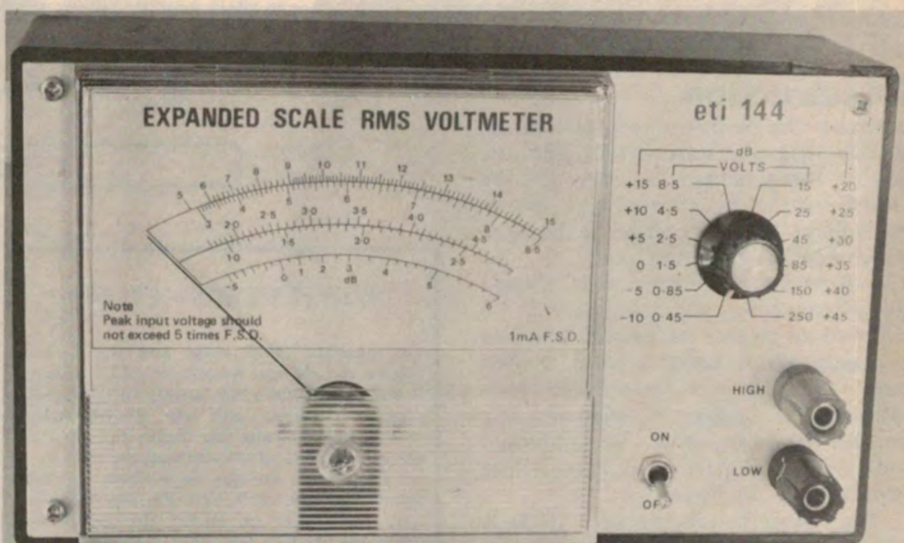
Expanded scale RMS voltmeter

Barry Wilkinson, of Nebula Electronics, needed to develop an RMS voltmeter to measure dc pulses in a particular application for a customer of his. It was only a few steps from there to this project.

THE LAST RMS voltmeter project we described appeared in the August 1977 issue, Project 134. This was an ac-only instrument that used an LH0091 RMS converter IC.

The instrument described here, while perhaps not as versatile in some ways as the ETI 134 which had a 0.3 mV to 30 V range and an A-weighting filter, is decidedly simpler to construct, will measure dc signals (square waves and pulses etc referenced to zero volts) and is less expensive.

This instrument will measure 150 mV to 270 V in 12 ranges and features a large (90 mm scale) meter, 2% accuracy and an expanded scale for ease of reading.



What is RMS?

At this stage, it would be a good idea to recap just what RMS means and its significance. Simply, the RMS value of any waveform is equal to that dc value which would produce the same heating effect in a resistor.

As an example, let's take the case of a light dimmer. The power in the light (the load) is varied using phase control in an SCR circuit. This varies the amount of time the load is connected to the mains over part of each mains cycle (see Fig. 1). The RMS value of the waveform across the load in this case is difficult to calculate, except at the point where it is half-on and half-off. The power is then obviously half the maximum value.

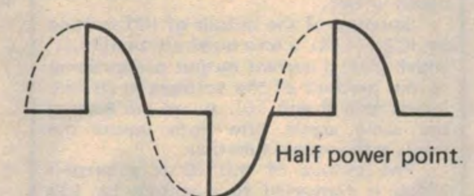


Fig. 1. The output waveform of a light dimmer running at half power.

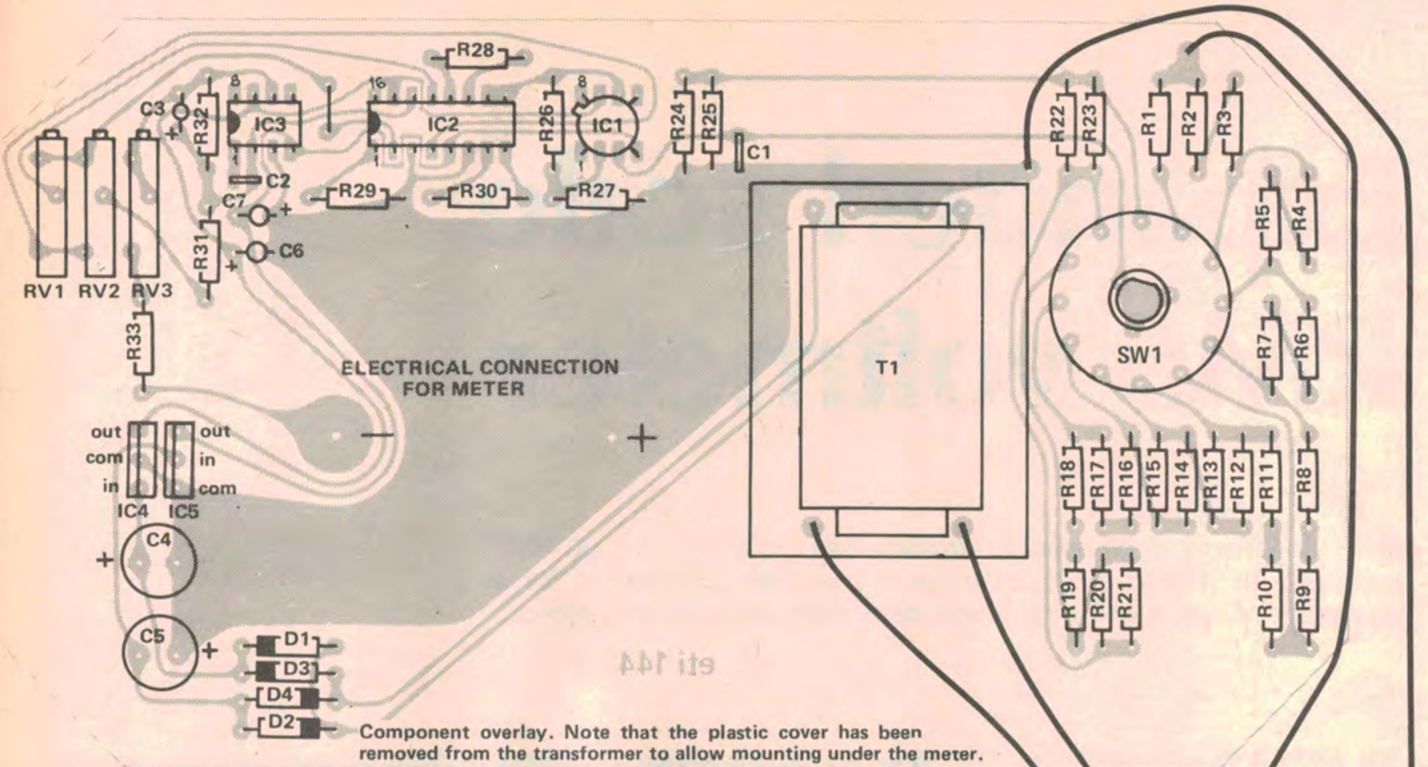
If the input voltage is 240 V and the load is 240 ohms, the power at maximum can be calculated from:—

$$P = \frac{E^2}{R} \text{ or } \frac{240 \times 240}{240} = 240\text{ W}$$

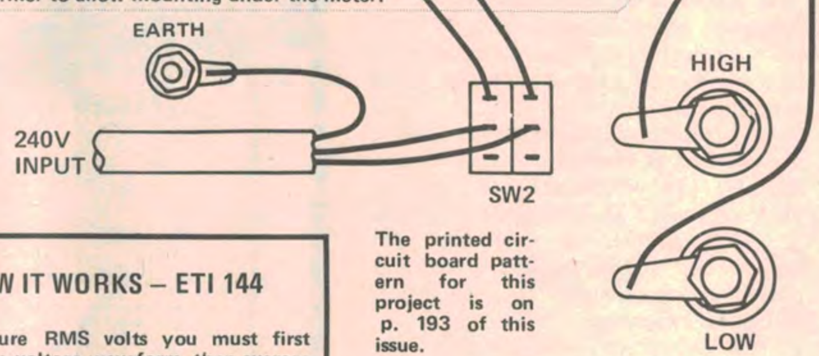
Half power is therefore 120 W. The voltage corresponding to this is given by:—

$$E = \sqrt{P \times R} \text{ or } 170\text{ V (rms)}$$

On a 'normal' meter this will read 120V, — an error of 30%. ▶



Component overlay. Note that the plastic cover has been removed from the transformer to allow mounting under the meter.



The printed circuit board pattern for this project is on p. 193 of this issue.

Construction

Assemble the pc board according to the overlay diagram, starting with the low height components. Do not fit the switch or the transformer yet. Watch the polarity and orientation of the components before soldering.

Before the transformer can be used the plastic cover and base have to be removed to reduce its height. This can be easily done using a small bladed screwdriver. Do not remove the internal plastic cover over the windings. The transformer can now be mounted and soldered in place keeping it as close as possible to the board.

The rotary switch specified (C & K 1054) is a pc-mounting type but may not be as readily available as the CK1034 type which has wiring connections. This can be used however if the very ends of the terminals are cut off carefully When fitting it to the pcb ensure that the No. 1 pin is toward the top of the board. Do not solder yet.

Fit the Scotchcal panel to the aluminium front panel and drill all the holes. Fit the meter to the panel. Assemble the power switch and terminal posts to the panel. Attach wires, about 100 mm long, to the terminal posts and also wire up the power switch. Earth the front panel using one of the meter retaining screws and leave about 50 mm of wire on the two outputs from the switch.

HOW IT WORKS – ETI 144

To measure RMS volts you must first square the voltage waveform, then average it and finally take the square root of that average. In this unit we electronically square and average the input but we use the meter scale to take the square root.

The input voltage is divided by the input network such that the input IC1 is 0.47 volts (dc or RMS) for full scale deflection. IC1 provides buffering and a gain of two.

Squaring of the output of IC1 is done by IC2 (1494), a four quadrant multiplier, which gives a current output proportional to the product of the voltages at its two inputs (pin 9 and 10). As we are feeding the same signal into both inputs the result is the square function.

The output of this IC is a current which is converted to a voltage by IC3 which also provides the averaging network (C3, R32). its output drives the meter whose scale is a square root function.

Adjustments are provided for the input offset of IC2 (RV1) output offset (RV2) and overall calibration (RV3).

As the power requirement of all the ICs is +/– 15 V we use a mains supply and three-terminal regulators. Current drain is about 15 mA on both supplies.

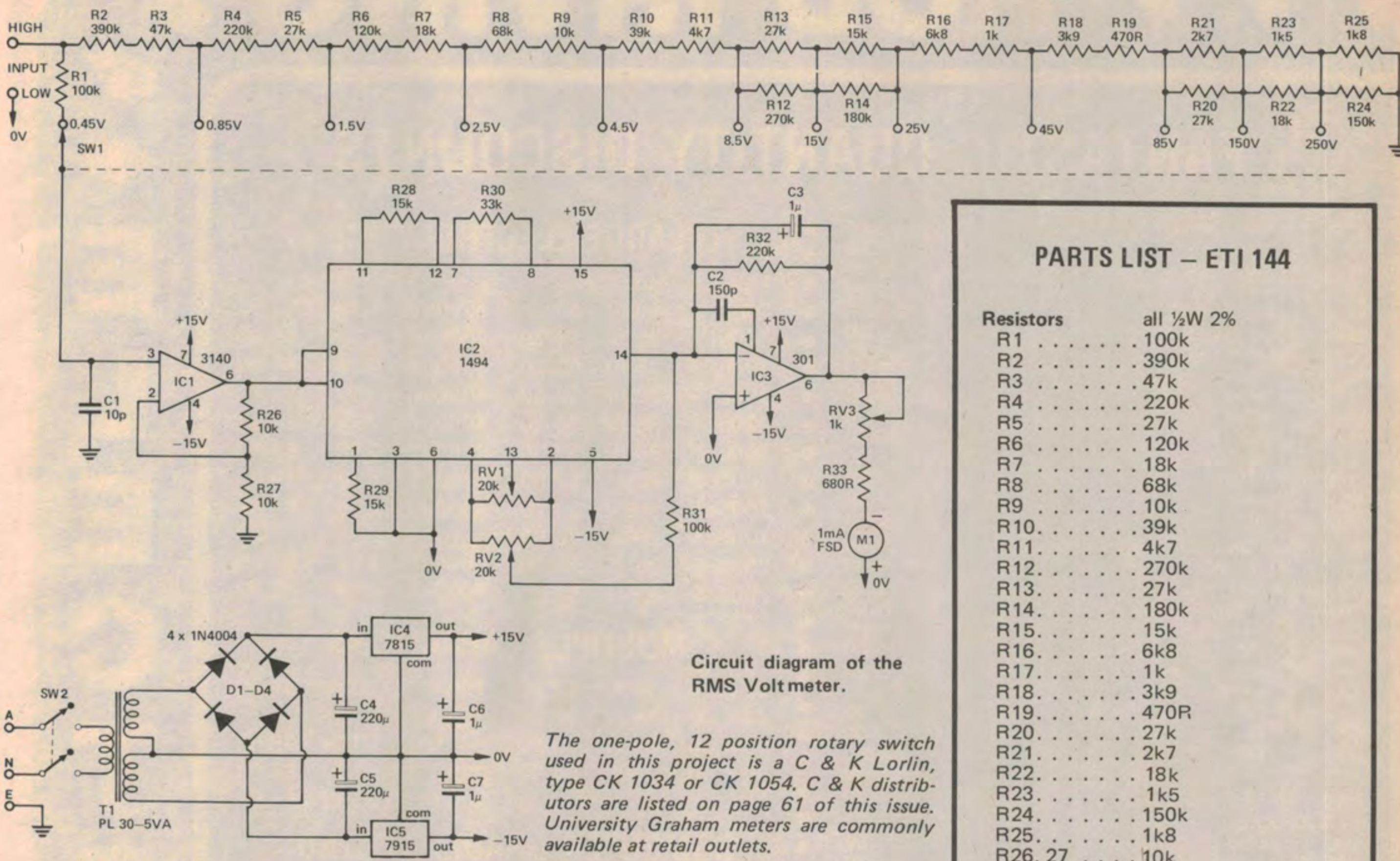
Now fit the pc board to the meter leaving the spring washers on the meter side of the board giving extra space to the front panel. As the switch now lines up with the front panel it can be soldered in place.

Connect the wires from the terminals to their position on the pc board. The 240 V wires from the switch come around the edge of the board and solder directly onto the terminals of the transformer. These connections should be covered with epoxy to prevent personal contact.

The meter scale can be fitted to the meter as follows:

Remove the clear cover from the meter (it clips on) then, carefully remove the existing scale. The scale should be sprayed white and allowed to dry.

Cut the Scotchcal to the borders marked, peel back the plastic a little and cut off about 5-10 mm of paper backing on one edge.



Circuit diagram of the RMS Voltmeter.

The one-pole, 12 position rotary switch used in this project is a C & K Lorlin, type CK 1034 or CK 1054. C & K distributors are listed on page 61 of this issue. University Graham meters are commonly available at retail outlets.

PARTS LIST – ETI 144

Resistors all ½W 2%

R1 . . . . 100k
R2 . . . . 390k
R3 . . . . 47k
R4 . . . . 220k
R5 . . . . 27k
R6 . . . . 120k
R7 . . . . 18k
R8 . . . . 68k
R9 . . . . 10k
R10. . . . . . . 39k
R11. . . . . . . 4k7
R12. . . . . . . 270k
R13. . . . . . . 27k
R14. . . . . . . 180k
R15. . . . . . . 15k
R16. . . . . . . 6k8
R17. . . . . . . 1k
R18. . . . . . . 3k9
R19. . . . . . . 470R
R20. . . . . . . 27k
R21. . . . . . . 2k7
R22. . . . . . . 18k
R23. . . . . . . 1k5
R24. . . . . . . 150k
R25. . . . . . . 1k8
R26, 27 . . . . 10k
R28, 29 . . . . 15k
R30. . . . . . . 33k
R31. . . . . . . 100k
R32. . . . . . . 220k
R33. . . . . . . 680R

Potentiometers

RV1, 2 . . . . . 20k 10 turn trim
R3 . . . . 1k 10 turn trim

Capacitors

C1. . . . . .10p ceramic
C2. . . . . .150p ceramic
C3. . . . . .1µ 35V tantalum
C4, 5 . . . . . . .220µ 35V electrolytic
C6, 7 . . . . . . .1µ 35V tantalum

Semiconductors

IC1 . . . . CA3140
IC2 . . . . MC1494
IC3 . . . . LM301A
IC4 7815
IC5 7915

D1–D4. . . . . IN4004

Miscellaneous

PC board ETI 144
Transformer PL30/5VA (Ferguson)
Meter TD118, 1mA FSD (University)
Meter scale to suit
Zippy box 196 x 113 x 60 mm
Scotchcal panel
2 pole power switch
1 pole 12 position rotary (see text)
Knob to suit
3 core flex, plug and clamp
2 terminal posts

ETI 144 EXPANDED SCALE RMS VOLTMETER

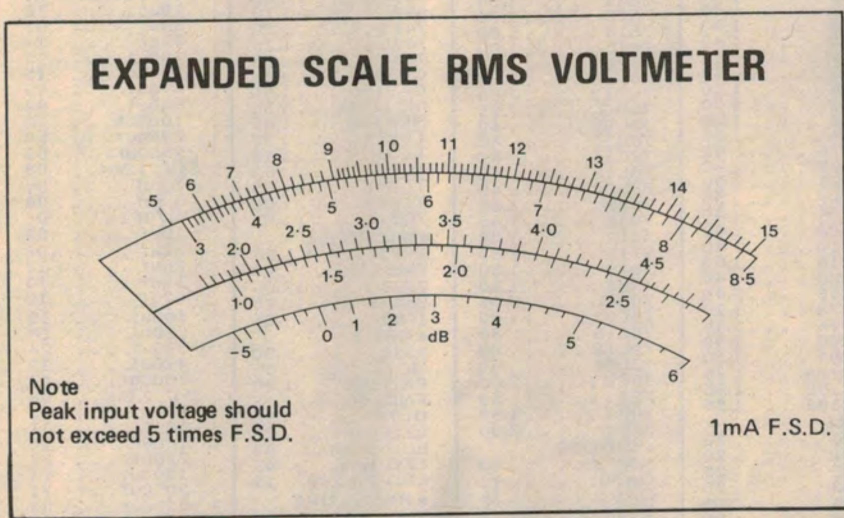
SPECIFICATIONS

Input range	150 mV to 270 V in 12 ranges, 5 dB apart
Accuracy	+/- 2% FSD
Crest factor	maximum, 10
Frequency response	dc to 50 kHz (sine wave)
Input impedance	1 M
Meter type	moving coil, RMS volts, expanded scale calibration

The Scotchcal panel can now be placed on the meter scale and lined up while holding the sticky edge off the panel. Now press down the sticky edge to locate the panel then fold it back on itself to allow the rest of the backing sheet to be removed. Press the panel down from the edge already fixed removing any air bubbles from under it.

The scale can now be refitted to the meter and the cover placed back. ▶

Project 144



Both of these drawings are reproduced full size so that, if you wish, you can cut them out of the magazine and use them directly.

Alignment and calibration

Equipment needed:
- variable dc power supply
- accurate dc voltmeter
- two-pole change over switch

Connect the power supply to the input terminals, via the switch, connected to give polarity reversal. Switch on the unit and with no input voltage adjust RV2 to give a reading about a quarter of the way up the scale.

Allow the unit about five minutes to warm up and stabilize. You could check to see if the internal supplies are giving the correct voltages while you wait.

Now, switch to the 15 volt range and apply about five or six volts to the input. Reverse the polarity of the input and note the change in the reading. Adjust RV1 until there is no difference, irrespective of polarity.

It will probably be necessary to adjust RV2 again to keep the reading on the scale. Note that it is not the actual reading that is important just that both polarities are the same. Increase the voltage to around 14 volts to ensure the adjustment is correct.

Now, with no input voltage adjust RV2 to give a zero reading. Apply 14 volts and adjust RV3 to read 14 volts. Adjustment is now complete.