# DIGITAL VOLTMETER

## DM2004

Digital Measurements Limited,
Salisbury Grove,
Mytchett,
Aldershot, Hants.

Telephone: Farnborough (Hants) 3551.

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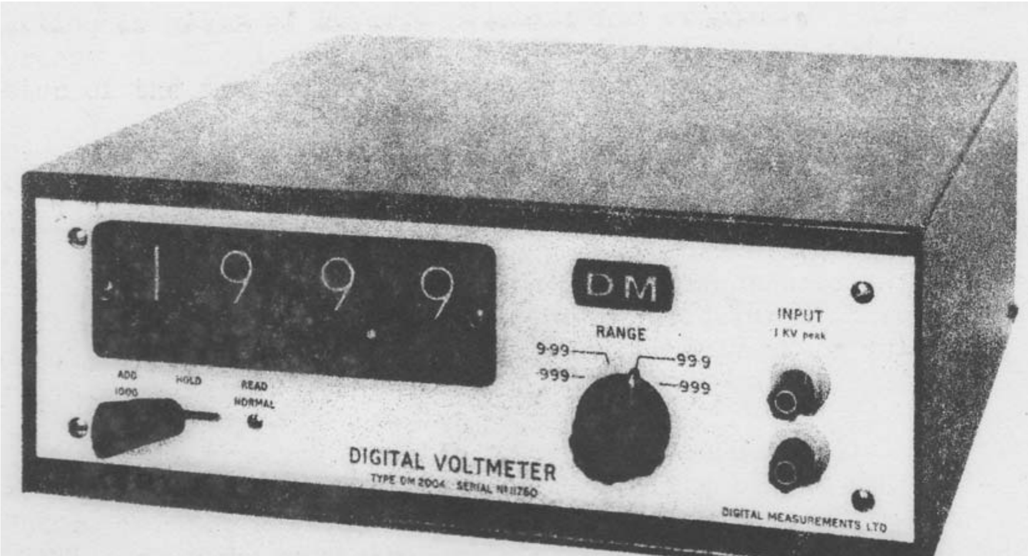
## DIAGRAMS




DIGITAL VOLTMETER DM2004

## 1. INTRODUCTION

The DM2004 is an inexpensive Digital Voltmeter designed for d.c. measurements in the range 1mV to 1KV. It has a scale of 1999 in two manually selected stages, these being 0-999 and 1000-1999.

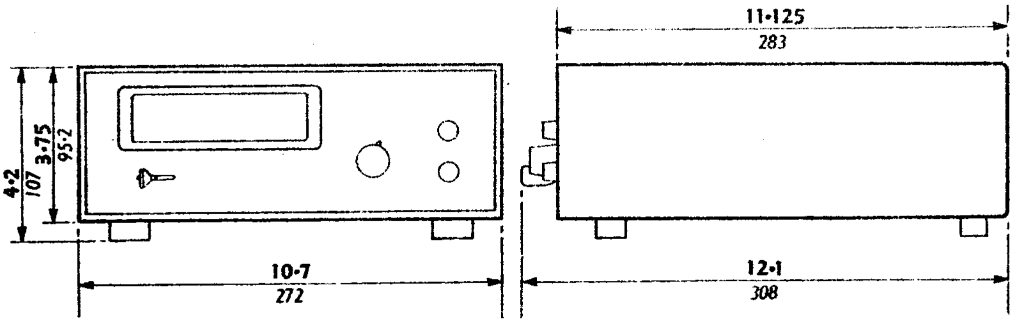
The instrument has a fully floating input, the connections of which must be made in the correct polarity; unambiguous indication is given of reverse polarity and overload. The measurement is displayed on numerical indicator tubes and the position of the decimal point is automatically shown.

The measuring principle uses the well-proven potentiometric technique and in operation the instrument continuously checks for a null between the input voltage and displayed reading. As soon as an unbalance is detected the potentiometer is driven to reduce the unbalance to zero. The continuous comparison process ensures that the indication is correct without the need for disturbing the display. Full accuracy is available immediately after switching on, no warm-up period being required.

The instrument is built to a very high mechanical and electrical standard and utilizes printed wiring boards and semi-conductors for all active circuits. Switching is performed by Post Office approved stepping switches used in such a way that an operating life of at least 5 years is predicted. These switches are of plug-in construction and so may easily be replaced should this ever be necessary.

## 2. SPECIFICATION

| | |
|---|---|
| RANGES | (1) 2V<br>(2) 20V<br>(3) 200V<br>(4) 1KV<br>The voltage between either input terminal and earth must not exceed 1KV |
| INPUT IMPEDANCE | Range 1:- 1MΩ<br>Ranges 2, 3 and 4:- 10MΩ |
| ACCURACY | 0.1% of reading ± 1 digit |
| TEMPERATURE COEFFICIENT | ± 0.01% per °C |
| TYPICAL RESPONSE TIME | 1.5 secs. |
| INPUT FILTER | 40dB at 50c/s, 60c/s or 400c/s filters supplied on request |
| COMMON MODE REJECTION | 120dB at d.c. with 1000Ω source unbalance |
| OPERATING MODES | (a) Read 999:- automatic change of reading with change of input. Scale of 0-999<br>(b) Add 1000:- as above, with a scale of 1000-1999<br>(c) Hold:- the display is held and input changes are not followed |
| RANGE SWITCHING | Manual |
| DECIMAL POINT INDICATION | Automatic with rnage switching |
| DISPLAY | In-line illuminated numerals |
| AMBIENT TEMPERATURE RANGE | 0-55°C |
| POWER SUPPLY | 100-125V and 200-250V, 50-400c/s |
| CONSUMPTION | Less than 20VA |




**DIMENSIONS IN INCHES**
*DIMENSIONS IN MILLIMETERS*

**WEIGHT: 13 lb.** *(5·9 Kg.)*

## 3. OPERATING INSTRUCTIONS

These instructions should be read through carefully before attempting to use the instrument.

CAUTION: On no account should the power supply lead on the instrument be connected to a d.c. power supply or serious damage will result.

### 3.1 CONNECTING TO THE A.C. POWER SUPPLY

The instrument is delivered with the transformer set for 240V. If the instrument is to be used with a different supply voltage, remove the cover and alter the supply connections to the primary of the power transformer as necessary. Replace the cover.

When operation is required on 60c/s or 400c/s power supplies, the instrument is supplied with the appropriate input filter fitted.

Connect the power supply lead as follows:-

| Cable Code | Power Supply |
|---|---|
| RED | LINE |
| BLACK | NEUTRAL |
| GREEN | EARTH |

### 3.2 OPERATION

Switch to the 1KV range and select HOLD. Switch the a.c. power supply on and note that a numerical display appears immediately.

WARNING: The voltage between the input terminals must not exceed 100V on the 1V and 10V ranges, and 1KV on the 100V and 1000V ranges. The voltage between either input terminal and mains earth must not exceed 1000V.

Connect the RED input terminal to the positive side of the voltage to be measured and the BLACK terminal to the negative side. Select READ NORMAL. If the input polarity is reversed, the display will be as follows:- -,*, 0, 0, where * indicates a display continuously stepping round, and - indicates no display.

The correct range should be determined in the manner indicated in the table below.

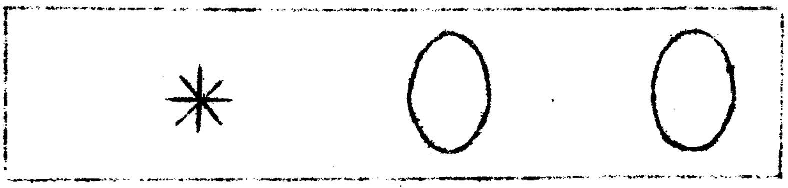
| READING | ACTION |
|---|---|
| Between -199 and -099 | Select ADD 1000 on the next lower range |
| Below -099 | Select READ 999 on the next lower range |

NOTE: The input of this instrument is fully floating and either INPUT terminal can be connected to earth without affecting the reading.

<u>Unambiguous Indication of Reverse Polarity and Overload</u>.

In the following diagrams, the asterisk indicates a display continuously stepping round.

REVERSE POLARITY

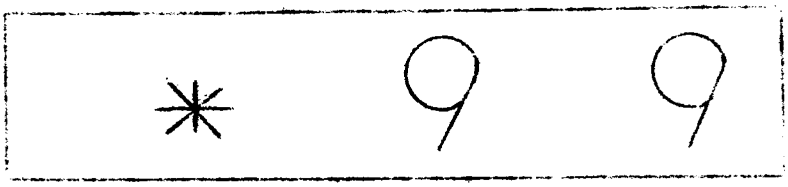



Reverse the input connections.

OVERLOAD

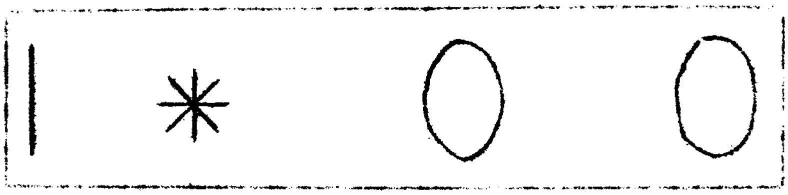

Select ADD 1000

OVERLOAD




Select the next higher range

LOW INPUT FOR RANGE




Select READ 999

UNSTABLE INPUT

Change to higher range to improve stability.

(Arbitary numbers displayed)

Source Impedance

When measuring inputs having appreciable source impedance, allowance must be made for the loading effect on the input of the voltmeter. In addition, the source impedance on the 20V range should not exceed 1MΩ and on the 2V range 20KΩ. If these values are exceeded, low input voltages on the particular range selected may give a "Reverse Polarity" or "Low Input for Range" indication, as appropriate.

Common Mode Rejection

The common mode rejection figure quoted (>120dB) is for the following input condition. The signal source has an impedance of 1000 ohms, and the common mode voltage is connected between the "High" input terminal and mains earth. If the common mode voltage is connected between the "Low" terminal and mains earth a very much higher rejection figure is obtained.

## 4. SYSTEM DESCRIPTION

The system is described in conjunction with the functional block diagram (Fig.1).

The voltmeter is designed in the form of a simple position servomechanism. The input is compared with a feedback voltage and the difference is amplified and used to drive three stepping switches. These stepping switches select the feedback voltage step required to give zero input to the amplifier, and also indicate this voltage step on three number tubes.

The signal input is fed via an attenuator, selected by the RANGE switch, and a band-stop filter to the input of the main amplifier. The feedback voltage is also connected to this point, and the error voltage produced is chopped at a frequency of about 16c/s. The error voltage is amplified and, at the output of the amplifier, a second chopper circuit gates the amplifier output. From the second chopper the signal is fed via a buffer amplifier to two bistable circuits. Since both bistable circuits are triggered by a negative input, the 'up' bistable is preceded by an inverter. Thus, if the output from the buffer amplifier is positive, the 'up' bistable will be triggered, and if negative, the 'down' bistable will be triggered. Whichever bistable operates, it inhibits the other bistable. Considering the 'up' bistable output, this is fed via a drive amplifier to contact 0 of switch wafers B2 and C2, and via an OR gate to all the other contacts except 9. Thus, each time the 'up' bistable is 'set' the wiper of C2 steps round one position until either the 'down' bistable is 'set' or contact 9 is reached. There is no 'up' signal on contact 9 and therefore switch C stops stepping and the inhibit is removed from the gate which connects solenoid B to wafer B2. The wiper of B2 then steps round, as for A2, until it reaches 9, when switch B stops stepping and the inhibit is removed from the gate to solenoid A. Switch A will then continue to step as long as there are 'up' pulses applied to it.

When the 'down' bistable is set, the stepping switches operate in exactly the same way as for the 'up' signal, but they stop at contact 0, since there is no 'down' signal on contact 0.

When HOLD is selected the stepping switch solenoids are disconnected from the supply.

The feedback voltage is obtained from a zener stabilized source via attenuators and a potentiometer chain. On all ranges the potentiometer produces voltage outputs in constant increments which are then selected by the stepping switches. The feedback attenuators are set to balance the 'tens' and 'units' increments against the 'hundreds' increments. The input signal is fed via input resistors and attenuators. Fine adjustments for errors in the input attenuator are made by altering the reference voltage across the potentiometer. When the input exceeds 999, i.e. an overload occurs, the ADD 1000 switch can be operated. This puts a fixed current bias on to the feedback line and the stepping switches then start to count up from zero.

The number tubes are controlled by the stepping switches and the decimal point lamps by the range switch.

The timing of the chopper and bistable circuits is controlled from an oscillator running at approximately 16c/s. The timing waveforms are shown on the block diagram to illustrate the operation. The oscillator output is fed via a buffer and an inverter to the first chopper. When the chopper is open a capacitor at the input of the main amplifier is charged to the error voltage. When the chopper is closed the capacitor is discharged into the input impedance of the amplifier and this produces a positive or negative 'spike' depending on the polarity of the error signal.

A 30ms delay is produced from the trailing edge of the oscillator pulse. While the 30ms delay pulse is present either bistable may be set by an up or down pulse as appropriate. During the rest of the cycle both bistables are held in the reset state and cannot be tripped. A 10µs delay pulse is also produced from the trailing edge of the oscillator pulse. This pulse is used to inhibit the first 10µs of the pulse which opens the second chopper circuit. The delayed edge is to compensate for the delay in the amplifier.

# 5. TECHNICAL DESCRIPTION

This section describes the circuit features of each functional element given in Section 4. The circuit diagram is shown in Fig. 2.

## 5.1 INPUT FILTER AND ATTENUATOR

The input filter consists of the twin-T circuit R5, R6, R7, C1, C3, and C4. The component values are chosen to give minimum transmission through the filter at 50c/s. Where filtering is required at 400c/s the values of the capacitors are chosen appropriately.

The attenuator resistors R1, R2, R3, R4, R8 and R9 together with R5 and R6 of the filter are selected by SA to provide the correct attenuation for each range. The switch also sets the input resistance on the low range to 1MΩ and on the other ranges to 10MΩ. The output resistance is maintained at 1MΩ on all ranges and the output current for a reading of 1000 is 1µA.

## 5.2 CHOPPER STABILIZED AMPLIFIER

The input signal from the attenuator is added to the feedback signal which, to obtain a balance, must always be of opposite polarity to the input (to do this connect the positive input to the red terminal and negative to black). The resultant error signal is applied to the chopper circuit C6, VT1. When VT1 is not conducting C6 acquires a charge proportional to the error voltage. At the instant VT1 conducts the charge is transferred to the input of the a.c. amplifier VT2 to VT6.

The resistors R12, RV1 and R11 provide an offset current to adjust the zero of the instrument by keeping the charge on C6 the same with chopper VT1 on and off, when the input terminals are connected together. The diode D2 is for overload protection purposes.

The a.c. amplifier consists of two feedback pair circuits with an overall feedback voltage fed in series with the input via R26, R17 and RV2. Adjustment of RV2 enables the gain of the amplifier to be set to the required factor (approximately 1000). Considering the first feedback pair, R13 provides shunt feedback for d.c. stabilization and R18, R17 and RV2 provide series feedback to control the a.c. signal gain. The gain of the stage is approximately equal to the ratio of R18 to R17, RV2. The second feedback pair is similar to the first pair except that C11 has been added in the a.c. feedback loop for high frequency correction of the amplifier response.

The second chopper VT6 opens slightly after the input chopper VT1 is switched on. The reason for this can be seen by referring to the typical amplifier output waveform shown in Fig. 3. There is a large 'spike' when the input chopper opens and another 'spike' when it closes again, immediately followed by the signal. To remove these 'spikes' VT6 is held conducting when the first chopper opens and for 10µs after it closes. The effect of this is shown on the waveform obtained at the junction of C14 with R33 (see Fig. 3). The capacitors C13 and C14 are for d.c. blocking, and C14 also forms an integrator circuit with R33 and the input resistance of the buffer amplifier VT7.

## 5.3 BUFFER AND INVERTER

The buffer VT7 drives the inverter VT8 and the 'down' bistable via D4 and C15. The inverter VT8 drives the 'up' bistable via D5 and C16.

## 5.4 'UP' AND 'DOWN' BISTABLE CIRCUITS

The complementary bistable circuits (VT9, VT12, and VT10, VT11) determine whether the indicated display should be reduced or increased for the particular input signal. Considering the 'up' bistable, it is set when a negative pulse on the base of VT9 exceeds the base bias. VT9 then starts conducting causing regeneration via VT12, until both transistors are locked in the conducting state. The negative output is fed from VT12 collector to VT14. When the 'up' bistable is set, any output from the 'down' bistable is inhibited by D7. The 'down' bistable operates in the same way as the 'up' bistable. Both bistables are reset and held reset by a negative-going pulse from VT23 during the period when the chopper VT6 is closed.

The diode D11 prevents variations of the base voltage of VT14 with temperature affecting the trip level of VT9. D9 is a catching diode to prevent the voltage at the base of VT12 falling to -24V when the transistor is not conducting. The diode D6 holds the emitter voltages of VT9 and VT10 at 0.5V when the reset signal is not present, and also provides temperature compensation for the $V_{be}$ of VT9 and VT10.

## 5.5 STEPPING SWITCH DRIVE AND GATING CIRCUITS

The stepping switch solenoids A10, B10 and C10 are driven by either VT13 or VT14 via a gating system utilizing contacts on wafer 2 of the switches. The B and C contacts of wafers 3 and 1 of the stepping switches control the feedback voltage and the numerical indicator tube display respectively.

The 'up' driver VT14 is connected directly to contact 0 of wafer B2 and C2, and is connected via D13, which is part of an OR gate with D14, to contacts 1 to 8. Each time VT14 receives a pulse from the 'up' bistable, the units switch C10 steps on one position until the wiper of C2 reaches contact 9 where there is no 'up' connection. The base of VT15 is then taken negative via the solenoid C10 and this transistor conducts. The 'up' pulses from VT14 then step the tens switch B10 on until the wiper of B2 reaches contact 9 where again there is no 'up' connection. VT15 then operates as an emitter-follower causing VT16 to conduct and the hundreds switch A10 to step. A10 will continue to step while there are 'up' pulses from VT14.

The 'down' driver VT13 is connected directly to contact 9 of wafer B2 and C2, and via D14 to contacts 1 to 8. The 'down' system operates in the same way as the 'up' system, but the switch wipers stop at 0 instead of 9, since there is no 'down' connection to contact 0.

The zener diode D15 and the diodes D16, D17 and D18 limit the switching transient across the stepping switch coils to 17V.

When HOLD is selected, the -24V supply to the stepping switch solenoids is removed by SB/1.

## 5.6 FEEDBACK VOLTAGE AND DISPLAY

The feedback voltage is obtained from the zener diode D19 (6.2V nominal) via attenuators and wafers A3, B3 and C3 of the stepping switches.

The stepping switches select the feedback voltage from a potentiometer chain R73 to R81 which has ten tappings giving equal voltage steps. The potentiometer chain is fed from the zener diode via attenuators (RV10, RV7, RV8, RV9, RV11) selected by the range switch. The outputs from the potentiometer are the same for each switch wafer, but since these represent units, tens and hundreds increments, further attenuation is required, set by RV4 and RV5, to produce the correct currents. When ADD 1000 is selected the voltage from RV6 is fed via SB and R66 to the feedback line. This current is equal to a 1000 increment.

The numerical indicator tubes V4, V5 and V6 are driven directly from stepping switch wafers C1, B1 and A1. The neon lamps V1, V2 and V3 provide the decimal point indication and are selected by the RANGE switch SA/6. The neon lamp V7 is lit when ADD 1000 is selected by SB.

## 5.7 TIMING CIRCUITS

The timing waveforms are shown in Fig. 3. The timing is controlled from the emitter-timed multivibrator VT17, VT18. The diode D24 is inserted to isolate VT18 emitter from the charging circuit and thus produce a rectangular output waveform at this point (Fig. 3A). C23 injects a charge into the base of VT19 to give a fast trailing edge to the waveform at the collector of VT19. The multivibrator output is fed via the buffer amplifier VT19 to the chopper inverter VT20 and to two delay circuits. The chopper inverter drives the first chopper VT1 via the diode D1. VT1 conducts and discharges C6 when the output of VT19 changes in a positive direction.

The timing circuit VT22, C25, R105 produces a delay as follows. Transistor VT22 is normally conducting by virtue of the current through R105. The positive-going edge at the end of the 10 millisecond pulse from VT19 is fed via C25 and switches VT22 off. C25 then charges from +12V through R105 towards -12V. When the potential at the base of VT22 reaches about -0.5V, VT22 again conducts and C25 stops charging. The charging circuit holds VT22 non-conducting for 30 milliseconds. At the beginning of the next 10 millisecond pulse VT19 is driven off by the multivibrator and C25 charges through R99 towards -24V. When about -12.5 volts is reached the catching diode D25 conducts and the voltage across C25 is maintained at 12V. The timing signal from VT22 is inverted by VT23 (Fig. 3G). The output of VT23 controls the second chopper VT6 and lifts the reset from the bistable circuits during the signal period of the amplifier.

The timing circuit VT21, C24, R103 operates in the same way as that described above, but produces a 10μs delay. The delay signal is connected to the collector circuit of VT23 via D26 to delay the opening of the second chopper VT6 for 10μs after the first chopper VT1 is closed. This action gates out the switching transient from the input chopper.

At the end of the timing pulse from VT22, transistor VT23 switches on, which closes the second chopper VT6 and resets the 'up' and 'down' bistables. Approximately 20ms later the multivibrator signal opens the first chopper VT1 again. The new unbalance signal is stored and the sequence is repeated.

When the input and reference signals are balanced the pulse output from the amplifier is insufficient to trip either bistable and no stepping switch coil is energized. Thus, at each cycle of the multivibrator the balance is checked, but no action takes place until unbalance has been detected.

5.8 POWER SUPPLIES

The +6V and general purpose -12V supplies are obtained from a 20V secondary on the power transformer T1, via a bridge rectifier (MR1), an RC filter (C18, C21, R90, R91) and zener diode stabilizers (D21, D22). To provide additional stabilization against variations in the power supply input voltage, the reference diode D19 is connected via R92 to the junction of R90, R91, C21.

A -24V unstabilized supply for the stepping switches is obtained from a 19V secondary on T1 via a bridge rectifier MR2 and a smoothing capacitor C19. A -12V stabilized supply is obtained from the zener diode D23 which is connected with R93 across the -24V supply. This -12V supply is used for the bistable circuits and for the reset drive amplifier (VT23).

The +210V supply for the numerical indicator tubes and neons is obtained from a 153V secondary on T1, via a half-wave rectifier D20 and a reservoir capacitor C20.

The primary of the mains transformer is fused by FS1.

# 6. MAINTENANCE

The use of printed wiring boards and solid state components makes for good reliability and it is very unlikely that faults will occur in normal use.

CAUTION: It is important to avoid short-circuiting any of the supply rails to chassis or to each other as this may cause damage to components. The normal precautions necessary when testing semiconductor circuits should be observed.

Figure 4 shows the positions of all the controls and the major components.

## 6.1 SETTING-UP INSTRUCTIONS

All internal controls are set-up at the factory and no re-adjustment should be necessary for at least 3 months. The settings should not be disturbed unless there is a definite indication that the unit is functioning incorrectly. If this occurs, or if a potentiometer or an associated component has been replaced, the internal controls should be set according to the following instructions.

### Equipment Required

(a) Variable Voltage Source 0 to ±2.5V, e.g. DM2201.
(b) D.C. Supply of 1.9V, 19V, 190V and 1000V with fine adjustment at each level.
(c) D.C. Voltmeter (100µV to 1KV) with an accuracy of 0.01%, e.g. DM2020.
(d) Oscilloscope, e.g. Telequipment.

### Procedure

(1) Remove the cover from the instrument, connect the oscilloscope to the TRIG. and AMP OUT test points on the printed wiring board.
(2) Switch on and examine the amplifier waveform (Fig. 3J). Short-circuit the input terminals and select the 2V range. If the display is not 000 (READ selected), select HOLD and adjust the stepping switches manually (press the armature) to obtain 000. Check that there is zero amplifier output. If necessary adjust the Set Zero control RV1. Check the zero on the other ranges. Remove the short-circuit and connect the DM2020 (item C) and the DM2201 (item A) across the input.

(3) Set the input to 0V and select READ on the 2V range. Increase the input slowly in a positive direction and observe the voltage at which the display trips to .001. Return the input to 0V and then increase it slowly in a negative direction and again observe the voltage at which the display trips. The sum of these two voltages should be 1.50mV. If necessary adjust the Gain control RV2 to obtain this voltage. The trip levels should occur at +0.75mV and -0.75mV ±0.03mV. If necessary readjust the Set Zero control to obtain these levels.

(4) Increase the input slowly from 000 to .009. Check that the amplifier output waveform is of approximately the same amplitude each time the display has tripped.

(5) Adjust the input to give a display of .100. Reduce the input slowly until the display just trips to .099. Check that the amplitude of the output waveform is approximately the same as that observed in (4) above. If necessary adjust RV4; release the cover of the box to make this adjustment but replace it ensuring good electrical contact before checking reading.

(6) Adjust the input to give a display of .010. Reduce the input slowly until the display just trips to .009. Check that the amplitude of the output waveform is approximately the same as that observed in (4) above. If necessary adjust RV5.

(7) Adjust the input to give a display of .999. Increase the input slowly until the display just trips. Select ADD 1000 and check that the amplitude of the output waveform is approximately the same as that observed in (4) above. If necessary adjust RV6.

(8) Repeat checks 4 to 7 if any adjustments have been made. Adjust the input to 1.9000V. Check that a display of 1.900 is obtained and that there is zero output from the amplifier. If necessary adjust RV7.

(9) Set the voltmeter to the 20V range and select ADD 1000. Replace item (a) with item (b) at the input. Adjust the input to 19.000V on the DM2020. Check that a display of 19.00 is obtained and that there is zero output from the amplifier. If necessary adjust RV8.

(10) Set the voltmeter to the 200V range with ADD 1000 selected. Adjust the input to 190.00V on the DM2020. Check that a display of 190.0 is obtained and that there is zero amplifier output. If necessary adjust RV9.

WARNING: High voltages are present in the next test. Provided a positive high voltage supply is used and provided the low terminal is connected to mains earth, only the high input terminal and input resistors will be at 1000V.

(11) Set the voltmeter to the 1kV range with ADD 1000 selected. Adjust the input to 1kV on the DM2020 - THIS VOLTAGE MUST NOT BE EXCEEDED. Check that a display of 1000 is obtained and that there is zero amplifier output. If necessary adjust RV11. Switch off the voltage source.

(12) Connect a 10 KΩ resistor between the input terminals. Connect the positive side of the voltage source (b) to the high input terminal and the negative side to the a.c. power supply earth. Adjust the input to 1000V, set the range switch to the 2V range, select READ and check that the display obtained is less than .010V. This checks that the d.c. common mode rejection is better than 1 part in $10^5$.

## 6.2 STEPPING SWITCH MAINTENANCE

The stepping switches are removed from the voltmeter by releasing the clamping bar holding the rear of the switches and then springing out the clip at the side of the switch, while pulling the switch out of its base (towards the rear).

The switch should be lubricated as follows:-

(1) Ratchet teeth: a light application of collodial graphite suspended in oil or grease (Gredag).

(2) Armature bearings, Wiper spindle: lubricate with a light machine oil.

(3) Wiper tip, Connector plug: lubricate with Electrolube. Only one wiper tip of each switch bank needs to be lubricated.

Since the units stepping switch does the most work, it is recommended that it is replaced by the hundreds switch and the units and tens switches are moved up one, after about a year's use. This ensures that over three year periods all the switches will have approximately the same wear.

## 6.3 CHANGING INDICATOR LAMPS

To change the numerical indicator tubes release the screws holding the plastic moulding behind the front panel. The tubes may then be changed. When replacing ensure that the numerals are vertical before tightening the screws.

To change a decimal point lamp unscrew the escutcheon on the front panel and push the faulty lamp backwards through the moulding at the rear of the panel. Push back the rubber sleeving and unsolder the lamp leads from the connecting wires. Reverse the procedure when fitting the new lamp.

To change the ADD 1000 lamp, unsolder the lead-out wires from the two pins in the plastic moulding behind the front panel. Release the screws holding the plastic moulding and pull the lamp out. When fitting the new lamp ensure that the glowing electrode is behind the other electrode, when viewed from the front.

## 6.4 CHANGING BOARD COMPONENTS

To gain access to the boards in the switch box proceed as follows:-

1. Loosen the capacitor clamp at the rear of the unit and slide the capacitors towards the rear. Remove the rear switch-box retaining screw.
2. Remove the cover from the switch-box taking care not to lose the nylon screws. Remove the screws holding the potentiometer bracket to the rear of the switch-box.
3. Loosen the nut holding the range switch to the front of the switch-box.
4. Lift the switch-box out from the unit leaving the switch and boards in position.

Replace the switch-box by reversing the above procedure.

To gain access to the printed wiring board at the side of the unit proceed as follows:-

1. Remove the four screws holding the board to the side plate and remove the two screws holding the front screen to the side plate.
2. Lift out the board.

## 5. PARTS LIST

The following list includes all replacement parts with circuit references, values and tolerances, where applicable, and part numbers.

When ordering, please quote the NAME, TYPE and SERIAL NUMBER of the instrument, together with the CIRCUIT REFERENCE and the DESCRIPTION OF PART.

### CHASSIS ASSEMBLY

| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| R84 | Resistor | 270K | $\frac{1}{4}$ W | 10% | B.T.T. |
| R85 | Resistor, H.S. | 47K | $\frac{1}{8}$ W | 1% | Electrosil NJ60 |
| R86 | " " | 47K | " | 1% | " " |
| R87 | " " | 47K | " | 1% | " " |
| R88 | Resistor | 120K | $\frac{1}{4}$ W | 10% | B.T.T. |
| R89 | " | 4.7K | " | 10% | " |
| R90 | " | 47 | $\frac{1}{2}$ W | 10% | B.T.A. |
| R91 | " | 47 | " | 10% | " |
| R92 | Resistor, H.S. | 6.8K | $\frac{1}{8}$ W | 5% | Electrosil NJ60 |
| R93 | Resistor | 220 | 2 W | 5% | Painton 306A |
| R115 | " | 1M | $\frac{1}{4}$ W | 10% | B.T.T. |
| RV4 | Resistor, variable | 30K | | | A.B.Metal 37 |
| RV5 | " " | 2.5K | | | " |
| | Pot.lock for RV4,RV5 | | | | Girdlestone 1050/5 |
| C17 | Capacitor | 0.01µF | 1250V | | Wima Durolit |
| C18 | " | 1000µF | 35V | | U.C.C. |
| C19 | " | 1000µF | 35V | | " |
| C20 | " | 8µF | 300V | | " |
| C21 | " | 1000µF | 35V | | " |
| MR1 | Diode, full wave | | | | 1B10J05 |
| MR2 | " " | | | | 1B20K05 |
| D20 | Diode | | | | 1S105 |
| D21 | " | | | | OAZ230 |
| D22 | " | | | | 1Z6.2T5 |
| D23 | " | | | | OAZ230 |

| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| V1 | Valve | | | | Hivac 23L |
| V2 | " | | | | " 29L |
| V3 | " | | | | " 29L |
| V4 | " | | | | " 29L |
| V5 | " | | | | Mullard Z520M |
| V6 | " | | | | " " |
| V7 | " | | | | " " |
| | Valveholder for V5,V6,V7 | | | | Mullard B8/700/67 |
| T1 | Transformer | | | | Gardners G54121 |
| SA | Switch,9 pole, 4 way,Range | | | | B108 0094 |
| SB | Switch,3 pole, 3 way,with knob | | | | Trolex Type LO |
| FS1 | Fuse, delay type | 100mA | | | Beswick TDC 11 |
| | Fuseholder | | | | Bulgin F27/2 |
| RLA | Stepping Switch | | | | A.E.I. 2353 |
| RLB | " " | | | | A.E.I. 2353 |
| RLC | " " | | | | A.E.I. 2353 |
| | Knob for SA | | | | Bulgin K465 |
| | Terminal, Red | | | | Belling & Lee L1568/31S |
| | " Black | | | | " " " |
| | Screw, Nylon for screened box | | | | Nettleford 6BA x ⅜" cheese head |
| | Escutcheon | | | | A100 0641 |
| | Filter for escutcheon | | | | A100 0646 |

MAIN PRINTED WIRING BOARD ASSEMBLY

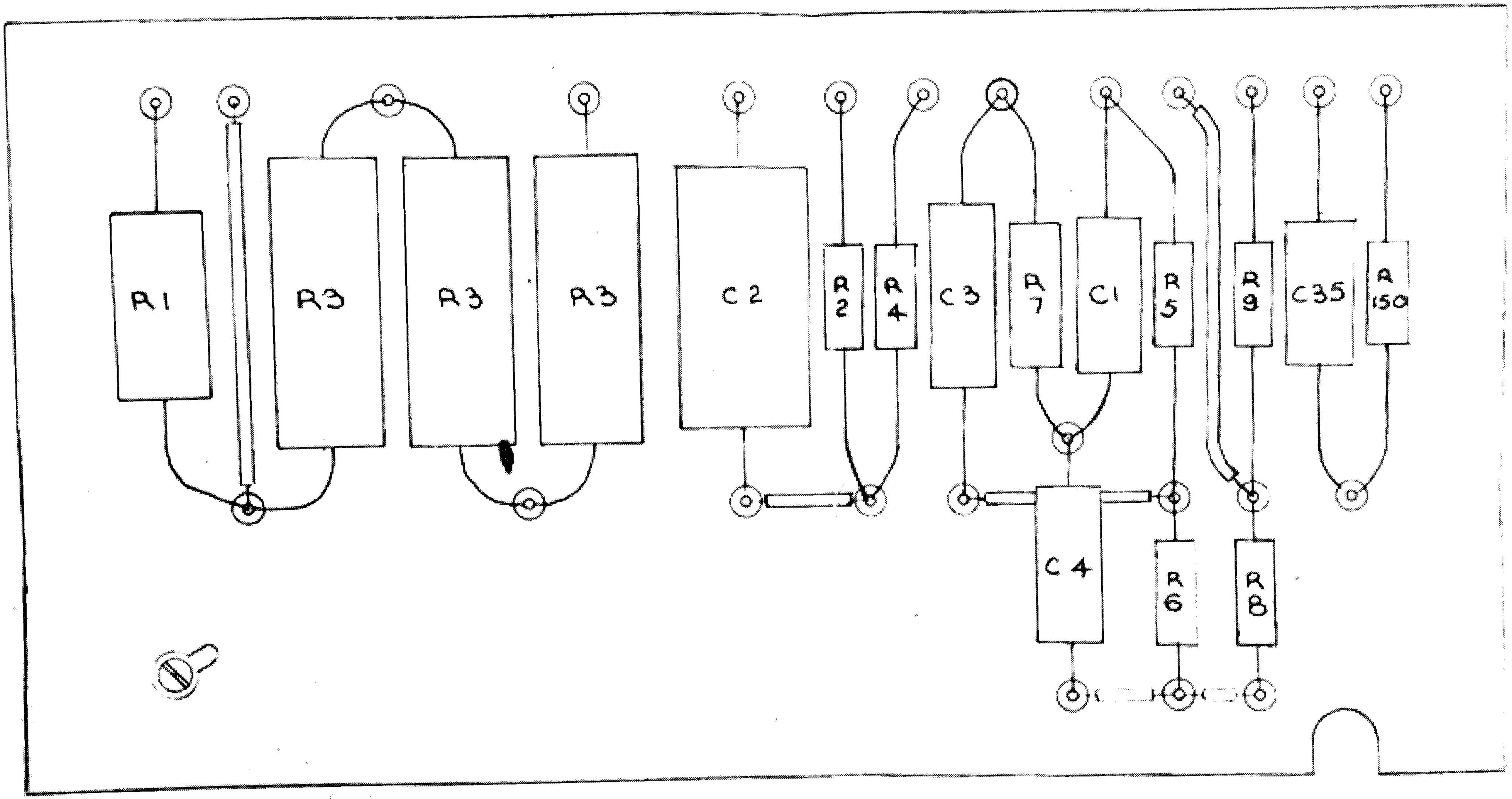
| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| | Complete printed wiring board assembly | | | | 105 0060/3 |
| R10 | Resistor | 10K | ¼ W | 10% | B.T.T. |
| R11 | " | 50M | | 5% | 5HS3 |
| R12 | " | 4.7K | ¼ W | 10% | B.T.T. |
| R13 | " | 10K | " | " | " |
| R14 | " | 22K | " | " | " |
| R15 | " | 4.7K | " | " | " |
| R16 | " | 6.8K | " | " | " |
| R17 | Resistor, H.S. | 100 | ⅛ W | 1% | Electrosil NJ60 |
| R18 | " | 33K | " | " | " |

| Circuit | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| R19 | Resistor | 3.3K | ¼ W | 10% | B.T.T. |
| R20 | " | 3.3K | " | " | " |
| R21 | " | 10K | " | " | " |
| R22 | " | 100 | " | " | " |
| R23 | " | 27K | " | " | " |
| R24 | " | 6.8K | " | " | " |
| R25 | Resistor, H.S. | 75 | ⅛ W | 1% | Electrosil NJ60 |
| R26 | " | 330K | " | " | " |
| R27 | " | 7.5K | " | " | " |
| R28 | Resistor | 3.3K | ¼ W | 10% | B.T.T. |
| R29 | " | 3.3K | " | " | " |
| R30 | " | 27K | " | " | " |
| R31 | Resistor, H.S. | 510 | ⅛ W | 1% | Electrosil NJ60 |
| R32 | Resistor | 39K | ¼ W | 10% | B.T.T. |
| R33 | Resistor, H.S. | 510 | ⅛ W | 1% | Electrosil NJ60 |
| R34 | " | 33K | " | " | " |
| R35 | " | 2.2K | " | " | " |
| R36 | Resistor | 18K | ¼ W | 10% | B.T.T. |
| R37 | Resistor, H.S. | 27K | ⅛ W | 1% | Electrosil NJ60 |
| R38 | " | 33K | " | " | " |
| R39 | " | 2.2K | " | " | " |
| R40 | Resistor | 100K | ¼ W | 10% | B.T.T. |
| R41 | " | 100K | " | " | " |
| R42 | " | 22K | " | " | " |
| R43 | Resistor, H.S. | 1K | ⅛ W | 1% | Electrosil NJ60 |
| R44 | Resistor | 1.8K | ¼ W | 10% | B.T.T. |
| R45 | " | 1.8K | " | " | " |
| R46 | " | 22K | " | " | " |
| R47 | " | 1.8K | " | " | " |
| R48 | " | 1.8K | " | " | " |
| R49 | Resistor, H.S. | 1K | ⅛ W | 1% | Electrosil NJ60 |
| R50 | Resistor | 3.3K | ¼ W | 10% | B.T.T. |
| R51 | " | 10K | " | " | " |
| R52 | " | 3.3K | " | " | " |
| R53 | " | 10K | " | " | " |
| R54 | Resistor, H.S. | 2.2K | ⅛ W | 1% | Electrosil NJ60 |
| R55 | " | 240 | " | " | " |
| R56 | Resistor | 680 | ¼ W | 10% | B.T.T. |
| R57 | Resistor, H.S. | 240 | ⅛ W | 1% | Electrosil NJ60 |
| R58 | Resistor | 680 | ¼ W | 10% | B.T.T. |
| R59 | " | 680 | ½ W | 10% | B.T.A. |
| R60 | " | 4.7K | ¼ W | 10% | B.T.T. |
| R61 | " | 680 | ½ W | 10% | B.T.A. |
| R62 | " | 4.7K | ¼ W | 10% | B.T.T. |

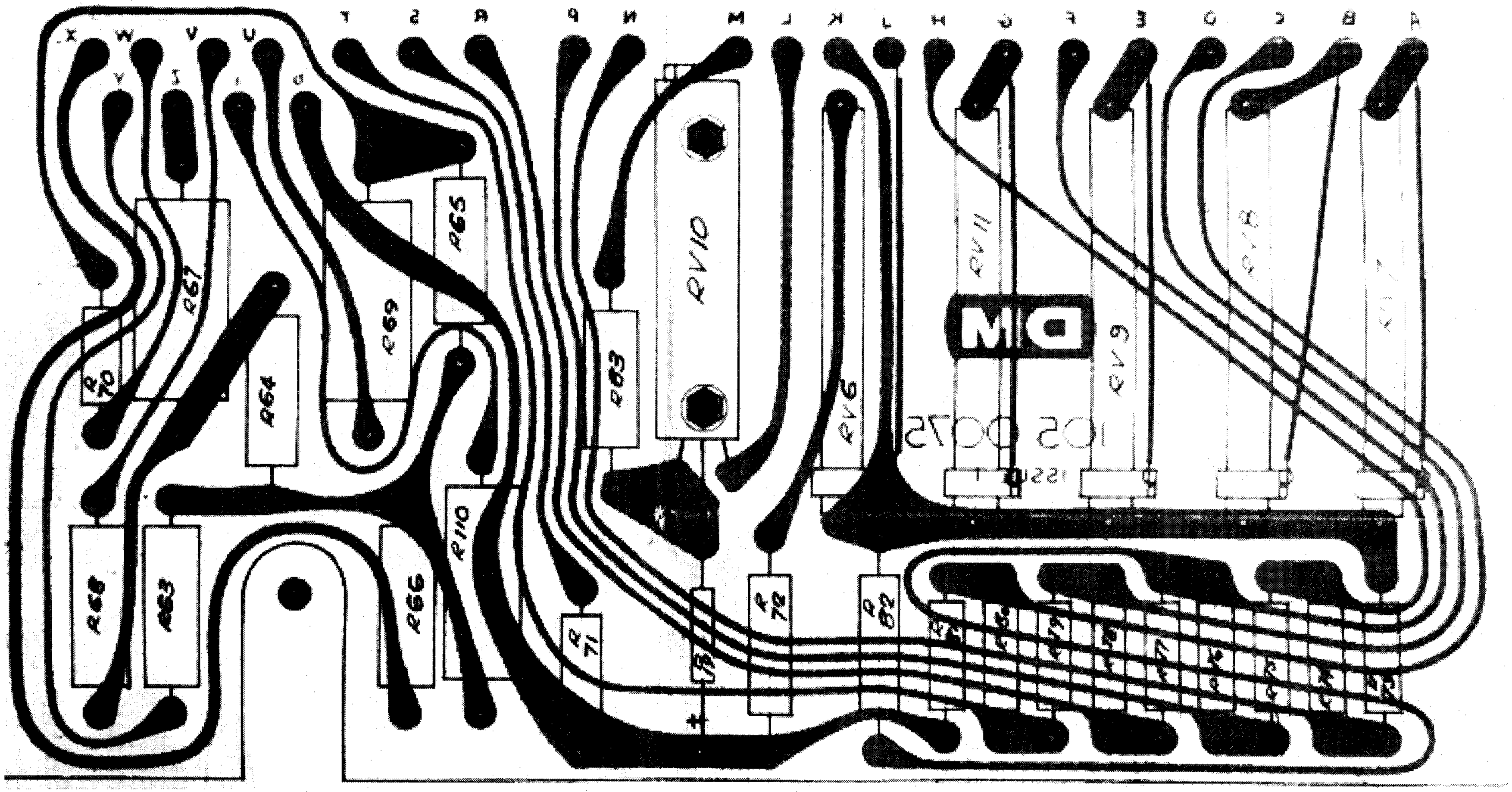
| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| R94 | Resistor | 22K | ¼ W | 10% | B.T.T. |
| R95 | Resistor, H.S. | 47K | ⅛ W | 1% | Electrosil NJ60 |
| R96 | " | 8.2K | " | " | " |
| R97 | Resistor | 10K | ¼ W | 10% | B.T.T. |
| R98 | " | 22K | " | " | " |
| R99 | " | 4.7K | " | " | " |
| R100 | " | 10K | " | " | " |
| R101 | " | 15K | " | " | " |
| R102 | " | 10K | " | " | " |
| R103 | Resistor, H.S. | 15K | ⅛ W | 1% | Electrosil NJ60 |
| R104 | Resistor | 4.7K | ¼ W | 10% | B.T.T. |
| R105 | Resistor, H.S. | 39K | ⅛ W | 1% | Electrosil NJ60 |
| R106 | Resistor | 22K | ¼ W | 10% | B.T.T. |
| R107 | " | 4.7K | " | " | " |
| R108 | " | 10K | " | " | " |
| R109 | " | 22K | " | " | " |
| RV1 | Resistor, variable | 1K | | | PCH 82 W |
| RV2 | " " | 250 | | | " |
| C5 | Capacitor | 250μF | 15V | | Tropyfol M |
| C6 | " | 2200pF | 400V | 10% | " F |
| C7 | " | 25μF | 15V | | " M |
| C8 | " | 2200pF | 400V | 10% | " F |
| C9 | " | 10μF | 6V | | " M |
| C10 | " | 1μF | 125V | 10% | " M |
| C11 | " | 2200pF | 400V | " | " F |
| C12 | " | 10μF | 6V | | " M |
| C13 | " | 0.22μF | 125V | 10% | " M |
| C14 | " | 0.01μF | " | " | " M |
| C15 | " | 0.47μF | " | " | " M |
| C16 | " | 0.47μF | " | " | " M |
| C22 | " | 1μF | 125V | 5% | Tropyfol M |
| C23 | " | 470pF | 400V | 10% | " F |
| C24 | " | 1000pF | 400V | 5% | " F |
| C25 | " | 1μF | 125V | 2% | " M |
| VT1 | Transistor | | | | DMS 10 |
| VT2 | " | | | | GET 887 |
| VT3 | " | | | | GET 887 |
| VT4 | " | | | | GET 887 |
| VT5 | " | | | | GET 887 |

| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| VT6 | Transistor | | | | DMS 10 |
| VT7 | " | | | | GET 887 |
| VT8 | " | | | | GET 887 |
| VT9 | " | | | | DMS 12 |
| VT10 | " | | | | DMS 12 |
| VT11 | " | | | | 2N1304 |
| VT12 | " | | | | 2N1304 |
| VT13 | " | | | | OC35 |
| VT14 | " | | | | OC35 |
| VT15 | " | | | | GET 538 |
| VT16 | " | | | | GET 538 |
| VT17 | " | | | | DMS 12 |
| VT18 | " | | | | GET 536 |
| VT19 | " | | | | GET 535 |
| VT20 | " | | | | GET 881 |
| VT21 | " | | | | GET 881 |
| VT22 | " | | | | DMS 12 |
| VT23 | " | | | | 2N1304 |
| D1 | Diode | | | | DMS 9 |
| D2 | " | | | | DMS 9 |
| D3 | " | | | | DMS 9 |
| D4 | " | | | | DMS 8 |
| D5 | " | | | | DMS 8 |
| D6 | " | | | | DMS 8 |
| D7 | " | | | | DMS 8 |
| D8 | " | | | | DMS 8 |
| D9 | " | | | | DMS 8 |
| D10 | " | | | | DMS 8 |
| D11 | " | | | | DMS 9 |
| D12 | " | | | | DMS 9 |
| D13 | " | | | | 1S100 |
| D14 | " | | | | 1S100 |
| D15 | Diode, zener | 15V | | | 1Z15T10 |
| D16 | Diode | | | | 1S130 |
| D17 | " | | | | 1S130 |
| D18 | " | | | | 1S130 |
| D24 | " | | | | DMS 9 |
| D25 | " | | | | DMS 8 |
| D26 | " | | | | DMS 8 |
| D27 | " | | | | DMS 8 |

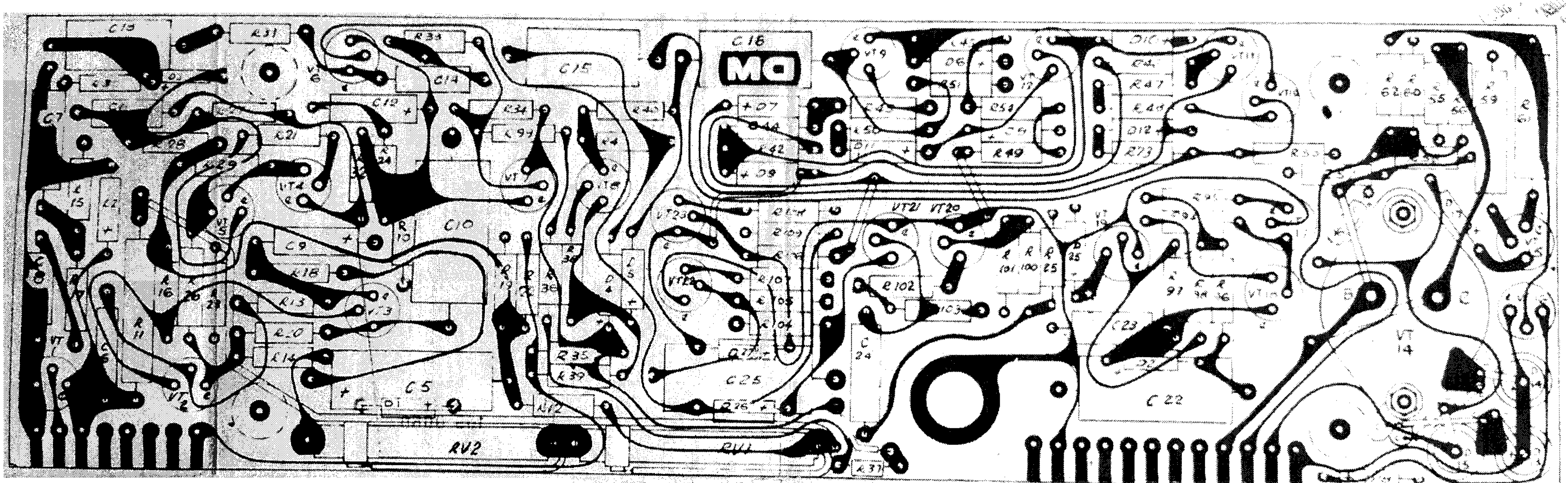
| Circuit Ref. | Description | Value | Rating | Tol. | Part Number |
|---|---|---|---|---|---|
| INPUT ATTENUATOR BOARD | | | | | |
| | Complete board assembly | | | | 105 0074/3 |
| R1 | Resistor | 1.11M | ) | | |
| R2 | " | 102K | ) Part of Dubilier Set | | |
| R3 R3A,R3B | " | .3M | ) 'T' | | |
| R4 | " | 10 | ) Not to be ordered | | |
| R5 | " | 320K | ) separately. | | |
| R6 | " | 320K | ) | | |
| R7 | Resistor, H.S. | 160K | $\frac{1}{8}$ W | 1% | Electrosil NJ65 |
| R8 | Resistor | 259K | ) | | |
| R9 | " | 101K | ) Part of Dubilier set 'T' | | |
| C1 | Capacitor | 0.01µF | 125V | 2% | Tropyfol F |
| C2 | " | 1µF | 125V | 10% | " M |
| C3 | " | 0.02µF | 125V | 2% | " F |
| C4 | " | 0.01µF | 125V | 2% | " F |
| REFERENCE DIVIDER BOARD | | | | | |
| | Complete board assembly | | | | 105 0075/3 |
| R63 | Resistor | 1M ) | | | |
| R64 | " | 1M ) | Part of Dubilier Set 'T' | | |
| R65 | " | 1M ) | Not to be ordered separately | | |
| R66 | " | 873K) | | | |
| R67 | Resistor, H.S. | 1M | $\frac{1}{2}$ W | 2% | Electrosil CJ42 |
| R68 | " | 110K | $\frac{1}{8}$ W | 1% | " NJ60 |
| R69 | " | 1M | $\frac{1}{2}$ W | 2% | " CJ42 |
| R70 | " | 9.1K | $\frac{1}{8}$ W | 1% | " NJ60 |
| R71 | " | 1K | " | " | " NJ60 |
| R72 | " | 33K | " | " | " NJ60 |
| R73 to R81 | Resistor | 68 | Dubilier Set 'S' | | |
| R82 | Resistor | 390K | $\frac{1}{4}$ W | 5% | Electrosil NJ65 |
| R83 | Resistor, H.S. | 330 | $\frac{1}{8}$ W | 1% | " NJ60 |
| R110 | Resistor | 1.31M | Part of Dubilier Set 'T' | | |
| RV6 | Resistor, variable | 2K | | | PCH 82 W |
| RV7 | " " | 25 | | | PCH 82 W |
| RV8 | " " | 25 | | | PCH 82 W |
| RV9 | " " | 25 | | | PCH 82 W |
| RV10 | " " | 100 | | | M.E.C. MP 31 |
| D19 | Diode, zener | 6V | | | DMS 15 |




INPUT ATTENUATOR PRINTED CIRCUIT BOARD




REFERENCE DIVIDER PRINTED CIRCUIT BOARD




MAIN PRINTED CIRCUIT BOARD

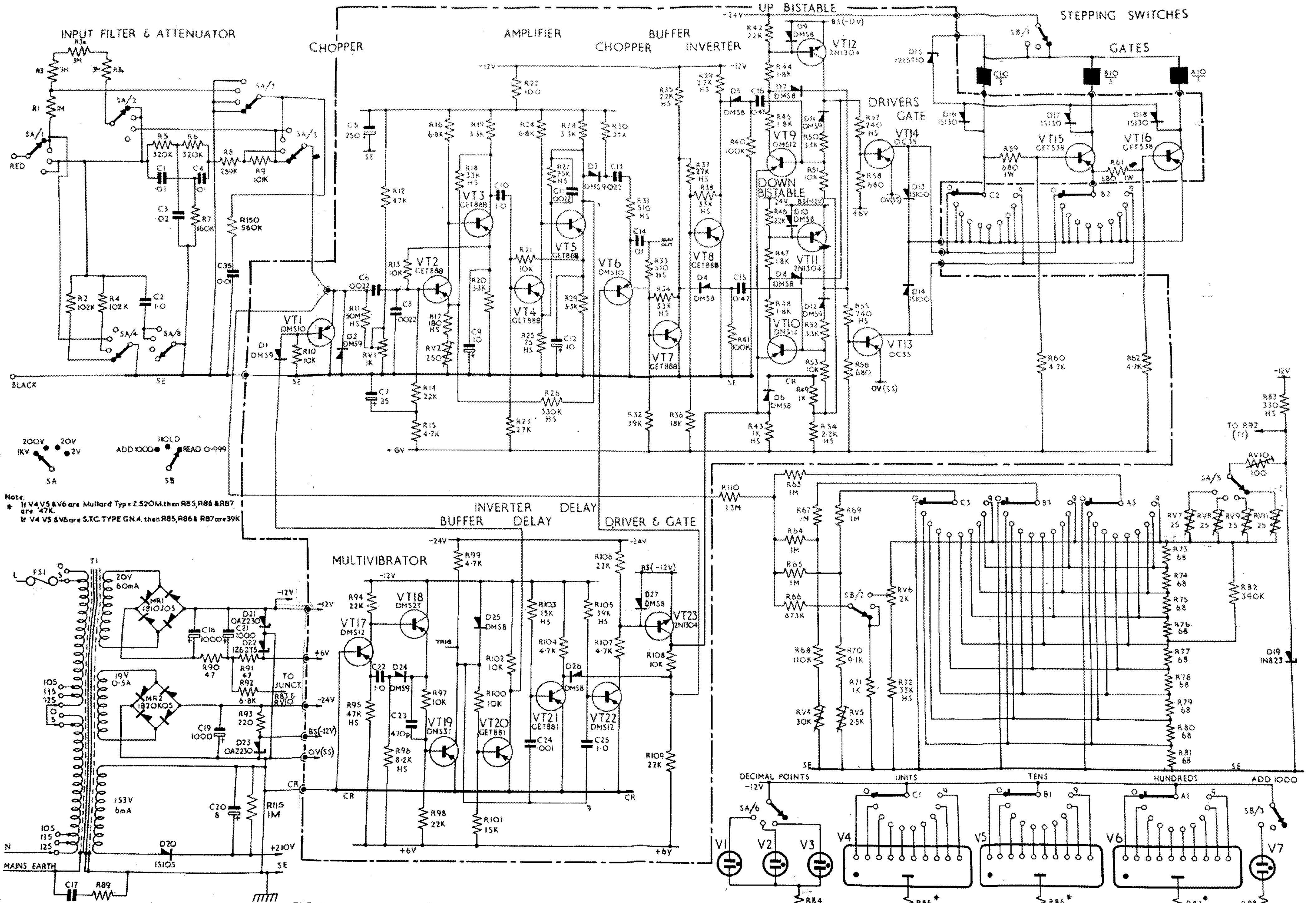



FIG.2 DIGITAL VOLTMETER DM2004 - CIRCUIT DIAGRAM