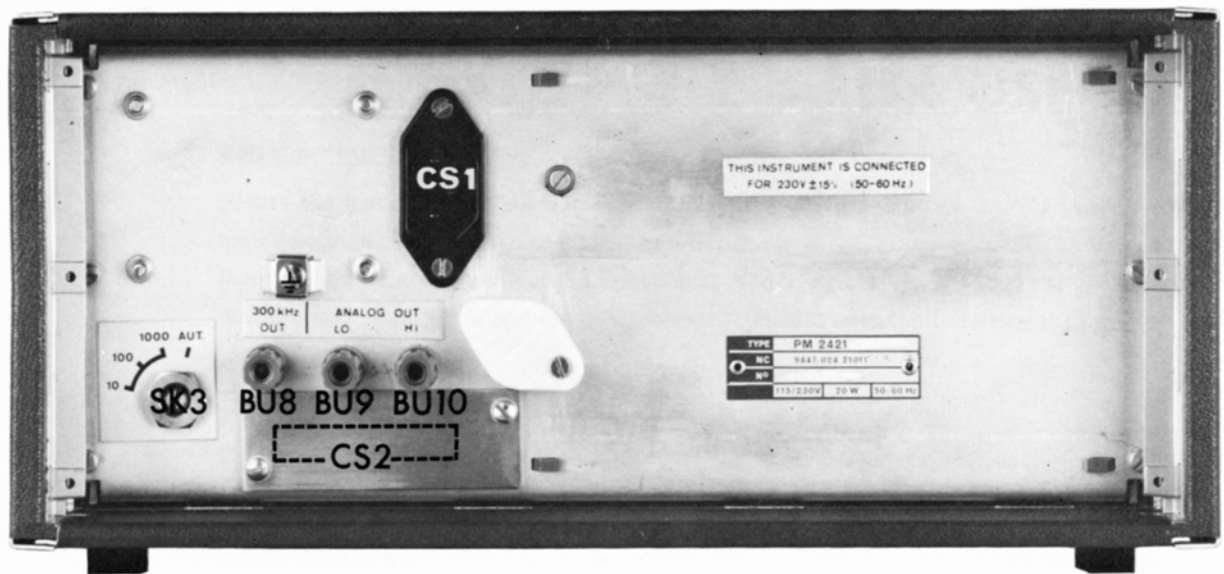


Fig. 13. Resoldering the jumpers on the mains transformer



MA5178A

Fig. 14. Rear view

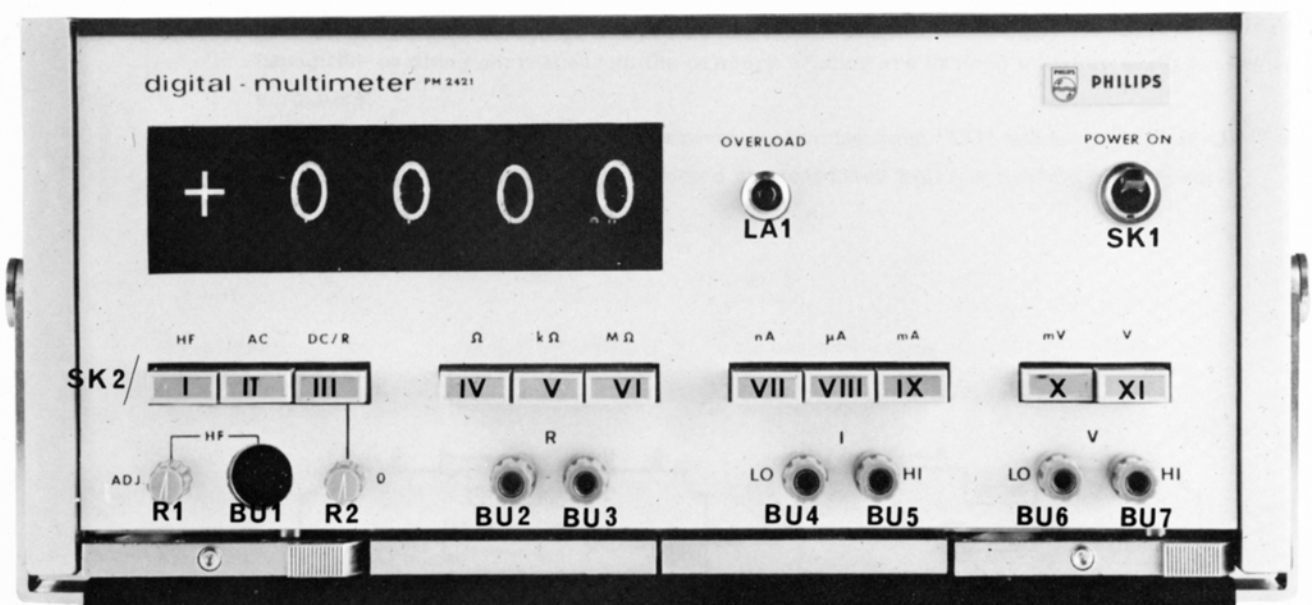


Fig. 15. Front view

3. Combining the instrument with other modules

The chassis of the PM 2421 may be accommodated in a 6-module cabinet (PM 9706) instead of the 4-module cabinet. The additional space in this cabinet can then be used for other units of the 3E modular system, being employed in conjunction with a digital voltmeter or independently.

This 6-module cabinet is suitable for mounting in 19" racks. When the additional space is not used, it can be closed off by means of a blank plug-in chassis.

For converting the instrument into the rack mounting version, proceed as follows:

- Remove the grey, plastic cable cover from the PM 9706 cabinet and take out the brackets.
- Remove the four screws at the two sides.
- Slightly lift the side plates at the front and remove the plastic plates which are now accessible. The brackets can now be placed in the free space.
- Refit the side plates and secure them with the four screws.
- Remove the four feet
- Mount the desired number of guide rails to the upper and lower crossbars. The appropriate holes in the crossbars are threaded.
- Slide the PM 2421 out of the 4-module cabinet and slide it into the 6-module cabinet.
- Fill the free space with one unit PM 9722 or two units PM 9721
- Lock the PM 2421 and PM 9722.

VI. OPERATION

1. Switching on

After connection to the mains and earthing, the instrument is ready for operation. By means of mains switch "POWER ON" the instrument is switched on; the display tubes light up. As no warm-up time is required, the measuring result can be read off immediately after selecting the desired mode of operation.

2. Mode selection

Mode

The mode is selected by push-buttons, by means of which simultaneously the range group is selected in steps of 10^3 i.e. 1:1, 1:1000 or 1:1000000.

Within these pre-selected ranges, dependent on the measuring value, the instrument is automatically switched over to ranges with a ratio 1:1, 1:10 or 1:100, with corresponding display of the decimal point.

The modes d.c. and R (direct current, direct voltage measurements and resistance measurements) have a common push-button switch.

Connection

For connection of the test circuit, separate sockets are available for voltage, current and resistance. Interaction between these circuits is impossible, because the push-button switches are interlocked. The left-hand "I" and "V" sockets are connected to the circuit zero and may be employed as LO (LOW).

For measuring H. F. voltages (> 1 MHz) the special H. F. probe (with T-connector for co-axial lines) should be employed. This probe must be connected to 5-pole socket "HF" on the front panel.

3. Measuring value display and measuring range selection

The measuring result is displayed by means of cold-cathode tubes, the decimal point being indicated by a spot in these tubes.

Changing over of the measuring ranges is effected automatically but may also be done manually.

Automatic operation

In the case of automatic operation the low-ohmic voltage divider receives switching commands which depend on the measuring value.

If the measuring value at the least sensitive ranges is 99 or less, a more sensitive range step is selected and if the measuring value is 1400 or higher a less sensitive position is selected, if possible.

This automatic switching process continues until either the indication lies between 100 and 1399 or until one of the two extreme range positions is attained. When the indication in the least sensitive range is 1400 or higher, pilot lamp "OVERLOAD" also lights up, because the guaranteed measuring limit of the relevant pre-selection range is then reached.

At the most sensitive range the indication is also stable below 99. In the range between 100 and 140 the display is also retained if a higher accuracy would be possible for values between 1000 and 1300. This situation arises when the least sensitive position is switched on due to overloading or fluctuation of the measuring quantity.

However, it is simple to force the automatic range selector to start the measurement at the most sensitive range so that an indication between 1000 and 1399 is obtained at corresponding measuring quantities.

In the case of voltage and current measurements it suffices to briefly switch on the higher coarse range by means of the corresponding push-button, or to interrupt the measuring circuit briefly. In the case of resistance measurements a brief short-circuiting of the R-sockets will cause the instrument to change over to the next, more sensitive range.

Manual operation

Manual range selection is more advantageous in the case of series measurements in a single range. For part of the measuring values the measuring speed is then increased, as the switching times are eliminated.

The switch for manual selection is located at the rear of the instrument and can be operated by means of a screwdriver.

The switch has 4 steps: 1000, 100, 10 and AUTO. In position "AUTO" range selection is effected automatically, in the other positions the relevant ranges are switched on.

4. Polarity indication

In the case of d. c. measurements the polarity is indicated automatically on a cold-cathode tube with the + or - symbol. This indication refers to socket HI (High). In the case of resistance measurements the tube extinguishes and in the case of a. c. and h. f. measurements symbol "~" lights up.

5. Direct voltage measurements

For the d. c. mode push-button "DC/R" should be depressed. Up to input voltages of 1.4 V the "mV" button should be depressed and at higher voltages the "V" button. Before the measuring voltage is applied, it should be checked that the most sensitive measuring range is switched on; the position of the decimal point should be 00.00.

Control "0" serves for zero adjustment; it should be adjusted so that in the case of an open-circuited measuring circuit all digits are zero. After this the zero control should be set to a position at which the polarity reverses, i. e. at the +/ - transition.

When the voltage to be measured is applied to sockets "V" the measuring value and the polarity of the voltage are displayed.

When measuring very low voltages (below a few mV) it may be desirable to measure the voltage without the thermal voltage arising in the measuring lead. In this case zero adjustment should be effected after short-circuiting the measuring leads near the source. Thermal voltages in the measuring circuit can easily be compensated for with the zero control.

After the adjustment and after removing the short-circuit the voltage source to be measured may be connected.

H. T. measurements

For measuring voltages between 1 kV and 30 kV H. T. probe GM 6070 is available. This probe should be connected to sockets "V", whereby the measuring pole should be connected to "HI" and the "⊥" pole of the plug to "LO".

The value indicated by the PM 2421 in the V-range should then be multiplied by factor 100.

Caution!

Always connect the earthing wire of the probe to chassis or the zero pole of the h. t. source, before the high voltage is touched with the probe.

6. Alternating voltage measurements

The AC mode is selected with push-button "AC". With buttons "mV" and "V" the coarse voltage ranges can be selected; up to 1.4 V button "mV" should be depressed and at higher voltages up to max. 500 V, button "V". When connecting the voltage source to be measured, it should be observed that the potential which is closest to earth potential is connected to socket "LO". To avoid measuring errors the measuring lead should be connected so that no loop formation occurs. Capacitively induced currents from the mains will cause voltage drops in the measuring leads, which may affect the measurement.

The applied alternating voltage may be superimposed onto a direct voltage up to 400 V.

7. Current measurement

In the case of voltage and resistance measurements sockets "I" are short-circuited and are connected to the circuit zero. For direct current measurements the "DC/R" button should be depressed and for alternating current the A.C. button. Dependent on the current to be measured, one of the three buttons "nA", " μ A" or "mA" should be depressed. If the order of magnitude of the current to be measured is not known, it is recommended to start at the highest measuring range, i.e. mA. Otherwise the shunt resistors may be damaged.

The current circuit, especially in the case of AC measurements, should be connected so that the potential which is closest to earth potential is connected to socket "LO". In the case of alternating current measurements check that no earthing loops arise!

The voltage drop is 1 mV per nA, per μ A or per mA, dependent on the selected range. If in the case of current measurements the voltage drop is of importance (at low internal resistance), the measurement may be effected in two different ranges. The influence of the different ranges can then be derived from the measuring result.

By means of corresponding separate shunt resistors it is possible to keep the voltage drop on the "I" sockets below 14.00 mV for all current values.

8. Resistance measurements

For measuring resistance values button "DC/R" should be depressed.

Sockets R serve for connecting the test object. By means of buttons Ω , k Ω , or M Ω the coarse range can be selected. The measurement is effected with the aid of direct current.

As a result, it is also possible to measure the resistance of coils and transformer windings.

Zero adjustment should be effected as follows:

Ω ranges:

At the Ω ranges sockets R should be short-circuited. The indication can then be set to 0000 with the zero control. When the resistance value of the measuring leads should not be included in the measuring result, the short-circuit should be made at the test object. If the indication is then set to 0000 with the DC zero control, the resistance of the measuring leads is compensated for within a small range.

k Ω and M Ω ranges

In these ranges the measuring arrangement is different (also see point IV.B.4). The zero adjustment then does not depend in the first place on the resistance value but on the gain. Therefore, the "V" button should be depressed for zero adjustment.

The indication should then be set to 0000 with the zero control.

After this release the "V" button again and depress the k Ω or M Ω button.

In this case it is not necessary to short-circuit the R-sockets. At very low resistance values it should be taken into account that possible thermal voltages may affect the measuring result.

In such critical cases it is advisable to effect the zero adjustment procedure as described under " Ω ranges". The short-circuit should then be made direct at the test object and not at the sockets.

In the Ω ranges a current of 1 mA flows through the unknown resistance.

On account of this it is also possible to compare semi-conductors as regards diode voltage and temperature drift at a forward current of 1 mA.

At higher resistance values (above 100 M Ω) the measuring time is relatively long on account of the low test current. Hum may then affect the measuring result. To prevent this it is recommended to screen the high-ohmic resistor, the screening being connected to the circuit zero, e. g. to socket LO of the I-input.

9. HF voltage measurements

For H. F. measurements at frequencies ≥ 1 MHz probe PM 9203 may be used and for measurements to co-axial lines T-connector PM 9253 is available.

By means of the latter H. F. voltages with frequencies up to 1200 MHz can be measured.

The measuring probe should be connected to the 5-pole socket at the front of the instrument.

The mode is selected with push-button H. F.

At voltages below 10 mV and in the case of large temperature variations calibration is necessary. For this control "ADJ" at the front and socket "300 kHz OUT" at the rear of the instrument should be used. The reference voltage available on socket "300 kHz OUT" serves for calibration.

Calibration:

- Switch on the instrument.
- Depress buttons "AC" and "mV".
- Connect socket "300 kHz OUT" at the rear to socket "V" - "HI" by means of a connection wire.
- Connect the HF probe to socket V-HI and connect the earthing wire of the probe to socket LO.
- Read the measuring result (observe a waiting time of approx. 20 sec).
- Depress button H. F.
- Accurately adjust the indication to the previous reading with potentiometer "ADJ".
- Fix the arrow of control "ADJ" so that the arrow points upwards in the calibrated condition.
- Disconnect the probe from socket V HI and remove the connection from socket "300 kHz OUT".

Usually this procedure will have to be carried out only once.

However, for H. F. measurements it should always be observed that the arrow of the control points exactly upwards, as the potentiometer is then in the calibrated position (provided that it has been correctly fitted during calibration).

Calibrated instruments should only be used in conjunction with the same probe as used for calibration. However, it is possible to calibrate several instruments with the same probe.

Measurement

Voltage measurements above 10 mV and at frequencies up to 300 MHz require no special measures. At low input voltage (below 5 mV) the indication is obtained rather slowly.

Possible interference caused by H. F. fields may be eliminated by short-circuiting sockets V (HI and LO) and simultaneously connecting the R-sockets to LO of socket V.

For all HF measurements it should be observed that the housing of the probe is connected to a proper measuring earth by means of the accessory earthing lead. The earthing connection should be kept as short as possible; if necessary, screen the circuit (to prevent H. F. interference caused by radio transmitters).

For measuring voltages at high frequencies it is recommended to use the T-connector.

This T-connector can be included in the test circuit by means of the co-axial cable with BNC connectors. The HF probe is connected to the H.F. leads by screwing it into the T-connector.

For measurements at the voltage range from 1.4 V 140 V a capacitive voltage divider with a division ratio of 100:1 is provided.

As this divider precedes the measuring diodes, the position of the decimal point will no longer be correct. Therefore, the indication in the mV range should be multiplied by 100.

10. Analogue output

In the analogue circuit all measuring voltages are converted into direct voltages of the same order of magnitude. The value of this direct voltage, within a certain range, is directly proportional to the input quantity and is 5 mV per digit; it follows that for the full-scale value of 1400 the output voltage will be 7 V. To prevent the indication from being affected in the case of short-circuiting of the analogue output, a 5.6 k Ω resistor has been connected in series with the analogue voltage source.

The analogue output is located at the rear of the instrument and the relevant sockets are marked "ANALOG OUT". Thus it is possible to use the PM 2421 as a sensitive d.c. amplifier and to record the measuring result with the aid of recording equipment.

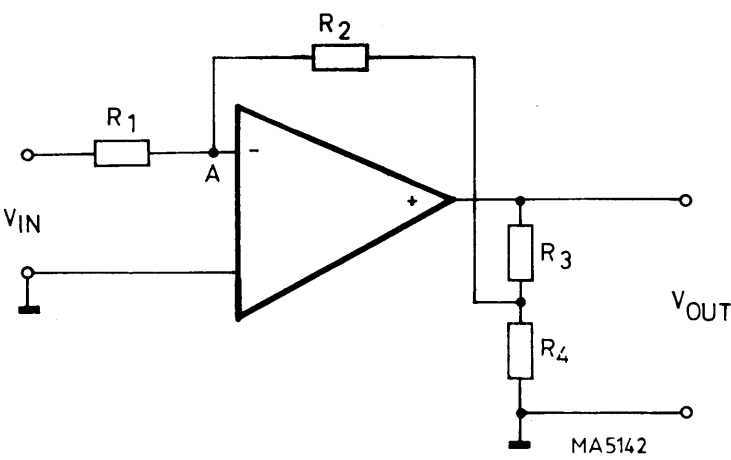


Fig. 16. D.C. amplifier

VII. CIRCUIT DESCRIPTION

SERVICE DATA

A. CHOPPER-STABILISED D.C. AMPLIFIER (U1) Fig. 19

1. General description

The chopper-stabilised d.c. amplifier is used for direct voltage, direct current and resistance measurements.

For HF measurements the amplifier is included in a control circuit.

Without negative feedback the d.c. amplifier has such a high d.c. gain that even without input signal (thermal voltages) it will give a maximum output. The working principle of this d.c. feedback amplifier is clarified with the aid of the simplified diagram shown in Fig. 16. At all the ranges of the PM 2421 a digital reading of 1000 will be obtained when the output voltage V_{out} is 5 V. If it is assumed that the internal gain is 5×10^7 , the voltage-on summing junction A will then be $\frac{5 V}{5 \times 10^7} = 0.1 \mu V$.

In the most unfavourable case (at maximum gain), the corresponding input voltage will then be $V_{in} = 10 \text{ mV}$. As the voltage drop is negligibly small compared with the input signal (max. 0.01 % of V_{in}), it follows from the above diagram that:

$$-\frac{V_{in}}{R1} = \frac{V_{out} \frac{R4}{R3+R4}}{R2} \text{ or } -\frac{V_{out}}{V_{in}} = \frac{R2}{R1} \left(\frac{R3}{R4} + 1 \right)$$

The minus sign shows that the amplifier operates as an inverter, i.e. it supplies a negative output voltage when the input signal is positive. In the case of direct voltage, direct current and resistance measurements (Ω ranges only) the value of $R1 = 1 \text{ M}\Omega$ and that of $R2 = 5 \text{ M}\Omega$. At the most sensitive range, the ratio $\frac{R3}{R4}$ is $\frac{99}{1}$, so that the voltage gain will be 500. At the middle range $\frac{R3}{R4} = 9$, and the gain is 50. At the least sensitive range $R3$ will be 0 and the voltage gain 5. In the case of $k\Omega$ and $M\Omega$ measurements V_{in} and $R1$ are constant; the unknown resistance is represented by $R2$. The output voltage at various resistance values can be calculated if it is known that $V_{in} = 10 \text{ mV}$, and that the value of $R1$ is $2 \text{ k}\Omega$ at the $k\Omega$ ranges and $2 \text{ M}\Omega$ at the $M\Omega$ ranges.

The amplifier comprises three main functional parts, viz.: the chopper-a.c. amplifier-demodulator, the differential d.c. amplifier and the chopper drive.

2. Input circuit

Before summing junction A resistor $R1$ has been included, which in fact is a low-pass filter consisting of $R101$ up to $R105$, $C101$, $C102$.

This low-pass filter serves to suppress possible interference voltages. Neon lamp $GL8$ serves for overload protection.

3. Chopper, auxiliary amplifier and demodulator

The a.c. component of the signal on the summing junction is applied to the inverting input of the differential amplifier via $R106$ and $C103$. Via low-pass filter $R160/C120$, which has a division ratio of approx. 0.6, the d.c. component is fed to the chopper.

The chopper, which is connected in series-parallel arrangement, consists of LDR's, exposed by means of pulse-controlled neon lamps. The duty cycle of this chopper is approx. 60 % and it supplies a squarewave voltage. Due to a special circuit arrangement and the small current through the first stage, transistors $TS116$, $TS117$ and $TS118$ have a very high input resistance at a small quiescent current.

Stabilisation of the working point is ensured by resistor R168, which for the chopper frequency is shunted by C124. Capacitors C122, C123 and C125 prevent feedback at the higher frequencies. TS119 boosts the overall gain of the a.c. amplifier to more than 5000. Transistor TS120 operates in common-base arrangement and effects phase inversion for the push-pull demodulator. Resistor R172 shunted by C128 serves for stabilising the working point of these two stages.

Transistors TS119 and TS120 supply currents which are equal but shifted 180° in phase with respect to each other. The symmetrical demodulator stages TS121 and TS122, which operate in push-pull, are also controlled by pulses derived from the chopper drive. These pulses are synchronous with the squarewave signal of the chopper drive and have a phase shift of 180° . Thus, after the demodulator and low-pass filter R175 and R176/C130, a direct voltage is obtained, which is amplified 800 times and inverted with respect to the input signal on point 3.

4. Differential d.c. amplifier

The voltage on C130 controls the non-inverting input of differential amplifier TS101. Parallel to this input two diodes are connected which after strong overloading ensure a short recovery time.

The current through R112, which can be adjusted with potentiometer "DC/R/0", enables compensation of interference signals in the measuring circuit. The first amplifier stage TS101 is followed by a symmetrically driven differential amplifier (TS102, TS103) which supplies an asymmetrical voltage across R120. TS104 operates as an emitter-follower and controls TS105 which is connected in common-base arrangement. TS106 is a constant current source, which represents a very high collector resistance for TS105.

The difference between the base voltages of TS107 and TS108 is compensated for by the direct voltage drop across GR105 and GR106.

Transistors TS107 and TS108 are connected as emitter followers.

Their base-emitter junctions are protected by GR115 and GR116, and resistors R130 and R133 prevent thermal overloading.

Network R116, C108 and capacitors C110, C111 and C112 serve to prevent H.F. oscillations. At the output of the amplifier, limiter networks have been included which prevent the output voltage from exceeding certain values.

When the output voltage exceeds the zener voltage of GR111 plus the diode knee voltages of GR109 and GR103 or the zener voltage of GR112 plus the knee voltages of GR110 and GR104, the low dynamic resistance of these diodes is included between the summing junction (3) and the output. Thus negative feedback is obtained which reduces the gain accordingly. When the amplifier is not overloaded the leakage currents of the diodes are drained to the circuit zero via resistor R121. This prevents the gain from being influenced by the cut-off diodes which are then connected between the summing junction and the circuit zero. GR107 and GR108 are only operative in the case of HF voltage measurements. In the event of overloading these diodes ensure that the recovery times are as small as possible.

5. Chopper drive

The chopper drive circuit supplies the voltages required for driving the photo-chopper and the demodulator. To avoid interference due to 50 Hz or 60 Hz hum and harmonics of these frequencies, a chopper frequency of 190 Hz has been chosen. Since the resistance of the photo-resistors increases only slowly after exposure, the exposure time has been made proportionally smaller with respect to the "dark" time. The demodulators operate practically without a delay, so that symmetrical squarewave voltages are required to drive these stages.

The first two transistors TS109 and TS110 form an asymmetrical astable multivibrator. Adjustment of the repetition frequency of 380 Hz is effected with resistor R134. Asymmetry is obtained by the different values for C116 and C115. The collector waveforms of transistors TS109 and TS110 are shown in Fig. 17.

The collector voltage of TS109 controls bistable multivibrator TS111-TS112 via C117, GR121 or C118, GR122.

The bistable changes over on every negative-going transient of the collector voltage of TS109. On the collectors of TS111 and TS112 squarewave voltages with a frequency of 190 Hz arise (Fig. 17). These voltages are applied to the demodulator via diodes GR119 and voltage divider R143, R139 and via diode GR120 and divider R144, R140.

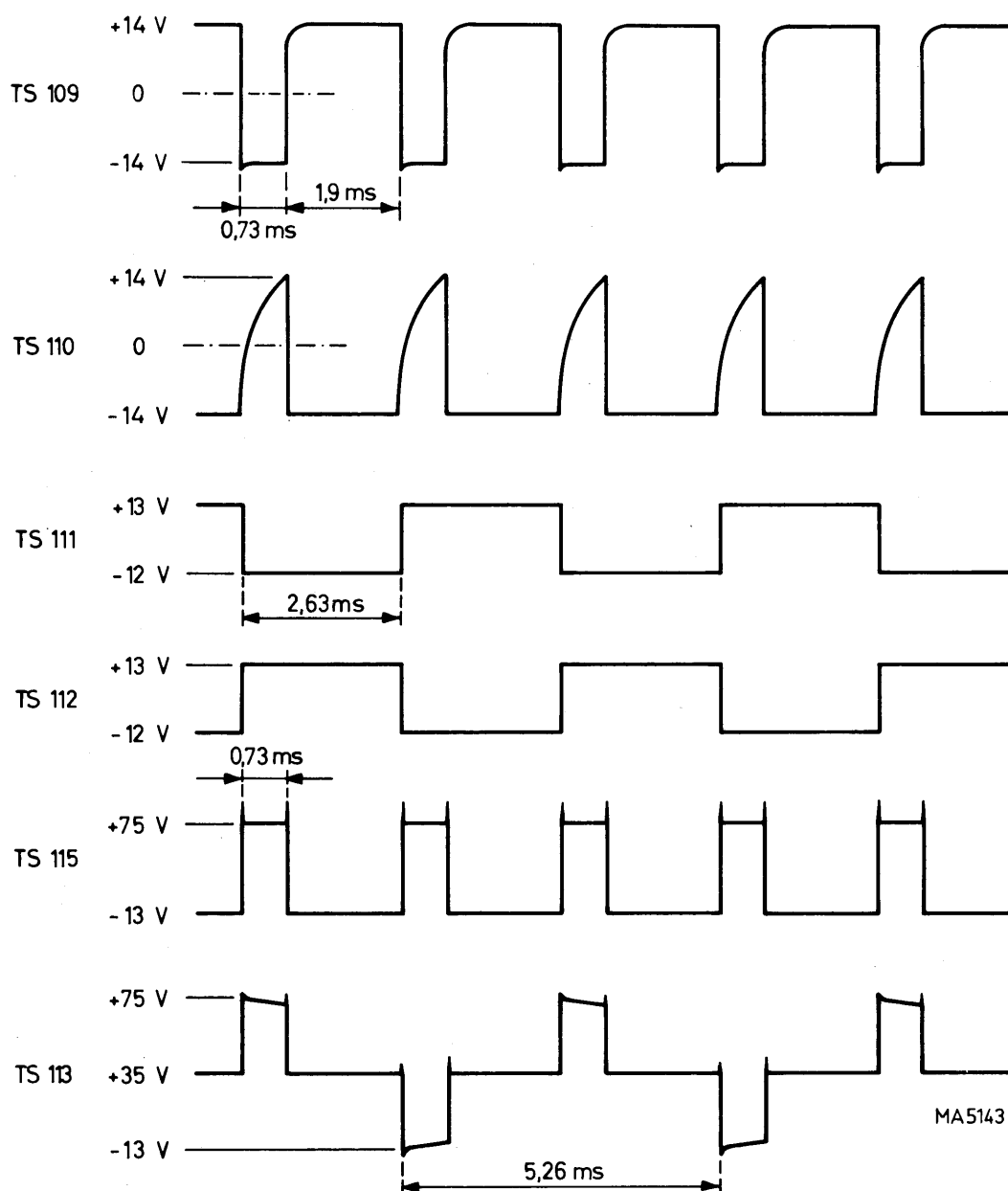


Fig. 17. Collector voltages in the chopper circuit

When TS113 or TS114 is conductive and a sufficiently high voltage is available, the neon lamp in the chopper will light up during this period. TS115 is driven by TS109 in such a way that TS115 is turned on during the longest time (1.9 msec) and turned off during the shortest time (0.73 msec), see Fig. 17.

When TS115 is conductive the voltage drop across R157 will be so high that the neon lamp cannot ignite. The neon lamps only light up during the short interval determined by TS113 or TS114. When the voltages on the collectors of TS110 and TS111 are simultaneously positive, diodes GR126 and GR127 will be cut off (AND-gate); transistor TS113 will become conductive and its collector voltage will decrease to -13 V (Fig. 17). The voltage in the collector circuit of TS113 will then be sufficiently high to strike the neon lamp. TS114 is turned on when the collector voltages of TS110 and TS112 are positive.

Sawtooth oscillation of the neon lamps is prevented by shunt resistors R155 and R156.

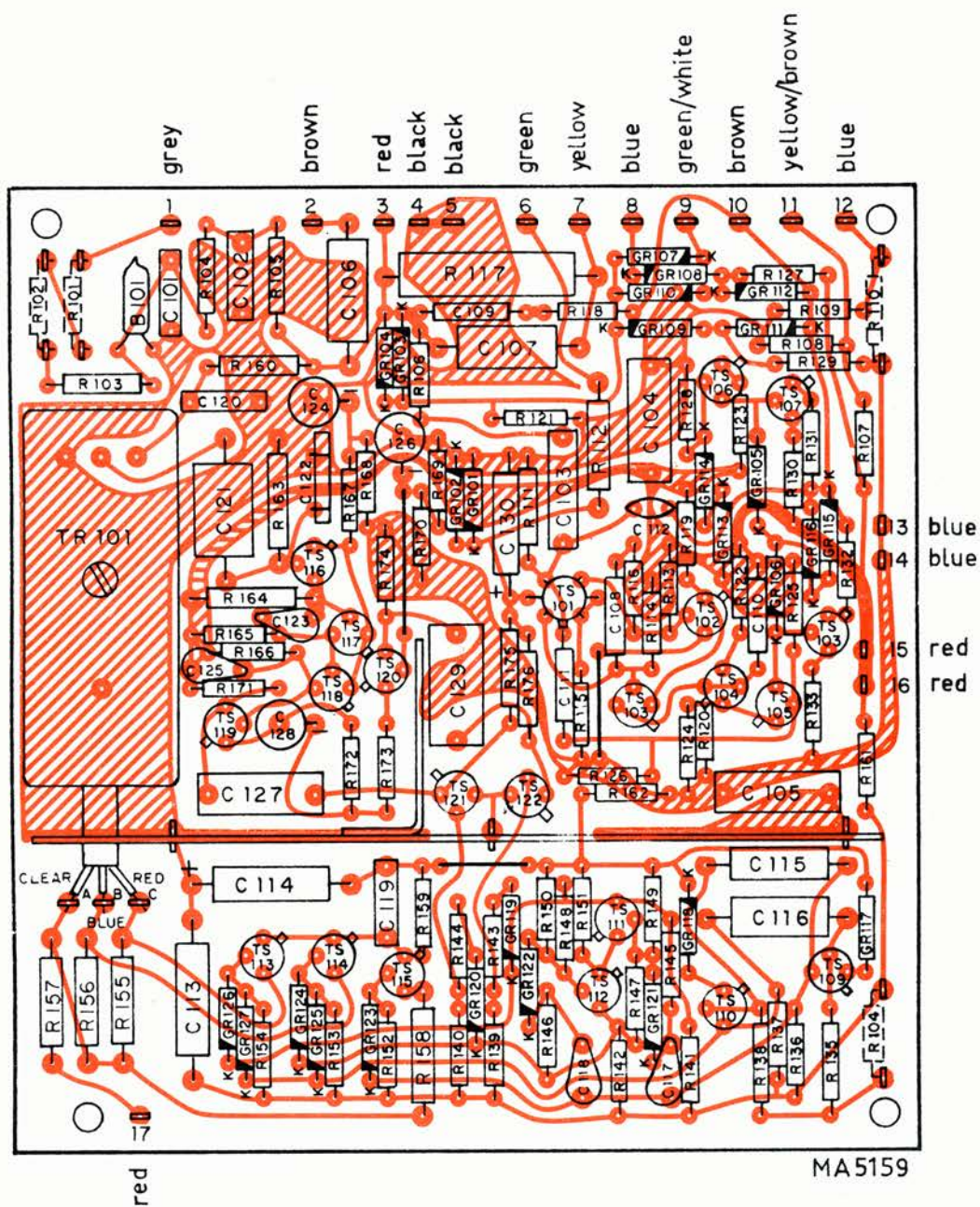


Fig. 18. Printed circuit board U1

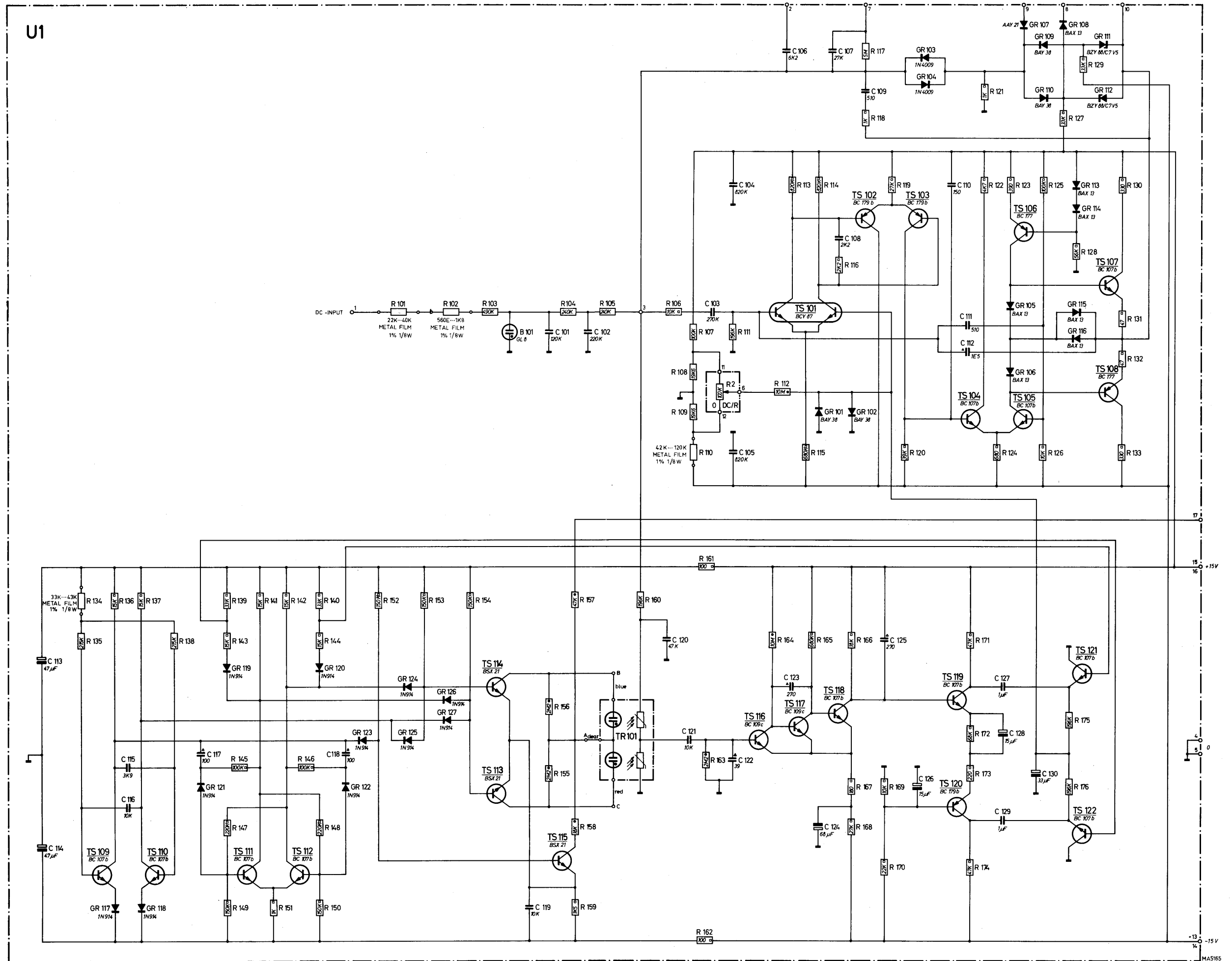


Fig. 19. Circuit diagram of the chopper-stabilised D.C. amplifier

B. AC-TO-DC CONVERTER (U2), Fig. 21

The high-ohmic voltage divider comprising resistors R201...R204 and capacitors C201...C203 is used at the V-ranges for direct and alternating voltage measurements. Its division ratio is 1000:1. This ratio can be adjusted with potentiometer R204 for direct voltages and alternating voltages with low frequencies. Frequency-independent voltage division is ensured by the capacitively adjusted divider (adjustment has also been effected for the varying stray capacitances of the circuit elements).

The impedance matching stage comprises field-effect transistor TS201 and transistors TS202 and TS203. TS201 and TS203 operate as a voltage amplifier; TS202 is an emitter follower. The high internal voltage gain is reduced to unity by negative feedback. The series-parallel feedback applied stabilises the voltage amplification and reduces the output impedance. Capacitor C204 at the input serves for blocking d.c. components superimposed on the alternating voltage to be measured. Resistor R208 and diodes GR201/GR202, which are reverse biased, protect the field-effect transistor against excessive input voltages. For direct voltages the gate of TS201 is connected to the circuit zero via R207. Consequently, the direct voltage on the collector of TS203 will correspond to the gate-source voltage of TS201 between +0.5 V and +3.5 V with respect to the circuit zero.

In the case of AC and HF operation the impedance matching stage is connected to the low-ohmic voltage divider via capacitor C207. The output voltage of this divider is applied to the input of the voltage amplifier via resistor R217.

The voltage amplifier consisting of transistors TS204, TS205 and TS206 has a high internal gain (more than 300). In the fed-back condition its voltage gain, dependent on the value of R229 and R224, is approx. 17 for alternating voltages up to more than 1 MHz. The feedback network includes several correction elements (C209, R223; C211; C210, R229; R228, C212), which permit of adjusting the desired frequency response.

With the aid of resistor R225 the gain is adjusted within limits of $\pm 0.3\%$. The entire circuitry following the low-ohmic voltage divider is d.c. coupled to the analogue output. This circuit arrangement enables short recovery times at a good LF frequency response.

Diodes GR203 and GR204 limit the input voltage in case of overloads. R228 serves for adjusting the working points of transistors TS207, TS208 and TS209. The direct voltage on the base of TS210 should be approx. -3.5 V. Stabilisation of the d.c. setting is effected with the aid of TS210.

The amplifier with transistors TS207, TS208 and TS209 has a very high no-load voltage gain. The rectifying diodes are included in the feedback circuit. In the absence of an input voltage there is no negative feedback; the internal gain is then very high. Even when the input voltage is increased slightly, the diodes will become more conductive.

The larger the current through the diodes, the more the feedback voltage increases; the voltage gain is then reduced. The rectifying network ensures that the current is proportional to the input voltage. This current causes a voltage drop across R241 and R242 whose value corresponds to the average value of the alternating input voltage. The slope (output direct current versus input alternating voltage) of the amplifier-rectifier circuit is in the first instance determined by R233 and R239.

The voltage across GR209 causes an apparent reduction of the knee voltages of GR208 and GR210.

Network GR211/R244 slightly improves the linearity. R242 permits of adjustment of the output voltage (accuracy better than 0.03 %).

The direct voltage obtained across R241/R242 after rectification is symmetrical with respect to the circuit zero. It comprises a d.c. component and an a.c. component. The low-pass filters consist of R243...R247, C220/C221; they serve to smooth the rectified mains voltage. One section of the differential amplifier, with TS213, TS212 and TS211, and the other section, with TS213, TS214 and TS215, each form an impedance matching stage. The offset voltages and currents of these impedance matching stages and of IC201 are compensated for by means of R249. On the outputs of the impedance matching stages, two superimposed direct voltages arise. One direct voltage is determined by the setting of TS209 and is the same for both sections of TS213. The other voltage is the difference between the direct voltages; it depends on the value of the input signal and provides asymmetrical drive for TS213. The following differential amplifier including IC201 and feedback resistors R255...R261 has a high common-mode rejection, which is accurately adjustable with the aid of R259. The gain for the difference signals is about ten. Thus, on the output of IC201 a direct voltage is obtained with respect to the circuit zero, whose value corresponds to the alternating voltage on the input and which contains practically no a.c. components.

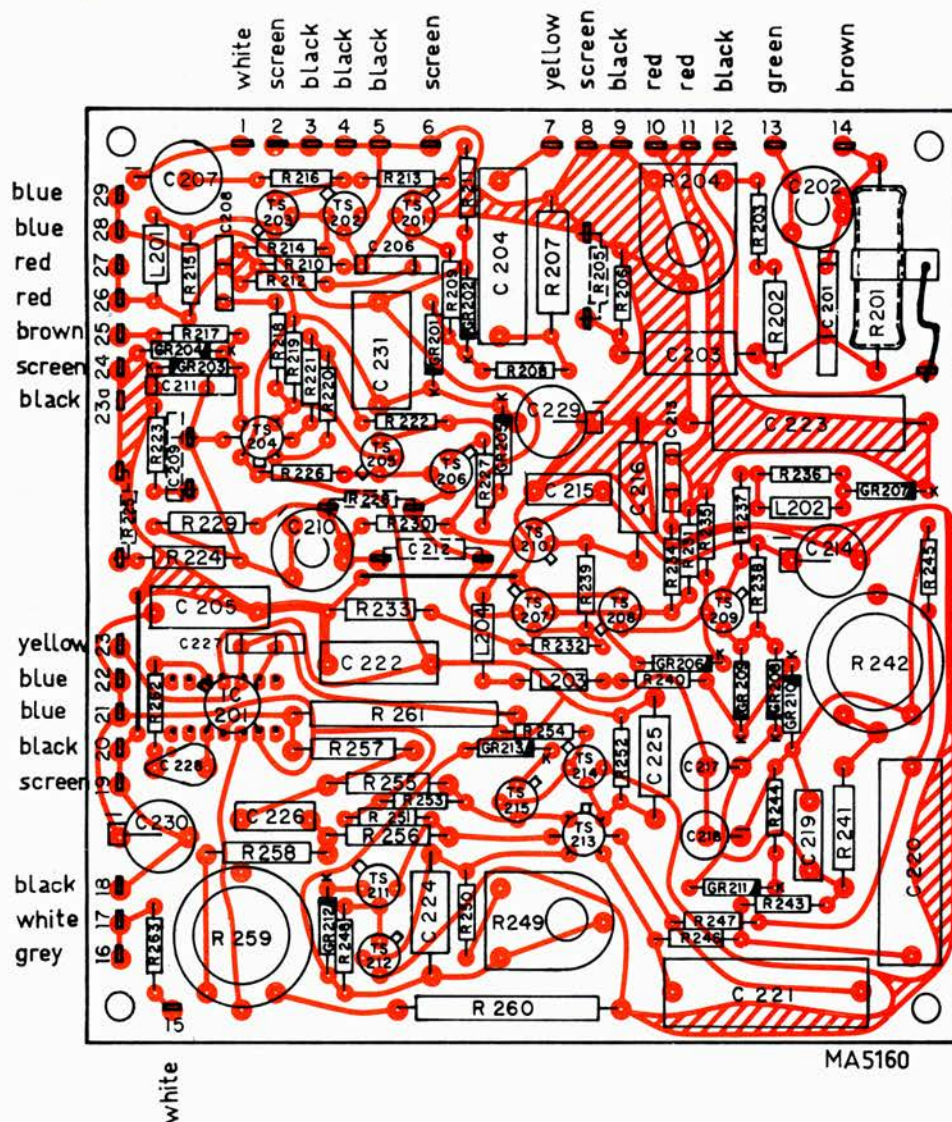


Fig. 20. Printed circuit board U2

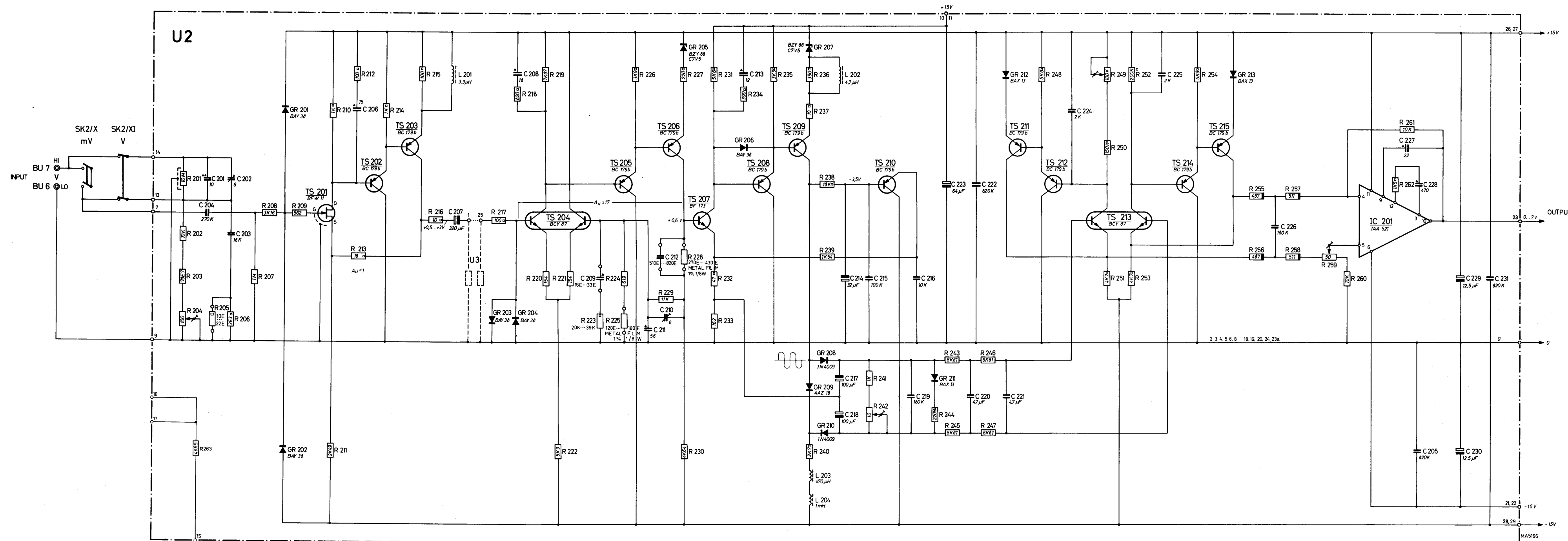


Fig. 21. Circuit diagram of the a.c. - to - d.c. converter

C. 300 kHz OSCILLATOR, CONTROL CIRCUIT, DC CURRENT GENERATOR AND AUTOMATIC CONTROLLED VOLTAGE DIVIDER (U3) Fig. 23

1. 300 kHz Oscillator

Transistor TS301 which is connected as an emitter follower operates as an oscillator. The voltage gain of an emitter follower lies slightly below unity. By means of the coil of the resonant circuit it is achieved, that the product of gain factor and feedback is slightly higher than one. The amplitude of the oscillator is determined by the coil, the current through TS301 and the limiter in the base-emitter circuit of TS301. The current supplied by TS301 is controlled by TS302. The output voltage of the d.c. amplifier is applied to point 27. When this voltage is almost equal to zero potential, TS302 is cut off. When the input d.c. voltage is increased by $-0.5 \dots -0.7$ V transistor TS302 will become more conductive, so that the oscillator voltage increases. Due to the oscillator output voltage, a current arises through R310 to the inputs of the regulator stages, i.e. to the emitters of TS303 and TS304. The distribution of the current among TS303 and TS304 is controlled by the direct voltage supplied by the d.c. amplifier. When this voltage is approximately equal to zero potential, the current will flow through TS303; TS304 is then cut off. The voltage drop across R314 is almost zero. When the d.c. input voltage is increased towards -0.7 V transistor TS303 becomes less conductive, so that the current through TS304 will increase accordingly. This direct current is superimposed on the 300 kHz voltage from the oscillator. Across R314 a voltage drop arises which is proportional to the current through TS304. As a result an alternating voltage of $0 \dots 1.7 \text{ V}_{\text{rms}}$ will arise on the collector of TS304, whose value depends on the value of the d.c. input voltage across R307 and R309 (between 0 and 0.7 V). Capacitor C310 serves for blocking the direct voltage and TS305 effects impedance matching.

Via voltage divider R304, R305 a calibration voltage of approx. 1.7 mV is obtained.

The regulator also includes adjusting networks which ensure the accuracy of the H.F. voltage measurements. At higher voltages the working points of the diodes in the probe can be made symmetrical by means of potentiometer R337. Adjustment of the working point is effected with R331 (coarse) and R1 "ADJ." (fine).

2. Direct current source (U3)

For resistance measurements a current source supplies a direct current of 1 mA at a very high output resistance.

The constant current is supplied by transistors TS307 and TS308 (the current through TS307 is very small with respect to the current through TS308). With the aid of voltage divider R321, R322 and R323 transistor TS306 is biased so that a current of 1 mA is obtained into R328.

Transistor TS306 compares the voltage across R328 with the voltage across R322 + R323. The right-hand section of TS306, together with TS307 and TS308, forms a control circuit which stabilises the voltage across R328 at the preset value across R322 + R323. During normal operation TS309 is cut off; in the case of output voltages above 2 V it functions as a limiter.

3. Automatically controlled voltage divider (U3)

The signals for changing over the voltage divider are obtained from the digital section. A detailed description of automatic control system is given in chapter VII. F. 13.

In the case of AC and HF measurements the voltage divider is included in the AC-to DC converter between connection points U2/1 and U2/25. In the case of DC and R measurements, the voltage divider is included in the feedback circuit of the d.c. amplifier.

On printed circuit unit U3 three reed relays RE301...RE303 are mounted, which switch over the voltage divider consisting of precision resistors R340...R343. This voltage divider has a division ratio of 1:1, 1:10 or 1:100, dependent on the positions of relays RE301...RE303.

Fine adjustment for the 1:100 division is effected with R340. The diodes GR301...GR303 serve to short-circuit the induction voltage arising when the relay coils are switched out of circuit. GR304...GR306 prevent undesired ignition of the decimal point indication via the relay coils.

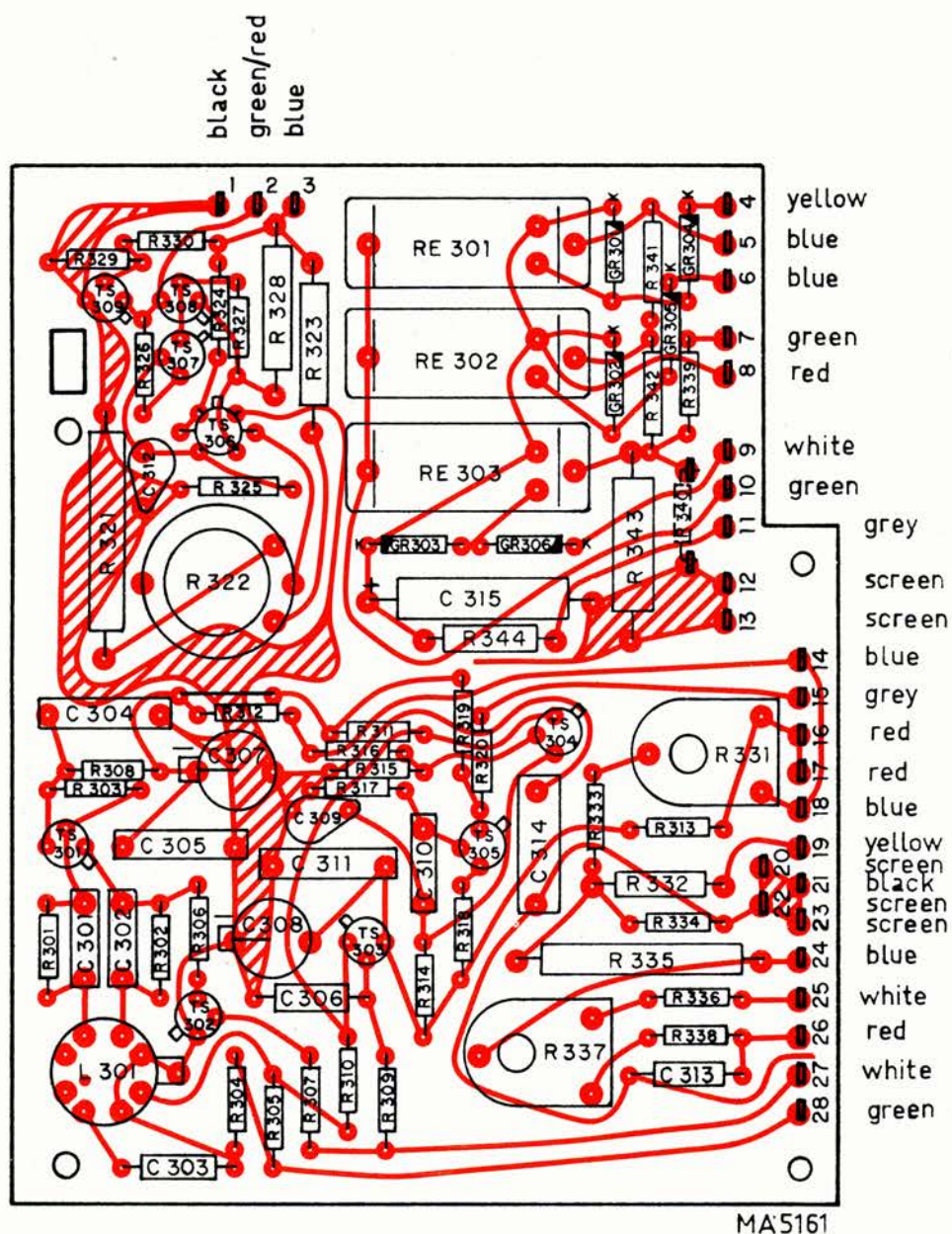


Fig. 22. Printed circuit board U3

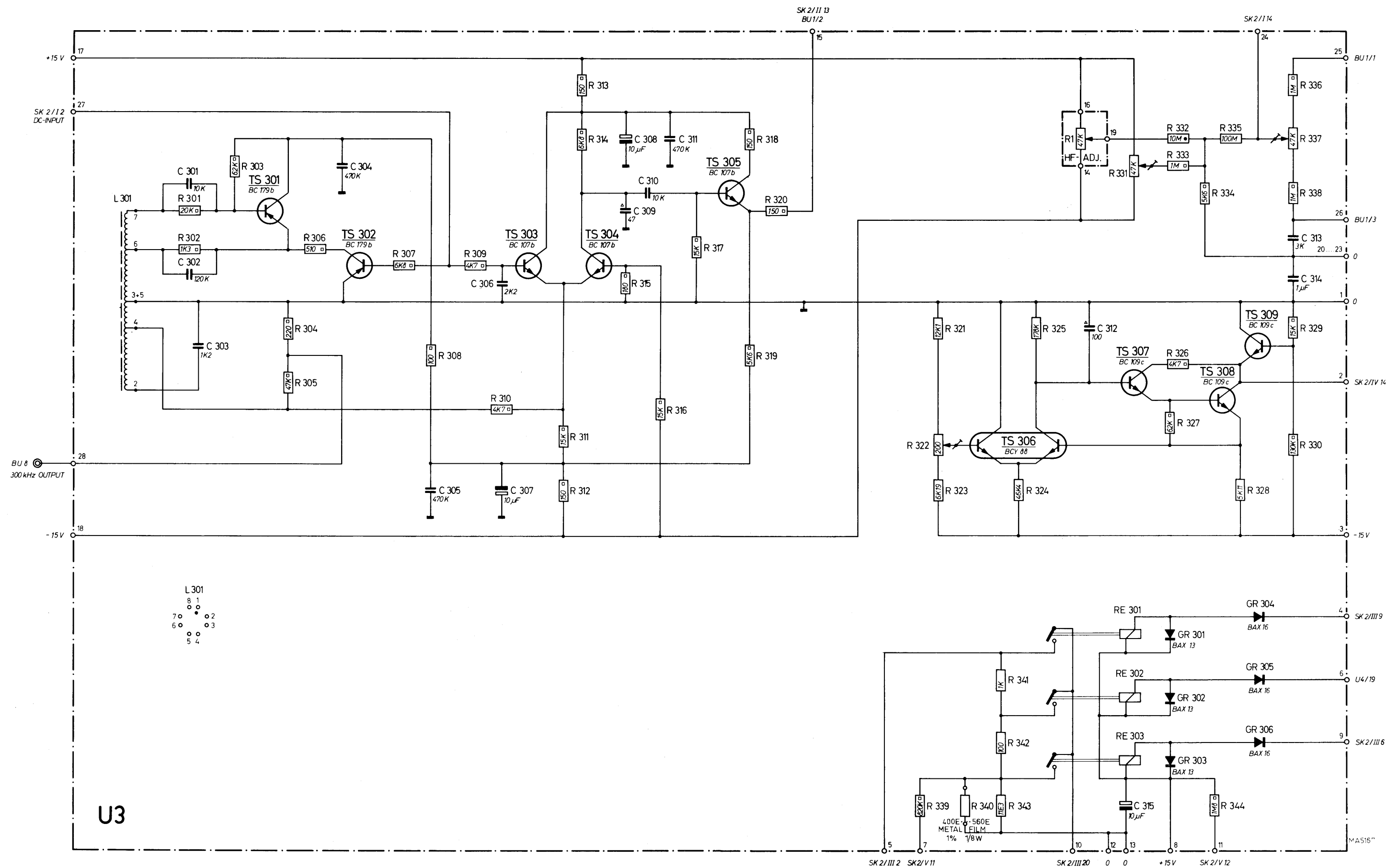


Fig. 23. Circuit diagram of H. F. section

E. DIGITAL SECTION (U4) Fig. 39

1. Working principle

The working principle is explained with the aid of the logic circuit diagram, Fig. 39 and pulse sequence diagram, Fig. 24.

The measuring cycle is started when:

1. the programme flip-flops IC415 (A-FF) and IC416 (B-FF) are in the zero position

$$(Q_A = 0, Q_B = 0).$$

2. Inputs J2 (4) and J3 (5) of flip-flop A (IC415) are in the "1" state.

Starting, however, is not effected until the negative edge of the next clock pulse appears

(sequence diagram, programme flip-flop A). Output Q_A will assume the "1" state. Nand-gate IC414/A supplies control signal T2 for the integrator.

Inputs 1 and 2 are "1", so that the output 3 is "0": the upward integration is initiated.

Simultaneously gate IC414/B at the input of the counter is opened (Input 4 is in the "1" state).

From the clock-pulse generator the clock pulses are now applied to the counter input (IC407/14) via IC414/B and IC414/D.

The counter is reset to 1000 by the preceding reset pulse, and because the counter gate is opened, it counts further to 2000, thus determining the duration of the upward integration period (100 msec.).

During counter position 1998, i.e. shortly before the end of the upward integration period, Nand-gate IC412 and IC417/C at the output of the counter supplies a pulse. The negative edge of this pulse triggers the polarity flip-flop (IC416/A, input 5). Thus the polarity of the integrator charge is stored.

At the same time, programme flip-flop IC416/B is switched over, so that output \overline{Q}_B becomes 1, thus initiating the downward integration. Gate IC414/B remains open; the counter is set from 1999 to 0 and starts counting down the clock pulses, while the integrator is discharged with a constant current.

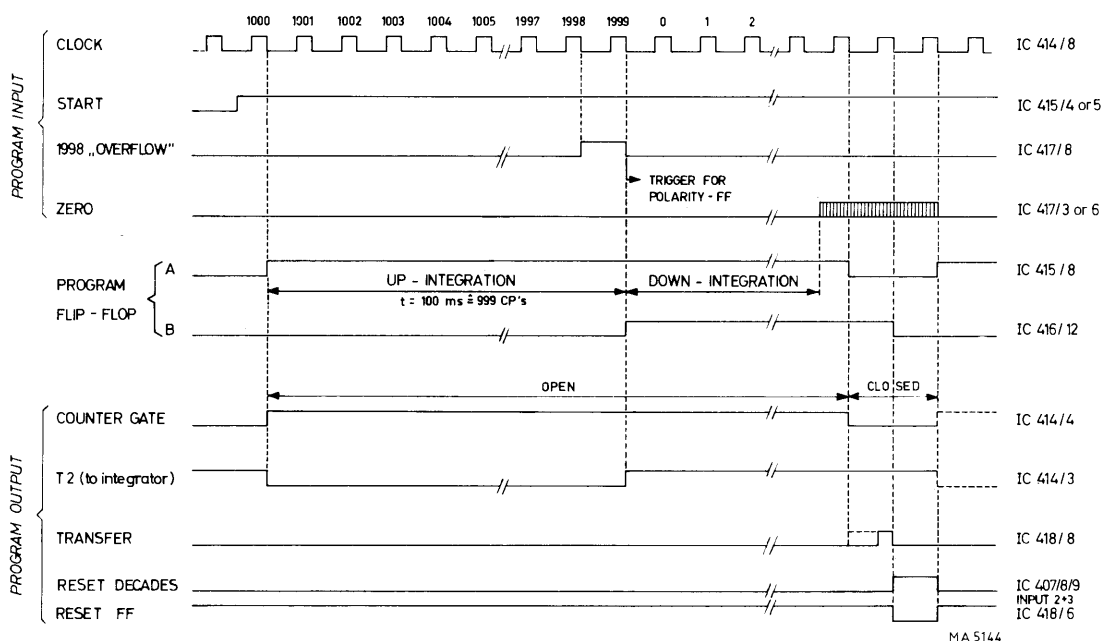


Fig. 24. Sequence diagram

When the integrator is discharged to zero, gate IC417/A or IC417/B supplies a "Zero" signal to the programme input (IC415 inputs 9 and 10). Upon the next negative edge of the clock pulse the programme is advanced one step. Gate IC414/B is closed (Q_A becomes 0), so that no more clock pulses can be applied to the counter. During the 1-condition of the next clock pulse the transfer pulse arises. As a result, the measuring result is transferred from the counter into the memory and is displayed by the indicator tubes via the BCD-to-decimal decodes/drivers IC401, IC402 and IC403.

The next clock pulse switches the programme to reset. Via the reset lines R1 and R2 the counter is then reset to 1000. Thus the circuit is ready for the following measuring cycle, which will be initiated by the next clock pulse if no stop signals are applied to J2 or J3 of IC415.

2. Input circuit

After processing in the relevant input stages, the various measurements yield d.c. signals which should be converted into digital form by the digital section. The first step in this process takes place in the input circuit with the integrator. This is in fact the main function of this instrument, because here the analogue measuring signal is converted into digital form. Moreover, this function is decisive of the measuring accuracy. Analogue-to-digital conversion is effected in the integrator, which operates as follows:

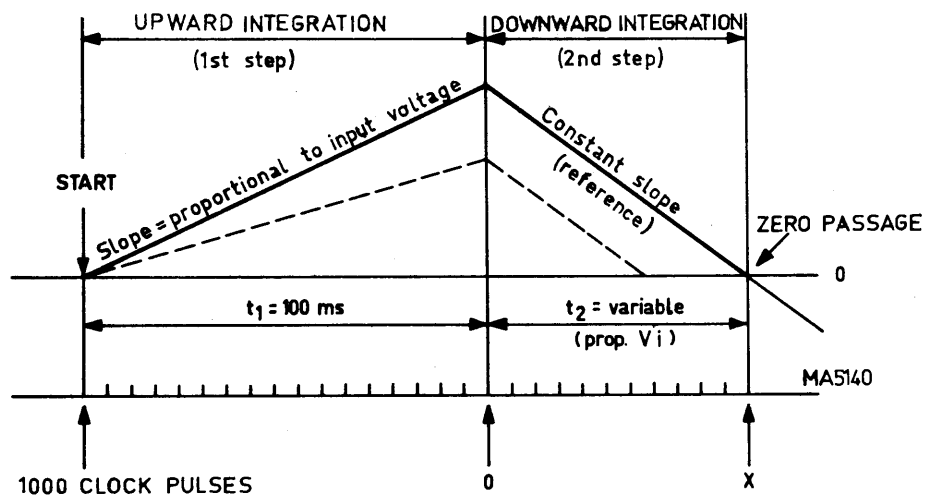


Fig. 25. Integration process

In the feedback circuit of operational amplifier IC424 integration capacitor C402 has been included (Fig. 26).

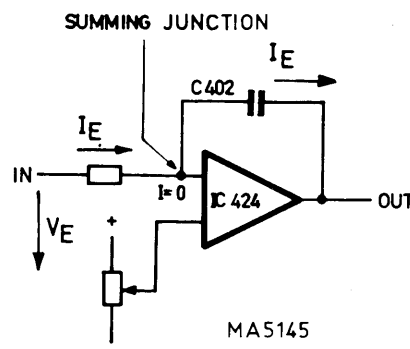


Fig. 26. Integration circuit

A current proportional to the input voltage to be measured U_E flows to the summing junction of the operational amplifier and into integration capacitor C402. At the end of the charging time (100 msec) the operational amplifier will supply an output voltage which is proportional to the unknown input voltage U_E .

The charging cycle (first step) is followed by the discharging cycle (second step), see Fig. 25.

Capacitor C402 is discharged with a constant current, determined by the positive or the negative reference voltage. The time required for a complete discharge (zero passage) is proportional to the input voltage. This time is measured by counting clock pulses and is processed for display (also see under IV. B. 5. Description of the block diagram).

To the summing junction of the integrator (IC424 point 2) three different signals may be applied via shunt switches TS401...TS403.

During the first step TS401 is cut off (this corresponds to an open contact). Simultaneously, TS402 and TS403 are conductive. The input voltage (input 9) causes a current through R409 and R412 to the summing junction of the integrator (IC424 point 2).

As the summing junction is almost at zero potential, no current will flow into R413 and R414, although these resistors are connected to earth via TS402 and TS403. Moreover, there will be practically no current into the operational amplifier, because its input is very high-ohmic. Consequently, the current to the summing junction will flow directly to integration capacitor C402 which is then charged. As a result, a voltage will arise at the integrator output, which increases linearly with time.

During the second step TS401 is conductive because a base current of 2 mA is applied. TS402 or TS403 is cut off. As a result, the discharge current from the integrator is applied to the summing junction, i.e. the integrator output voltage changes to zero. The discharge current is determined by the reference voltage and resistors R401, R402, R403, R407, R410, R413 or R404, R405, R406, R408, R411 and R414.

For the operational amplifier a supply voltage of +15 V and -15 V is required. This voltage is applied to IC424 via smoothing filters R445/C411 and R447 + R448/C414. RC-circuit R423/C404 and C403 serves for phase correction. This is necessary to prevent oscillation of the amplifier which has a high degree of feedback.

Resistor network R415...R422 and R424 serve to compensate for the offset voltage.

Coarse adjustment is effected with R424 and fine adjustment with R418.

3. Comparator

Via R427 the output signal of the integrator is applied to the comparator which has a gain of 1000...2000. At the end of the first step the comparator determines whether the polarity of the integrator output is positive or negative. Via a Schmitt trigger and switch drivers TS406 or TS407 it moreover selects the reference voltage for discharging the integration capacitor via TS402 or TS403. The offset voltage of the comparator does not affect the measuring accuracy.

The +12 V and -6 V supply voltages are derived from the +/- 15 V voltage by means of zener diodes GR406 and GR407.

4. Schmitt trigger

To drive the IC logic, very steep pulses are required. These pulses are obtained by means of a Schmitt trigger consisting of TS404 and IC423/D.

TS405 is cut off, and its collector potential becomes -3 V (determined by R436/R437). In that case switching transistor TS401 is cut off.

- b. Input T2 logic 1 (approx. 3.5 V ; Fig. 28b).

Diode GR403 is cut off, TS405 becomes conductive. The emitter current is distributed among R436, R437 and the base of TS401. The base current of TS401 is approx. 2 mA so that transistor TS401 is now conductive.

2. The criteria for driving TS402 or TS403 are determined by Nand-gates IC423/A or IC423/B.

Within these criteria there are two possibilities:

- a. During charging $T2 = 0$. Pulse $J (= P)$ from the Schmitt trigger may be "0" or "1". However, during charging the output of gate IC423/A is always "1" so that GR404 is cut off.

Pulse \bar{P} will be "1" or "0" so that the output of gate IC423/B is also "1" and GR405 is cut off.

As a result TS402 and TS403 will be conductive during charging.

- b. During discharging $T2 = "1"$.

Depending on the polarity, output P or \bar{P} will be "1". The output of the gate of which both inputs are "1" will be "0" and the corresponding diode will be conductive.

Consequently TS402 or TS403 will be cut off.

6. Working of transistor switch TS401... TS403

These transistors operate as shunt switches for the three inputs of the integrator. They are inversely connected, in order to obtain favourable properties as regards leak resistance and offset voltage (in the case of inverse operation the collector and the emitter function have been interchanged, i.e. driving is effected at the base-collector junction). Transistors TS401... TS403 have been selected as regards leak resistance, offset voltage and leakage current.

7. Zero passage

Via the comparator and the Schmitt trigger the zero transient is applied to the programme flip-flops as a stop signal. The programme circuit then closes the gate at the counter input and the other programme steps are initiated. T2 remains "1" for the rest of the programme. After the zero transient the integrator automatically remains at zero. This is effected by alternately connecting the positive and the negative reference voltage to summing junction IC424/2.

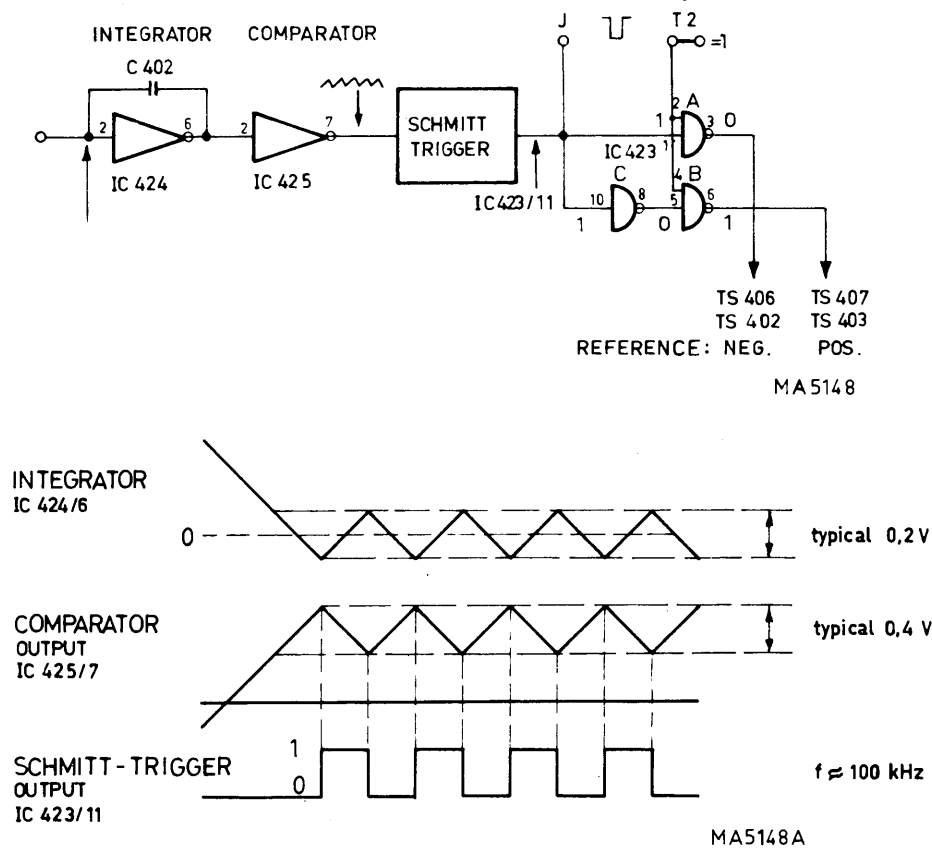
The control process is as follows:

Assume that the output voltage of the integrator changes from a positive potential to zero (Fig. 29). On the output of the comparator a positive-going voltage arises, which at approx. $+0.7\text{ V}$ sets the Schmitt trigger to the "1" state. Via gate IC423/A, TS406 and TS402 the negative reference will now control the integrator output in the positive direction. The voltage on the comparator output goes negative, passes through the hysteresis of the Schmitt trigger and sets the latter to 0 at approx. 0.3 V . As a result, the positive reference voltage will be applied etc. The accuracy of this process is approx. 0.2 mV , which corresponds to less than $1/10$ digit, so that it will not affect the measuring accuracy.

8. Polarity flip-flop

The polarity signals P and \bar{P} from the integrator are applied to set inputs J and K of polarity flip-flop IC416/A. When the 1998th pulse arrives (via gate IC417/C) at the clock input (5), the flip-flop is set for the duration of one clock pulse. The flip-flop then takes over and stores the polarity of the integrator charge and controls transistors TS410 and TS411, via gates

GR410/GR411 and GR412/GR413. Transistors TS410 and TS411, which control the anodes of the polarity indicator B405, are only turned on in the case of direct voltage or direct current measurements (SK2/III).



9. Programme circuit

The programme circuit consists of flip-flops FF-A (IC415) and FF-B (IC416/B). The programme steps are controlled via inputs J_A , K_A and J_B and are synchronously with the clock generator. By means of gate circuits IC418/A and IC414/A the Reset, Up, Down and Transfer pulses are derived from the output signals Q_A , Q_A , Q_B and Q_B . These programme steps are represented in the table, Fig. 30.

		A_n	B_n	A_{n+1}	B_{n+1}	$J_A = \text{Start}$	$K_A = \text{Zero}$	$J_B = \text{Overflow}$	K_B	
Carry out programme step	RESET	0	0	1	0	1	X	0	X	1
	UP	1	0	1	1	X	0	1	X	2
	DOWN	1	1	0	1	X	1	X	0	3
	TRANSFER	0	1	0	0	0	X	X	1	4
Carry out no programme step	RESET	0	0	0	0	0	X	0	X	5
	UP	1	0	1	0	X	0	0	X	6
	DOWN	1	1	1	1	X	0	X	0	7
	TRANSFER	0	1	0	1	0	X	X	0	8

Fig. 30. Table representing the program steps

The columns J_A/K_A and J_B/K_B contain the input signals which yield the required positions of the flip-flops. The indication X means that this input has no effect on the positions of the flip-flops, i.e. either a "1" or a 0-signal may be applied.

Meanings of the indications:

A_n, B_n	Condition of the flip-flop before a clock pulse is applied.
A_{n+1}, B_{n+1}	Position of the flip-flop after a clock pulse has been applied.
J_A, K_A	Input signals. These determine the flip-flop positions.
J_B, K_B	
X	Means that the input signal has no influence on the flip-flop position, i.e. a 1 or a 0-signal may be applied.

Description of the process (see table Fig. 30).

RESET: Q_A (IC415/8) = 0, Q_B (IC416/12) = 0.

This condition is maintained when J_{2A} or J_{3A} are "0" (5th line). This is possible by means of an external stop signal or by the delay circuit.

The requirements for changing over the A flip-flop are met when the two input J_A are "1" (1st line).

UP: $Q_A = 1, Q_B = 0$.

The length of this period is determined by counting the clock pulses in the counter. The 1998th pulse is applied to input J of FF-B, i.e. the flip-flop is set and changes over upon the next clock pulse.

DOWN: $Q_A = 1, Q_B = 1$.

The programme circuit remains in this condition during the downward integration. For this, a 0-signal is required on one K-input of the A flip-flop (IC415); this signal is supplied by IC417/A or IC417/B, depending on the polarity of the integrator output signal.

When the integrator passes through zero, the polarity of P will change from "1" into 0 and a "1"-signal is supplied to the output of IC417/A. IC417/B will remain "1", because the polarity flip-flop still supplies a 0-signal to IC417/4 (Fig. 31). All three inputs of FF-A are then "1" and flip-flop A will change over to the A=0 position on the negative edge of the next clock pulse, so that Q_A becomes "0" (3rd line).

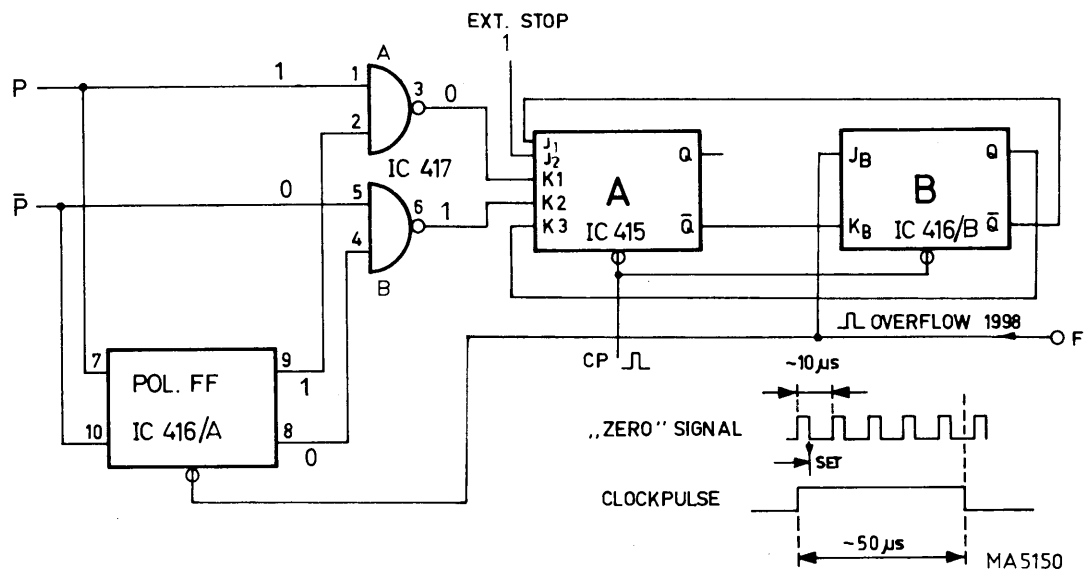


Fig. 31. Zero signal

TRANSFER: $Q_A = 0$, $Q_B = 1$.

The duration of the transfer is only 50 μ secs. The output signal "1" of flip-flop A is present on input K of flip-flop B, i.e. flip-flop B is prepared to change over to $Q_B = 0$ on the negative edge of the next clock pulse (4th line).

RESET: $Q_A = 0$, $Q_B = 0$.

An 0-signal on input J2 or J3 of flip-flop A will stop the programme for an arbitrary time (5th line). If no external stop signal is given and the delay circuit is not released the duration of the reset period will be only one clock pulse.

Upon the next clock pulse, Q_A will become "1" (2nd line). Thus the following measuring cycle is initiated.

Overflow

This signal is derived from the counter by means of IC412, 417/D and 417/C. Only for counter position 1998 all the inputs of IC412 are in the "1" state. This state is used to control the programme circuit and to trigger the polarity flip-flop.

10. Counter

The counter consists of three integrated counting decades IC407...409 for the units, tens and hundreds. The thousands are counted by flip-flop IC410. The clock pulses are applied to the counter via gates IC414/B and IC414/D. Gate IC414/B can be blocked by applying an 0-signal to input IC414/4. By means of the reset pulse the counter decades are reset by applying a "1" signal to inputs 2 and 3 via lines R1 and R2.

At the same time gate IC418/B produces an 0-signal for the thousands flip-flop IC410/A, which is set to $Q = 0$. After counting 1000 pulses during the first programme cycle, the counter will be exactly at 0000 and is ready for the second programme cycle. The counter result (IC407...409) is available on outputs 12 (A), 9 (B), 8 (C) and 11 (D) for further processing.

11. Memory

The counter decades are used for measuring the upward and the downward integration time during each measuring cycle. To ensure convenient and jitter-free reading of the measuring result, the instantaneous measuring result should be stored until the next measuring value is supplied.

Storing takes place in three Quadruple bistable latches (IC404...406) and one J-K flip-flop (IC410/B). During the transfer pulse these flip-flops are connected to the counter decades with an "1"-signal on clock inputs 4 and 13, or 5 for IC410, and the measuring result in BCD-code is then transferred from the counting decades to these flip-flops. The transfer pulse is produced by gates IC418/A and IC418/C.

By applying a 0-signal to input M of IC418/C continuous transfer is possible for testing purposes. The memory is then disabled and the display tubes will directly follow the instantaneous counter position.

12. Decoding and display section

The output signals of the memory, which are available in the 1-2-4-8 code, should be converted into the digits 0... and displayed. Decoding is effected in IC401...403, which moreover comprise the switching amplifier for driving the cathodes of indicator tubes B401...403. Tubes B404 (1000), B405 and the lamp "Overload" are driven by transistor amplifiers.

As the polarity indication and the a.c. sign depend on the mode of operation, the relevant indications are controlled by push-button switches (AC (SK2/II) and DC/R (SK2/III)). The

a.c. symbol is directly switched on and the polarity indication via AND-gates GR410/GR411 for the + sign or GR412/GR413 for the - sign.

13. Automatic range selection

The automatic range selector supplies the control signals for the three reed relays in the analogue section which automatically change over the sensitivity in three steps of 1:10:100.

The change over points lie at 1400 and 100 units, which are derived from the counter. Digital values higher than 1400 cause changing over to the next less sensitive range; if no such range is available, pilot lamp "OVERLOAD" will light up.

This indicates that the measuring value has exceeded the specified limits and that the next higher range should be selected manually. In the case of digital values below 100 the automatic range selector changes over to the next more sensitive range. At the most sensitive range the reading will be maintained.

The range selector also triggers the delay circuit via IC419/A ("D" pulse) during every step of the automatic range selector. The delay circuit provides a delay of approx. 100 msecs and serves to delay the measuring programme in order to allow the DC or AC pre-amplifiers to respond to the new measuring value. The switching information (> 1400 and < 100) is programmed by means of gates which are connected to the counter outputs. For measuring values greater than 1400 units the four gates IC413/A...IC413/D are operative and for values smaller than 100 IC411.

< 100 (output "Z").

This output signal is obtained from the memory by means of signals \bar{A} , \bar{B} , \bar{C} , \bar{D} from the "hundreds" decade and Q of the "thousands" decade.

At counter positions < 100 the 5 inputs of IC411 are "1", so that a 0-signal arises on the output of IC411. The table in Fig. 26 shows that for all the other counter positions at least one input of IC411 has zero potential so that a "1" will arise on the output.

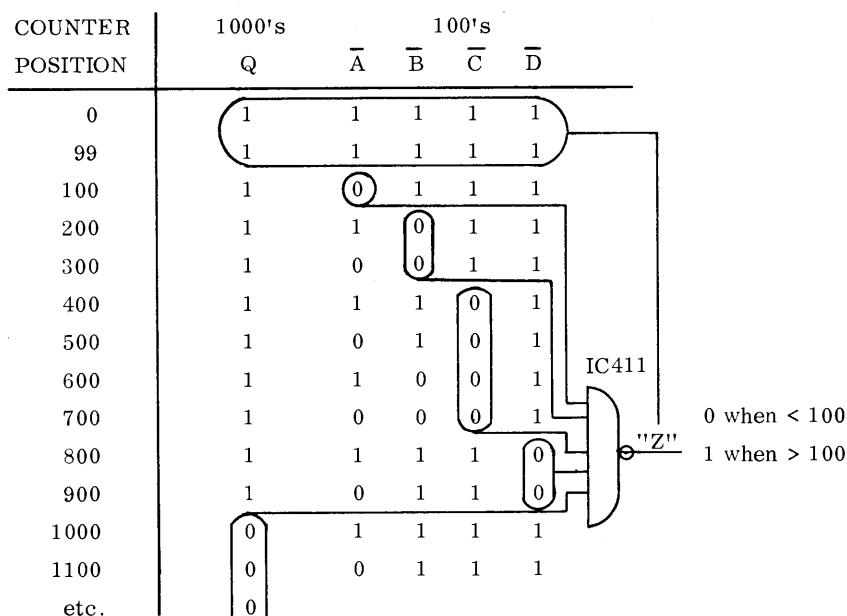


Fig. 32. The "Z" signal (< 100)

> 1400 (output "Y").

At a measuring quantity larger than 1400, IC413/A or IC413/D will supply a 0-signal to the input of IC413/C. As a result, the output of IC413/C will be "1". In all the other situations both inputs will be "1", so that the output will be 0. IC413/B supplies the complementary signal to IC413/C.

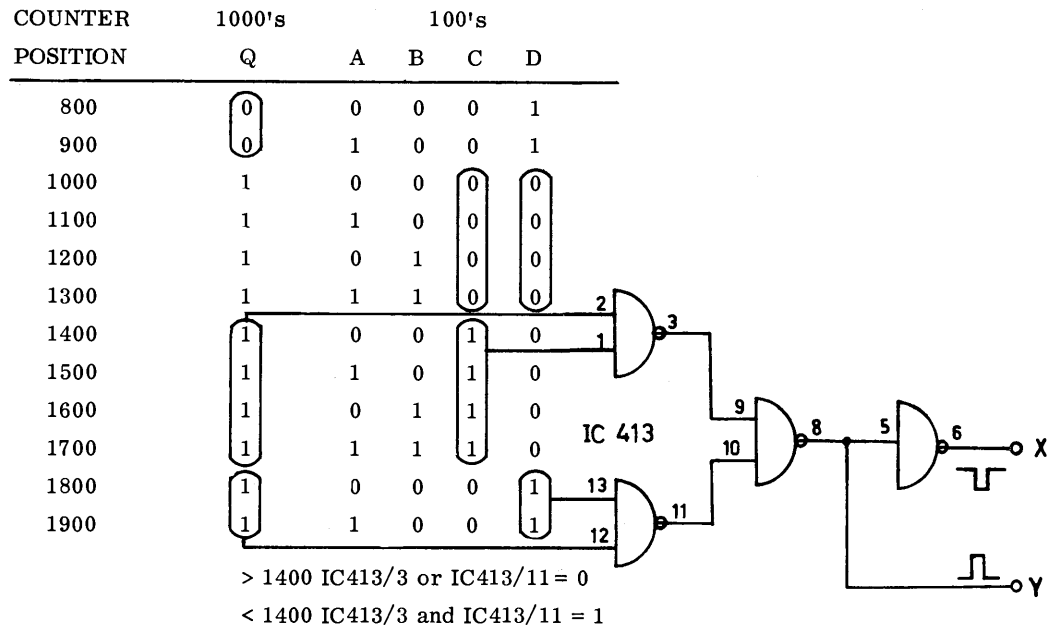


Fig. 33. The "Y" signal (> 400)

The signals from the counter which contain the information necessary for operating the relays, should be processed in a decoding circuit, together with the positions of flip-flops IC422/A (A-FF) and IC422/B (B-FF). The decoding circuit consists of NAND gates IC419/B, -C, -/D, IC420/B, -/C, -/D and IC421, whose output signals control the A-FF and the B-FF so that the desired reed relay is operated or lamp "OVERLOAD" lights up. The output signals of FF-A and FF-D (IC422/A and -/B) are again decoded by means of gates (GR419...425) which supply the control signals for the switching amplifiers TS417...TS420.

	1	2	3	4	5	6	7		
	Range not changed	Range change upwards	Range change downwards	Range -FF (IC422) A B	>1400 <100 Y Z	Range -FF (IC422) A _{n+1} B _{n+1}	FF - inputs (IC422) A _D B _D		
a	10			0 0	0 0	0 0	0 0		0
b	10			0 0	0 1	0 0	0 0		0
c	100			1 0	0 1	1 0	1 0		0
d	1000			0 1	0 1	0 1	0 0		1
e	Overload			1 1	1 1	1 1	1 1		1
f		10 100		0 0	1 1	1 0	1 0		0
g		100 1000		1 0	1 1	0 1	0 0		1
h		1000 Overl.		0 1	1 1	1 1	1 1		1
i			Overl. 1000	1 1	0 1	0 1	0 0		1
k			Overl. 100	1 1	0 0	1 0	1 0		0
l			1000 100	0 1	0 0	1 0	1 0		0
m			100 10	1 0	0 0	0 0	0 0		0

Fig. 34. Truth table of automatic range selector

In table 34:

- Columns 1, 2, 3 : Kind of range selection
- Column 4 : Position of FF-A and FF-B before the transfer pulse.
- Column 5 : Control signals Y (> 1400) and Z (< 100) from the counter, which determine whether range change-over is necessary.
- Column 6 : Position of FF-A and FF-B after the transfer pulse.
- Column 7 : The control signals D which should be applied to flip-flops A and B to obtain the desired change-over.
- Transfer : These signals are produced by gates IC419... 421.
- Transfer : This pulse is supplied by the programme circuit after completion of the measuring cycle. The flip-flops of the automatic range selector are operated by the positive edge of the transfer pulse.

a. No range selection

The measuring range is correct, i.e. the measuring result lies between 100 and 1400. The control signals "Y" and "Z" are 0, and the flip-flops remain in the same position (lines a, c, d). Besides, switching to another position is impossible when the range selector is already at the highest or lowest range and the measuring value is below 100 or above 1400 (lines b and e in the table of Fig. 34).

b. Switching to a higher range

This control signal is given when the counter measures a value ≥ 1400 . Input Y will then be 1 (lines f, g and h).

c. Switching to a lower range

This control signal is given when the counter measures a value < 100. Input Z will then be 1 (lines i, k, l, m of the table in Fig. 34).

14. Relay drivers (Fig. 36)

The relay drivers serve to amplify the signals from the automatic range selector to drive the relays. The output levels of flip-flops A and B (IC422) are decoded by means of diode gates GR419...425. The control signals are applied to switching amplifiers TS417...420. When the inputs are 1 the amplifier will be operative and the relevant relay will be energised. Simultaneously, the decimal points in the indicator tubes will light up.

AC-DC change-over:

Range relays A, B and C are allocated to outputs A, B and C in accordance with the mode of operation of the instrument.

Changing over is effected by the AC/DC mode selector (SK2/II/III).

Arrangement of relays:	Range	AC mode	DC mode
	10	A	C
	100	B	B
	1000	C	A

Manual operation:

If required, the automatic range selector can be overridden.

The measuring range is selected via switch SK3 at the rear of the instrument. Yet, the range selection logic will remain operative because it drives the Overload lamp. As the logic must effect four steps to switch on the overload lamp, the lamp will light up with a delay of up to 1 sec.

15. Clock pulse generator (Fig. 35 and 36)

Astable multivibrator TS413/TS414 produces the clock signal which has a frequency of 10 kHz. IC414/C operates as an isolating amplifier.

Working:

Assume TS414 is turned on. The negative voltage transient (1) is transferred to the base of TS413 via C418. As a result the base potential becomes approx. 0 (2).

The capacitor is then charged via R457 and R_X (3). Emitter-follower TS413 follows this voltage and is turned off when U_E is reached (4).

TS414 is also turned off (5) and the positive voltage transient on the collector of TS414 is transferred via C418 to the base of TS413 (6) due to the feedback. The capacitor is discharged via R457/ R_X (7) until TS413 is turned on again (8). As a result TS414 is also turned on (9) and the process is repeated.

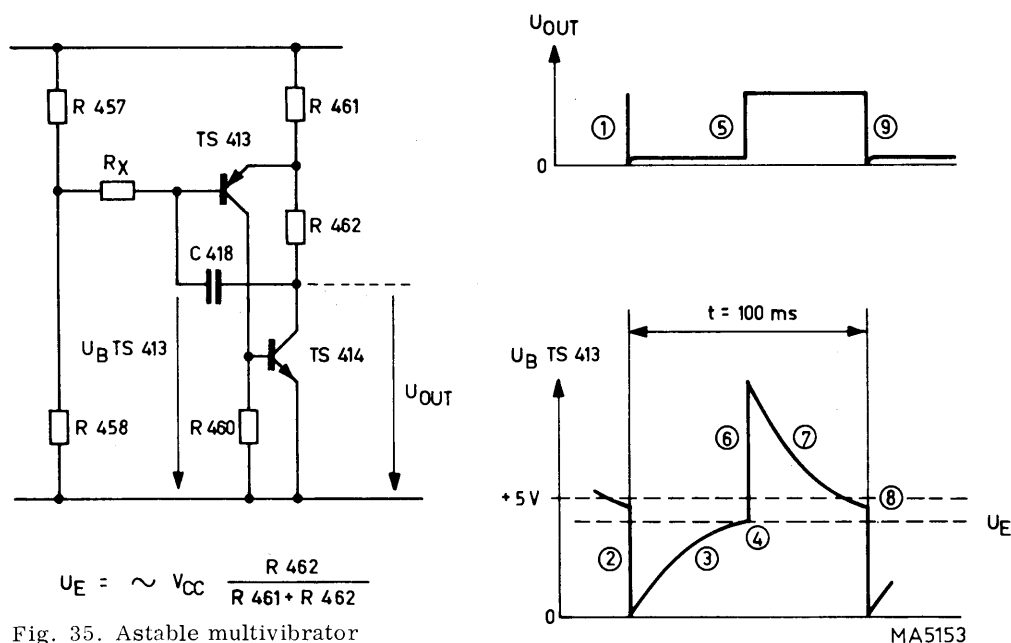


Fig. 35. Astable multivibrator

MA5153

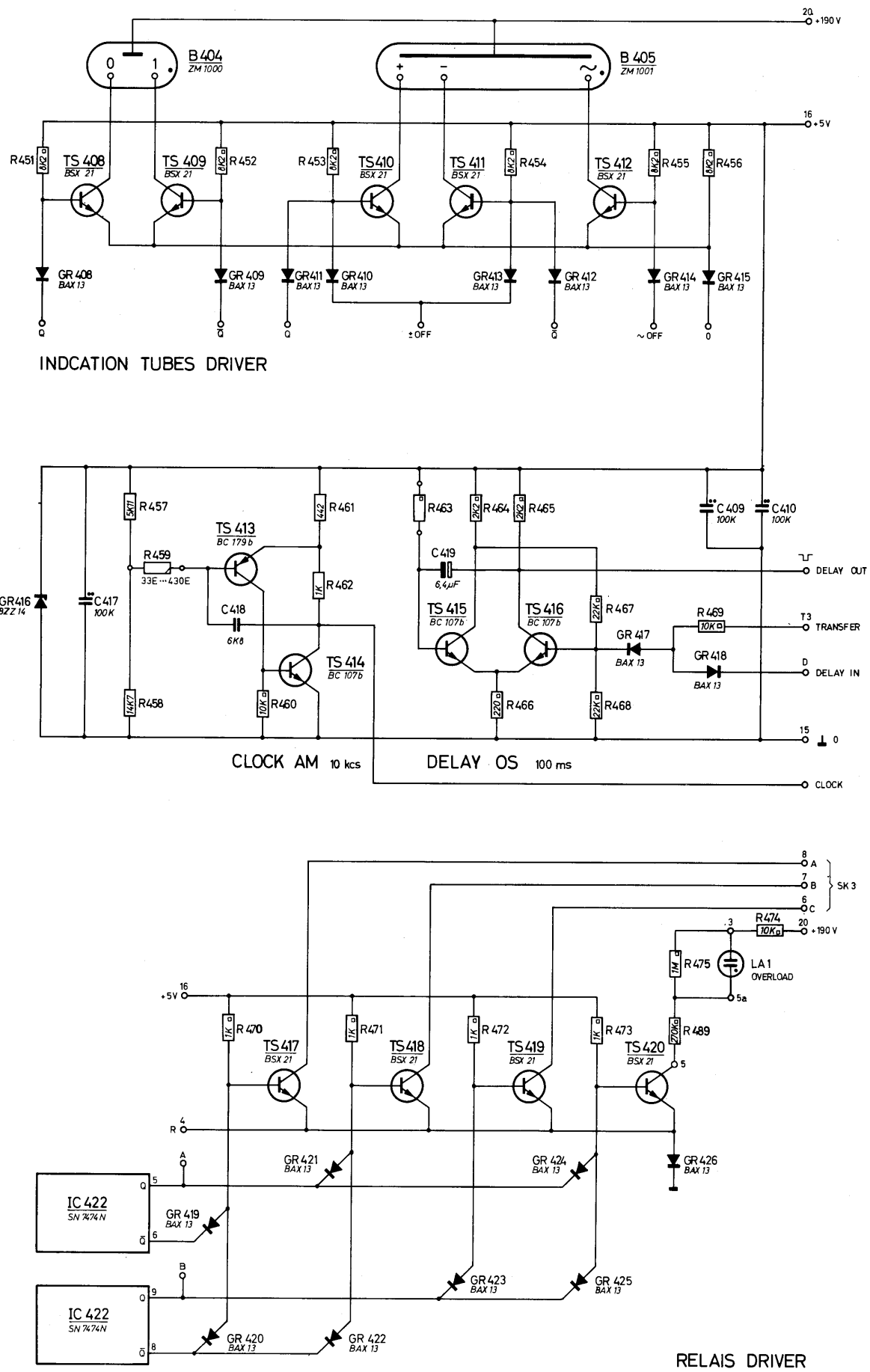


Fig. 36. Circuit diagram indication tube driver, clock oscillator delay one shot and relay driver

The frequency is determined by R457, R458, R461, R462 and C418.

Adjustment is effected with the aid of Rx. The circuit has been designed so as to obtain a temperature coefficient of 100 ppm/ $^{\circ}$ C.

16. Delay circuit (Fig. 36)

This circuit serves to delay the programme approx. 100 msecs when the automatic range selector has effected one step. The delay is necessary to allow the pre-amplifiers (AC, DC, HF etc) to adapt themselves to the new measuring value.

The monostable multivibrator is of the conventional design. In the rest position TS415 is turned on via R463 and TS416 is turned off. If "1" signals are applied to inputs T3 and D, transistor TS416 is turned on and switches the monostable multivibrator to its quasi-stable position. The duty cycle is determined by means of R463 and C419.

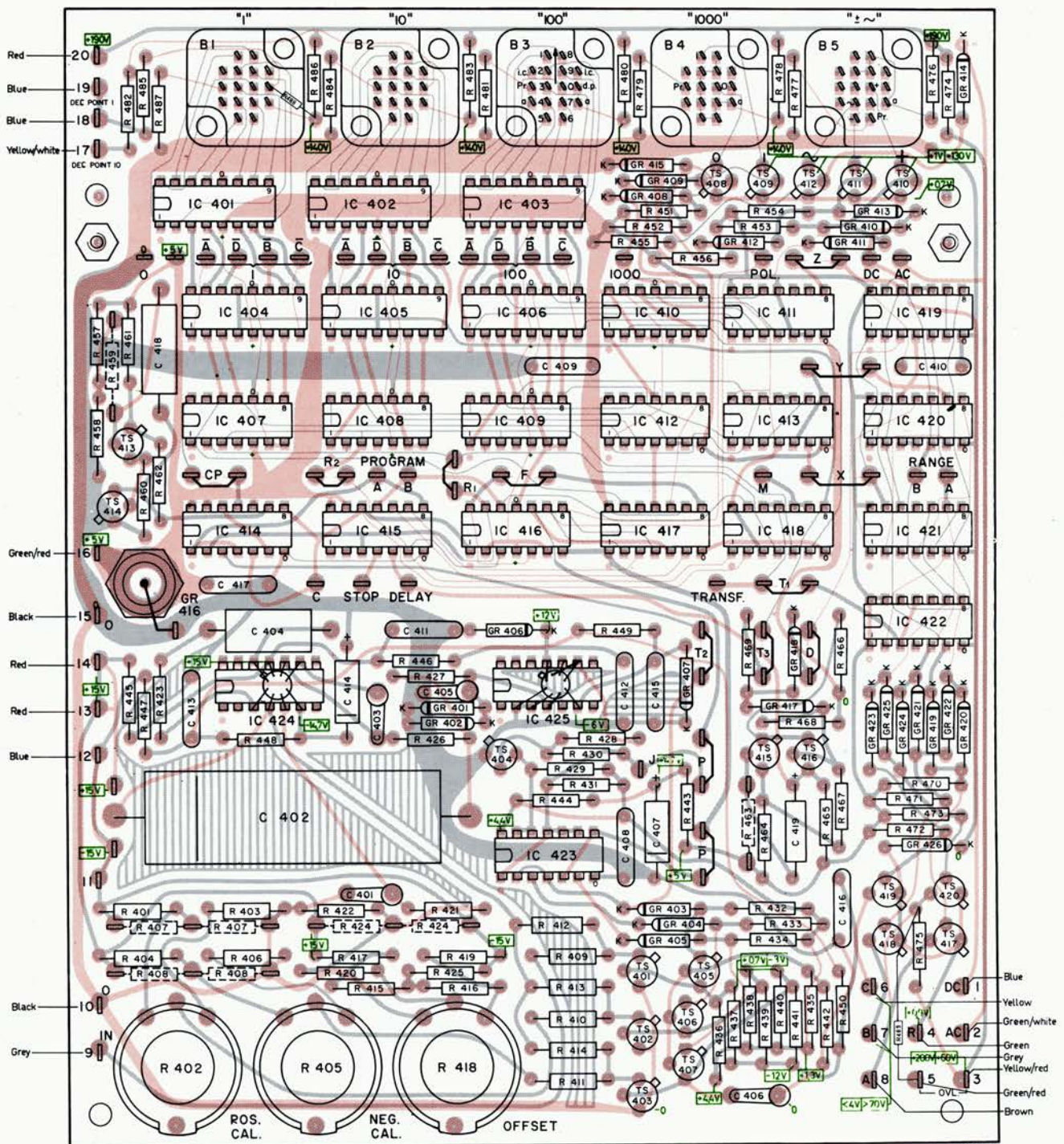


Fig. 38. Printed circuit board U4

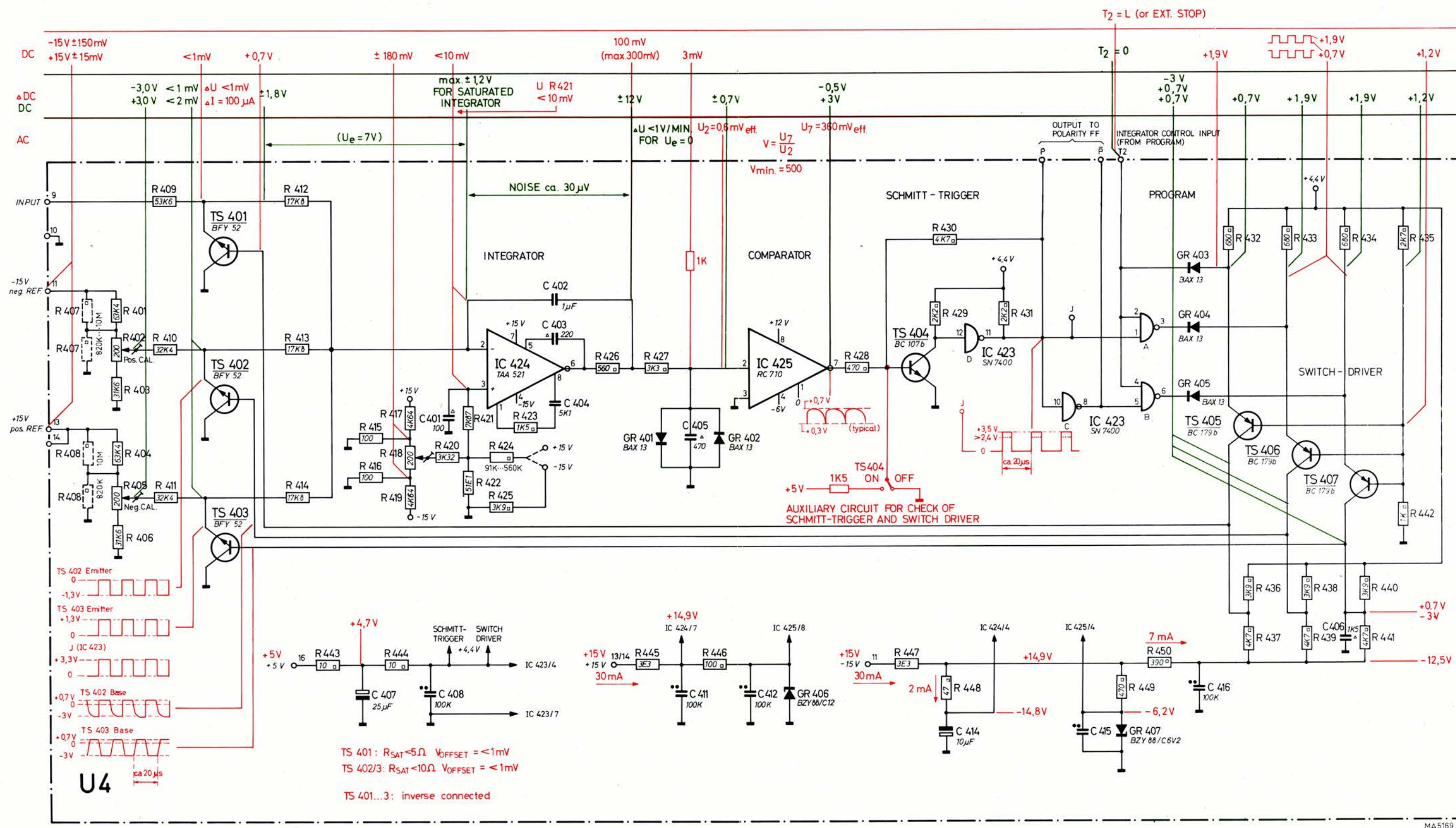
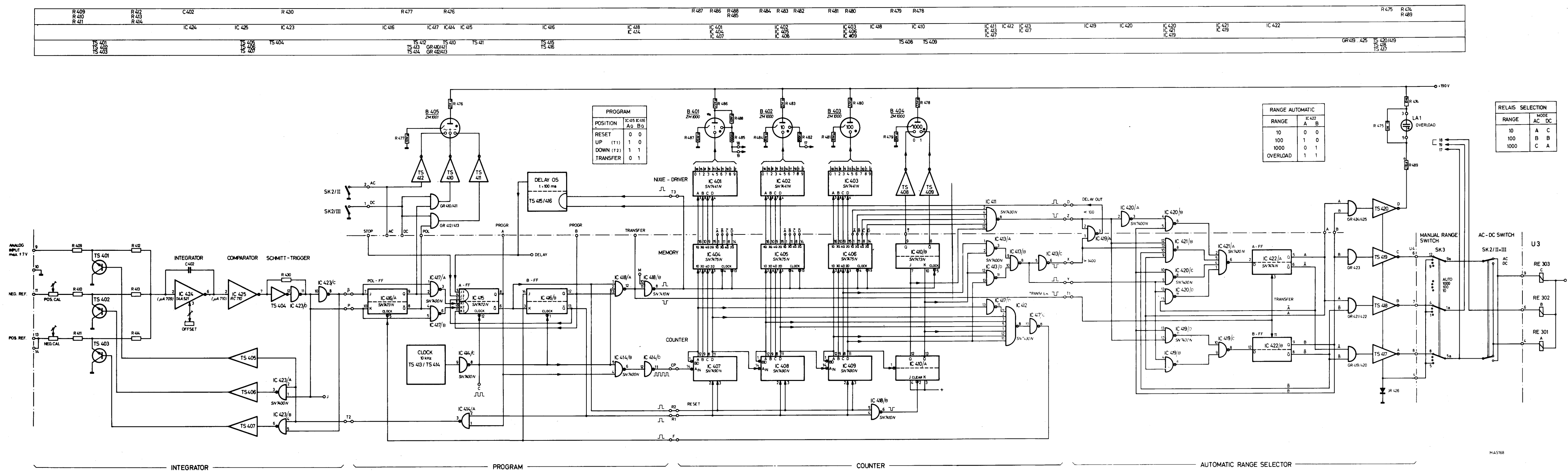


Fig. 37. Input circuit of the digital part



G. SUPPLY SECTION (U5) Fig. 41

The instrument comprises four stabilised supply sources.

The indicator tubes and the chopper lamps are supplied with a voltage of approx. 190 V. This source is only current stabilised. The output current of this stabiliser is adjusted so that the voltage drop across zener diode GR502 and the voltage drop across the base-emitter junction of TS1, R501 and R502 are equal. As the total current consumption of the lamps does not change, the voltage on the output will be constant.

The positive and the negative 15 V voltages do not only serve as supply sources but also as reference sources for the integrator.

The long-term stability and the low temperature coefficient are achieved by using one reference diode (GR509) and by using precision wire-wound resistors for all the critical voltage dividers. The positive output voltage is divided by resistors R526, R528 and R530 in such a way that both sections of TS506 have the same base voltage. When the output voltage decreases (due to an increasing load or due to a decrease in mains voltage), the voltage on the right-hand base of TS506 will be smaller than the reference voltage across GR509. This base voltage then causes a collector current decrease, so that the base voltage of TS505 will increase.

After being amplified twice and after phase inversion the voltage on the base of TS501 will also increase. This emitter-follower then compensates for the original voltage drop because its collector-emitter resistance decreases. The circuit is short-circuit proof, i.e. the series regulators are automatically disconnected.

When the voltage drop across R506 is larger than that across GR505 (the base-emitter voltage of TS502 is compensated for by GR504), the current through TS502 and, consequently, that through TS501 will be limited. The circuit has no thermal protection against prolonged overloading.

The working of the stabilisation and the short-circuit protection of the negative 15 V supply is similar to that of the positive section. In this case the circuit zero serves as a reference and the voltage divider is included between the positive and the negative output.

The reference voltage for the +5 V supply is derived from the +15 V source by means of voltage divider R540 and R541. In case of a short-circuit the voltage drop across R535 will exceed the threshold voltage of GR516; thus the currents through transistors TS510 and TS2 are limited. The integrated circuits in the digital section are thus protected against excess voltages in the 5-V supply. Moreover on digital unit U4 zener diode GR416 is connected in parallel with the 5 V supply.

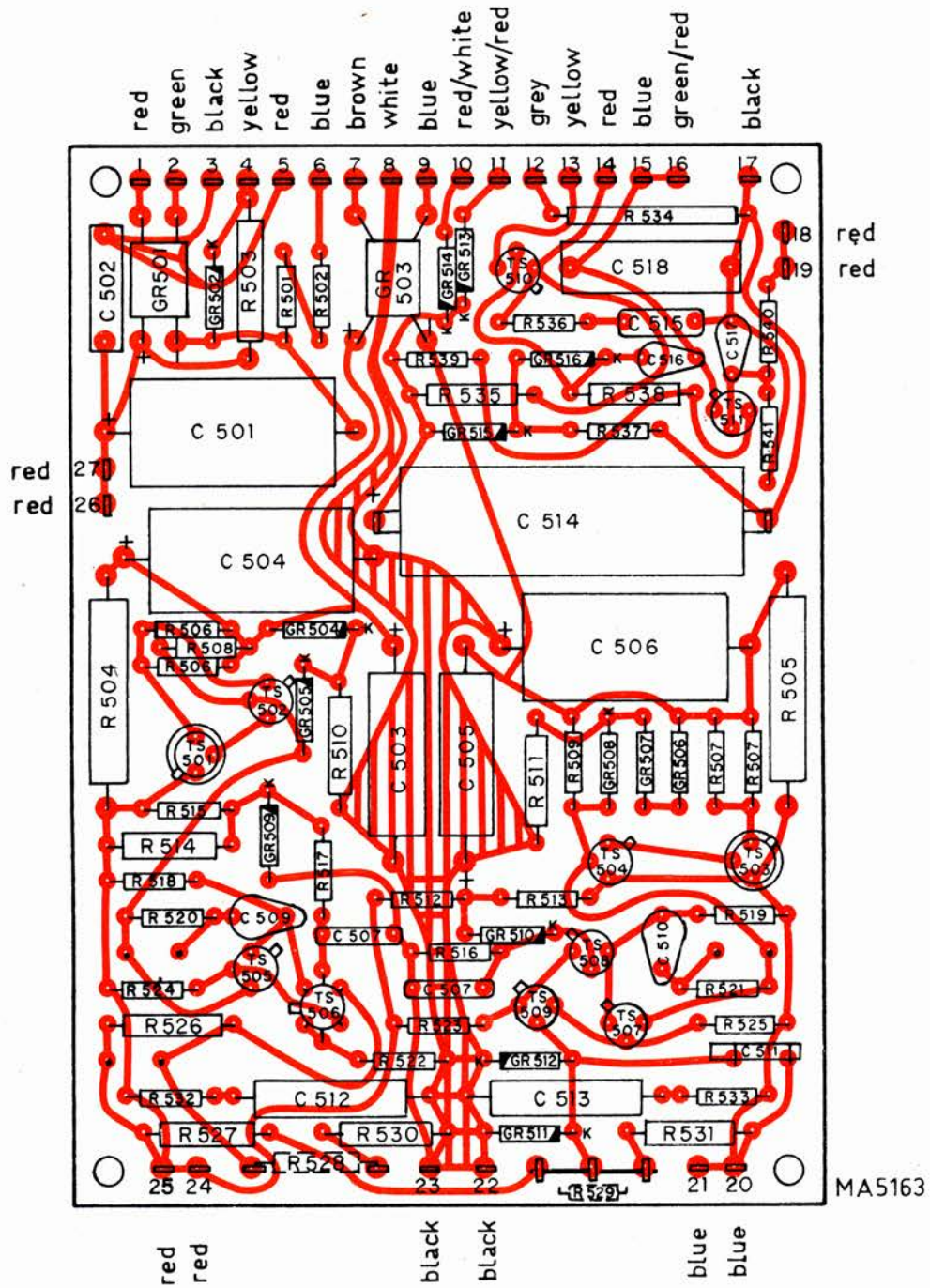
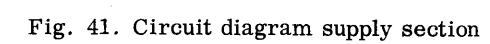


Fig. 40. Printed circuit board U5



VIII. GAINING ACCESS TO THE PARTS

1. Removing the cabinet (Fig. 42)

The instrument chassis is constructed as a compact plug-in chassis and is accommodated in a 3-module standard cabinet. The chassis can be pulled out of the cabinet by means of the two locking devices at the front. When these locking devices cannot be hinged out, the two locking screws at the front should be loosened (do not remove them). The chassis can then be pulled out of the cabinet.

Caution: Pull out the mains plug before removing the chassis out of the cabinet



Fig. 42. Pulling the instrument chassis out of the cabinet

2. Electrical parts

To replace the components on the printed circuit boards, the relevant printed circuit board should be taken out. The connection wires are provided with AMP-connectors and can be pulled out individually. Do not pull at the wires but hold the connector at the clamped part with flat-nosed pliers and pull it out perpendicular to the board. Note the wire colours! These colours are indicated in the drawings of the printed circuit boards, but deviations are possible.

When soldering proceed with due care. Use a vacuum soldering iron and only acid-free solder with a small wire diameter!

Do not unsolder the IC's but cut the wires near the soldering tags and then unsolder the individual soldering tags. Printed circuit board U4 should be handled with great care because it has very fine printed circuit tracks.

3. Push-button switch

Replacement of the complete push-button assembly should only be effected when strictly necessary. This is because it is possible to replace the contact assembly of each button individually. For this purpose all the connection wires should be unsoldered from the contact plate (note connection and wire colour, see Fig. 55). Slightly compress the relevant tags; the wafer together with the cursors can then be taken out.

Caution: When taking out the contact plate check that the button is depressed. Otherwise the button will pop out and cannot be refitted due to the locking plate at the front. It is therefore recommended to hold the push-button in place by means of adhesive tape at the front so that it cannot drop out.

The plastic slide which operates the contacts can be replaced after removal of the contact plate.

The contact plates are not separately available, only the complete set of push-buttons is supplied (see List of mechanical parts for the code number). However, it is possible to fit the contact plate of the new push-button assy. in the assembly already mounted. This procedure is much simpler than replacing the complete push-button assembly.

4. Photo-chopper

a. Replacing the complete chopper

Photo-chopper TR101 on unit U1 can be replaced after removal of the complete printed circuit board.

To de-solder the four soldered connections on the wiring side, use a vacuum soldering iron. Alternately heat the soldered spots, and carefully pull out the complete block.

Before the chopper is removed, unsolder the 3 connection wires A, B and C from the soldering tags (note the wire colours). After replacement of the chopper, carry out adjustments according to chapter XII.3.

b. Replacing chopper components

The photo-resistors and the neon lamps may be individually replaced if this is more efficient. In that case printed circuit unit U1 should be removed completely.

Remove the cover from the chopper (remove the screw). On the side of the cable outlets the neon lamps are located; the photo-resistors are located on the other side.

See list of electrical parts for the code number.

After replacement, carry out adjustments according to chapter XII.3.

IX. MAINTENANCE AND SERVICE

Digital voltmeter PM 2421 requires no maintenance because the instrument contains no components which are subject to wear.

However, to ensure reliable and faultless operation, the instrument should not be exposed to moisture, heat, corrosive vapours and excessive dust.

Service hints

To enable rapid servicing, the printed circuit board on which the defect is located can be readily replaced. This procedure is greatly facilitated by the simple construction and the use of wiring connectors.

If service work is to be carried out the following points should be taken into account to avoid damage to the instrument.

- When working on an instrument from which the cabinet has been removed, always pull out the mains plug. (When the mains switch is set to the off-position, the mains voltage is still present on fuse VL1 on the mains transformer, with the consequent risk of shocks).
- In the case of measurements on a switched-on instrument proceed carefully to avoid short-circuits by means of measuring clips or measuring hooks. The measuring connectors stated in chapter XIII are extremely suitable for test purposes. When connecting test plugs, always switch off the mains-voltage.
- For soldering use absolutely acid-free solder.
- The IC-circuits are especially sensitive to negative potentials, which will damage the IC.
- If an IC is to be replaced, it is recommended to cut the defective IC at the soldering tags by means of cutting pliers. The soldering tags can then be readily unsoldered.
- For all soldering work on the printed circuit boards, use a miniature soldering iron, if possible a vacuum soldering iron.

X. FAULT FINDING

A. GENERAL

The division of the digital voltmeter into functional units, which are both electrically and mechanically separated from each other, permits of efficient and systematic fault-finding in case of a defect.

The link between the various functional sections is formed by the push-button assembly which interconnects the various circuits.

The fault may already be located roughly by checking whether the fault is restricted to a single mode of operation. If the display section is suspected, it suffices to check the voltage on the analogue output (BU9 and BU10) by means of a proper d.c. voltmeter. The voltage on these sockets should be exactly 5 mV per digit. For a reading of, for example, 1000 (independent of the measuring range) the output voltage should be 5 V.

When the output voltage on BU9 and BU10 corresponds to the digital reading, the integrator and the display section of the instrument will be in order.

Thus, the fault source can be traced down to a certain functional section, i.e., d.c. amplifier U1, a.c. amplifier U2, HF section U3 or digital section U4. However, the supply section should be in order, which can be determined by measuring the supply voltages.

B. D.C. AMPLIFIER U1

- Depress buttons "DC/R" and "mV".

Checking the amplifier output

- Without input signal the output voltage on point 10 should be 0 ± 3 mV; the zero-setting can be adjusted with R2 (0-control on the front).
- Check the base voltages of TS101 with respect to \perp ; both should be -6 mV.
- Check the signal on the emitters of TS121 and TS122 with an oscilloscope. During cut-off the signal will contain noise, and the signal on TS121 will be shifted 180° in phase with respect to the signal on TS122 (Fig. 43).

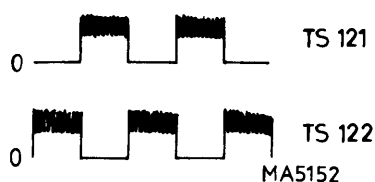


Fig. 43. Emitter signals of TS121 and TS122

Checking the chopper drive

- Check the signal on the collector of TS109 and TS110 of the astable multivibrator.
On TS111 and TS112 a squarewave signal should be present (190 Hz). See Fig. 44.
- Check the lamp voltage on the collectors of TS113 and TS114 (see Fig. 45). When a lamp is defective, the waveform will deviate.

Checking the pre-amplifier

- Unsolder R106 from point 3. Disconnect R175, R176, C130, GR101 and GR102 from the base of TS101 and interconnect the terminals of R175, R176 and C130.
- Apply 1 mV d.c. to the input, point 3; the voltage on the junction of C130/R175/R176 should now be 600...900 mV.
When the photo-resistors have deteriorated, this voltage will be considerably lower.

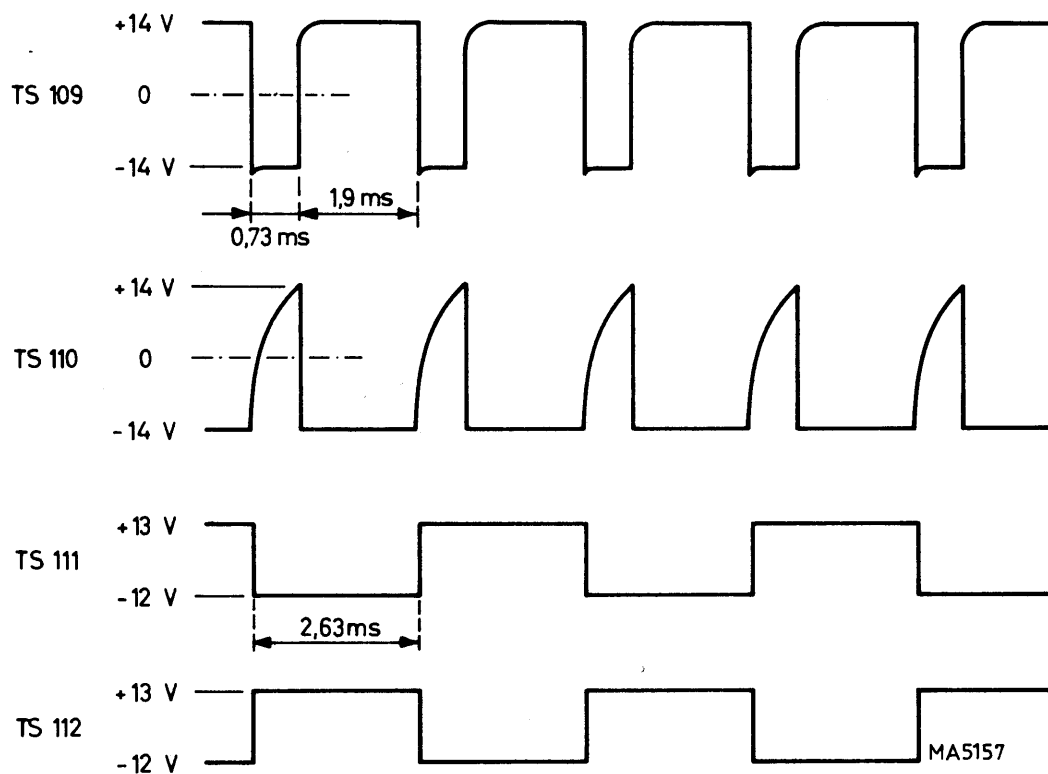


Fig. 44. Signals of TS109...TS112

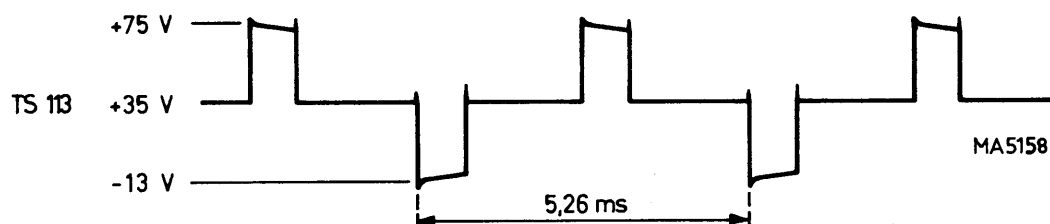


Fig. 45. Collector signal of TS113

C. AC AMPLIFIER U2

- Depress buttons "AC" and "mV".
- Measure the voltage on the base of TS210; this should be $-3\text{ V} \pm 1\text{ V}$.
- With short-circuited input the output voltage on point 23 should be $0\text{ V} \pm 5\text{ mV}$.
- The voltage on the pulse pole of C207 should be $+0.5 \dots +3\text{ V}$.
- Apply 100 mVa.c. to BU6 and BU7; this voltage should also be present on point 1.
- The voltage on point 25 should be 10 mV and the voltage on the base of TS207 approx. 170 mV $\pm 10\%$.
- Check the waveform on GR208 with an oscilloscope and measure the voltage across GR211 and R244 or R241 and R242; this voltage should be 0.5 V.
- There should also be a voltage difference of 0.5 V between the emitters of TS213, and the voltage on the output, point 23 should be 5 V with respect to \perp .

D. HF SECTION U3

Current generator

- Depress buttons "DC/R" and " Ω ".
- Measure the current across BU2 and BU3 with a second PM 2421.
This should be 1000 μA .
- Check the base voltages of TS306; these should be equal ($-10\text{ V} \pm 1\text{ V}$ with respect to \perp).
Deviation with respect to each other $< 20\text{ mV}$. Otherwise, there is a defect in the circuit (TS307...TS309).

Oscillator

- Depress buttons "HF" and "mV", do not connect the probe.
- Unsolder the wire from point 27 and apply a voltage between 0 and -600 mVd.c. to point 27.
- At 0 V the voltage measured on point 15 should lie between 0 and 20 mV (300 kHz).
- When -600 mV is applied to point 27 the voltage on point 15 should be min. 1.5 Vrms.
- Check the oscillation on C203.
- Connect the measuring probe and carry out the calibration (as described in chapter VI. 9).
If one of the diodes in the probe is defective, calibration will be impossible.

Relay drive

- Switch over SK3 manually and observe the decimal point.
- Depress button "AC".
- Apply an alternating voltage of 1 V to BU6 and BU7.
- The voltage on point 5 should be 1 V, across R341/R342 100 mV, and across R342/R343 10 mV.

E. DIGITAL SECTION U4

To facilitate fault-finding in the digital section, the fault-finding system of Fig. 46 may be used. This series of measurements is the most efficient method to trace the defective section. The individual tests are further described in the instructions below.

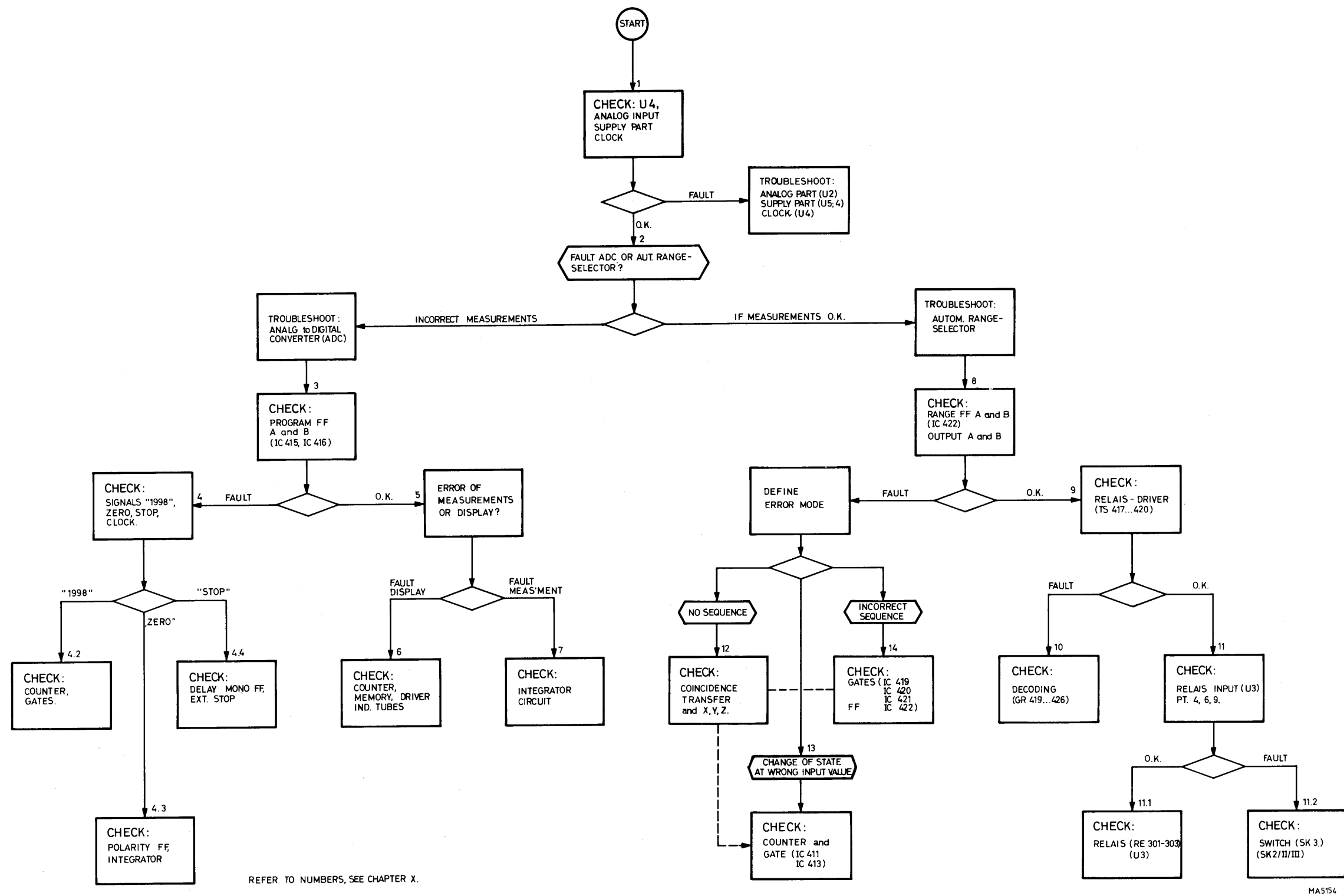


Fig. 46. Fault tracing survey

1. Test of analogue input, supply and clock signal

Before checking the digital section first check:

- the analogue input voltage (see XII.10).
- the supply voltages (see XII.1).
- the clock signal (see XII.2.4.1).

2. Fault-finding in the analogue-to-digital converter

Determine whether the fault is located in the measuring section (ADC) or in the automatic range selector.

Disable the automatic range selector with SK3 and apply approx. 500 units, and 100 and more than 1400 units. Check the reading and the working of the automatic range selector.

3. Checking the programme flip-flops A and B

Apply an input voltage of 0...500 units.

Check the programme run-down, the oscillogram (Fig. 24) and the truth table (Fig. 30).

Trigger flip-flop A, IC415/8 with positive or negative edge.

For locating faults in the programme circuit it may be necessary to external control the inputs "ZERO", "1998" (F), and "STOP". Thus the individual programme steps can be checked (except the Transfer-Reset transition).

4. Checking the control signals ("1998", Zero, Stop)

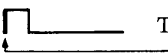
4.1. Clock signal: Check the signal on IC415/12 and IC416/B/1; the frequency should be approx. 10 kHz, $T = 100 \mu\text{secs}$.


4.2. Pulse signal "1998".

Condition: The counter should operate properly (see Counter, if necessary, check 1:10 ratio).

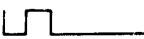
Oscillogram: Input voltage = 0, if necessary, disconnect delay circuit.


Outputs:


IC417/8 "1998" (F)  Triggering is effected on the positive edge of the 1998 pulse.


IC412/8 "1998" (\bar{F}) 


Inputs


IC417/13 "1" (A) 


IC412/4 "1" (\bar{A}) 


IC412/2 "8" (D) 

IC412/3 "10" (A) 

IC412/5 "80" (D) 

IC412/12 "100" (A) 

IC412/11 "800" (D) 

IC412/1 "1000" (T) 

Fault symptoms:

a. Several "1998" pulses

Reading e.g. 1992 at input voltage = 0: fault in one of the input circuits of IC412.

b. No "1998" pulse (programme circuit in position "Upward")

One input of IC412 is permanently connected to earth.

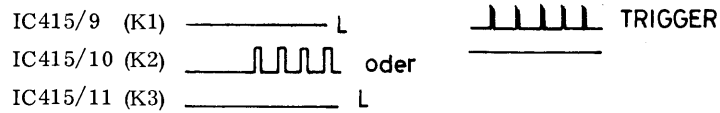
c. "1998" pulse has a duration of 200 μsecs

This results in incorrect triggering of the polarity flip-flop at a small input voltage.

Cause: \bar{A} fails on input IC412/4.

4.3. "ZERO" signal (input voltage = 0)

Check the switching conditions of IC415 during zero passage.



Possible faults: „1998" (F)

- One polarity cannot be measured (IC415/4 or IC415/5 continually 1).
 - Check polarity flip-flop IC416/A.
 - The programme circuit is in position "Downward" (IC415/4 or IC415/5 continually 0).
- Check polarity flip-flop and integrator:

4.4. "STOP" signal

Switching conditions:

IC415/4 should not be connected or be "1" (by means of external stop signal)

IC415/5 should be 1 (from delay circuit)

- Possible faults:
- Programme stops at reset.
 - Delay during range selection inoperative.

5. Measuring or reading errors

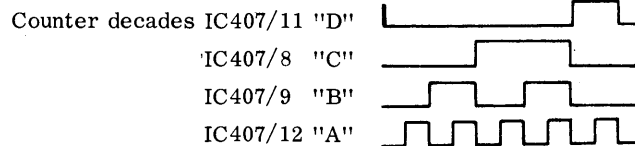
- Reading errors → check counter etc.
- Measuring errors → check integrator.

6.1. Counter

Adjustments:

- Block the programme circuit in position "Upwards" 1998 = 0
- Switch on memory permanently M = CP
- Connect an external clock generator $f = 1 \text{ Hz} \dots 1 \text{ kHz}$ to CP.

Check:



Also check IC408 and IC409 in the same way.

Trigger on negative edge of "D".

Check Reset: Adjustment: $R1 = 1$, $R2 = 1$

Check : All counter flip-flops at 0 (A, B, C, D)
IC410/13 = 1 (1000)

6.2. Memory

Adjustment: $M = 0$ Memory follows counter → same oscillogram as under "Counter decade"

$M = 1$ Result is stored.

Output signals:

Signals of < 100 , > 1400 , "1998" can be statically checked (see truth table, Fig. 32-33).

6.3. Drivers and indicator tubes

- Check the reading while applying corresponding input voltages.
- By holding an oscilloscope probe at approx. 5-10 mm from one of the drivers, this can be checked for oscillation.

7. Integrator

Check +15 V, -15 V and 0 V supply, and check printed circuit board for interruptions etc.

7.1. By adjusting T2 to 1 practically the entire integrator can be checked (see Fig. 37, red indications).

TS401 Excessive offset/leak resistance, insufficient drive current

Non-linearity

IC424 Excessive offset, excessive quiescent current, offset network

No adjustment.

Temperature

coefficient too large

IC425 Offset, quiescent current, gain

Too large

hysteresis

Zero frequency

too low (should be 50 kHz).

Unstable reading at small positive input voltage

Non-linearity

(error at full-scale value)

TS404 }
IC423 } Schmitt trigger

TS405 }
TS406 } Switch driver network
TS407 }

If one of the above-mentioned components or networks is defective, the integrator will be driven into positive or negative saturation → Locate error.

If this is impossible, the circuit may be controlled at the input of the Schmitt trigger (see Fig. 47).

This enables static fault-finding in the Schmitt trigger, switch-drivers etc.

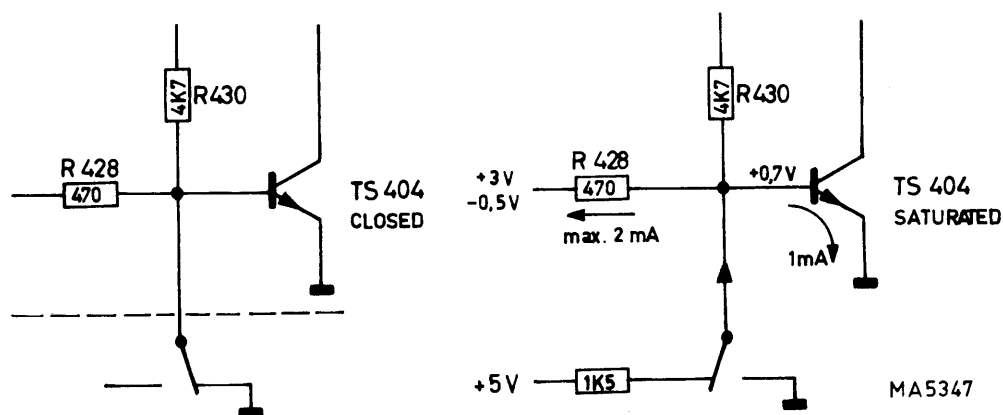


Fig. 47. Applying an external signal to the Schmitt trigger

7.2. Adjustment T2 = 0 (see Fig. 37, green indications)

The input is disconnected from circuit zero (TS401 cut off), the reference voltage is switched off.

This will enable static fault-finding in the following circuits:

TS401/TS402/TS403 Input switches/switch drivers

IC424

Integrator:

At V_{in} (input voltage) = 0 (9), V_{out} = (output voltage) constant (adjust with potentiometer R428, Offset)

Drift should be less than 1 V per minute.

Oscillations cause non-linearity.

By slowly varying the integrator output from -12 V to +12 V (V_{in} = 5 mV) and checking the output voltage with an oscilloscope and voltmeter, deviations can be detected.

Cause:

E. g. blocking capacitor C411 or C414 defective.

Measure the gain of the operational amplifier.

Connect the integrator as an amplifier.

R_p = 71K4 parallel to C402. V = -1.0 (for DC)

Measure the open-loop gain

V_{in} = 5 Vrms f = 5 Hz

U_a = approx. 2 V, gain min. = 15000 → non-linearity

U_2 = < 150 μ V (typical 60 μ V) Noise approx. 30 μ V.

This method can also be used to check the working of the comparator, its gain and the working of the Schmitt trigger (if necessary use high frequencies).

7.3. Automatic range selector

The working of the automatic range selector can be checked by checking the reading and the decimal points. Proceed in accordance with test scheme.

8. Range flip-flops A and B

Apply a direct voltage of < 100/≥ 1400 units to the analogue input (9). Check whether the flip-flops change over properly (in accordance with truth table in the circuit diagram Fig. 39).

9. Relay drivers (if test 8 yields correct result)

If necessary, load +15 V with 705 Ω , depending on result.

10. Decoder (in accordance with diagram Fig. 39)

11. Relay inputs (in accordance with diagram Fig. 39)

11.1. Check relays RE301...RE303 on U3.

11.2. Check SK3, SK2/II/III.

If test 8 indicates incorrect operation of flip-flops A and B, proceed with point 12, 13 or 14, depending on symptoms.

12. Does not change over

Coincidence of transfer signal T1, X, Y and Z.

Trigger on negative edge of T1.

13. Changes over at incorrect input voltage

Check counter with signal < 100, ≥ 1400 (gates IC411/IC413).

14. Incorrect sequences

Carry out static check of gates IC419...421 and FF422 in accordance with table below.

For this, the three inputs X, Y, Z (if necessary T1) should be disconnected and external input signals should be applied in accordance with column "Input signal". To cause the flip-flop to change over, a single input signal should be applied to the automatic range selector via T1. This signal can be obtained with a button via T1 or by initiating a single measurement at the stop input.

Checking the automatic range selector:

	Position before triggering				"Input Signal"			IC421				IC419			
	FFA	FFB	DRIVER OUT		IC422										
	(IC422)														
	5	9	1	0	X	Y	Z	2	12	1	2	4	5	9	10
No change-over	0	0	A		1	0	1	0	0	1	1	1	1	1	1
	1	0	B		1	0	1	1	0	1	1	1	0	1	1
	0	1	C		1	0	1	0	1	1	1	1	1	1	0
	1	1	C+D		1	0	1	1	1	1	1	0	1	0	0
"UPWARDS"															
10→100	0	0	A		0	1	1	1	0	0	1	1	1	1	1
100→1000	1	0	B		0	1	1	0	1	1	1	1	1	0	1
1000→0VL	0	1	C		0	1	1	1	1	0	1	0	1	1	0
"DOWNWARDS"															
0VL→1000	1	1	C+D		1	0	1	0	1	1	1	1	1	1	0
0VL→100	1	1	C		1	0	0	1	0	1	0	1	1	1	1
1000→100	0	1	B		1	0	0	1	0	1	0	1	1	1	1
100→10	1	0	A		1	0	0	0	0	1	1	1	1	1	1

Explanation:

- 1st column : Desired range selection (e.g. from range 10 to 100)
- 2nd column : Logic condition of the range flip-flop and relay drivers before trigger pulse T1 is applied.
- 3rd column : Input signals X, Y, Z which control the process indicated in column 1.
- 4th, 5th, 6th column : Logic levels on various points of gate network IC421/IC419.

If a fault is detected with the aid of the table, the defect can be located via IC421/8 or IC419/20.

XI. SURVEY OF ADJUSTING ELEMENTS

The following table gives a survey of all the adjustment of digital voltmeter PM 2421.

For a complete adjustment adhere to the sequence of chapter XII.

Adjustment no.	Adjustment	Adjusting element	Adjustment data
1.	+15 V supply	R528	$15 \text{ V} \pm 0.3 \% \text{ (DC)}$
2.1	Digital zero adjustment	R418	
2.2	Nominal digital adjustment	$\left\{ \begin{array}{l} \text{R402} \\ \text{R405} \end{array} \right.$	$7 \text{ V} \pm 0.02 \% \text{ (DC)}$
2.4	Digital clock frequency	R459	$10 \text{ kHz} \pm 1 \%$
2.5	Digital delay circuit	R463	100 msecs
3.5	Voltage divider	R101	DC nominal value $1.2 \text{ V} \pm 0.2 \%$
	DC amplifier	R102	
3.8	DC amplifier	R340	DC nominal value $10 \text{ mV} \pm 0.05 \%$
3.9	Chopper frequency	R134	$190 \text{ Hz} \pm 1 \%$
4.4	High-ohmic voltage divider DC	R204	DC nominal value $10 \text{ V} \pm 0.02 \%$
5.1	Ω ranges	R322	Nominal value $1 \text{ k}\Omega \pm 0.02 \%$
5.2	$\text{k}\Omega$ ranges	R5/R11	Nominal value, $100 \text{ k}\Omega \pm 0.1 \%$
5.3	$\text{M}\Omega$ ranges	R12	Nominal value $10 \text{ M}\Omega \pm 0.2 \%$
8.1	Zero adjustment, AC	R249	
	Common mode rejection	R259	According to checking instructions
8.2	Sensitivity AC amplifier	R342 (R225)	Nominal value $1 \text{ V} \pm 0.05 \% \text{ 1 kHz}$
8.3	Frequency response	C210	Nominal value at $1 \text{ V} \pm 0.05 \% \text{ 1 MHz}$
	Frequency response	C209	Nominal value at $1 \text{ V} \pm 0.05 \% \text{ 300 kHz}$
	Frequency response	C212	Nominal value at $1 \text{ V} \pm 0.05 \% \text{ 600 kHz}$
8.4	High-ohmic voltage divider AC	C202	Nominal value $10 \text{ V} \pm 0.05 \% \text{ 300 kHz}$
		R205	Nominal value $10 \text{ V} \pm 0.05 \% \text{ 1 MHz}$
		R201 (C-adj.)	Nominal value $10 \text{ V} \pm 0.05 \% \text{ 5 kHz}$
8.5	Setting of TS207... TS209	R228	According to instructions
9.3	HF section	R337	Nominal value $1.4 \text{ V} \pm 1 \% \text{ 300 kHz}$
9.6	HF section	R331	Nominal value $5 \text{ mV} \pm 1 \% \text{ 300 kHz}$

XII. CHECKING AND ADJUSTING

The tolerances stated in this chapter correspond to the factory data, which only apply to a completely re-adjusted instrument. These tolerances may deviate from those mentioned in the Technical Data (Chapter III).

A survey of the adjustments and adjusting elements is given in chapter XI.

For a complete readjustment of the instrument the sequence in this chapter should be adhered to. When individual components, especially semiconductors, are replaced, the relevant section should be completely readjusted.

To calibrate this measuring instrument only reference voltages and measuring equipment with the required accuracy should be applied. If such equipment is not available, comparative measurements can be made with another calibrated PM 2421. However, theoretically the tolerances may be doubled in the extreme case.

The measuring arrangement should be such that the measurement cannot be affected by external influences. Protect the circuit against temperature variations (fans, sun).

With all the measurements the cables should be kept as short as possible; at higher frequencies coaxial leads should be used.

Non-screened measuring cables act as aeriels so that the measuring instrument will measure HF voltage values or hum voltages.

For the accurate measurement of HF voltages which are to be used as reference for calibration, the method with thermocouple is extremely suitable. A combined measuring arrangement for DC, AC and HF voltage measurements is shown in Fig. 48 and the principle of this method is given in Fig. 49.

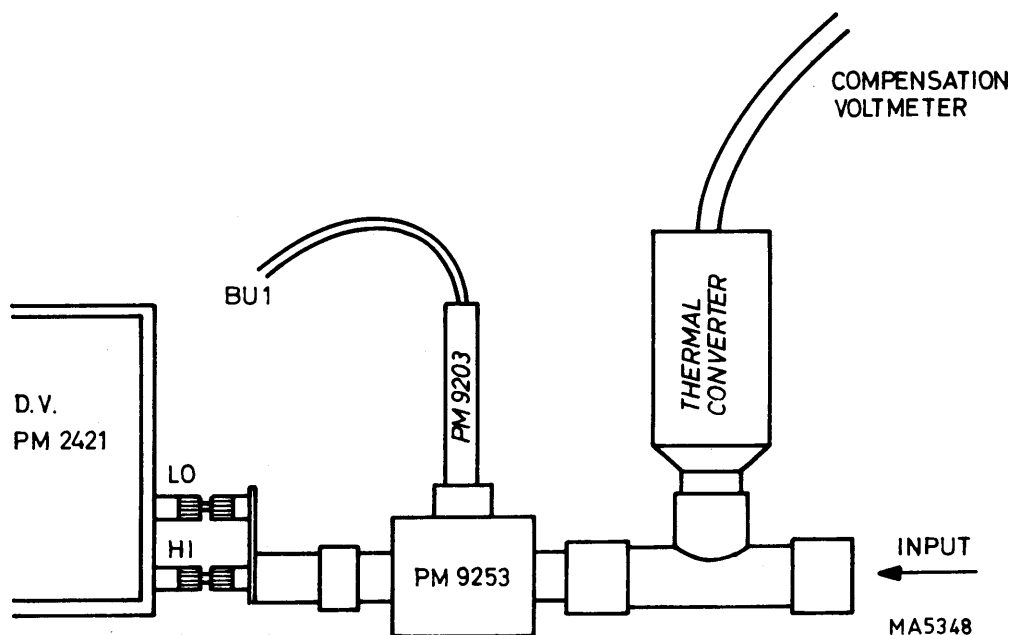


Fig. 48. Combined measuring arrangement set-up

1. Voltages

1.1. +190 V supply

This supply source has current stabilisation at 13 mA. At this current the voltage will be 175-195 V (185 V typical).

Check the voltage on points U5/3 (-) and U5/26/27 (+).

Adjustment is not necessary.

1.2. +15 V supply

The accuracy of this voltage is $+15\text{ V} \pm 0.3\%$. Check by means of a digital voltmeter connected to points U5/24/25 (+) and U5/22/23 (-), at a load current of 100 mA (this is about equal to the current during normal operation).

Adjustment to nominal value is possible with R528.

1.3. -15 V supply

The accuracy of this voltage is $-15\text{ V} \pm 0.5\%$. Check by means of a digital voltmeter connected to points U5/20/21 (-) and U5/22/23 (+) at a load current of approx. 100 mA. When the output voltage of the +15 V supply is correct, the -15 V supply will in general also lie within the tolerances. Adjustment is possible with R529, but normally this will not be necessary.

1.4. +5 V supply

The tolerance of this supply source is $\pm 5\%$ at a load current of 400...500 mA. Adjustment is not necessary. Measuring point U5/16 (+) and U5/17 (-). In the case of a deviation there will be a fault in the circuit.

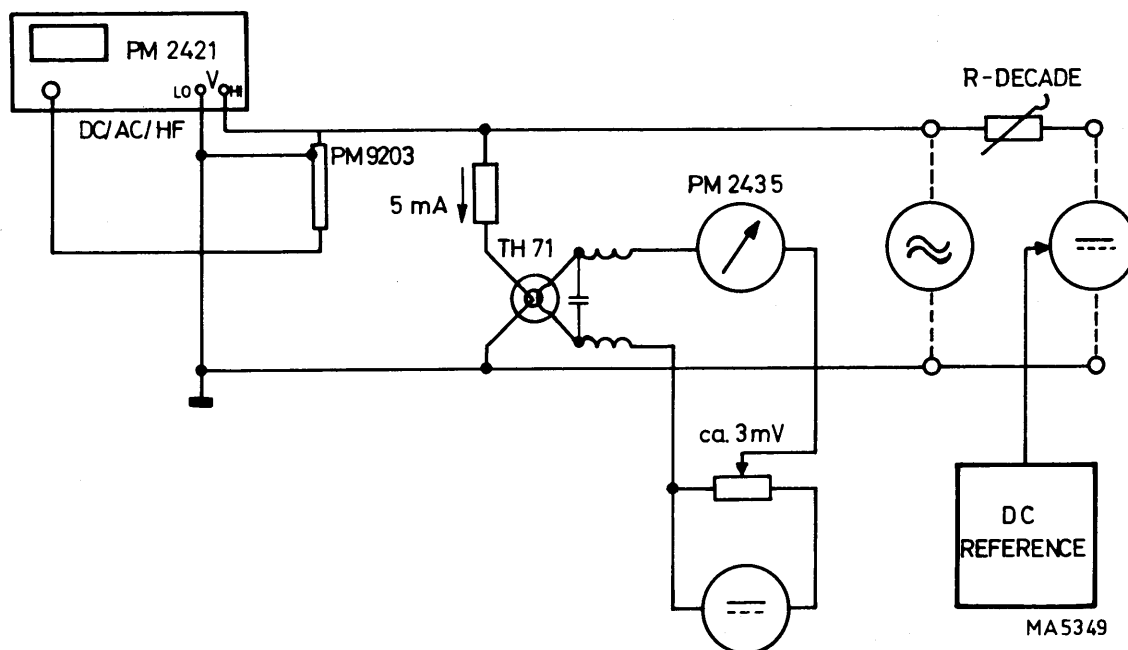


Fig. 49. Principle diagram of the measuring arrangement

2. Digital section

2.1. Zero adjustment

- 2.1.1. Pull the AMP connector from connection pin U4/9 and interconnect pins 9 and 10 (wire of connection 9 should remain free).
- 2.1.2. Switch on the instrument and depress button "DC/R".
- 2.1.3. Adjust potentiometer "OFFSET" (R418) so that the polarity indication alternately indicates + and -.

2.2. Adjustment to nominal value

- 2.2.1. Remove the interconnection between pins 9 and 10 and apply a voltage of $7\text{ V} \pm 0.02\%$ to these pins (+ to point 9).

Attention

The digital section has a low input resistance, therefore no voltage dividers should be used.

- 2.2.2. Adjust the reading to 1400 with potentiometer "POS. CAL." (R402).
- 2.2.3. Check the linearity at some intermediate values, e.g. $1\text{ V} \pm 0.02\%$. Indication: 200
 $3\text{ V} \pm 0.02\%$. Indication: 600
 $5\text{ V} \pm 0.02\%$. Indication: 1000
- 2.2.4. Reverse the polarity of the test voltage applied ($7\text{ V} \pm 0.02\%$) at points 9 and 10, i.e. + to point 10.
- 2.2.5. Adjust the reading to 1400 by means of potentiometer "NEG. CAL." (R405).
- 2.2.6. Check the linearity according to 2.2.3.
- 2.2.7. If the control range of R402 or R405 is insufficient, adaptation is possible by means of shunt resistors R407 or R408 (Fig. 54).
- 2.2.8. Refit the AMP connector on pin 9.

2.3. Checking the automatic range selector

- 2.3.1. At a reading of 1000 digits or higher the decimal point indicator extinguishes.
- 2.3.2. For checking the other switching actions, refer to point 6.

2.4. Clock oscillator frequency

- 2.4.1. The 10 kHz clock frequency can be checked on connection point U4/C (or on IC414/C/8).
- 2.4.2. Adjustment to $10\text{ kHz} \pm 1\%$ is effected with R459.

2.5. Delay circuit

- 2.5.1. The delay time of one shot TS415/TS416 is determined by the RC ratio of R463/C419 and should be approx. 100 msecs (normal tolerance of C419 is permissible).
- 2.5.2. Adjustment is possible by selection of R463.

3. DC amplifier

- 3.1. Depress buttons "DC/R" and "mV".
- 3.2. Interconnect input sockets BU6/BU7 with a short cable.
- 3.3. Adjust the reading to zero by means of R2 (0 control).
 If the control range of R2 is not sufficient, an adjustment can be made with R110 (set R2 to mid position).

- 3.4. Eliminate the short circuit between BU6/BU7 and apply a direct voltage of 1.2...1.4 V.
The reading should have an accuracy of at least $\pm 0.2\%$ with respect to the input value.
 - 3.5. Adjust the reading with R101/R102 (coarse and fine) to the nominal value.
 - 3.6. Reverse the polarity of the input voltage and check the value at the reverse polarity.
If there is a deviation, pos. or neg. CAL. (see 2.2.).
 - 3.7. Apply an accurate direct voltage of 10...13 mV $\pm 0.05\%$ to BU6/BU7. (When the automatic range selector does not change over to the most sensitive range, briefly interrupt the input voltage).
 - 3.8. When the reading does not exactly correspond to the nominal value, adjust with R340.
A deviation of \pm one digit is permissible.
Important: When soldering on R340, wait at least 5 minutes before the check is repeated.
 - 3.9. Adjustment of the chopper frequency to 190 Hz is effected with R134. Check this with the aid of an oscilloscope and a test generator on the collector of TS111 or TS112.
4. High-ohmic voltage divider
 - 4.1. Depress buttons "DC/R" and "V".
 - 4.2. Carry out zero adjustment with R2 (0 control).
 - 4.3. Apply a direct voltage of 10...13 V $\pm 0.02\%$ to BU6/7.
 - 4.4. Adjust to nominal value with R204.
 - 4.5. Check the reading at reversed polarity.
5. Resistance ranges
 - 5.1. Ω ranges
 - 5.1.1. Depress buttons DC/R and V.
 - 5.1.2. Set the instrument to zero with R2 (0 control).
 - 5.1.3. Connect a measuring resistor of 1...1.4 $\Omega \pm 0.02\%$ (resistance decade) to BU2/BU3 and depress button Ω .
 - 5.1.4. Adjust the nominal value with R322.
 - 5.1.5. Check the 100 Ω and 10 Ω ranges by connecting corresponding resistors.
 - 5.2. K Ω ranges
 - 5.2.1. Depress buttons "DC/R" and "k Ω ".
 - 5.2.2. Connect a measuring resistor of 100...130 k $\Omega \pm 0.1\%$ to BU2/BU3.
 - 5.2.3. Adjust R5 to nominal value with the aid of R11 (series or in parallel).
 - 5.3. M Ω ranges
 - 5.3.1. Depress buttons "DC/R" and M Ω .
 - 5.3.2. Connect a measuring resistor of 10 M $\Omega \pm 0.2\%$ to BU2/BU3.
 - 5.3.3. Adjust to nominal value with R12.
6. Checking the range selection
 - 6.1. Automatic range selection
 - 6.1.1. Depress buttons "DC/R" and "mV", set switch SK3 to "AUT".

- 6.1.2. Short-circuit BU6 and BU7 and set the instrument to zero with R2 (0 control).
- 6.1.3. Connect a variable voltage source to BU6/BU7.
- 6.1.4. Adjust the source to 14 mV (increase gradually from 0); the reading should be 13.99. Then slightly increase the voltage. The new reading is e.g. 014.0.
- 6.1.5. Slowly reduce the voltage again. At 10 mV the reading is still 010.0 and at a lower value the automatic range selector changes over to e.g. 09.99.
- 6.1.6. Adjust the voltage to 139.9 mV. At a higher value changing over to e.g. 0140 will take place.
- 6.1.7. Slowly reduce the voltage. At 0100 mV the reading will change from 0099 to e.g. 099.9 (Fig. 50).

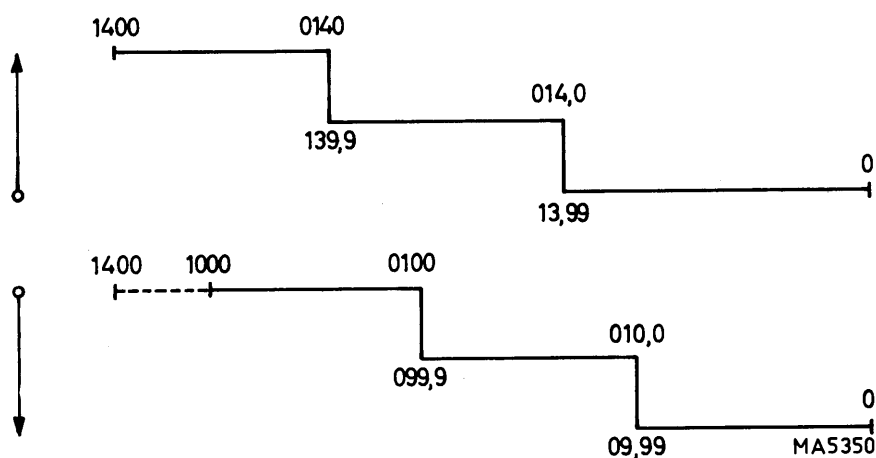


Fig. 50. Checking the range selection

6.2. Manual range selection

- 6.2.1. Set the switch at the rear of the instrument to the ranges 1000, 100 and 10 by means of a screwdriver.
- 6.2.2. Check the position of the decimal point at the ranges:
 - 1000 = 0000
 - 100 = 000.0
 - 10 = 00.00

7. Checking the "OVERLOAD" indicator

- 7.1. The instrument indicates a value of 1399 and the "OVERLOAD" lamp does not light up.
- 7.2. As soon as this value is exceeded with 1 digit, i.e. at 1400, lamp "OVERLOAD" should light up.

8. AC amplifier

8.1. Zero setting

- 8.1.1. Depress buttons "AC" and "mV".
- 8.1.2. Connect a d.c. voltmeter (e.g. another digital voltmeter) to analogue output BU9/BU10.
- 8.1.3. Short circuit capacitor C220 and connect this line to the circuit zero.

- 8.1.4. Adjust the d.c. output signal (test instrument) with R249 to zero \pm 1 mV.
- 8.1.5. Disconnect the wire to the circuit zero, but leave C220 short-circuited.
- 8.1.6. Adjust the common mode suppression to zero \pm 1 mV with R259.
- 8.1.7. Re-connect the short-circuit to the circuit zero and check again that the output voltage is 0 \pm 1 mV. In case of a deviation repeat the adjustment.
- 8.1.8. Remove the connection to the circuit zero and remove the short-circuit from C220.

8.2. Sensitivity adjustment

- 8.2.1. Short-circuit BU6/BU7.
- 8.2.2. Observe the reading; this should run down to 0001 or 0002.
- 8.2.3. Apply a voltage of 1...1.3 V_{rms}, 1 kHz \pm 0.05 % to BU6/BU7.
- 8.2.4. Adjust the sensitivity to the nominal value with R242.
- 8.2.5. If this adjustment does not give the correct result, correct with R225 until the control range of R242 is approximately in the centre.
- 8.2.6. Caution: R225 should never be unsoldered when the instrument is switched on, and the instrument should not be switched on when R225 is disconnected. This would cause a chain reaction of defects!

8.3. Frequency response

- 8.3.1. Apply a voltage of 1...1.3 V_{rms}, \pm 0.05 %, 1 MHz to BU6/BU7.
- 8.3.2. Adjust for nominal value with trimmer C210.
- 8.3.3. Adjust the frequency to 300 kHz and check the nominal value. If necessary, correct with C209 and re-check at 1 MHz (point 8.3.1).
- 8.3.4. When both adjustments are correct adjust the frequency to 600 kHz and check whether the reading corresponds to the nominal value. For correction, change the value of C212 and repeat the complete adjustment of point 8.3.

8.4. AC adjustment of the high-ohmic voltage divider

- 8.4.1. Depress buttons "AC" and "V".
- 8.4.2. Apply an alternating voltage of 10...13 V \pm 0.05 %, 20...50 Hz to BU6/BU7. The reading should correspond to the nominal value, otherwise the d.c. adjustment is not correct.
- 8.4.3. Adjust the frequency to 300 kHz. Adjust for nominal value with trimmer C202.
- 8.4.4. Adjust the frequency to 1 MHz. Adjust for nominal value with R205.
- 8.4.5. Carry out the check at 300 kHz.
- 8.4.6. Adjust the frequency to 5 kHz.
- 8.4.7. Position the screening clip on the 10 M Ω resistor R201 until the reading is correct.
- 8.4.8. Repeat the complete adjusting procedure 8.4 and readjust, if necessary, until the nominal value is attained throughout the frequency range.

8.5. Setting of TS207...TS209

- 8.5.1. Measure the voltage on C214 with a DC milli-voltmeter.
Without drive signal the voltage should be -3 V \pm 0.8 V with respect to the circuit zero.

8.5.2. If this voltage deviates, adjust with R228.

8.5.3. If a considerable variation occurs (resistance variation > 50 ohms), adjusting procedures 8.2, 8.3 and 8.4 should be completely repeated.

9. HF section

9.1. Depress buttons "HF" and "mV".

9.2. Connect the HF measuring probe (PM 9203) to BU1 and apply a voltage of $1.4 V_{\text{rms}} \pm 1 \%$, 300 kHz to the probe via leads which are as short as possible (max. 5 cm).

9.3. Adjust for nominal value with R337 (the alternating voltage may also be checked at the AC range of the PM 2421).

9.4. Set potentiometer R1 (HF Adj.) to the mid position.

9.5. Apply a voltage of $2 \dots 5 mV_{\text{rms}} \pm 1 \%$, 300 kHz to the probe.

9.6. Adjust for nominal value with R331.

9.7. Effect zero adjustment.

9.7.1. Depress buttons "AC" and "mV".

9.7.2. Connect BU8 (300 kHz OUT) to BU7 via a connection cable.

9.7.3. Connect the HF measuring probe to BU7 and connect the earthing lead of the probe to BU6.

9.7.4. Read and note the measured value (take the reading after approx. 20 secs.).

9.7.5. Depress button HF.

9.7.6. Adjust the instrument accurately to the noted reading with R1 (HF Adj.).

9.7.7. Fix the arrow of R1 so that it points vertically upwards when the adjustment is correct.

Note: This adjustment only applies to the probe with which it has been carried out.

9.7.8. Disconnect the probe from BU7 and remove the connection with BU8.

10. Analogue output

10.1. Depress buttons "DC/R" and "mV".

10.2. Apply a variable direct voltage of $0 \dots 1.4 V$ to BU6/BU7.

10.3. Connect a second PM 2421 digital voltmeter to BU9/BU10.

10.4. The output voltage across BU9/BU10 is 5 mV per digit.
Therefore, the output voltage will be 7 V at 1400 mV input voltage. Check at various input voltages.

10.5. The polarity of the output voltage on BU10 (HI) is reversed with respect to the d.c. input voltage on BU7 (HI).

XIII. LIST OF PARTS

A. MECHANICAL

Item	Fig.	Qty	Ordering number	Description
1	51	1	4822 134 20066	Indication lamp LA1
2	51	1	4822 277 10021	Mains switch SK1
3	51	1	4822 455 90345	Text plate
4	4+51	9	4822 290 40011	Socket BU2...BU10
5	51	2	4822 413 30156	Knob R1 + R2
6	51	2	4822 413 70067	Arrow for knob item 5
7	51	1	4822 267 40039	5 pole connection socket BU1
8	51	1	4822 276 80059	Push-button assembly SK2
9	51	1	4822 450 60068	Plexiglass window, red
10	51	1	4822 460 60019	Ornamental strip
11	52	1	4822 273 50099	Range selector SK3
12	52	1	4822 265 30066	Mains socket CS1
13	52	4	4822 462 40109	Rubber stud
14	53+54	14	4822 404 50375	Support for printed circuit board (for U1, U2, U3 and U4)
15		4	4822 693 40002	Support for printed circuit board (for U5)
16		5	4822 255 70145	Valve holder
17*		1	4822 263 50028	Measuring cable, complete
			4822 321 20087	
18		1	4822 266 20015	Measuring probe 1 : 1
19		1	4822 268 10039	Measuring hook
20		1	4822 264 20009	Measuring clip
21		1	4822 321 20096	Earthing cable
22		1	4822 268 10029	Measuring pin
23		1	4822 290 40077	Measuring terminal
24		1	4822 395 50085	Allen key 2.5 mm
25		1	4822 321 10071	Mains lead
26		1	4822 264 20006	Measuring clip, black
27		1	4822 264 20007	Measuring clip, red

* The measuring cable supplied is provided with two 4-mm plugs at the instrument side.

As replacement a cable with a BNC connector will be delivered. Adaptation from BNC connector to 4-mm sockets is possible by means of an adapter 4822 263 50028.

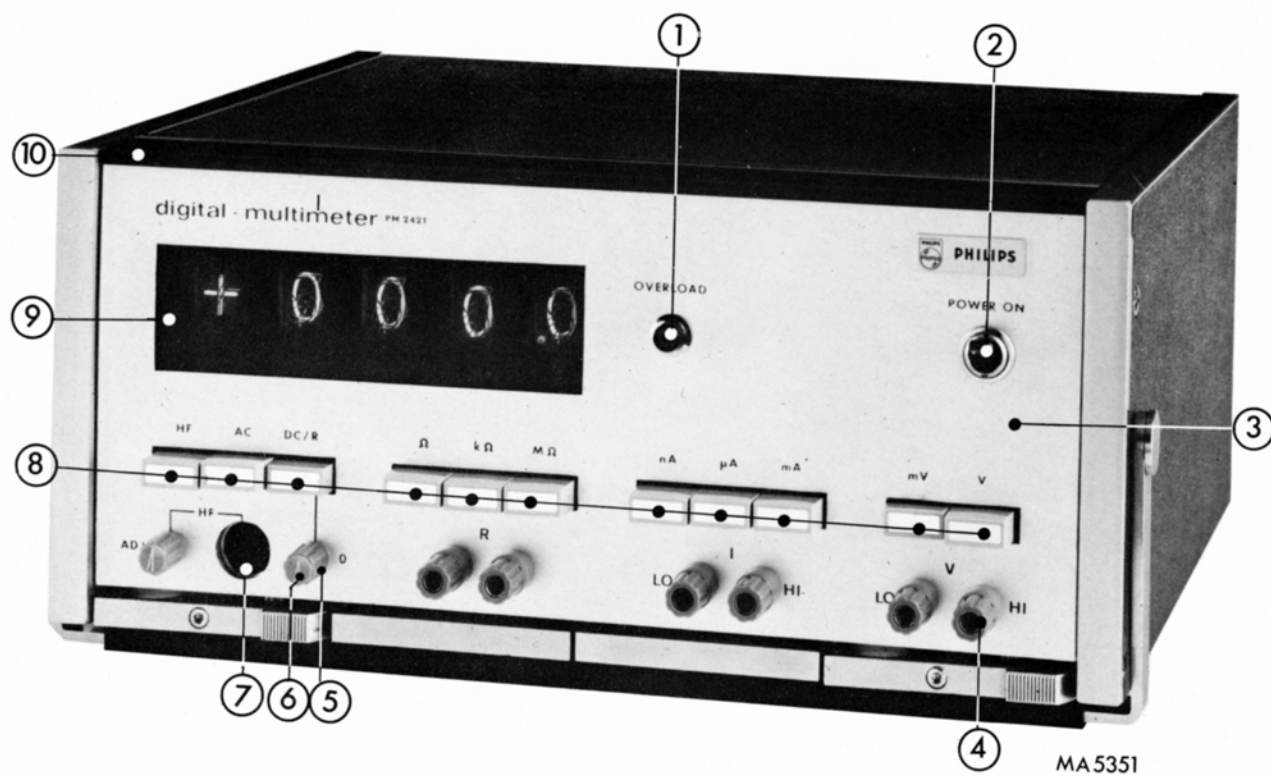


Fig. 51. Front view with item numbers

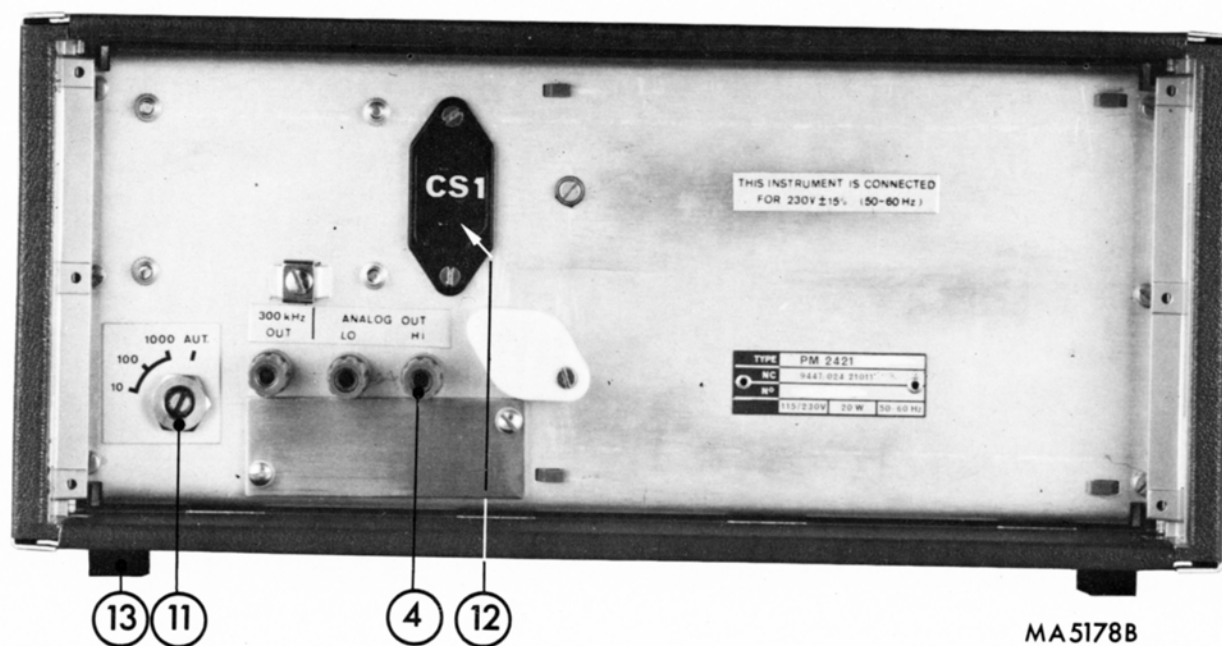


Fig. 52. Rear view with item numbers

B. ELECTRICAL — ELEKTRISCH — ELEKTRISCH — ELECTRIQUE — ELECTRICOS




















This parts list does not contain multi-purpose and standard parts. These components are indicated in the circuit diagram by means of identification marks. The specification can be derived from the survey below.

Diese Ersatzteilliste enthält keine Universal- und Standard-Teile. Diese sind im jeweiligen Prinzipschaltbild mit Kennzeichnungen versehen. Die Spezifikation kann aus nachstehender Übersicht abgeleitet werden.

In deze stuklijst zijn geen universele en standaardonderdelen opgenomen. Deze componenten zijn in het prinsipschema met een merkteken aangegeven. De specificatie van deze merktekens is hieronder vermeld.

La présente liste ne contient pas des pièces universelles et standard. Celles-ci ont été repérées dans le schéma de principe. Leurs spécifications sont indiquées ci-dessous.

Esta lista de componentes no comprende componentes universales ni standard. Estos componentes están provistos en el esquema de principio de una marca. El significado de estas marcas se indica a continuación.

	Carbon resistor E24 series Kohleschichtwiderstand, Reihe E24 Koolweerstand E24 reeks Résistance au carbone, série E24 Resistencia de carbón, serie E24	$\left. \begin{array}{l} 0,125 \text{ W} \\ 5\% \end{array} \right\}$		Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 1 \text{ W} \leq 2,2 \text{ M}\Omega, 5\% \\ > 2,2 \text{ M}\Omega, 10\% \end{array} \right\}$
	Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 0,25 \text{ W} \leq 1 \text{ M}\Omega, 5\% \\ > 1 \text{ M}\Omega, 10\% \end{array} \right\}$		Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 2 \text{ W} \\ 5\% \end{array} \right\}$
	Carbon resistor E24 series Kohleschichtwiderstand, Reihe E24 Koolweerstand E24 reeks Résistance au carbone, série E24 Resistencia de carbón, serie E24	$\left. \begin{array}{l} 0,5 \text{ W} \leq 5 \text{ M}\Omega, 1\% \\ > 5 \text{ M}\Omega, 2\% \\ > 10 \text{ M}\Omega, 5\% \end{array} \right\}$		Wire-wound resistor Drahtwiderstand Draadgewonden weerstand Résistance bobinée Resistencia bobinada	$\left. \begin{array}{l} 0,4 - 1,8 \text{ W} \\ 0,5\% \end{array} \right\}$
	Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 0,5 \text{ W} \leq 1,5 \text{ M}\Omega, 5\% \\ > 1,5 \text{ M}\Omega, 10\% \end{array} \right\}$		Wire-wound resistor Drahtwiderstand Draadgewonden weerstand Résistance bobinée Resistencia bobinada	$\left. \begin{array}{l} 5,5 \text{ W} \leq 200 \Omega, 10\% \\ > 200 \Omega, 5\% \end{array} \right\}$
		$\left. \begin{array}{l} 10 \text{ W} \\ 5\% \end{array} \right\}$			
	Tubular ceramic capacitor Rohrkondensator Keramische kondensator, buistype Condensateur céramique tubulaire Condensador cerámico tubular	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$		Polyester capacitor Polyesterkondensator Polyesterkondensator Condensateur au polyester Condensador polyester	$\left. \begin{array}{l} 400 \text{ V} \end{array} \right\}$
	Tubular ceramic capacitor Rohrkondensator Keramische kondensator, buistype Condensateur céramique tubulaire Condensador cerámico tubular	$\left. \begin{array}{l} 700 \text{ V} \end{array} \right\}$		Flat-foil polyester capacitor Miniatur-Polyesterkondensator (flach) Platte miniatuur polyesterkondensator Condensateur au polyester, type plat Condensador polyester, tipo de placas planas	$\left. \begin{array}{l} 250 \text{ V} \end{array} \right\}$
	Ceramic capacitor, "pin-up" Keramikkondensator "Pin-up" (Perltyp) Keramische kondensator "Pin-up" type Condensateur céramique, type perle Condensador cerámico, versión "colgable"	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$		Paper capacitor Papierkondensator Papierkondensator Condensateur au papier Condensador de papel	$\left. \begin{array}{l} 1000 \text{ V} \end{array} \right\}$
	"Microplate" ceramic capacitor Miniatur-Scheibenkondensator "Microplate" keramische kondensator Condensateur céramique "microplate" Condensador cerámico "microplaca"	$\left. \begin{array}{l} 30 \text{ V} \end{array} \right\}$		Wire-wound trimmer Drahttrimmer Draadgewonden trimmer Trimmer à fil Trimmer bobinado	
	Mica capacitor Glimmerkondensator Micakondensator Condensateur au mica Condensador de mica	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$		Tubular ceramic trimmer Rohrtrimmer Buisvormige keramische trimmer Trimmer céramique tubulaire Trimmer cerámico tubular	



For multi-purpose and standard parts, please see PHILIPS' Service Catalogue.

Für die Universal- und Standard-Teile siehe den PHILIPS Service-Katalog.

Voor universele en standaardonderdelen raadplege men de PHILIPS Service Catalogus.

Pour les pièces universelles et standard veuillez consulter le Catalogue Service PHILIPS.

Para piezas universales y standard consulte el Catálogo de Servicio PHILIPS.

Resistors

No	Ordering number	Value	%	W	Description
R1	4822 101 20323	47 kΩ			Potentiometer
R2	4822 101 20242	100 kΩ			Potentiometer
R3	4822 116 50281	1 MΩ	0.25	0.25	Metal film
R4	4822 116 50281	1 MΩ	0.25	0.25	Metal film
R5	4822 116 50101	2 kΩ	0.25	0.125	Metal film
R6	4822 116 50424	1 kΩ	0.25	0.25	Metal film
R9	4822 112 10054	10 Ω	0.5	0.4	Wire wound
R10	4822 112 10027	1 Ω	0.25	0.4	Wire wound
R103	4822 116 50574	490 kΩ	0.5	0.125	Metal film
R104	4822 116 50575	240 kΩ	0.5	0.125	Metal film
R105	4822 116 50575	240 kΩ	0.5	0.125	Metal film
R107	4822 116 50244	100 kΩ	1	0.125	Metal film
R108	4822 116 50217	19.6 kΩ	1	0.125	Metal film
R109	4822 116 50217	19.6 kΩ	1	0.125	Metal film
R111	4822 116 50576	196 kΩ	1	0.25	Metal film
R117	4822 116 50735	5 MΩ	0.5		Metal film
R135	4822 116 50577	215 kΩ	1	0.25	Metal film
R138	4822 116 50577	215 kΩ	1	0.25	Metal film
R160	4822 116 50576	196 kΩ	1	0.25	Metal film
R175	4822 116 50576	196 kΩ	1	0.25	Metal film
R176	4822 116 50576	196 kΩ	1	0.25	Metal film
R201	4822 116 50736	10 MΩ	0.5		Metal film
R202	4822 116 50463	10 kΩ	0.25	0.125	Metal film
R203	4822 116 50578	78.7 Ω	1	0.125	Metal film
R204	4822 101 10108	100 Ω	20	0.15	Carbon potentiometer
R207	4822 116 50022	1 MΩ	1	0.25	Metal film
R208	4822 116 50579	3.16 kΩ	1	0.125	Metal film
R209	4822 116 50096	562 Ω	1	0.125	Metal film
R211	4822 116 50581	2.49 kΩ	1	0.125	Metal film
R219	4822 116 50458	7.87 kΩ	1	0.125	Metal film
R220	4822 116 50506	154 Ω	1	0.125	Metal film
R221	4822 116 50506	154 Ω	1	0.125	Metal film
R222	4822 116 50583	5.9 kΩ	1	0.125	Metal film
R224	4822 116 50584	619 Ω	1	0.25	Metal film
R229	4822 116 50009	11 kΩ	1	0.25	Metal film
R230	4822 116 50484	4.64 kΩ	1	0.125	Metal film
R233	4822 116 50585	162 Ω	0.5	0.25	Metal film
R239	4822 116 50586	1.54 kΩ	1	0.125	Metal film
R241	4822 112 10107	1 kΩ	0.25	0.4	Wire wound
R242	4822	10 Ω		2	Wire wound potentiometer
R243	4822 116 50104	6.81 kΩ	1	0.125	Metal film
R245	4822 116 50104	6.81 kΩ	1	0.125	Metal film
R246	4822 116 50104	6.81 kΩ	1	0.125	Metal film

No	Ordering number	Value	%	W	Description
R247	4822 116 50104	6.81 k Ω	1	0.125	Metal film
R249	4822 101 10022	100 k Ω	20	0.15	Carbon potentiometer
R255	4822 113 10102	487 Ω	0.5	0.4	Wire wound
R256	4822 113 10102	487 Ω	0.5	0.4	Wire wound
R257	4822 113 10139	511 Ω	0.5	0.4	Wire wound
R258	4822 113 10139	511 Ω	0.5	0.4	Wire wound
R259	4822 103 10074	50 Ω		2	Wire wound potentiometer
R260	4822 113 40059	10 k Ω	0.25	0.7	Wire wound
R261	4822 113 40059	10 k Ω	0.25	0.7	Wire wound
R263	4822 116 50587	4.99 k Ω	0.25	0.125	Metal film
R321	4822 113 40143	12.1 k Ω	0.5	0.7	Wire wound
R322	4822 103 10121	200 Ω		2	Wire wound potentiometer
R323	4822 113 40144	6.19 k Ω	0.5	0.6	Wire wound
R324	4822 116 50557	46.4 k Ω	1	0.125	Metal film
R325	4822 116 50441	178 k Ω	1	0.125	Metal film
R328	4822 113 40145	5.11 k Ω	0.5	0.6	Wire wound
R331	4822 101 10027	47 k Ω	20	0.15	Carbon potentiometer
R335	4822 111 50323	100 M Ω	10	1	Carbon
R337	4822 101 10027	47 k Ω	20	0.15	Carbon potentiometer
R341	4822 116 50274	1 k Ω	0.1		Metal film
R342	4822 116 50268	100 Ω	0.1		Metal film
R343	4822 113 40146	11.3 Ω	0.5		Wire wound
R401	4822 116 50588	63.4 k Ω	0.5	0.1	Metal film
R402	4822 103 10121	200 Ω		2	Wire wound potentiometer
R403	4822 116 50589	31.6 k Ω	0.5	0.1	Metal film
R404	4822 116 50588	63.4 k Ω	0.5	0.1	Metal film
R405	4822 103 10121	200 Ω		2	Wire wound potentiometer
R406	4822 116 50589	31.6 k Ω	0.5	0.1	Metal film
R409	4822 116 50362	53.6 k Ω	0.5	0.1	Metal film
R410	4822 116 50427	32.4 k Ω	0.5	0.1	Metal film
R411	4822 116 50427	32.4 k Ω	0.5	0.1	Metal film
R412	4822 116 50361	17.8 k Ω	0.5	0.1	Metal film
R413	4822 116 50361	17.8 k Ω	0.5	0.1	Metal film
R414	4822 116 50361	17.8 k Ω	0.5	0.1	Metal film
R415	4822 116 50268	100 Ω	1	0.125	Metal film
R416	4822 116 50268	100 Ω	1	0.125	Metal film
R417	4822 116 50484	4.64 k Ω	1	0.125	Metal film
R418	4822 103 10121	200 Ω		2	Wire wound potentiometer
R419	4822 116 50484	4.64 k Ω	1	0.125	Metal film
R420	4822 116 50538	3.32 k Ω	1	0.125	Metal film
R421	4822 116 50591	7.87 k Ω	0.5	0.1	Metal film
R422	4822 116 50159	51.1 Ω	1	0.125	Metal film
R457	4822 116 50158	5.11 k Ω	1	0.125	Metal film
R458	4822 116 50525	14.7 k Ω	1	0.125	Metal film
R461	4822 116 50592	442 Ω	1	0.125	Metal film

No	Ordering number	Value	%	W	Description
R462	4822 116 50274	1	k Ω 1	0.125	Metal film
R512	4822 116 50009	11	k Ω 1	0.125	Metal film
R513	4822 116 50009	11	k Ω 1	0.125	Metal film
R514	4822 113 20015	910	Ω 1	0.4	Wire wound
R515	4822 116 50009	11	k Ω 1	0.125	Metal film
R526	4822 113 10141	2.49	k Ω 0.5	0.4	Wire wound
R527	4822 113 10142	1.96	k Ω 0.5	0.4	Wire wound
R530	4822 113 10143	1.27	k Ω 0.5	0.4	Wire wound
R531	4822 113 10142	1.96	k Ω 0.5	0.4	Wire wound
R532	4822 116 60005	1	Ω 10	0.125	Carbon
R533	4822 116 60005	1	Ω 10	0.125	Carbon
R534	4822 113 60005	1	Ω 10	1	Wire wound
R535	4822 112 10027	1	Ω 1	0.4	Wire wound
R536	4822 116 60005	1	Ω 10	0.125	Carbon
R540	4822 116 50593	16.2	k Ω 1	0.125	Metal film
R541	4822 116 50463	10	k Ω 1	0.125	Metal film

Capacitors

No	Ordering number	Value	%	V	Description
C101	4822 121 40183	0.12 μ F	10	100	Polycarbonate
C102	4822 121 40232	0.22 μ F	10	100	Polycarbonate
C103	4822 121 40175	0.27 μ F	10	100	Polycarbonate
C104	4822 121 40245	0.82 μ F	10	100	Polycarbonate
C105	4822 121 40245	0.82 μ F	10	100	Polycarbonate
C106	4822 121 50272	6.2 nF	1	63	Polystyrene
C107	4822 121 50347	27 nF	1	63	Polystyrene
C108	4822 121 50415	2.2 nF	5	63	Polystyrene
C109	4822 121 50416	150 pF	5	125	Polystyrene
C110	4822 121 50416	150 pF	5	125	Polystyrene
C111	4822 121 50056	510 pF	5	125	Polystyrene
C113	4822 124 20371	47 μ F		25	Electrolytic
C114	4822 124 20371	47 μ F		25	Electrolytic
C115	4822 121 50089	3.9 nF	1	63	Polystyrene
C116	4822 121 50097	10 nF	1	63	Polystyrene
C119	4822 121 40047	10 nF	10	250	Polycarbonate
C120	4822 121 40055	0.047 μ F	10	100	Polycarbonate
C121	4822 121 50097	10 nF	1	63	Polystyrene
C124	4822 124 20377	68 μ F		16	Electrolytic
C126	4822 124 20357	15 μ F		63	Electrolytic
C127	4822 121 40197	1 μ F	10	100	Polycarbonate
C128	4822 124 20357	15 μ F		63	Electrolytic
C129	4822 121 40197	1 μ F	10	100	Polycarbonate
C130	4822 124 10091	33 μ F		10	Electrolytic
C202	4822 125 50044	6 pF			Trimmer

No	Ordering number	Value	%	V	Description
C203	4822 121 50229	18 nF	1	63	Polystyrene
C204	4822 121 40246	0.27 μ F	10	400	Polycarbonate
C205	4822 121 40245	0.82 μ F	10	100	Polycarbonate
C207	4822 124 20402	330 μ F		6.4	Electrolytic
C210	4822 125 50044	6 pF			Trimmer
C214	4822 124 20365	32 μ F		10	Electrolytic
C215	4822 121 40059	0.1 μ F	10	100	Polycarbonate
C216	4822 121 50097	10 nF	1	63	Polystyrene
C217	4822 124 20383	100 μ F		10	Electrolytic
C218	4822 124 20383	100 μ F		10	Electrolytic
C219	4822 121 40206	0.18 μ F	10	100	Polycarbonate
C220	4822 121 40224	4.7 μ F	10	100	Polycarbonate
C221	4822 121 40224	4.7 μ F	10	100	Polycarbonate
C222	4822 121 40245	0.82 μ F	10	100	Polycarbonate
C223	4822 124 20377	64 μ F		16	Electrolytic
C224	4822 121 50079	2 nF	5	63	Polystyrene
C225	4822 121 50079	2 nF	5	63	Polystyrene
C226	4822 121 40206	0.18 μ F	10	100	Polycarbonate
C229	4822 124 20356	12.5 μ F		25	Electrolytic
C230	4822 124 20356	12.5 μ F		25	Electrolytic
C231	4822 121 40245	0.82 μ F	10	100	Polycarbonate
C301	4822 121 40047	0.01 μ F	10	250	Polycarbonate
C302	4822 121 40183	0.12 μ F	10	100	Polycarbonate
C303	4822 121 50438	1.2 nF	5	63	Polystyrene
C304	4822 121 40175	0.47 μ F	10	100	Polycarbonate
C305	4822 121 40175	0.47 μ F	10	100	Polycarbonate
C306	4822 121 50415	2.2 nF	5	63	Polystyrene
C307	4822 124 20353	10 μ F		16	Electrolytic
C308	4822 124 20353	10 μ F		16	Electrolytic
C310	4822 121 40047	0.01 μ F	10	250	Polycarbonate
C311	4822 121 40175	0.47 μ F	10	100	Polycarbonate
C313	4822 121 50414	3 nF	5	63	Polystyrene
C314	4822 121 40197	1 μ F	10	100	Polycarbonate
C315	4822 124 20353	10 μ F		16	Electrolytic
C402	4822 121 40013	1 μ F		100	Polystyrene
C404	4822 121 50299	5100 pF	1	63	Polystyrene
C407	4822 124 20047	25 μ F		6.4	Electrolytic
C414	4822 124 20355	10 μ F		16	Electrolytic
C418	4822 121 50234	6800 μ F	1	63	Polystyrene
C419	4822 124 20049	6.4 μ F		6.4	Electrolytic
C501	4822 124 20037	16 μ F		400	Electrolytic
C502	4822 121 40247	39 nF		400	Polycarbonate
C503	4822 124 10073	6.4 μ F		25	Electrolytic
C504	4822 124 20407	400 μ F		40	Electrolytic
C505	4822 124 10073	6.4 μ F		25	Electrolytic
C506	4822 124 20407	400 μ F		40	Electrolytic

No	Ordering number	Value	%	V	Description
C512	4822 124 10004	10	μF	16	Electrolytic
C513	4822 124 10004	10	μF	16	Electrolytic
C514	4822 124 70085	800	μF	16	Electrolytic
C518	4822 121 40248	1.8	μF 10	100	Polycarbonate

Miscellaneous

No	Ordering number	Description
T1	4822 146 30254	Mains transformer
VL1	4822 253 30009	Fuse 160 mA, delayed action (220 V mains)
VL1	4822 253 30013	Fuse 250 mA, delayed action (110 V mains)
VL2	4822 252 20001	Thermal fuse 125°C
U1	4822 216 20148	Printed circuit board (without chopper)
U2	4822 216 20149	Printed circuit board, complete
U3	4822 216 20151	Printed circuit board, complete
U4	4822 216 20152	Printed circuit board, complete
U5	4822 216 20153	Printed circuit board, complete
B101	4822 134 20016	Neon lamp GL8
TR101	4822 280 10052	Photo-chopper
		Neon lamp
		Photo-resistor
		} in Photo-chopper
L201	4822 158 10275	Coil 3.3 μH
L202	4822 158 10276	Coil 4.7 μH
L203	4822 158 10277	Coil 470 μH
L204	4822 158 10278	Coil 1 mH
IC201	4822 209 80068	Operational amplifier TAA 521
L301	4822 158 50032	Oscillator transformer
RE301	4822 280 20023	Reed relay
RE302	4822 280 20023	Reed relay
RE303	4822 280 20023	Reed relay
IC401	4822 209 80069	BCD - to - decimal decoder/driver SN 7441 AN (Texas Instruments)
IC402	4822 209 80069	
IC403	4822 209 80069	
IC404	4822 209 80071	Quadruple bistable latch SN 7475 N (Texas Instruments)
IC405	4822 209 80071	
IC406	4822 209 80071	
IC407	4822 209 80072	Decade counter SN 7490 N (Texas Instruments)
IC408	4822 209 80072	
IC409	4822 209 80072	
IC410	4822 209 80073	Dual J-K master-slave flip-flop SN 7473 N (Texas Instruments)
IC411	4822 209 80074	8-Input Nand gate SN 7430 N (Texas Instruments)
IC412	4822 209 80074	
IC413	4822 209 80075	Quadruple 2-input Nand-gate SN 7400 N (Texas Instruments)
IC414	4822 209 80075	
IC415	4822 209 80076	J-K master-slave flip-flop SN 7472 N Texas Instruments
IC416	4822 209 80073	Dual J-K master-slave flip-flop SN 7473 N Texas Instruments
IC417	4822 209 80075	Quadruple 2-input Nand-gate SN 7400 N Texas Instruments
IC418	4822 209 80077	Triple 3-input Nand-gate SN 7410 N Texas Instruments

No	Ordering number	Description
IC419	4822 209 80075	} Quadruple 2-input Nand-gate SN 7400 N (Texas Instruments)
IC420	4822 209 80075	
IC421	4822 209 80024	Dual 4-input Nand-gate FJH 111
IC422	4822 209 80079	Dual D-type edge-triggered flip-flop SN 7474 N (Texas Instruments)
IC423	4822 209 80075	Quadruple 2-input Nand-gate SN 7400 N
IC424	4822 209 80099	Operational amplifier TAA 521 (selected)
IC425	4822 209 80081	Comparator RC 710 (Raytheon)
B401		Indicator ZM 1000
B402		Indicator ZM 1000
B403		Indicator ZM 1000
B404		Indicator ZM 1000
B405		Indicator ZM 1001

Transistors

TS1	4822 130 40503	MJE340	(Motorola)	TS207	4822 130 40326	BF173
TS13	4822 130 40504	BD124		TS208	4822 130 40369	BC179B
TS101	4822 130 40423	BCY87		TS209	4822 130 40369	BC179B
TS102	4822 130 40369	BC179B		TS210	4822 130 40369	BC179B
TS103	4822 130 40369	BC179B		TS211	4822 130 40369	BC179B
TS104	4822 130 40332	BC107B		TS212	4822 130 40369	BC179B
TS105	4822 130 40332	BC107B		TS213	4822 130 40423	BCY87
TS106	4822 130 40354	BC177		TS214	4822 130 40369	BC179B
TS107	4822 130 40332	BC107B		TS215	4822 130 40369	BC179B
TS108	4822 130 40354	BC177		TS301	4822 130 40369	BC179B
TS109	4822 130 40332	BC107B		TS302	4822 130 40369	BC179B
TS110	4822 130 40332	BC107B		TS303	4822 130 40332	BC107B
TS111	4822 130 40332	BC107B		TS304	4822 130 40332	BC107B
TS112	4822 130 40332	BC107B		TS305	4822 130 40332	BC107B
TS113	4822 130 40321	BSX21		TS306	4822 130 30187	BCY88
TS114	4822 130 40321	BSX21		TS307	4822 130 40144	BC109C
TS115	4822 130 40321	BSX21		TS308	4822 130 40144	BC109C
TS116	4822 130 40144	BC109C		TS309	4822 130 40144	BC109C
TS117	4822 130 40144	BC109C		TS401	4822 130 40505	BFY52 ^x
TS118	4822 130 40332	BC107B		TS402	4822 130 40506	BFY52 ^x
TS119	4822 130 40332	BC107B		TS403	4822 130 40506	BFY52 ^x
TS120	4822 130 40369	BC179B		TS404	4822 130 40332	BC107B
TS121	4822 130 40332	BC107B		TS405	4822 130 40369	BC179B
TS122	4822 130 40332	BC107B		TS406	4822 130 40369	BC179B
TS201	4822 130 40408	BFW11	FET	TS407	4822 130 40369	BC179B
TS202	4822 130 40369	BC179B		TS408	4822 130 40321	BSX21
TS203	4822 130 40369	BC179B		TS409	4822 130 40321	BSX21
TS204	4822 130 40423	BCY87		TS410	4822 130 40321	BSX21
TS205	4822 130 40369	BC179B		TS411	4822 130 40321	BSX21
TS206	4822 130 40369	BC179B		TS412	4822 130 40321	BSX21

^xSelected

TS413	4822 130 40369	BC179B	GR126	4822 130 30009	1N914	
TS414	4822 130 40332	BC107B	GR127	4822 130 30009	1N914	
TS415	4822 130 40332	BC107B	GR201	4822 130 40256	BAY38	
TS416	4822 130 40332	BC107B	GR202	4822 130 40256	BAY38	
TS417	4822 130 40321	BSX21	GR203	4822 130 40256	BAY38	
TS418	4822 130 40321	BSX21	GR204	4822 130 40256	BAY38	
TS419	4822 130 40321	BSX21	GR205	4822 130 30287	BZY88/C7V5	Zener
TS420	4822 130 40321	BSX21	GR206	4822 130 40256	BAY38	
TS501	4822 130 40356	BFY51	GR207	4822 130 30287	BZY88/C7V5	Zener
TS502	4822 130 40354	BC177	GR208	4822 130 30323	1N4009	
TS503	4822 130 40356	BFY51	GR209	4822 130 30084	AAZ18	
TS504	4822 130 40332	BC107B	GR210	4822 130 30323	1N4009	
TS505	4822 130 40144	BC109C	GR211	4822 130 40182	BAX13	
TS506	4822 130 30187	BCY88	GR212	4822 130 40182	BAX13	
TS507	4822 130 40369	BC179B	GR213	4822 130 40182	BAX13	
TS508	4822 130 40369	BC179B				
TS509	4822 130 40369	BC179B	GR301	4822 130 40182	BAX13	
TS510	4822 130 40369	BC179B	GR302	4822 130 40182	BAX13	
TS511	4822 130 40144	BC109C	GR303	4822 130 40182	BAX13	
<hr/>			GR304	4822 130 30273	BAX13	
<u>Diodes</u>			GR305	4822 130 30273	BAX13	
GR101	4822 130 40256	BAY38	GR306	4822 130 30273	BAX16	
GR102	4822 130 40256	BAY38	GR401	4822 130 40182	BAX13	
GR103	4822 130 30323	1N4009	GR402	4822 130 40182	BAX13	
GR104	4822 130 30323	1N4009	GR403	4822 130 40182	BAX13	
GR105	4822 130 40182	BAX13	GR404	4822 130 40182	BAX13	
GR106	4822 130 40182	BAX13	GR405	4822 130 40182	BAX13	
GR107	4822 130 30087	AAY21	GR406	4822 130 30353	BZY94/C12	Zener
GR108	4822 130 40182	BAX13	GR407	4822 130 30286	BZY88/C6V2	Zener
GR109	4822 130 40256	BAY38	GR408	4822 130 40182	BAX13	
GR110	4822 130 40256	BAY38	GR409	4822 130 40182	BAX13	
GR111	4822 130 30287	BZY88/C7V4	GR410	4822 130 40182	BAX13	Zener
GR112	4822 130 30287	BZY88/C7V5	GR411	4822 130 40182	BAX13	Zener
GR113	4822 130 40182	BAX13	GR412	4822 130 40182	BAX13	
GR114	4822 130 40182	BAX13	GR413	4822 130 40182	BAX13	
GR115	4822 130 40182	BAX13	GR414	4822 130 40182	BAX13	
GR116	4822 130 40182	BAX13	GR415	4822 130 40182	BAX13	
GR117	4822 130 30009	1N914	GR416	4822 130 30267	BZZ14	Zener
GR118	4822 130 30009	1N914	GR417	4822 130 40182	BAX13	
GR119	4822 130 30009	1N914	GR418	4822 130 40182	BAX13	
GR120	4822 130 30009	1N914	GR419	4822 130 40182	BAX13	
GR121	4822 130 30009	1N914	GR420	4822 130 40182	BAX13	
GR122	4822 130 30009	1N914	GR421	4822 130 40182	BAX13	
GR123	4822 130 30009	1N914	GR422	4822 130 40182	BAX13	
GR124	4822 130 30009	1N914	GR423	4822 130 40182	BAX13	
GR125	4822 130 30009	1N914	GR424	4822 130 40182	BAX13	

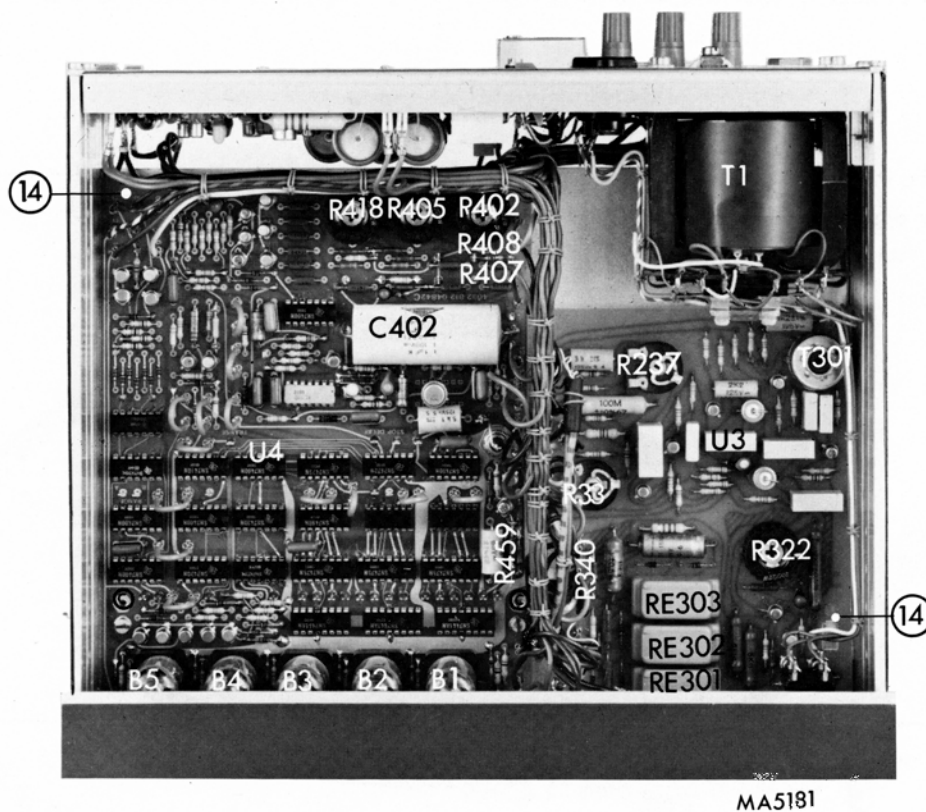


Fig. 54. Top view (chassis removed)

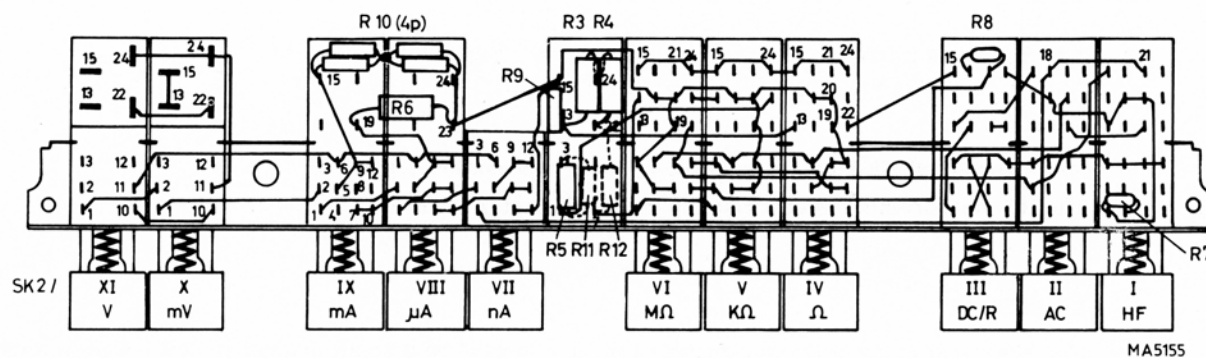


Fig. 55. Push button assembly SK2

XIV. HF PROBE PM 9203 AND HF T-PIECE PM 9253

APPLICATION

HF Probe PM 9203 is suitable for measuring H.F. voltages from 2 mV up to 1.4 V in combination with digital multimeter PM 2421. For voltages from 1.4 V up to 140 V a capacitive voltage divider with a division ratio of 100:1 is provided.

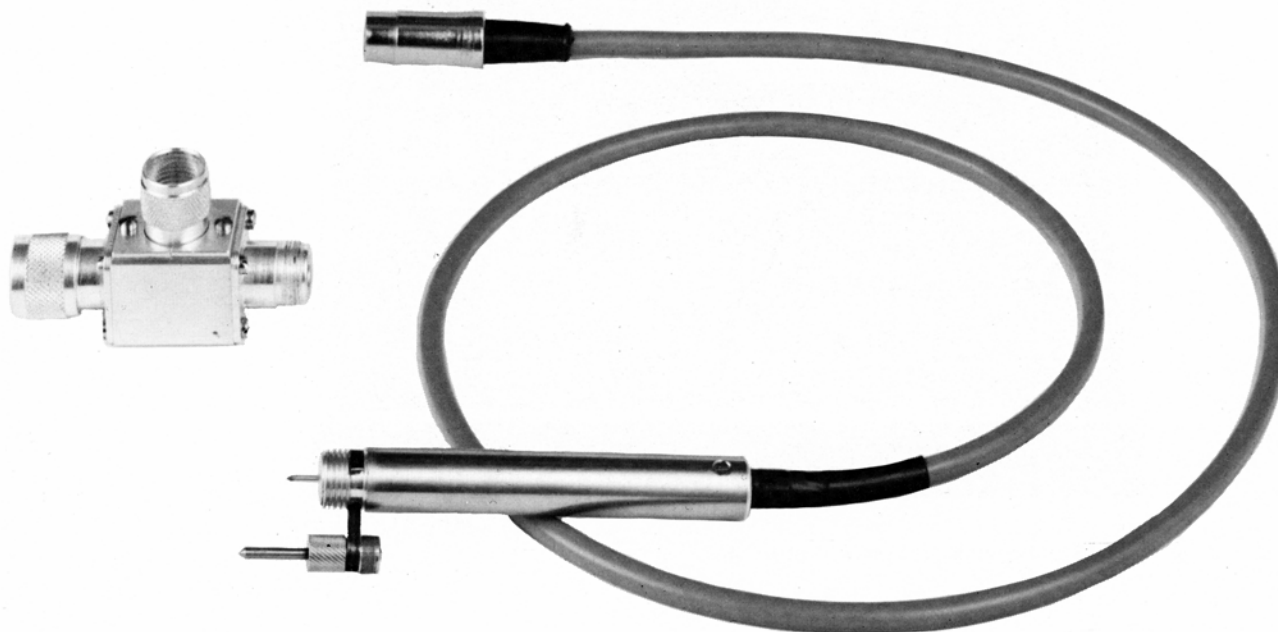


Fig. 56. HF-probe PM 9203 and T-piece PM 9253

TECHNICAL DATA

Probe PM 9203

Frequency response	300 kHz ... 700 MHz
Input capacitance	≤ 2 pF
Parallel damping resistance	10 k Ω ... 200 k Ω , depending on voltage and frequency
Accuracy	see graph, Fig. 57

HF - T - Piece PM 9253

Frequency response	300 kHz ... 1200 MHz
Impedance	50 Ω
Accuracy	< + 5 dB < - 0 dB
Standing-wave ration	see graph, Fig. 58

Principle

Measurement of HF voltages is based on the compensation principle.
The HF measurement is described in detail in chapter IV.B.3.

Components

The electrical parts of the measuring probe are located on a small printed circuit board to which the probe tip is also fixed.

In the case of damage to or defects in these parts the complete printed circuit unit should be replaced.

The diodes have been selected as regards certain properties; therefore they should not be replaced individually. It is urgently disadvised to solder in the circuitry, as thermal effects may impair the properties of the circuit elements.

Therefore, it is only permitted to solder on the connection cable.

The connection cable of the measuring probe is of a special type and should not be replaced by a substitute.

Replacing the printed circuit board in the probe.

- Slightly cut out the transparent insulation sleeve at the place of the screw.
- Remove the screw.
- The casing can be readily slid off the probe.
- Carefully unsolder the connection wires and mark them.
- Remove the two small screws with which the printed circuit board is fixed in the holder.
- Pull the printed circuit board carefully out in backward direction.
- Fit the new printed wiring board, solder the cable in place and refit the casing.

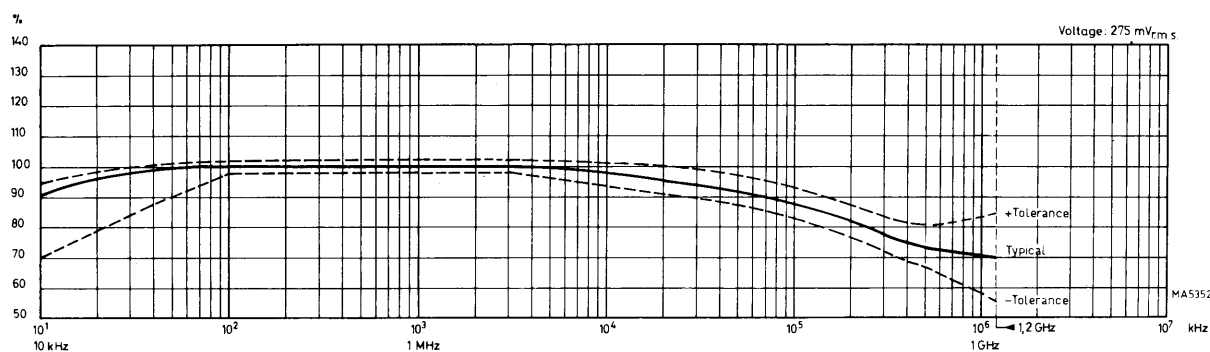


Fig. 57. Accuracy-curve of PM 9203 with PM 9253

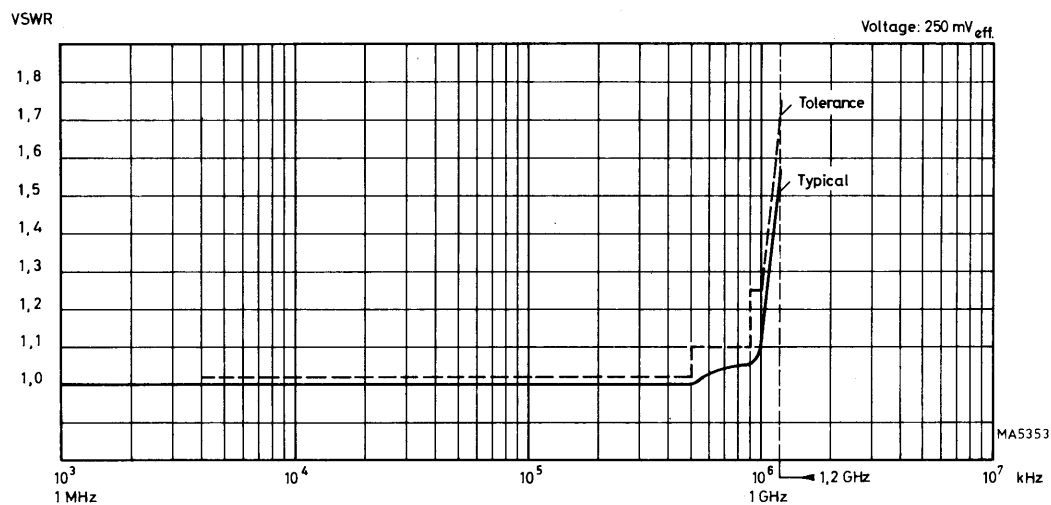


Fig. 58. Standing wave ratio of PM 9253

List of components PM 9203

Qty	Ordering number	Description
1	4822 216 70129	Printed circuit board, with measuring pin and components
1	4822 492 6154	Earthing clip
1	4822 264 20022	Earthing pin
1	4822 322 30005	Cable
1	4822 264 40023	5-pole plug

List of components PM 9253

1	4822 265 10014	Plug
1	4822 267 10042	Connector
1	4822 268 20046	Interconnection piece (between plug and connector)
1	4822 268 20045	Contact pin
1	4822 532 50803	Contact disc.

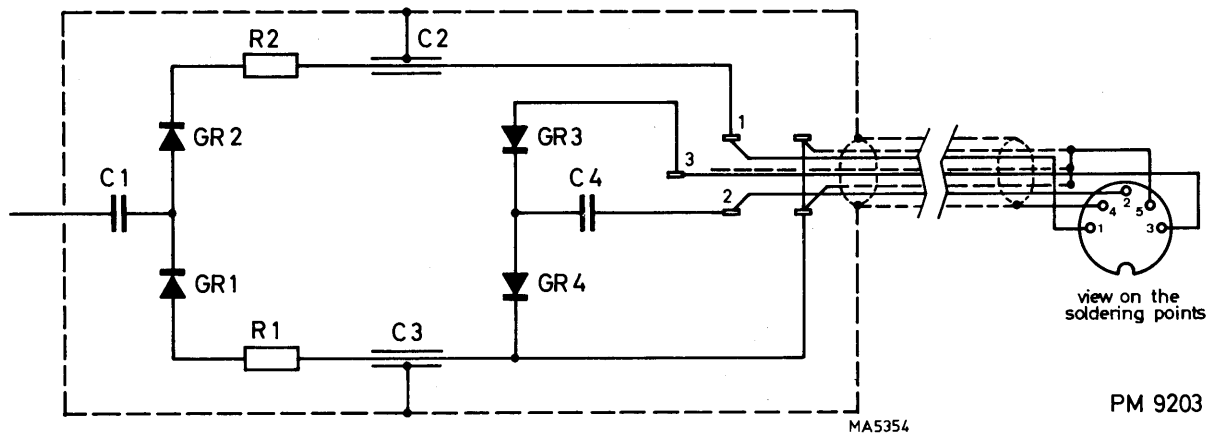


Fig. 59. Circuit diagram of probe PM 9203

XV. DIGITAL OUTPUT UNIT PM 9221

INTRODUCTION

By means of this unit (separately available) instrument PM 2421 can be provided with a digital output. The information as regards result, polarity, range, overload, AC/DC, the transfer signal and the stop signal is taken from the memory and the other circuits via 20 isolation amplifiers and is transferred to the output.

The isolation amplifiers ensure feedback-free connection of the outputs to the instrument, so that the measuring result will not be affected.

The digital output may be used for controlling a printer, a parallel-series converter, limit selector, go/no-go test equipment, digital-to-analogue converter etc.

However, it should be taken into account that this output is galvanically coupled to the "LO" socket of the measuring inputs.

When the digital output is used the automatic range selector should be switched off in certain cases.

However, it is sometimes also possible to suppress undesired signals which may occur after change-over to another range by means of an external circuit.

Technical data

Output/Input		Output contact at CS2 (rear of PM 2421) and at U6 (PM 9221)				
		A	B	C	D	
Result	"1"	1	2	3	4	13 BIT, from memory.
	"10"	5	6	7	8	BCD-Code (1-2-4-8)
	"100"	9	10	11	12	
	"1000"	13				
Polarity		20				1 BIT. + = "1"
Range		a	b			2 BIT a and b
		17	18			
Measuring mode						Range
						a
						b
						10
						1
						100
						0
						1000
						1
						0
Transfer						OV.L.
						0
						0
						2 BIT ac and dc
						Measuring mode
Stop		ac	dc			ac
		22	21			dc
						mode
						AC/HF
Start						0
						1
						DC
Circuit zero						1
						0
						Ω

Assembly

The digital output unit PM 9221 consists of:

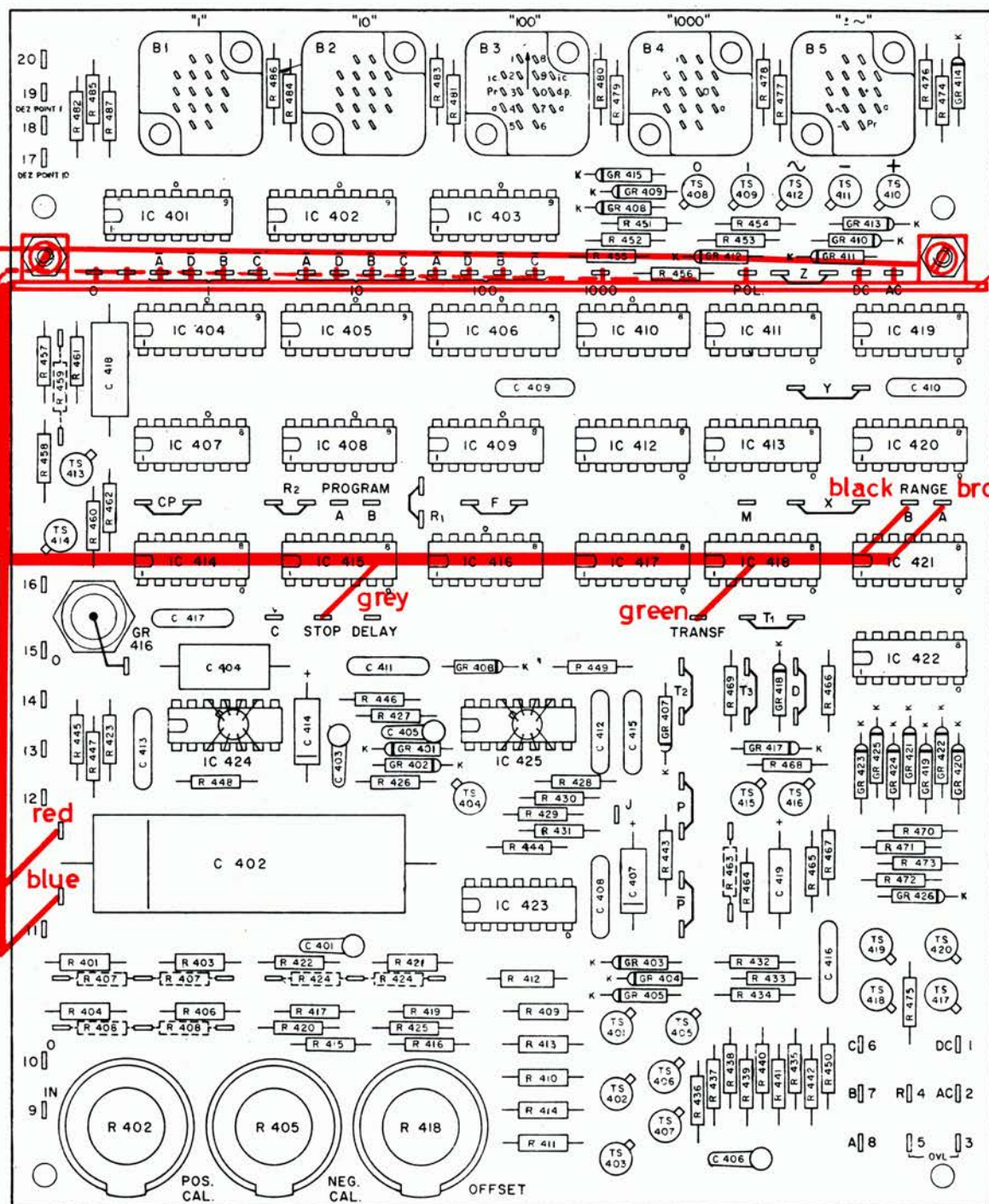
- 1 printed circuit board (U6)
- A wiring assembly
- A 24-pole amphenol connector.

Mounting

- Disconnect the PM 2421 from the mains and pull the chassis out of the cabinet.
- Fit the additional printed circuit board onto digital unit U4 (fig. 60) and secure the printed circuit board with two M3x5 mm screws.
- Connect the connection cable to the digital printed circuit board by means of the AMP connectors, in accordance with connection diagram Fig. 60.
- Detach the rear panel of the PM 2421 by loosening the 6 screws and pull the plate about 2 to 3 cm backwards.

The connections to the supply unit should remain intact.

- Remove the cover plate for the digital output socket and fit the 24-pole socket block. The cable form is so as to permit the socket being brought in position and secured from the inside of the instrument.
- Refit the rear panel and tie up the cable form at a few spots.
- Slide the instrument chassis back into the cabinet.



MA5356

Fig. 60. Digital output unit PM 9221 fitted on digital unit U4

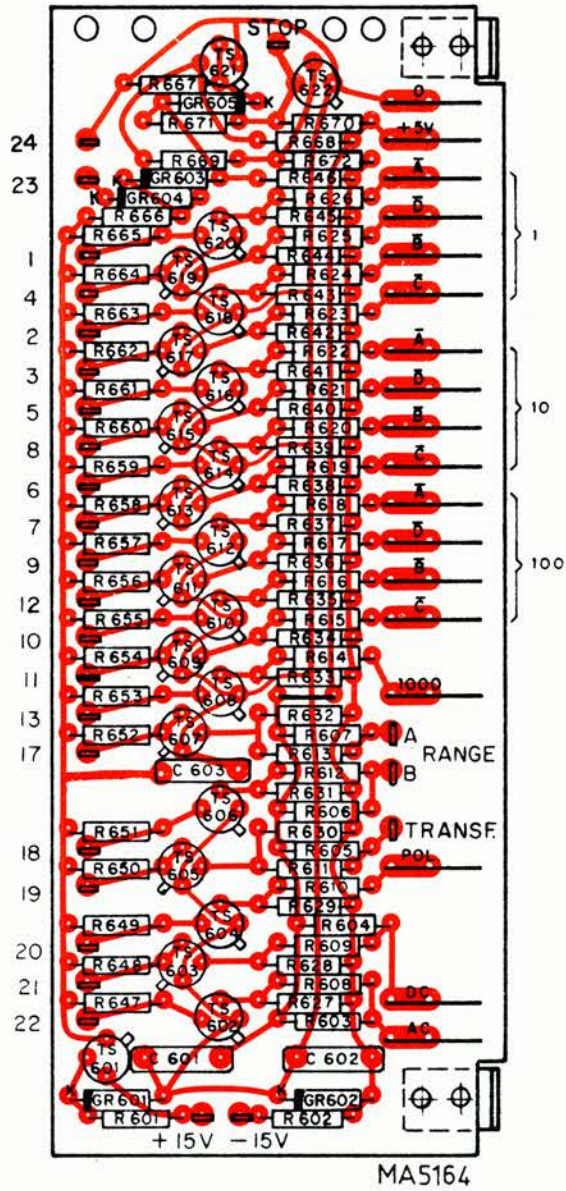


Fig. 61. Printed circuit board PM 9221 (U6)

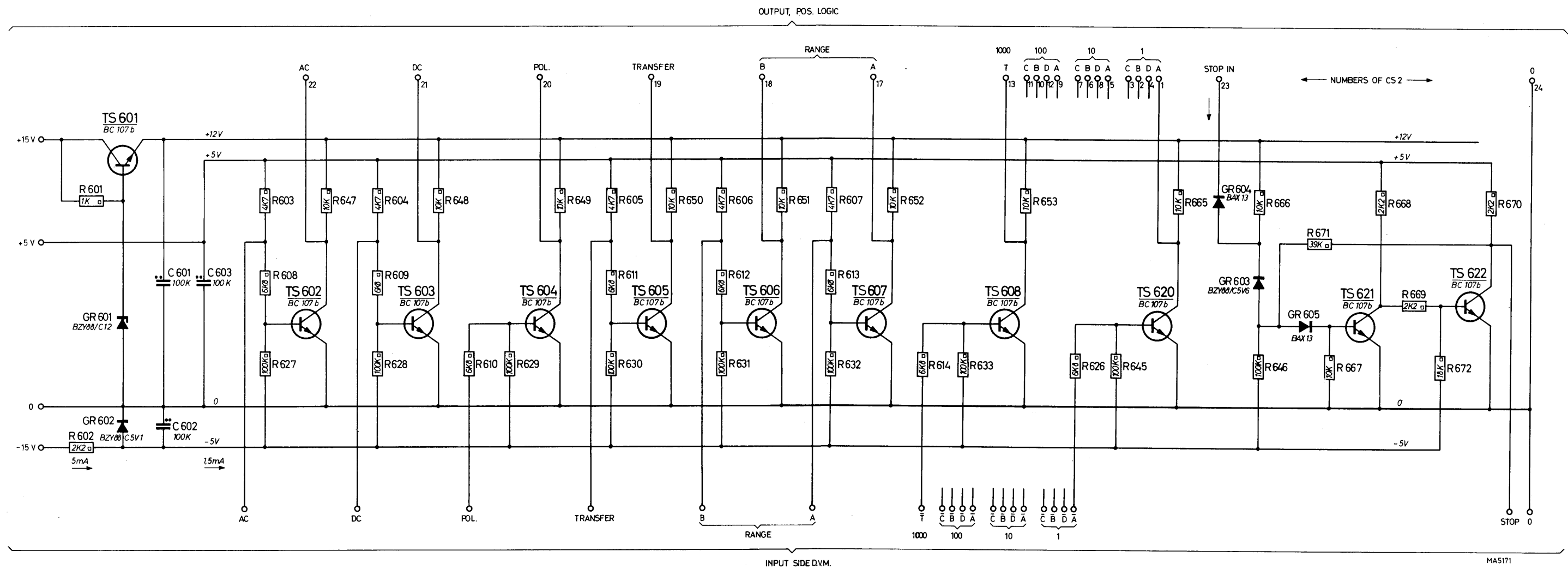


Fig. 62. Circuit diagram PM 9221

XVI. INFORMATION ON INTEGRATED CIRCUITS

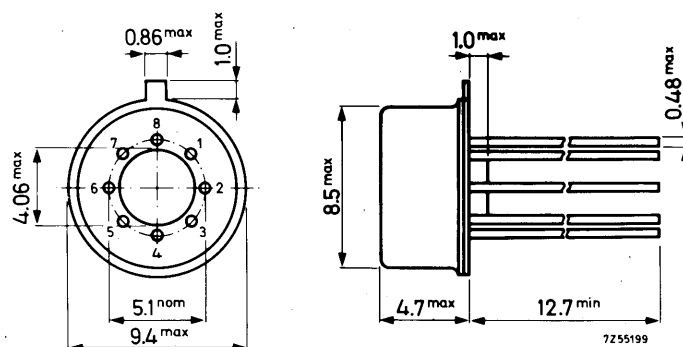
1. Operational amplifier TAA521 (IC201 + IC424)

The TAA521 is a silicon monolithic integrated operational amplifier.

It has a high gain, low offset, high input impedance, high output voltage swing and low power dissipation.

Characteristics (at supply voltages +15 V and -15 V, $T_{amb.} = 25^{\circ}\text{C}$)

<u>Voltage gain</u>	> 15000
$(R_L \geq 2 \text{ k}\Omega; V_0 = \pm 10 \text{ V})$	typical 45000
<u>Input offset voltage</u>	typical 2.0 mV
$(R_s \leq 10 \text{ k}\Omega; V_p = -V_n = 9 \text{ to } 15 \text{ V})$	$< 7.5 \text{ mV}$
<u>Input bias current</u>	typical 0.3 μA $< 1.5 \mu\text{A}$
<u>Input offset current</u>	typical 0.1 μA $< 0.5 \mu\text{A}$
<u>Common mode rejection ratio</u>	$> 65 \text{ dB}$
$(R_s \leq 10 \text{ k}\Omega)$	typical 90 dB
<u>Input voltage range</u>	$> \pm 8.0 \text{ V}$ typical $\pm 10 \text{ V}$
<u>Differential input resistance</u>	$> 50 \text{ k}\Omega$ typical 250 k Ω
<u>Output resistance</u>	typical 150 Ω
<u>Supply voltage rejection ratio</u> ($R_s \leq 10 \text{ k}\Omega$)	typical 25 $\mu\text{V/V}$ $< 200 \mu\text{V/V}$
<u>Peak output voltage swing</u>	$R_L \geq 10 \text{ k}\Omega: > \pm 12 \text{ V}$ typical $\pm 14 \text{ V}$ $R_L \geq 2 \text{ k}\Omega: > \pm 10 \text{ V}$ typical $\pm 13 \text{ V}$
<u>Power dissipation at $V_0 = 0$</u>	typical 80 mW $< 200 \text{ mW}$
<u>Supply</u>	positive supply max. 18 V negative supply max. 18 V common mode voltage max. $\pm 10 \text{ V}$ differential mode voltage max. $\pm 5 \text{ V}$
<u>Temperature</u>	Operating ambient temperature 0 to 75°C Storage temperature -55 to 125°C .



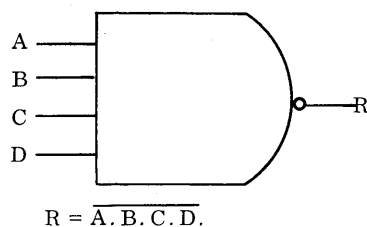
2. Dual 4-input NAND gate FJH111 (IC421)

The FJH111 is a TTL silicon monolithic integrated circuit for medium speed digital equipment, comprising two 4-input Nand gates.

Each gate comprises a multi-emitter AND input gate followed by an inverting amplifier and a totem pole output stage.

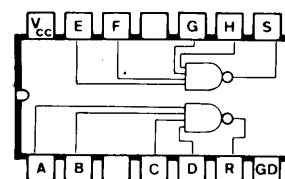
Characteristics ($T_{amb} = 25^{\circ}\text{C}$)

Output level in 0 condition	max. 0.4 V	(supply 4.75 V; $I_{output} = 16 \text{ mA}$)
Output level in 1 condition	min. 2.4 V	(supply 4.75 V; $I_{output} = -0.4 \text{ mA}$)
Input current in 0 condition	max. 1.6 mA	(supply 5.25 V)
Input current in 1 condition	max. 40 μA	(supply 5.25 V)
Output current in 0 condition	max. 16 mA	
Output current in 1 condition	max. 0.4 mA	
Supply current in 0 condition	typical 3.0 mA	(supply 5 V)
Supply current in 1 condition	typical 1 mA	(supply 5 V)
Supply voltage	max. 7 V	
Output voltage	max. 5.5 V	
Gate input voltage	0 to 5.5 V	
Operating ambient temperature	0...+70 $^{\circ}\text{C}$	



Truth table

A	B	C	D	R
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	1	1	1
1	0	0	0	1
1	1	1	1	0

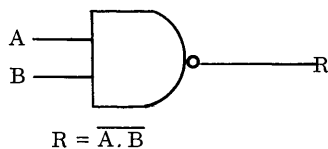


3. Quadruple 2-input Nand gate SN7400N (IC413, 414, 417, 419, 420 and 423)

The SN7400N is a TTL monolithic integrated circuit, comprising four 2-input NAND gates.

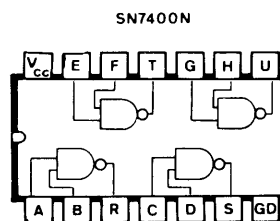
Characteristics

(see characteristics of FJH111)



Truth table

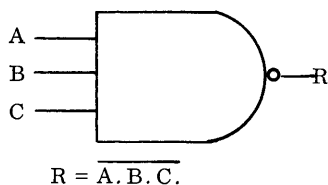
A	B	R
0	0	1
0	1	1
1	0	1
1	1	0



4. Triple 3-input NAND gate SN7410N (IC418)

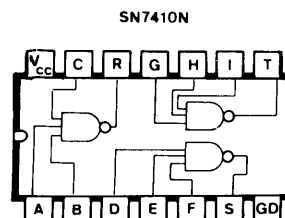
The SN7410N is a TTL monolithic integrated circuit, comprising three 3-input NAND gates.

Characteristics (see characteristics of FJH111)



Truth table

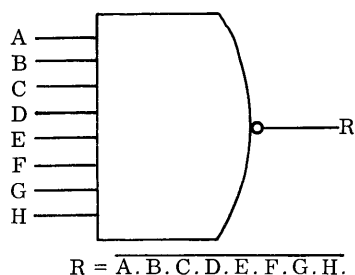
A	B	C	R
0	0	0	1
0	0	1	1
0	1	0	1
1	0	0	1
1	1	0	1
0	1	1	1
1	1	1	0



5. 8-Input NAND gate SN7430N (IC411 and IC412)

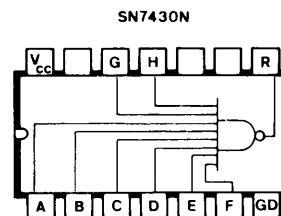
The SN7430N is a TTL monolithic integrated circuit, comprising one 8-input NAND gate.

Characteristics (see characteristics of FJH111)



Truth table

A	B	C	D	E	F	G	H	R
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	1	0	1
0	0	0	0	0	1	0	0	1
0	0	0	1	1	0	0	0	1
1	1	0	0	0	1	1	0	1
1	0	0	0	0	0	0	1	1
1	1	1	1	1	1	0	0	1
1	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	0



6. BCD-to-decimal decoder/driver SN7441N (IC401-403)

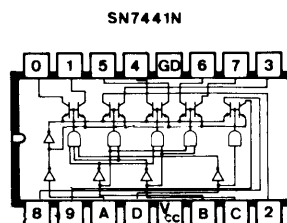
The SN 7441 N is a monolithic, BCD-to-decimal decoder for use as indicator driver. The decoder consists of familiar TTL gate circuits which select one of the ten decimal output drivers.

Characteristics

Supply voltage	4.75 to 5.25 V
Maximum voltage on any output	55 V
Logical 1 input voltage	min. 2 V (supply 4.75 V)
Logical 0 input voltage	max. 0.8 V (supply 4.75 V)
On-state output voltage	max. 2.5 V (supply 4.75 V; $I_{on} = 7$ mA)
Off-state reverse current	max. 200 μ A (supply 4.75 V; output voltage 55 V)
Logical 1 level input current at B, C or D	40 μ A (input voltage 2.4 V; supply 5.25 V) 1 mA (input voltage 5.5 V; supply 5.25 V)
Logical 1 level input current at A	80 μ A (input voltage 2.4 V; supply 5.25 V) 1 mA (input voltage 5.5 V; supply 5.25 V)
Logical 0 level input current at B, C or D	- 1.6 mA (supply 5.25 V; input voltage 0.4 V)
Logical 0 level input current at A	- 3.2 mA (supply 5.25 V; input voltage 0.4 V)
Supply current	21 mA (supply 5 V; $T_{amb} 25^{\circ}$ C)

Truth table

Output "on"	Input			
	A	B	C	D
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1



7. J-K master-slave flip-flop SN7472N (IC415)

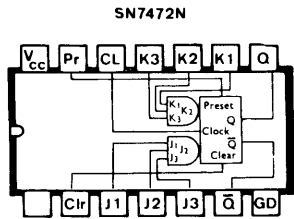
The SN7472N J-K flip-flop which is based on the master-slave principle, has three J and three K inputs (AND function). The circuit operates at frequencies up to 15 MHz. The information at the J and K input enters the master when the clock input is "1". Afterwards, when T is "0" the information is transferred from the master to the slave and appears at the outputs.

Characteristics

Supply voltage	4.75 to 5.25 V
Width of clock pulse	≥ 20 ns
Width of preset pulse	≥ 25 ns
Width of clear pulse	≥ 25 ns
Input voltage required to ensure logical 1 at any input terminal	min. 2 V
Input voltage required to ensure logical 0 at any input voltage	max. 0.8 V
Logical 1 output voltage	min. 2.4 V
Logical 0 output voltage	max. 0.4 V
Logical 0 level input current at J1, J2, J3, K1, K2 and K3	- 1.6 mA
Logical 0 level input current at preset, clear or clock	- 3.2 mA
Logical 1 level output current at J1, J2, J3, K1, K2 or K3	40 μ A (at input voltage 2.4 V) 1 mA (at input voltage 5.5 V)
Logical 1 level input current at preset, clear or clock	80 μ A (at input voltage 2.4 V) 1 mA (at input voltage 5.5 V)
Supply current	8 mA

Truth table

t_n		t_{n+1}
J = J1, J2, J3	K = K1, K2, K3	Q
0	0	Q_n
0	1	0
1	0	1
1	1	$\overline{Q_n}$



t_n = Bit time before clock pulse
 t_{n+1} = Bit time after clock pulse
Low input to preset sets Q to logical 1
Low input to clear sets Q to logical 0
Preset and clear are independent of clock

8. Dual J-K master-slave flip-flop SN7473N (IC410 and IC416)

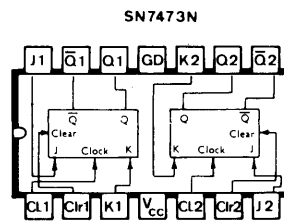
The SN7473N contains two independent flip-flops, each provided with one J and one K input and based on the master-slave principle. The circuit operates at frequencies up to 15 MHz. The information at the J and K inputs enters the master when the clock is "1". Afterwards, when the clock is "0", the information is transferred from the master to the slave and appears at the outputs.

Characteristics

See characteristics of SN7472N, except for the preset pulse.

Truth table (each flip-flop)

t_n		t_{n+1}
J	K	Q
0	0	Q_n
0	1	0
1	0	1
1	1	\bar{Q}_n



t_n = Bit time before clock pulse

t_{n+1} = Bit time after clock pulse

Low input to clear sets Q to logical 0

Clear is independent of clock

9. Dual D-Type edge triggered flip-flop SN7474N ((C422)

The SN7474N is a monolithic integrated circuit comprising two D type edge-triggered flip-flops with direct clear and preset inputs and complementary outputs. The information on the D input is transferred to the Q output on the positive edge of the clock pulse.

Characteristics

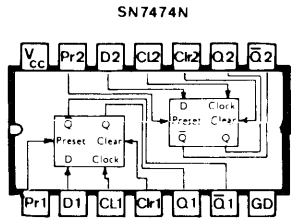
Supply voltage	4.75 to 5.25 V
Width of clock pulse	≥ 30 ns
Width of preset pulse	≥ 30 ns
Width of clear pulse	≥ 30 ns
Input voltage required to ensure logical 1 at any input terminal	min. 2 V
Input voltage required to ensure logical 0 at any input terminal	max. 0.8 V
Logical 1 output voltage	min. 2.4 V
Logical 0 output voltage	max. 0.4 V
Logical 0 level input current at preset or D	- 1.6 mA
Logical 0 level input current at clear or clock	- 3.2 mA
Logical 1 level input current at D	40 μ A (at 5.25 V supply and 4.5 V input) 1 mA (at 5.25 V supply and 5.5 V input)

Logical 1 level input current at preset or clock	80 μ A (at 5.25 V supply and 2.4 V input) 1 mA (at 5.25 V supply and 5.5 V input)
Logical 1 level input current at clear	120 μ A (at 5.25 V supply and 2.4 V input) 1 mA (at 5.25 V supply and 5.5 V input)
Supply current (each flip-flop)	8.5 mA

Truth table

t_n	t_{n+1}	
Input D	Output Q	Output \bar{Q}
0	0	1
1	1	0

t_n = Bit time before clock pulse
 t_{n+1} = Bit time after clock pulse



10. Quadruple bistable latch SN7475N (IC404...IC406)

The SN7475N is a monolithic integrated circuit comprising four bistable latches with complementary outputs. Information present at data (D) input is transferred to the Q output when the clock is "1" and the Q output will follow the data input as long as the clock remains "1". When the clock goes to "0", the information is retained at the Q output until the clock is permitted to go to "1".

Characteristics

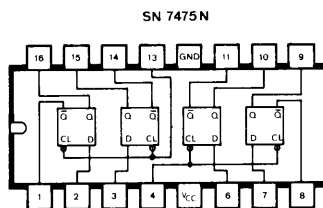
Supply voltage	4.75 V to 5.25 V
Input voltage required to ensure logical 1 level at any input terminal	min. 2 V
Input voltage required to ensure logical 0 level at any input terminal	max. 0.8 V
Logical 1 output voltage	min. 2.4 V
Logical 0 output voltage	max. 0.4 V
Logical 0 level input current at D	max. -3.2 mA
Logical 0 level input current at clock	max. -6.4 mA
Logical 1 level input current at D	80 μ A (at supply 5.25 V; input 2.4 V) 1 mA (at supply 5.25 V; input 5.5 V)
Logical 1 level input current at clock	160 μ A (at supply 5.25 V; input 2.4 V) 1 mA (at supply 5.25 V; input 5.5 V)
Supply current	32 mA

Truth table (each flip-flop)

t_n	t_{n+1}	
D	Q	\bar{Q}
1	1	0
0	0	1

t_n = Bit time before clock pulse

t_{n+1} = Bit time after clock pulse



11. Decade counter SN7490N (IC407...408)

The SN7490N is a high-speed, monolithic decade counter consisting of four master-slave flip-flops internally interconnected to provide a divide-by-two counter and a divide-by-five counter. Gated direct reset lines are provided to inhibit count inputs and return all outputs to logical zero or to a binary coded decimal count of 9.

When used as a binary coded decimal counter, the BD input must be externally connected to the A output.

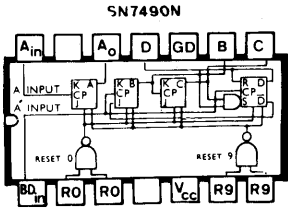
Characteristics

Supply voltage	4.75 V to 5.25 V
Width of input count pulse	≥ 50 ns
Width of reset pulse	≥ 50 ns
Input voltage required to ensure logical 1 at inputs A, R0 and R9	min. 2 V (at supply 4.75 V)
Input voltage required to ensure logical 1 at input BD	min. 2.2 V (at supply 4.75 V)
Input voltage required to ensure logical 0 at inputs A, R0 and R9	max. 0.8 V (at 4.75 V supply)
Input voltage required to ensure logical 0 at input BD	max. 0.6 V (at 4.75 V supply)
Logical 1 output voltage	min. 2.4 V (at 4.75 V supply; $I_{out} = -400 \mu A$)
Logical 0 output voltage	max. 0.4 V (at 4.75 V supply; $I_{out} = -16$ mA)
Logical 1 level input current at R0, R9	40 μA (at 5.25 V supply; 2.4 V input) 1 mA (at 5.25 V supply; 5.5 V input)
Logical 1 level input current at input A	80 μA at 5.25 V supply; 2.4 V input 1 mA at 5.25 V supply; 5.5 V input
Logical 1 level input current at input BD	160 μA at 5.25 V supply; 2.4 V input 1 mA at 5.25 V supply; 5.5 V input
Logical 0 level input current at R0 or R9	-1.6 mA at 5.25 V supply; 0.4 V input
Logical 0 level input current at input A	-3.2 mA at 5.25 V supply; 0.4 V input
Logical 0 level input current at input BD	-6.4 mA at 5.25 V supply; 0.4 V input
Supply current	32 mA

Truth table

Count	Output				RESET INPUTS				OUTPUT			
	D	C	B	A	R0 (1)	R0 (2)	R9 (1)	R9 (2)	D	C	B	A
0	0	0	0	0	1	1	0	x	0	0	0	0
1	0	0	0	1	1	1	x	0	0	0	0	0
2	0	0	1	0	x	x	1	1	1	0	0	1
3	0	0	1	1	x	0	x	0	count			
4	0	1	0	0	0	x	0	x	count			
5	0	1	0	1	0	x	x	0	count			
6	0	1	1	0	x	0	0	x	count			
7	0	1	1	1								
8	1	0	0	0								
9	1	0	0	1								

x indicates that either a "1" or a "0" may be present

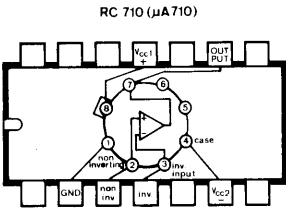


2. Differential voltage comparator RC710 (IC425)

The RC710 is a monolithic high speed differential voltage comparator. Characteristic of the RC710 is the low offset voltage and low drift as well as high accuracy and fast response.

Characteristics (T_{amb} = 25°C; + supply = 12 V; - supply = 6 V)

Positive supply voltage	+14 V
Negative supply voltage	-7 V
Differential input voltage	± 5 V
Input voltage	± 7 V
Operating temperature range	0...70°C
Input offset voltage	max. 5 mV
Input offset current	max. 5 µA
Input bias current	max. 25 µA
Voltage gain	min. 800
Output resistance	200 Ω
Response time	40 ns
Average temperature coefficient of input offset voltage	max. 20 µV/°C
Average temperature coefficient of input offset current	25°C...125°C: max. 50 nA/°C 25°C...-55°C: max. 100 nA/°C
Common mode rejection ratio	min. 70 dB
Positive supply current	max. 9 mA
Negative supply current	max. 7 mA
Power consumption	max. 150 mW



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France: Philips Industrie S.A., 105 Rue de Paris, 93 Bobigny (Seine); tel. 845 25-55, 845 27-09

Ghana: Philips (Ghana) Ltd., P.O.B. M 14, Accra

Great Britain: Pye Unicam Ltd., Manor Royal, Crawley (Sussex); tel. 28787

- Guatemala:** Philips de Guatemala S.A., Apartado Postal 238, Guatemala City; tel. 20607-08-09
- Hellas:** Philips S.A. Hellénique, B.P. 153, Athènes; tel. 230476
- Hong Kong:** Philips Hong Kong Ltd., P.O.B. 2108, Rooms 1006/1008 Prince's Building, Hong Kong; tel. 33728, 28548
- India:** Philips India Ltd., Shivsagar Estate, Block „A“, Dr. Annie Besant Road, P.O.B. 6598, Worli Bombay 18; tel. 246-231; 245-144
- Indonesia:** Philips Delegate Office, Djalan Pegangsaan Timur 33, P.O.B. 2287, Djakarta
- Iran:** Philips Iran Ltd., P.O.B. 1297, Teheran; tel. 48344-68344
- Iraq:** Philips (Iraq) W.L.L., P.O.B. 5749, South Gate Post Office, Baghdad; tel. 98844
- Ireland:** Philips Electrical (Ireland) Ltd., Newstead, Clonskeagh, Dublin 14; tel. 976611
- Island:** Mr. Snorri P.B. Arnar, P.O.B. 354, Reykjavik; tel. 13869
- Islands Canarias:** Philips Ibérica S.A.E., Triana 132, Las Palmas; Casilla 39-41 Santa Cruz de Tenerife
- Italia:** Philips S.p.A., Casella Postale 3992, Milano; tel. 69.94
- Kenya:** Philips (Kenya) Ltd., P.O.B. 9970, Nairobi
- Liban:** Philips Liban S.A., P.O.B. 670, Beyrouth; tel. 232303-232458/59
- Malaya:** William Jacks & Co. Ltd., Jalon Mountbatten, P.O.B. 286, Kuala Lumpur
- Malaysia:** Philips Singapore Ltd., 8th Floor, International Bld, 360 Orchard Road, P.O.B. 1358, Singapore; tel. 9414 Messrs. William Jacks and Co. 63/4 m.s. Bukit Timah Road, P.O.B. 4049, Singapore
- Maroc:** Société Anonyme Marocaine de Télécommunications, 2, Rue de Bapaume, Casablanca; tel. 439-92
- Mexico:** Philips Commercial S.A. de C.V.; Uruapan 7, Apdo 24-328, Mexico 7 D.F.
- Nederland:** Philips Bedrijfsapparatuur Nederland N.V., Boschdijk VB, Eindhoven; tel. 3-33-33
- Ned. Antillen:** Philips Antillana N.V., Postbus 523, Willemstad, tel. Curaçao 36222-35464
- New Zealand:** Electronic Development and Applications Co. Ltd., 18-20 Lorne Street, P.O.B. 6415, Wellington; tel. 54-039
- Nigeria:** Philips (Nigeria) Ltd., Philips House, 6, Ijora Causeway, P.O.B. 1921, Lagos; tel. 56051/2
- Nippon:** Philips Products Sales Corporation of Japan, Koku-sai Building, 7th Floor, Marunouchi, Chiyoda-Ku, Tokyo; tel. (216) 2441
- Norge:** Norsk A.S. Philips, Postboks 5040, Oslo; tel. 463890
- Österreich:** Philips GmbH, Abt. Industrie, Triesterstrasse 64, 1101 Wien X; tel. 64 55 11
- Pakistan:** Philips Electrical Co. of Pakistan Ltd., Bunder Road, P.O.B. 7101, Karachi; tel. 70071
- Paraguay:** Philips del Paraguay S.A., Casilla de Correo 605, Asunción; tel. 8045-5536-6666
- Perú:** Philips Peruana S.A., Apartado Postal 1841, Lima; tel. 34620-40265
- Philippines:** Electronic Development & Application Center, Room 715, Don Santiago Bld., 1344 Taft Avenue, Manila
- Portugal:** Philips Portuguesa S.A.R.L., Rua Joaquim Antonio d'Aquiar 66, Lisboa; tel. 683121/9
- Rhodesia:** Philips Rhodesian (Private) Ltd., P.O.B. 994, Gordon Avenue, Salisbury; tel. 29081
- Rwanda:** Philips S.A.R.L., B.P. 448, Kigali
- Schweiz-Suisse-Svizzera:** Philips A.G., Binzstrasse 38, 8027 Zürich; tel. 051 - 44 22 11
- South Africa:** South African Philips (Pty) Ltd., P.O.B. 7703, 2, Herb Street, New Doornfontein, Johannesburg; tel. 24-0531
- Sudan:** Gellatly Hankey & Co. (Engineering) Ltd., P.O.B. 150, Khartoum; tel. 71183
- Suomi:** Oy Philips Ab, P.O.B. 10255, Helsinki 10; tel. 10915
- Sverige:** Svenska A.B. Philips, Fack, Lidingövägen 50, Stockholm 27; tel. 08/635000
- Syrie:** Philips Moyen Orient S.A., P.O.B. 2442, Damas; tel. 18605-21650
- Taiwan:** Yung Kang Trading Co. Ltd., 6 Nan King East Road, 1 Section, P.O.B. 1467, Taipei; tel. 43540
- Tanzania:** Philips (Tanzania) Ltd., P.O.B. 20104, Dar Es Salaam
- Thailand:** Philips Thailand Ltd., 283 Silom Road, Bangkok; tel. 36985-8
- Tunisie:** Société Tunisienne d'Industrie Electronique et de Télévision, 32 bis, Rue Ben Ghedhahem, Tunis
- Türkiye:** Türk Philips Ticaret A.S., Posta Kutusu 504, Istanbul; tel. 447486
- Uruguay:** Philips de Uruguay, Avda Uruguay 1287, Montevideo; tel. 956 41-2-3-4
- U.S.A.:** Philips Electronic Instruments, 750 South Fulton Ave., Mount Vernon, N.Y. 10550; tel. (914) 664-4500
- Venezuela:** C.A. Philips Venezolana, Apartado Postal 1167, Caracas; tel. 72 01 51
- Zambia:** Philips Electrical Ltd., P.O.B. 1878, Lusaka