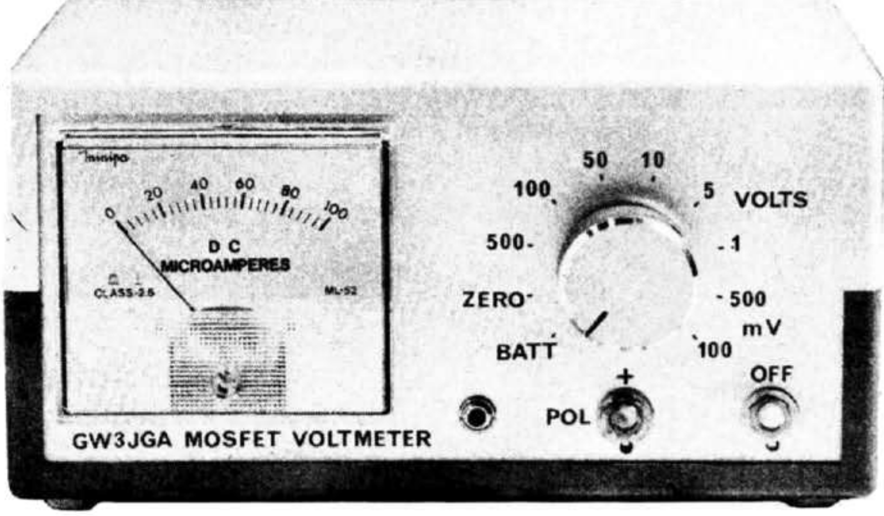
# High Impedance MOSFET Voltmeter




*Following the success of the PW FET Dip Oscillator John Thornton Lawrence GW3JGA has produced another equally useful piece of test equipment in this High Impedance MOSFET Voltmeter.*

One of the major causes of errors when making electrical measurements on radio and electronic equipment is the loading effect on the circuit caused by the measuring instrument. Voltage measurements suffer from the loading effects of the voltmeter resistance, current measurements from the voltage drop across the ammeter and oscilloscope measurements from capacitive effects introduced by the scope leads or probe.

For instance, when you measure the voltage in a d.c. circuit, the internal resistance of the voltmeter will load the circuit and cause the voltage to fall to some extent. The error between the actual voltage and the measured voltage increases as the loading effect increases.

To give a practical example, take a simple potential divider circuit consisting of two 100kΩ resistors connected in series across a 12 volt supply as shown in Fig. 1. We know instinctively that the voltage at the centre point will be 6 volts. Calculate it if you wish,

$$V2 = V1 \times \frac{R2}{R1+R2} = 12 \times \frac{100k}{200k} = 6 \text{ volts}$$

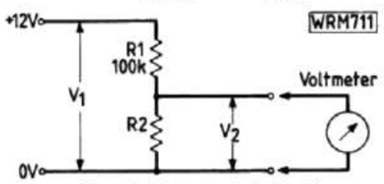



**Fig. 1: Potential divider**

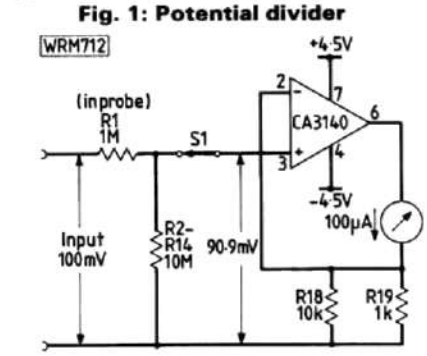



**Fig. 2: Basic circuit (shown on 100mV Range)**

Now see what happens when you make a practical measurement using a voltmeter, (10V range)

| | |
|---|---|
| Calculated Voltage | 6V |
| 1kΩ/V meter (10kΩ) | 1V |
| 20kΩ/V meter (200kΩ) | 4·8V |
| MOSFET Voltmeter (11MΩ) | 5·97V |

For many years the Avometer Model 8 (20kΩ/V) has been widely used in radio, television and electronics servicing. As a result, most service manuals quote the voltages in various parts of the circuit when measured using such a meter, and in practice this has worked very well.

However, for experimental purposes there is much to be said for knowing the voltage that is actually present and this is where the MOSFET Voltmeter comes into its own.

The instrument to be described has an input resistance of 11MΩ on all ranges and will cause negligible loading when making measurements on virtually all electronics circuits in common use. The voltmeter covers from 100mV to 500V (full scale) in 8 ranges arranged in a 5:1 sequence. Positive and negative voltage are catered for by means of a reversal switch. The voltmeter draws 5·5mA and is powered by a 9 volt transistor radio battery, 6-F22 (PP3) or similar. An a.c. voltage probe is provided for measurements in the radio frequency range.

## Circuit Description

The heart of the voltmeter is the CA3140, IC1. This is an op-amp which has a gate-protected m.o.s.f.e.t. device in the input stage giving it an input impedance 1·5TΩ (1 500 000MΩ). The output of the device has a bipolar transistor to provide adequate current sourcing capability. One might think of it as a super high impedance version of the well known 741 op-amp.

In the simplified circuit shown in Fig. 2, the 100µA meter is connected in a feedback circuit where the incoming voltage to pin 3 causes IC1 to drive current through the meter and R18 and R19 until the voltage drop across these resistors equals the incoming voltage.

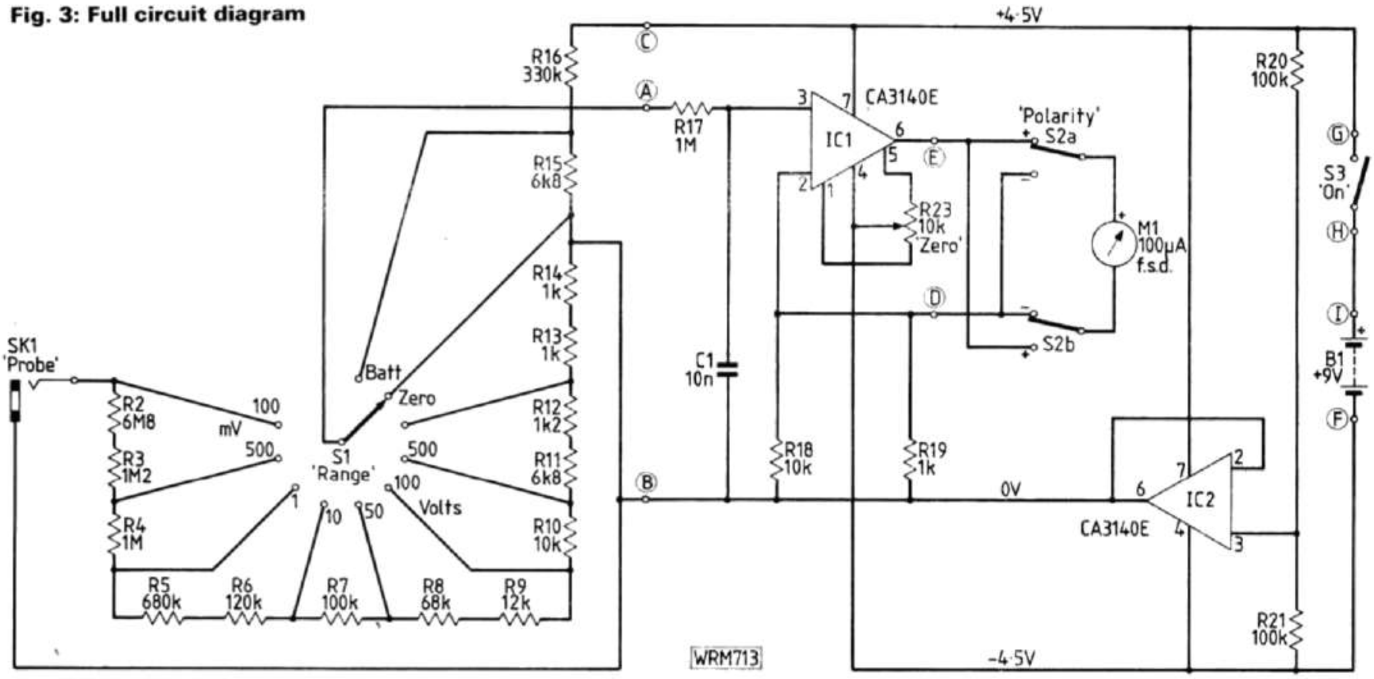
Because the probe has a 1MΩ resistor, R1, built in it, the actual voltage across R2–R14 is less than the input voltage. For example, on the 100mV range, an input voltage of 100mV causes a voltage of 90·9mV to appear at pin 3 of IC1. The value of R18 and R19 are chosen so that with 100µA through the meter, the voltage appearing at pin 2 of IC1 is also 90·9mV thus the meter is indicating full scale deflection (f.s.d.) of "100" for a 100mV input.

In the full circuit as shown in Fig. 3, the input voltage is always applied across R1–R14. Range switch S1 selects the appropriate tapping point for the range in use. A "zero" check position and battery voltage check are included. Resistor R17 and C1 form a low-pass filter to prevent a.c. voltages and pick-up from overloading IC1. Switch S2 is the meter reversing switch which allows the measurement of negative voltages without the inconvenience of having to cross over the test leads. Resistor R23 is the "zero" control which corrects any off-set existing in IC1. Integrated circuit IC2, also a CA3140, has the mundane job of centre tapping the single 9 volt supply and providing equal positive and negative supply voltages to IC1.

## DC Voltage Probe

The d.c. voltage probe must always be used when measuring d.c. as it is part of the input network, the input resistance is then 11MΩ on all ranges. As the 1MΩ resistor, R1, is built into the tip of the probe, this allows d.c. voltage measurements to be made in the presence of a.c. signals with very little capacitive loading, just a few picofarads, on the circuit under test.

**Fig. 3: Full circuit diagram**



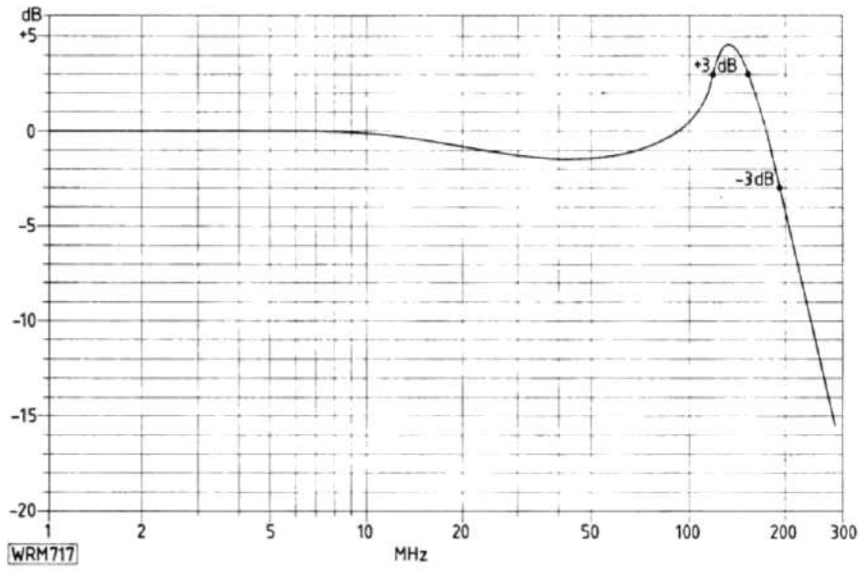




**Fig. 4: Frequency response of a.c. diode probe**

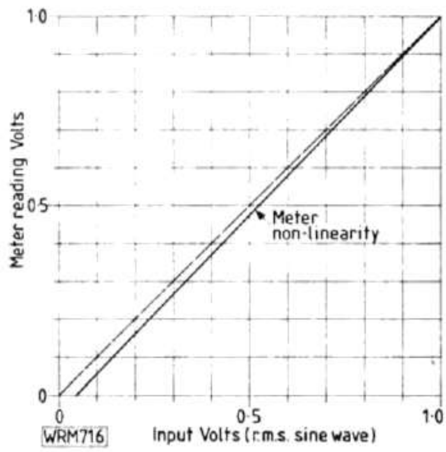



**Fig. 5: Non-linearity of a.c. diode probe below 1V r.m.s.**

## AC Voltage Probe

The a.c. voltage probe is intended for measuring voltages up to 10V r.m.s. (28V peak-to-peak) in the frequency range 50Hz to about 200MHz, covering the audio, video and radio frequencies and part of the v.h.f. spectrum. Voltages greater than 10V r.m.s. cannot be accommodated because of the reverse voltage rating of D1, the BAT85 silicon Schottky barrier diode. The frequency response of the prototype probe is shown in Fig. 4. It has a reasonably level response ±1dB (±10%) up to about 100MHz, a rising response to 150MHz and falling away at 200MHz. As with all simple diode rectifying circuits there is some non-linearity at very low signal levels due to the curvature of the diode characteristic and this non-linearity is shown in Fig. 5. For a.c. voltages above 1V r.m.s. it can, for all practical purposes, be ignored.

## SHOPPING LIST

**Resistors**

| | | |
|---|---|---|
| *0·25W 1% Metal Film* | | |
| 1kΩ | 3 | R13,14,19 |
| 1·2kΩ | 1 | R12 |
| 6·8kΩ | 2 | R11,15 |
| 10kΩ | 2 | R10,18 |
| 12kΩ | 1 | R9 |
| 68kΩ | 1 | R8 |
| 100kΩ | 3 | R7,20,21 |
| 120kΩ | 1 | R6 |
| 330kΩ | 1 | R16 |
| 680kΩ | 1 | R5 |
| 1MΩ | 3 | R1,4,17 |
| *0·5W 5% Carbon Film* | | |
| 1·2MΩ | 1 | R3 |
| 4·7MΩ | 1 | R22 |
| 6·8MΩ | 1 | R2 |
| *Miniature Pre-set* | | |
| 10kΩ | 1 | R23 |

**Semiconductors**

| | | |
|---|---|---|
| BAT85 | 1 | D1 |
| CA3140 | 1 | IC1,2 |

**Capacitors**

| | | |
|---|---|---|
| *Lead-through Ceramic* | | |
| 1nF | 1 | C2 |
| *160V 20% Polyester* | | |
| *10nF* | *1* | *C1* |

**Miscellaneous**

Case (Vero 202-21039); meter 100µA (Cirkit 37-00520); rotary switch 1p.12w. (1); miniature toggle switches d.p.c.o. (1), s.p.s.t. (1); 3·5mm jack socket; 3·5mm jack plugs (2); miniature insulated crocodile clips (2); miniature coaxial cable; pen cases; battery connector; p.c.b.

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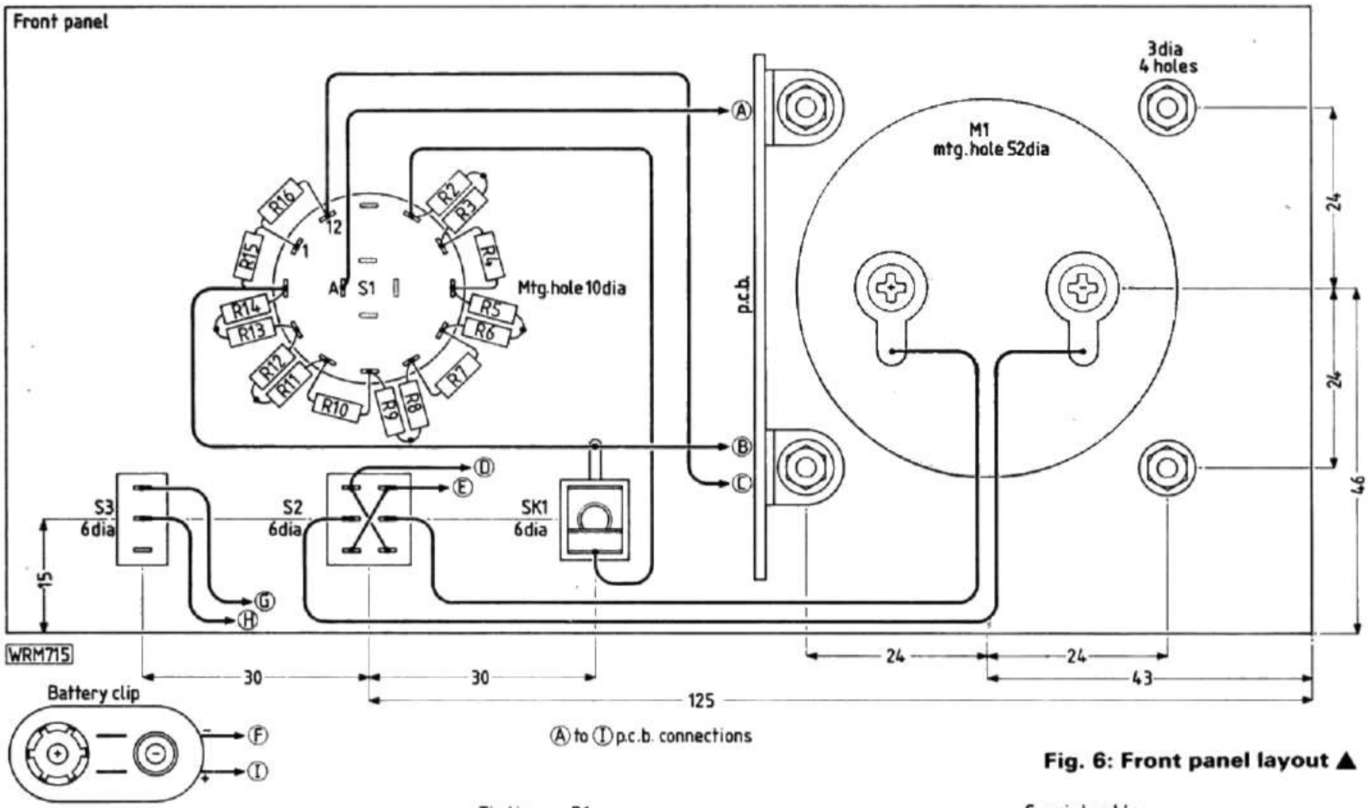
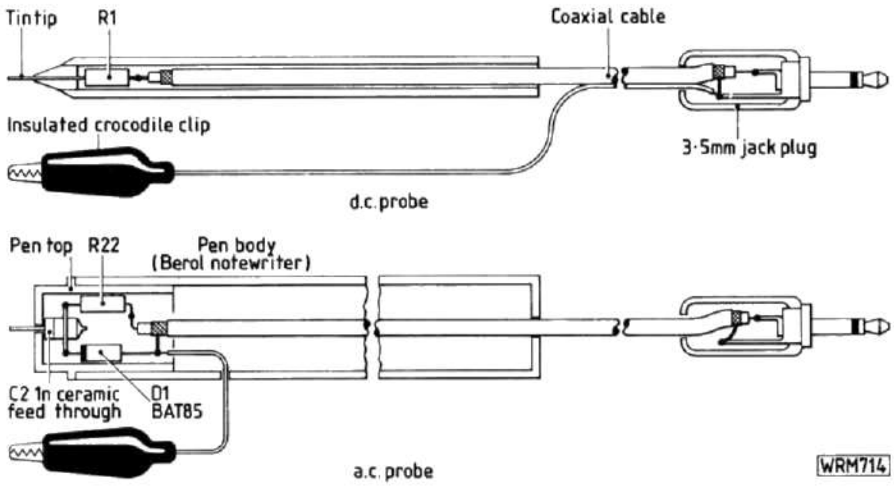



Fig. 6: Front panel layout ▲

## Construction

The MOSFET Voltmeter is housed in an abs plastics case, size 160 × 12 × 90mm, with aluminium front and rear panels. The meter and controls are mounted on the front panel with small right angle brackets secured under the meter fixing nuts. The d.c. probe houses R1, and the a.c. probe D1, C2 and R22. The resistors R2 to R16 are mounted directly on the range switch, S1, and all the remaining components including IC1 and IC2 are mounted on the p.c.board, as shown in Fig. 7. The panel may be lettered using press-on lettering.

Both probes are made using discarded pen cases, almost any type will suit the d.c. probe where the resistor is mounted right at the end with the axial lead-out wire forming the tip. The a.c. probe requires a case with an internal diameter of approximately 9mm and a Berol Notewriter case, when used the reversed way round, is ideal. The coloured top is removed and drilled to suit the centre pin of the lead-through capacitor C2.




## In Use

Initially, the MOSFET Voltmeter will require the "zero" adjusting. This is done by rotating the range switch to the ZERO position and with the supply on, adjusting R23 for zero reading.

With the d.c. probe connected, the MOSFET Voltmeter can be used in the same way as a conventional multi-range d.c. voltmeter.

With the a.c. probe connected and the polarity switch set to positive (+), voltages up to 10V r.m.s. can be measured in audio and video equipment, in low power transmitters. However, do not attempt to measure a.c. signals greater than 10V r.m.s. and avoid transients greater than 30V peak-to-peak or damage to D1 may occur. In the BATTERY CHECK position the meter reads 10V full scale. ***PW***

**Fig. 7: Copper track pattern and component layout**