F.E.T. VOLTMETER

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SOME people, once they become the proud possessors of a digital frequency meter, wonder how on earth they managed without one for so long! The writer feels like that about his slide-back FET voltmeter and wonders why he did not make one years ago!

The meter measures the peak voltage of audio and radio signals over the range 50mV to 2·5V and consists of a control box to which may be connected one or more probes. The box houses two potentiometers, 8 x HP7 batteries and a microammeter, while the probe houses an FET, a resistor and two capacitors.

Operation

The slide-back principle is simply that of providing a variable voltage so connected as to oppose the input voltage to be measured. When no current is drawn from the input then the two voltages are equal and opposite. At balance such a voltmeter therefore presents an infinite input impedance. The scale is linear and this may be provided, as shown in Fig. 1, by a voltmeter across the variable internal supply or by calibrating the potentiometer dial.

Since a microammeter is needed to detect the balance point such a meter must be protected against a large unbalance current with a series resistance and a diode shunt, Fig. 2. To achieve a balance one must be able to detect a movement of the meter pointer for a very small current. Meters with fine pointers and fine graduations may be better than more "sensitive" meters with thicker pointers and graduations. The length of the pointer also plays a part for the end of a longer pointer may move more, for the same current, than the shorter pointer of a more "sensitive" meter. The writer settled for a 50μA meter whose overall dimensions were 60 x 45mm.

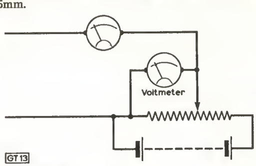
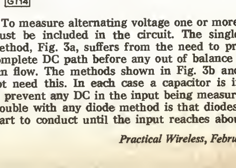


Fig. 1: above, method of providing a known variable voltage when using the slide-back method of voltage measurement.

Fig. 2: below, use of a diode to prevent damage to meter by large out-of-balance currents.



To measure alternating voltage one or more diodes must be included in the circuit. The single diode method, Fig. 3a, suffers from the need to provide a complete DC path before any out of balance current can flow. The methods shown in Fig. 3b and 3c do not need this. In each case a capacitor is included to prevent any DC in the input being measured. The trouble with any diode method is that diodes do not start to conduct until the input reaches about 0·5V

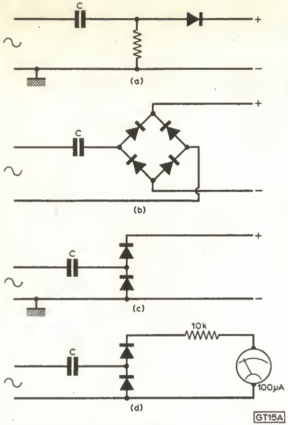


Fig. 3: Methods of rectifying the alternating voltage input. (d) is the circuit used to provide curve A in Fig. 4.

and the scale is not really linear until some 10V are reached. Fig. 4 curve A shows the response curve for a simple diode meter using the circuit shown in Fig. 3d while curve B shows the response of the slide-back FET voltmeter.

The gate-to-source junction of an FET has the characteristics of a silicon diode, but it is used in the reverse bias condition so that its operating current is only a few nanoamps and the input resistance many megohms. The drain-to-source junction acts as a resistor whose value depends on the gate-to-source voltage.

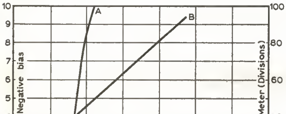


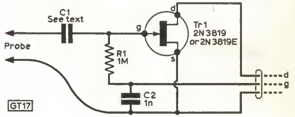
Fig. 4: Curve A is obtained using the circuit of Fig. 3(d) above. Curve B is the response curve of the FET voltmeter described in the article.

★ components list

Resistor R1, 1MΩ1/20W. Rx, see text, about 3·9kΩ. Capacitor C1, see text. C2, 1nF, ceramic. Diodes D1 and D2, 1N914 or similar. Transistor Tr1, 2N3819 or 2N3819E. Meter M1, 50µA FSD, 60 x 45mm (Watford Electronics). Batteries, 8 x HP7, with two holders. Aluminium box 5¼ x 2¾ x 1½in. or similar. Potentiometers VR1, VR2, 5kΩ lin. with knobs. 3-pin plug and socket. Probe cable and material, see text. Switch S1, double pole on-off.

Circuit

Fig. 5 shows the circuit of the probe and Fig. 6 that of the control box. It will be seen that the drain current is measured by the meter which is protected, as already described, but with two diode shunts D1/2, placed back to back. Negative bias is applied to the gate via R1. The bias needed to reduce the drain current to zero varies between samples and it was found, in the case of the 2N3819E used, that about −3·65V were required. The resistance Rx, in series with the zero set potentiometer VR1, is chosen so that the cutoff point is within the range of that control when the negative bias potentiometer VR2 is set at zero. In the case of the prototype the value required turned out to be 3·9kΩ. Thus the operation of the negative bias control could add another 2·25V.



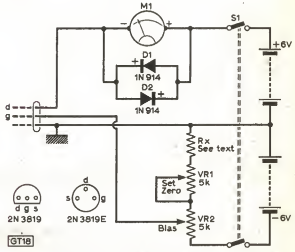


Fig. 5: above, is the circuit of the probe used with the control box, Fig. 6, below. Two probes will cover most AF and RF requirements.

Two 6V batteries are needed, one to provide +6V for the drain circuit and the other to provide up to −6V bias but since the current drawn is less than 1mA small batteries can be used. Since the writer finds a substantial 12V supply useful for other purposes eight HP7's were used, in two boxes each holding four batteries and fitted with press studs.

Construction

The parts of the probe are assembled on a strip of Veroboard, 3 holes wide and 24 holes long, Fig. 7a. The FET and resistor R1 are soldered to terminal pins while the stiff earth wire is soldered to two such pins. The capacitor C1 is soldered in and three other terminal pins serve as connections to the three-core cable which is anchored to the board by wire loops. The aluminium box is used upsidedown, with the lid underneath. Fig. 7b shows the wiring. The use of a three-pin socket allows more than one type of probe to be used with the control box. The coupling capacitor C1 is chosen to suit the frequency range i.e. its reactance needs to be small compared with the voltmeter input impedance. For the audio range C1 should not be less than 0·5μF and for radio frequencies not less than 100pF. This capacitor needs to have a very low leakage if the zero point is not to be altered when the load is connected to the input.

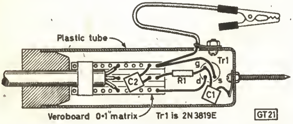
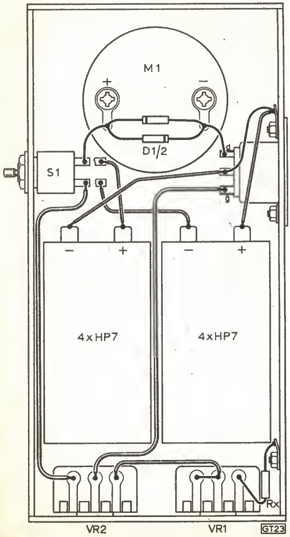


Fig. 7(a) above, shows the method of constructing the simple probe while (b) below, illustrates the location of the few components in the control box and the wiring.



Operation

The operation of the voltmeter is as follows:—

1. Set the bias potentiometer to zero, i.e. towards the end connected to the set zero potentiometer.

2. With no input voltage, set the set zero potentiometer to give a zero meter reading. This is best approached by reducing the meter reading very slowly to zero and then giving a slight movement in reverse. A movement of the pointer should then be just detectable. Care should be taken to see that the pointer is not pressing on any mechanical stop.

3. The input is then connected and this time the negative bias potentiometer used to reduce the meter reading to zero. The final position of this potentiometer is then read off.

If the meter is to be used only as a detector then the bias need only be set to give a convenient reading.