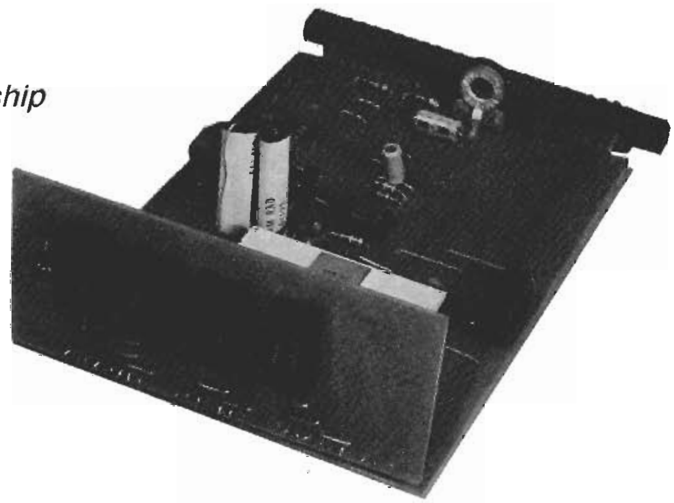
BUILD

3½-Digit DMM

The digital panel meter has the same relationship to the DMM as the D'Arsonval panel meter has to the analog multimeter. Build your own multimeter using a DPM



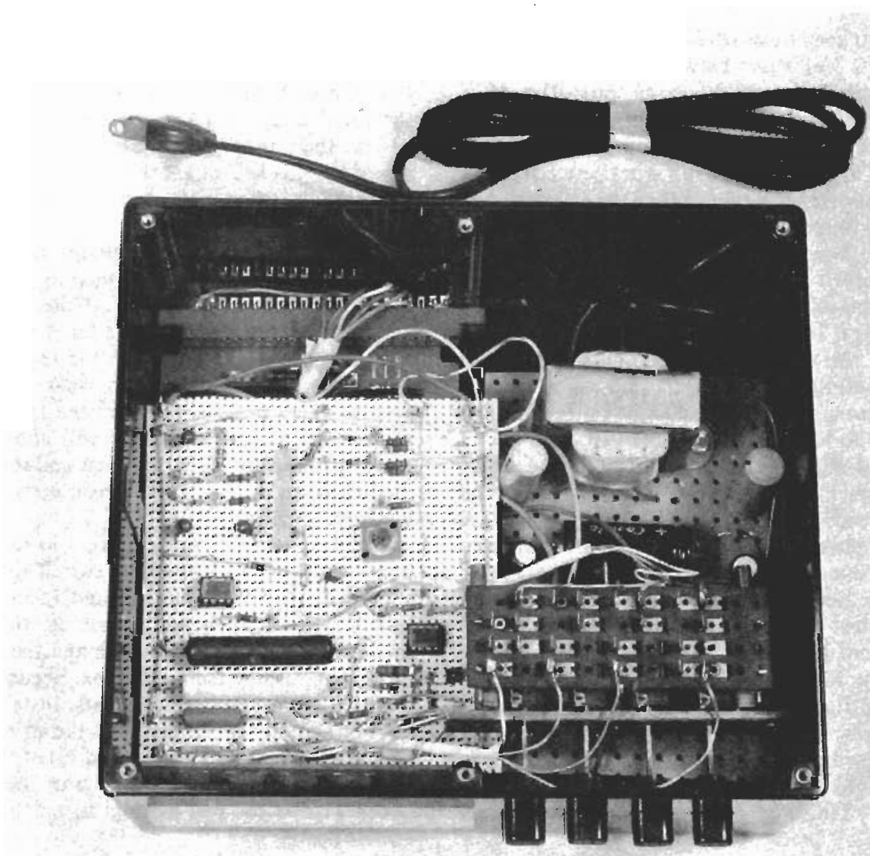
DR. E. H. BORNEMAN AND ROBERT BENWARD

A DIGITAL PANEL METER IS THE HEART OF every digital multimeter. This article describes a relatively simple circuit for a 2-volt DPM (*D*igital *P*anel *M*eter) using readily available IC's that can be easily converted into a digital multimeter (DMM) by adding some voltage-divider and current-shunting circuits. The resulting instrument, including power supply, can be simply packaged to become a very functional and rather attractive digital multimeter.

DPM circuit and operation

The basic DPM circuit is shown in Fig. 1. It uses a minimum number of parts, with most of the circuitry in two IC's; one a signal conditioner, the other a digital processor. These IC's include an onboard clock and a medium quality internal reference (40 ppm/°C). The measuring system uses dual-slope integration with its advantages of noncritical clock frequency, high rejection of AC signals and use of noncritical components.

The 8052 signal conditioner has three phases of signal conversion, these being auto-zero, integrate input and integrate reference. At the end of a measurement the system automatically reverts to auto-zero mode until a new measurement is started. If no overload has occurred in the previous measurement, it takes 10 milliseconds for the auto-zero to null. At power-on or after an overload it takes 100



INTERIOR OF A DIGITAL MULTIMETER based on a version of the digital panel meter in the head photo above. The DPM (at left) used point-to-point wiring on perforated board. See Fig. 8 for layout drawing.

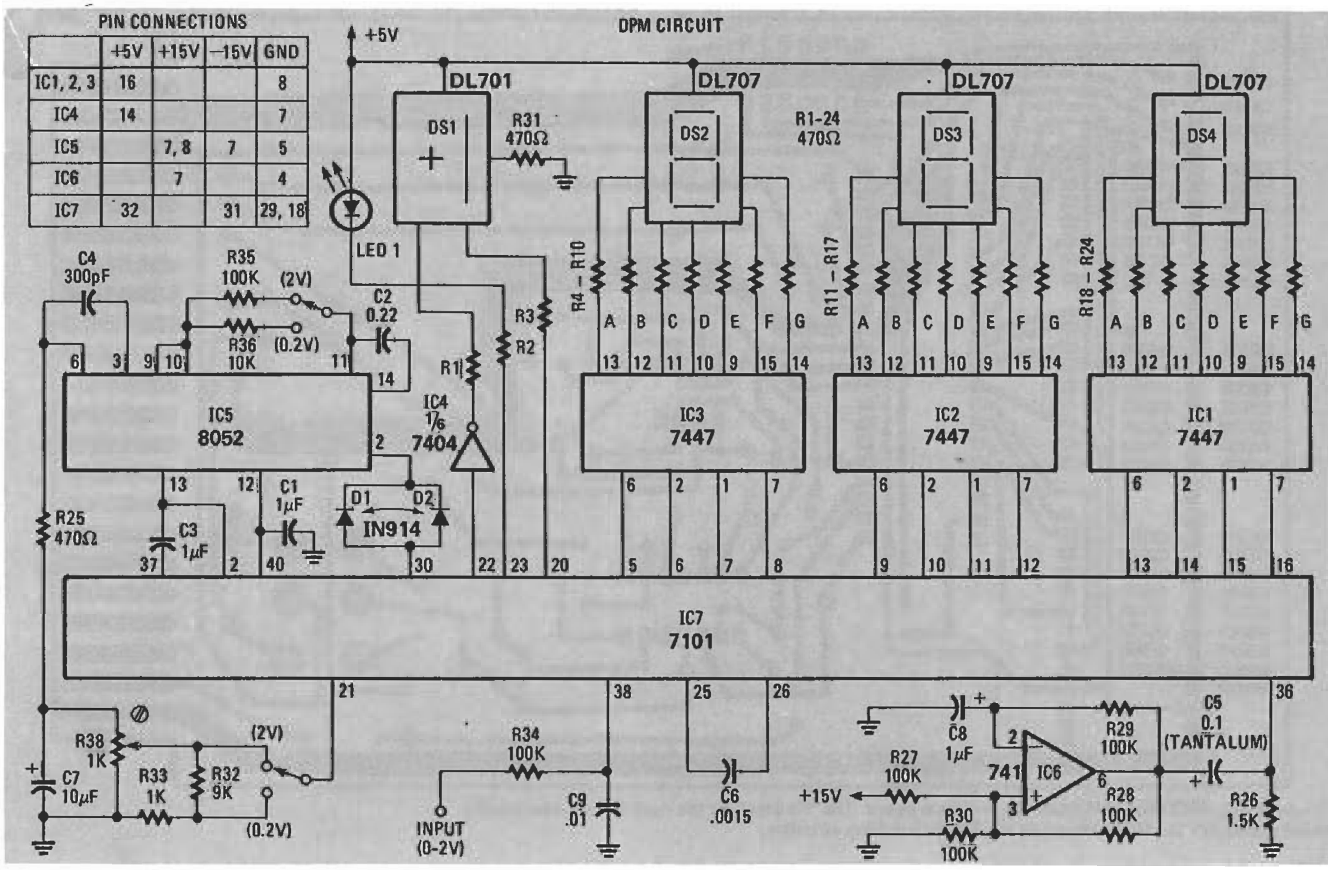


FIG. 1—DIGITAL PANEL METER SCHEMATIC. The unit is simple and easy to construct; using either point-to-point wiring or a couple of PC boards.

DPM PARTS LIST

All resistors ¼ watt, 10% or better
R1, R2, R4-R25, R31—470 ohms
R26—1500 ohms
R27-R30, R34, R35—100,000 ohms
R32—9000 ohms
R33—1000 ohms
R36—10,000 ohms
R38—1000 ohms, miniature potentiometer
All capacitors 10 volts DC or higher
C1, C3—1 μF, Mylar
C2—0.22 μF, polypropylene
C4—300 pF, disc
C5—0.1 μf, tantalum or metallized film
C6—.0015 μF, disc
C7—10 μF, electrolytic
C8—1 μF, electrolytic
C9—0.01 μf, disc
Semiconductors
D1, D2—1N914 diode
DS1—+1 LED digit, Litronix DL701 or equal
DIS2-DIS4—7-segment LED digit, Litronix DL707 or equal
LED1—Red LED, 0.2-in. diameter
Integrated circuits
IC1-IC3—7447 BCD/7-segment decoder/driver
IC4—7404 hex inverter
IC5—8052 signal conditioner
IC6—741 op-amp
IC7—7101 digital processor

milliseconds to null.

None of the circuit component values are critical in determining the accuracy of the instrument. For example, the reference capacitor and auto-zero capacitor (C1 and C3) are both shown as 1.0 μF. These rather large values minimize the effect of PC board leakage. The 0.22-μF value of the integration capacitor C2 is selected for PC board considerations alone, since the very small leakage at the integration input is nulled at auto-zero. It is very important that this capacitor have very low dielectric absorption.

The DPM is calibrated by putting a standard mercury cell across the input (any convenient reference source less than 2 volts can be used) and adjusting the 1K pot until the reference voltage is correctly displayed on the readout.

Initially the DPM circuit was built on a perf board, but the later models were constructed on two PC boards with one board containing the displays and the second, with a 15-pin edge connector, containing all the circuitry.

The foil pattern for the main PC board is in Fig. 2. The parts are positioned as shown in Fig. 3. Figure 4 is the pattern for the display board. Figure 5-a shows the jumpers that are installed from the front side of the board. Figure 5-b shows the locations of three jumpers connected to the 7-segment displays. The drawings in Fig. 5-c show how the jumpers can be added. The main and display boards are joined by 26 jumpers as detailed in Fig. 3 and Fig. 5-d.

Start with scraps of leads clipped off the resistors and other components that have been installed. Insert the leads from the foil side of the display board and solder in place. Insert the unattached lead ends in the holes in the main board, adjust the boards so they are close together and at right angles. Solder one end, check board alignment and then solder the other. Solder the connections between the ends.

Electrical characteristics of the DPM are as follows:

Power supply: +5 V @ 200 mA; +15 V @ 25 mA; −15 V @ 25 mA.
Linearity (full scale): 0.1 count typ.; +1 count max.
Rollover [differential in equal (+V=−V=2V)]: 0.1 count typ.; +1 count max.
Noise (full scale): −0.05 counts
Leakage current into input: 5 pA typ.; 30 pA max.

The following are available from Hobbi House, 969 Ball Ave., Union, NJ 07083 (800-631-7485).

Digital Panel Meter, includes all parts listed in the DPM Parts List plus PC boards, $29.95.

Set of PC boards for DPM (2 boards), $6.95.

Digital Multimeter, includes all parts listed in DMM, DPM and Power Supply Parts Lists, $49.95.

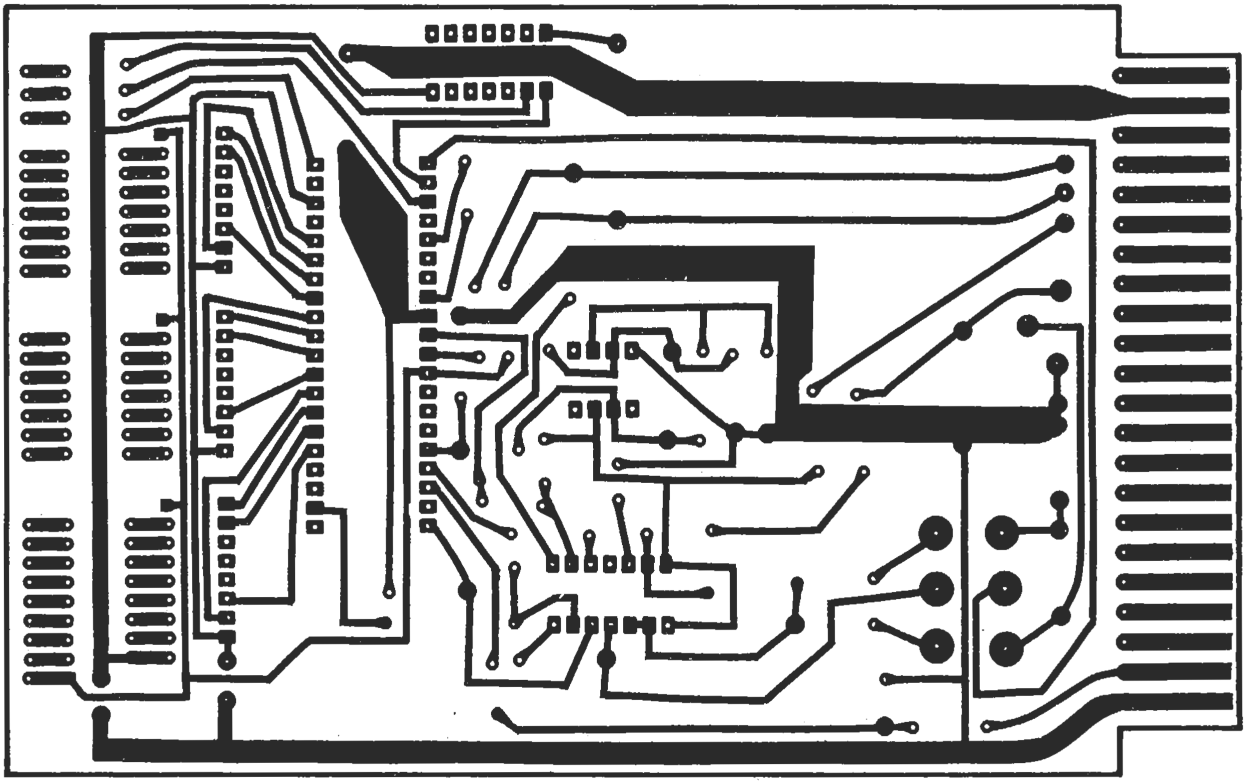


FIG. 2—FULL-SIZE FOIL PATTERN for the main board. The "fingers" on the right fit into a female PC board connector for connections to the DMM switching circuitry.

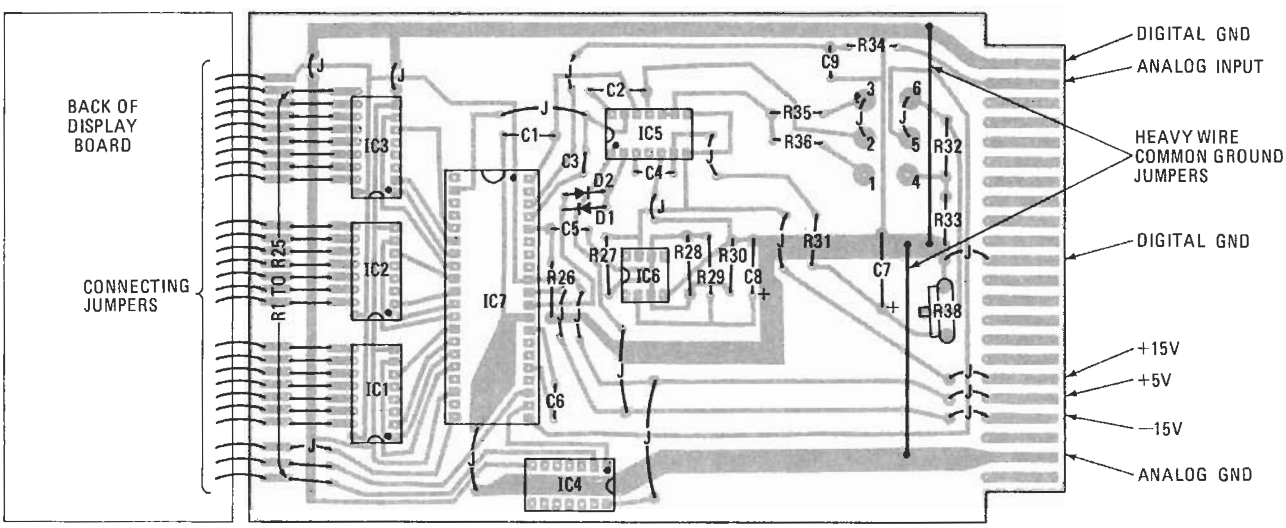


FIG. 3—HOW COMPONENTS ARE PLACED on the main board. Note the location of jumpers, IC positioning and electrolytic capacitor lead polarity.

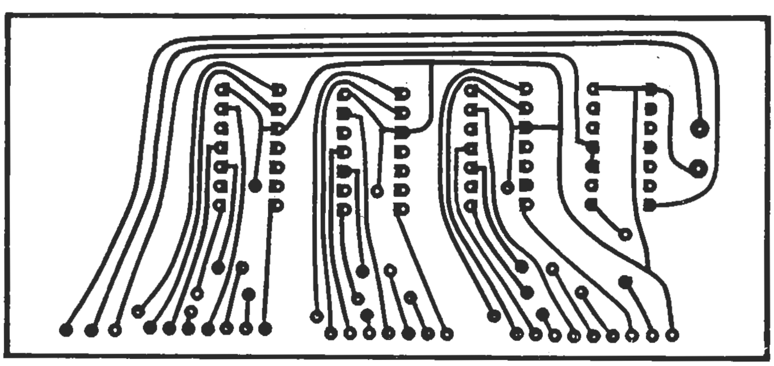


FIG. 4—DISPLAY BOARD foil pattern is full-size. Jumpers must be installed on both sides of the board as detailed in another figure.

The power supply for the DPM must deliver regulated outputs of +5 volts, +15 volts, and −15 volts DC. A circuit diagram for the power supply is shown in Fig. 6.

Although rather low currents are required for the DPM, the output currents supplied by this circuit will operate all the additional functions of the multimeter circuitry to be described. Good regulation is required (0.1%), so three voltage regulator IC's are used.

Conversion of DPM into digital multimeter

The basic DPM can be converted into a

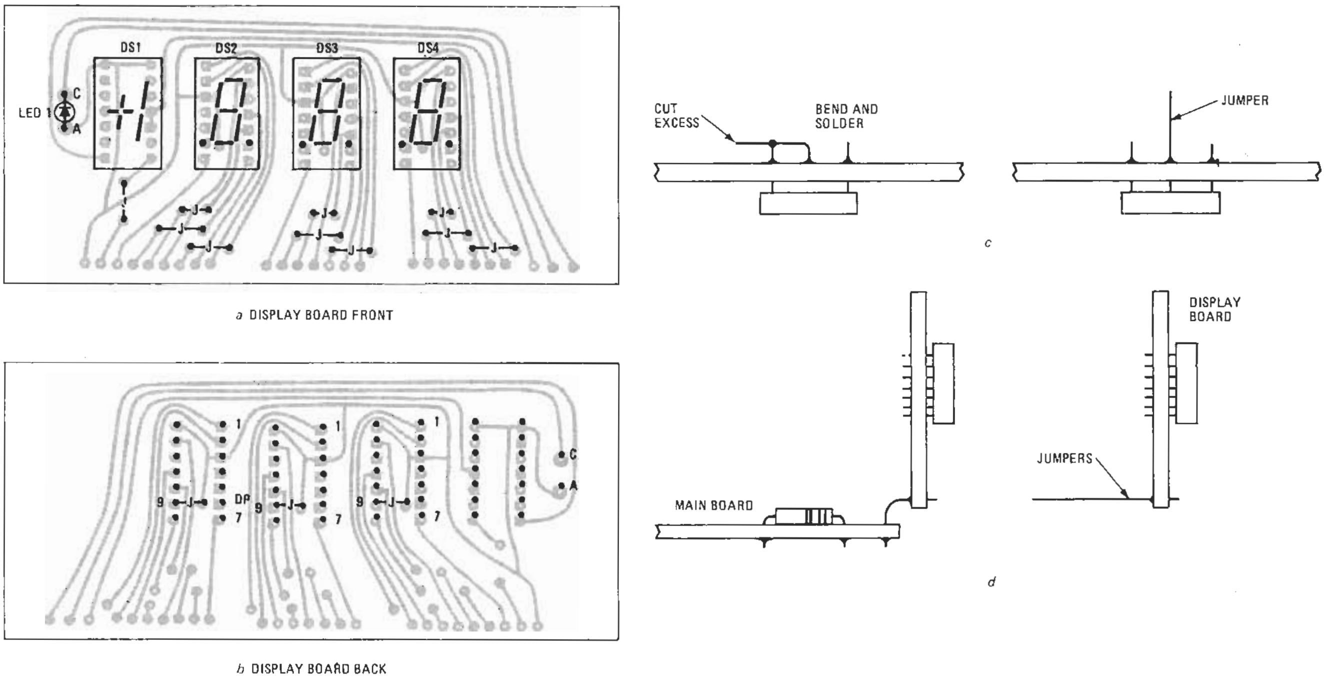
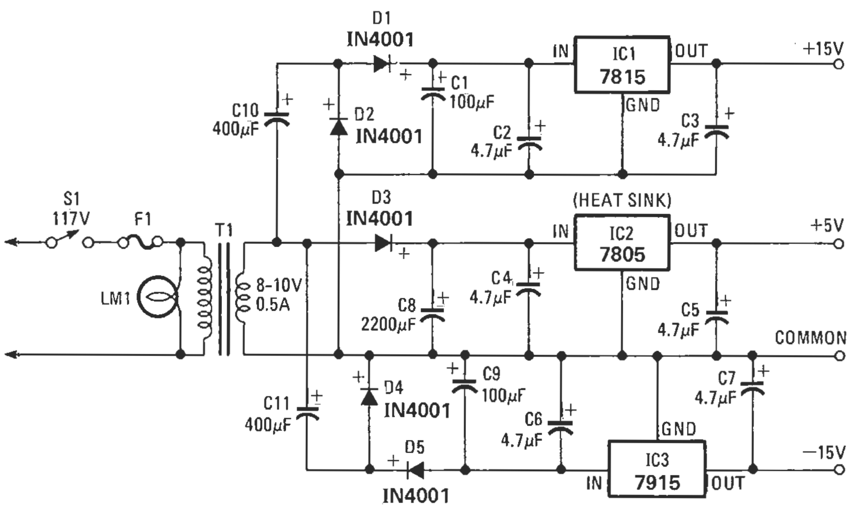


FIG. 5—MOUNTING AND JUMPER DETAILS for display board. Drawing *c* shows how back-of-board jumpers are formed while *d*, along with Fig. 3 shows how boards are joined by jumpers.



POWER SUPPLY PARTS LIST

Capacitors 25 volts DC or higher
C1, C9—100 μF, electrolytic
C2-C7—4.7 μF, tantalum
C8—2200 μF, electrolytic
C10, C11—400 μF, electrolytic
Semiconductors
D1-D5—1N4001 diodes
IC1—7815 positive 15-volt regulator
IC2—7805 positive 5-volt regulator
IC3—7915 negative 15-volt regulator
S1—SPST switch
T1—power transformer, 8-10-volt, 0.5-A secondary
LM1—117-volt pilot lamp
F1—0.25-ampere fuse

FIG. 6—POWER SUPPLY DIAGRAM. Three solid-state voltage regulators set the levels of voltages needed to operate the multimeter.

digital multimeter by adding the circuitry shown in Fig. 7. This circuit uses pushbutton DPDT switches. However, these can be replaced with a multisection rotary switch. Functions performed by the digital multimeter are listed in the following table.

DC volts: 2, 20, 200, 2000
AC volts: 2, 20, 200, 2000 (RMS)
Ohms: 2K, 20K, 200K, 2 megohms, 20 megohms
Direct current: 200 mA, 2A, 10A
Alternating current: 200 mA, 2A, 10A (RMS)

The circuit shown in Fig. 7 connects directly into the input of the 2-volt DPM.

Accuracy of the multimeter functions depends on the precision resistors used in the voltage-divider and current-shunt circuits. I recommend 1% or better, to take advantage of the inherent high accuracy of the DPM. Unless otherwise indicated, all other resistors in the circuit are ¼ watt, 10%.

ADD-ON MULTIMETER PARTS

All resistors ¼ watt, 5% unless noted
R1—9 megohms, ½ watt, 1% or better
R2—900,000 ohms, ¼ watt, 1% or better
R3—90,000 ohms, ¼ watt, 1% or better
R4—9000 ohms, ¼ watt, 1% or better
R5—1000 ohms, ¼ watt, 1% or better
R6—0.1 ohm, 10 watts (20 watts optional) 1% or better
R7—1.0 ohm, 10 watts, 1% or better
R8—10 ohms, 1 watt, 1% or better
R9—100 ohms, ½ watt
R10, R30—30,000 ohms
R11, R21—1 megohm
R12—10 megohms
R13—6200 ohms
R14—750 ohms
R15—4300 ohms
R16—910 ohms
R17—1000 ohms, miniature potentiometer
R18—4700 ohms
R19, R23—3300 ohms
R20, R22—9100 ohms
R24—470,000 ohms
R25, R26—10,000 ohms
R27, R29—5100 ohms
R28—2500 ohms, miniature potentiometer

All capacitors 25-volts DC or higher
C1—.01 μF, ceramic
C2—150 pF, ceramic
C3-C5—4.7 μF, tantalum
Semiconductors
D1, D2—1N914
D3-D6—1N4003
D7—6.2-volt Zener diode
Q1, Q2—2N3904
IC1, IC2—LM308 op-amps
Miscellaneous
S1, S3-S9—DPDT pushbutton switch or equivalent
S2—4-pole DT pushbutton switch or equivalent

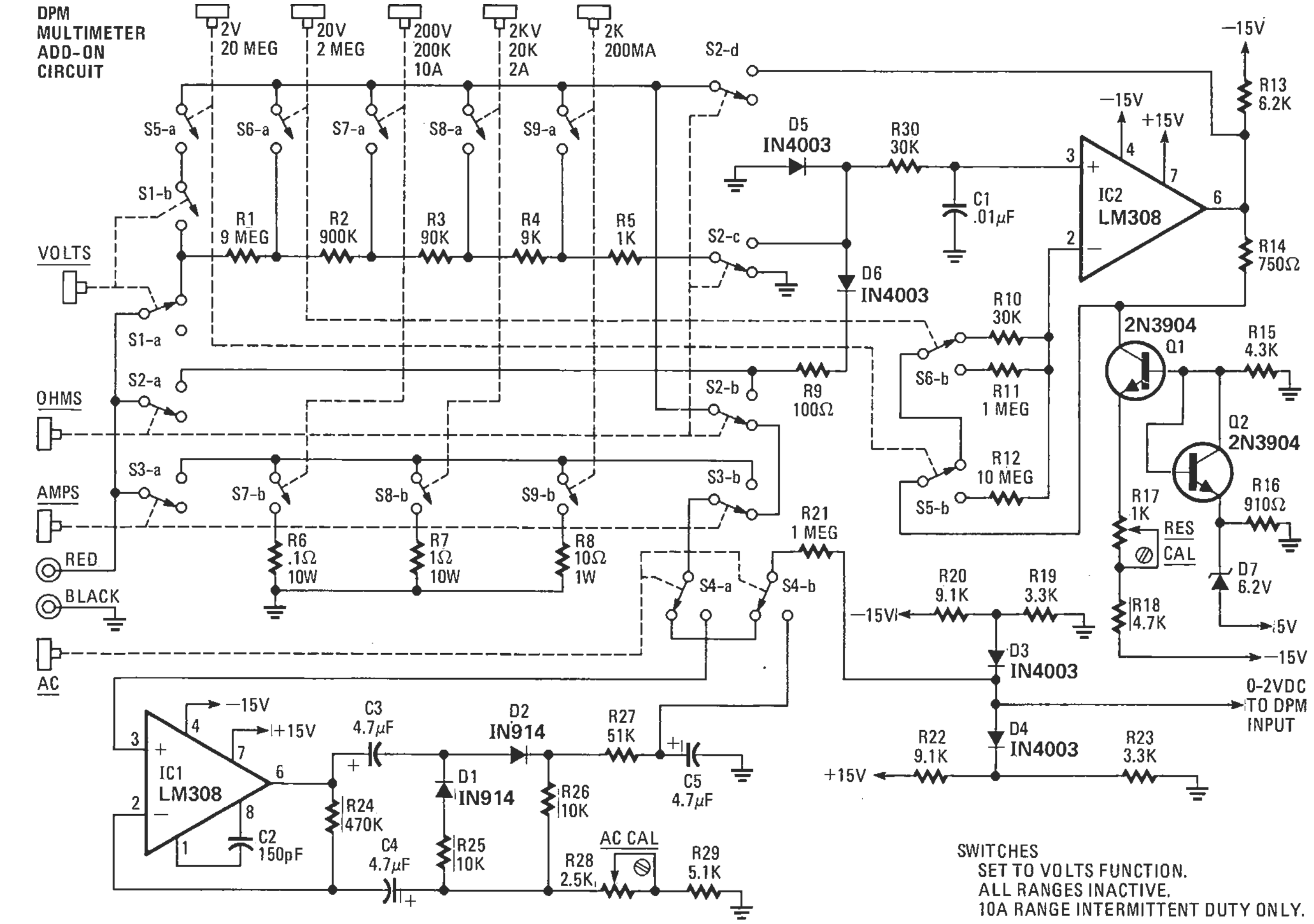


FIG. 7—CIRCUITRY TO CONVERT DPM TO DMM includes function selector switching, multiplier and shunt resistor networks and a few active components.

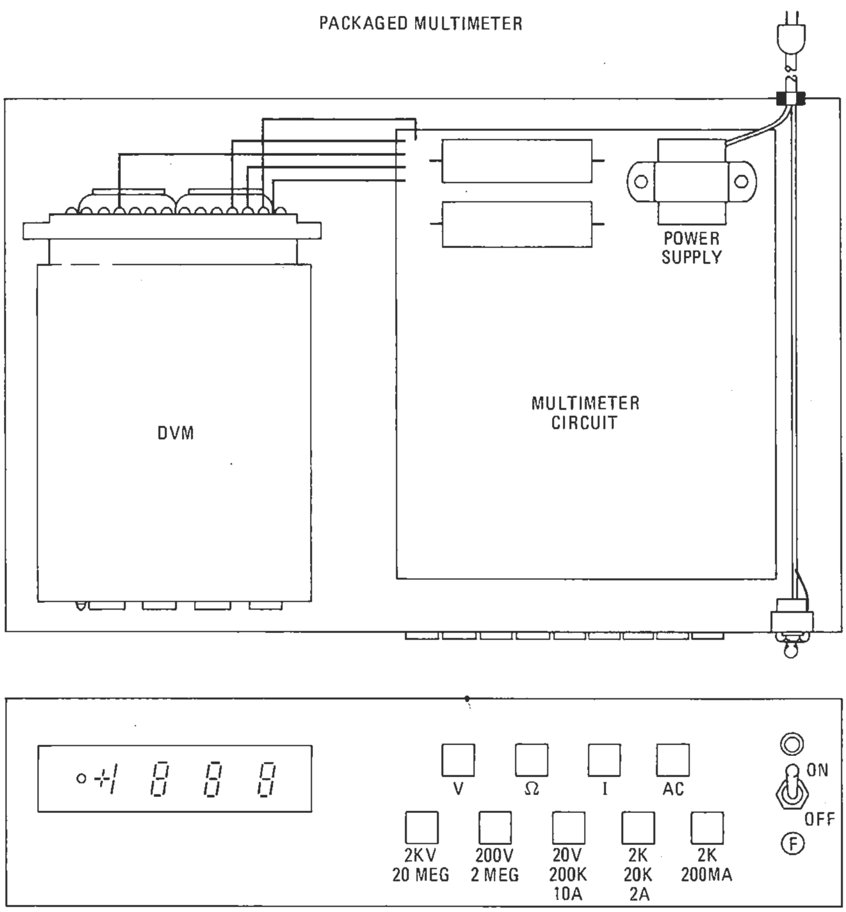


FIG. 8—HOW BASIC PARTS ARE LAID OUT in a typical instrument case. The DPM connects to the multimeter circuit through an edge connector and a short length of cable.

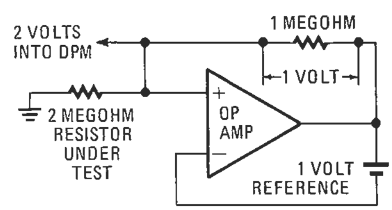


FIG. 9—SIMPLIFIED OHMMETER CIRCUIT. Equal voltages at op-amp inputs are essential to proper ohmmeter operation.

The multimeter can now be made into a finished packaged instrument by housing it in a chassis case similar to that shown in Fig. 8 and the photograph. Here the basic DPM is mounted on the left side of the chassis with the display showing through a tinted red or gray acrylic plastic window, the power supply plus multimeter circuitry being housed in the right side. On-off and function switches are mounted in the right front panel. Such a packaged instrument, though home built, can offer a very attractive and useful meter for both amateur and professional use.

DMM operation

The DMM circuit is built around relatively simple and well-proven circuit principles. The circuit diagram in Fig. 7 shows all functions are fed into the DPM on the 0–2-volt scale. The DC voltage input to the DMM feeds into a precision resistor voltage divider, with the scale

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switches arranged so that the maximum coming off the divider into the DPM input is always 2 volts.

The AC volts input goes through the same voltage divider and then into a "precision rectifier circuit" that converts the signal into DC to feed the input to the DPM. The 2.5K pot in this circuit lets you calibrate the output of the precision rectifier on a one-time basis against a standard AC input signal.

The ohmmeter circuit is shown in simplified form in Fig. 9. Here, one leg of the op-amp contains a standard reference voltage that is adjustable through the 1K pot to exactly 1 volt. The other leg contains the portion of the voltage divider that is active for measuring a particular resistance range. In the illustration the 1-meg resistor shown is used to measure 2 megohms full scale. Since the op-amp operation dictates that the inputs to both legs must be equal, and since the outputs are common, exactly 1 volt must also appear across the 1-meg resistance. This constant voltage forces a constant current through the resistance being measured; in this particular case 2 megohms. The 2 volts developed across the 2-megohm resistor is then fed into the DPM, registering a full-scale reading. Other resistance values for the unknown will, of course, produce proportional voltages feeding into the DPM.

The resistance circuit is calibrated on a one-time basis by adjusting the 1K pot with a standard resistor across the input. When the DPM registers the correct reading of resistance, it has been calibrated. An alternate method is to adjust the pot so that exactly 1 volt appears across the 750-ohm resistor (R14) at the output of the op-amp.

The direct current input is taken off the three shunt resistors, R6, R7 and R8. Each resistor develops exactly 2 volts across it for maximum scale readings. Note that the high current scale is limited to 10 amps only because of the low wattage (10 watts) of the 0.1-ohm resistor (R6). If you make this a 20-watt resistor, you can read 20 A full scale. These resistors should be at least 1 percent tolerance or better for good measurement accuracy.

The multicontact pushbutton switches shown in the circuit diagram are of course the easiest to wire, although layered rotary switches can also be used. The correct decimal point for each scale can be displayed by connecting pin 6 of the appropriate display number (DS-2, 3 or 4) through the appropriate scale switch to ground through a 470-ohm resistor.

The entire DMM circuit can easily be layed out and assembled on a 4½ × 6-inch piece of perforated circuit board with 0.1-inch hole spacings. **R-E**