BUILD THIS LOW-COST CAPACITANCE METER

Five linear ranges to 10,000 µF

BY THOMAS McGAHEE

WHEN a capacitor is connected to a constant-voltage source through a resistor, the charge on the capacitor increases *exponentially*. If the source supplies a constant current, however, the charge on the capacitor increases *linearly*. This linear charging principle is used here in the design of a capacitance meter which will measure values outside the range of most such meters. By using a constant-current source, the meter determines the time it takes to match the charge on the unknown capacitor to a known reference voltage. The meter has five full-scale ranges of 1, 10, 100, 1000, and 10,000 µF. On the 1-µF scale, values as small as 0.01 µF can be read easily.

How It Works. As shown in Fig. 1, *D1, D2, R6, Q1* and one of the resistors (*R1* through *R5*) selected by *S1A* provide five decades of constant current. With *S2* in the position shown in Fig. 1, this current is shunted to ground via *S2A*. When *S2* is placed in its alternate position, the constant current will be pumped into the unknown capacitor connected across *BP1* and *BP2*, forcing it to charge in a linear fashion.

Op amp *IC1* is connected as a comparator, with its noninverting (+) input connected to *R8*, which determines the reference voltage. When the voltage developed across the unknown capacitor, connected to the inverting input (−) of *IC1*, becomes a few millivolts higher than the preset reference voltage, the comparator output will switch from +12 volts to −12 volts.

The output of the comparator drives a constant-current source consisting of *D3, D4, D5, R10, R11,* and *Q2*. When *S2A* was switched to ground, so was *S2B*. This action shorts across storage capacitor *C1*, therefore the voltage across this capacitor is zero.

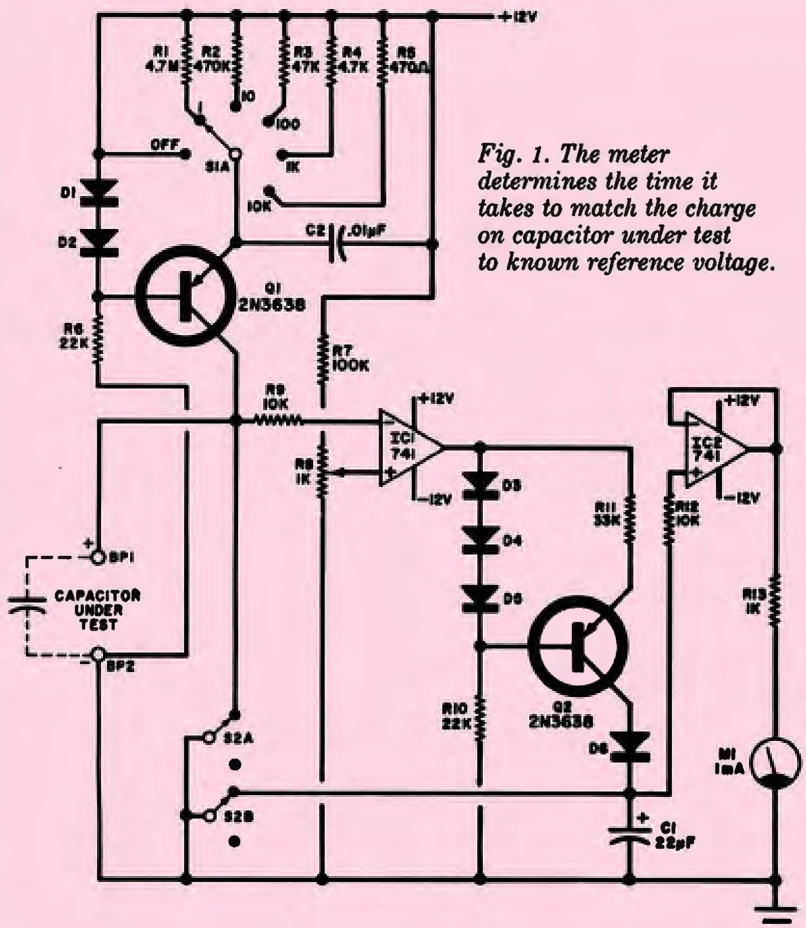


Fig. 1. The meter determines the time it takes to match the charge on capacitor under test to known reference voltage.

PARTS LIST

BP1, BP2—Five-way binding posts (one red, one black)
C1, C4—22-µF, 35-volt electrolytic capacitor
C2—0.01-µF ceramic disc capacitor
C3—220-µF, 35-volt electrolytic capacitor
D1 to D6—1N914 diode
D7, D8—50-volt, 500-mA silicon rectifier
D9, D10—12-volt zener diode
IC1, IC2—741 mini-DIP case
M1—0-1-mA meter (Radio Shack 22-052 or equiv.)
Q1, Q2—2N3638 transistor
R1—4.7-megohm, ½-w 5% resistor
R2—470,000-ohm, ½-w 5% resistor
R3—47,000-ohm, ½-w 5% resistor
R4—4700-ohm, ½-w 5% resistor
R5—470-ohm, ½-w 5% resistor
R6, R10—22,000-ohm, ½-w resistor
R7—100,000-ohm ½-w resistor
R8—1000-ohm, pc-type trimmer potentiometer
R9, R12—10,000-ohm, ½-w resistor
R11—33,000-ohm, ½-w resistor
R13—1000-ohm, ½-w resistor
R14—560-ohm, ½-w resistor
R15—470-ohm, ½-w resistor
S1—Dp 6-pos. rotary switch (Radio Shack 275-1386 or equiv.)
S2—Dpst or dpdt pushbutton or rocker switch
T1—Transformer, secondary 12-V, 300 mA (Radio Shack 273-1385 or equiv.)
Misc.—Suitable enclosure (Radio Shack 270-627 or equiv.), line cord, insulated wire, spacers, rubber feet (4).

When *S2* is opened, the constant current flowing into *C1* causes the voltage across it to rise linearly. When the voltage across the capacitor under test causes the comparator to switch, diode *D6* becomes reverse biased, preventing *C1* from charging any more. Since *C1* only charges until the comparator switches, the voltage generated across it is directly proportional to the capacitance value of the unknown capacitor.

To prevent *C1* from discharging while measuring its voltage, a high-impedance buffer, formed by *IC2*, is used. While this buffer draws very little current, it does draw some, and this results in a very slow downward drift of the meter—but this drift is actually too slow to cause any problems. Resistor *R13* and meter *M1* make up a simple voltmeter readout of approximately 1 volt full scale. If desired, an external voltmeter can be used as long as it has a full-scale range of less than 8 volts. (If you use such an external meter, set *R8* on the 1-µF range, so that a known 1-µF capacitor indicates 1 volt.) Capacitor *C2* is used to prevent oscillation of the *Q1* constant-current source, while *R9* and *R12* protect the op amps in case the power is turned off while the test capacitor and *C1* are charged, otherwise they might discharge via the op amps, causing damage.

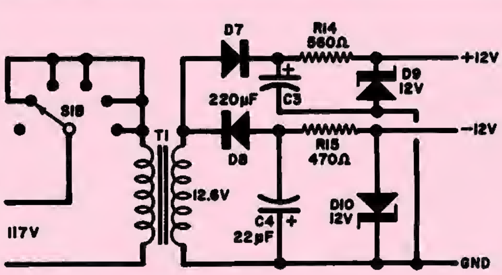


Fig. 2. Power supply delivers sufficient current for meter.

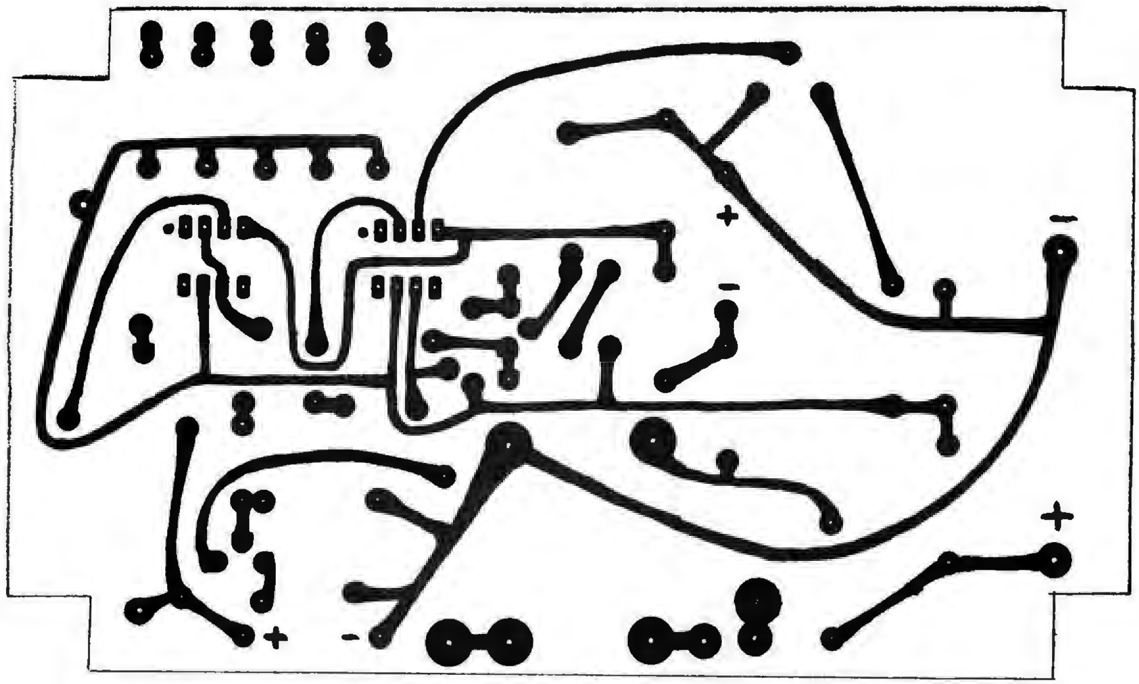
The power supply whose circuit is shown in Fig. 2, can supply sufficient current to power the meter.

Construction. The circuit can be built on the pc board whose foil pattern is shown in Fig. 3, along with the component installation on the nonfoil side of the board. Be sure to observe the polarity of the two electrolytic capacitors and the various diodes. The IC's are identified by a notch code.

The prototype was assembled in a 6¼" by 3¾" by 2" plastic box having a metal cover. The cover was drilled to accept *M1*, range switch *S1*, switch *S2*, and the two binding posts (*BP1*, *BP2*). Note that a red binding post was used for *BP1* as this side is to be connected to the positive lead of the capacitor under test. The line cord exits through a small hole in the side of the plastic box.

Meter *M1* is linearly calibrated to 1 mA full scale. Carefully open up the meter and using press-on type, or other printing medium, mark the scale "MFD" or "µF."

The accuracy of the capacitance meter depends on two factors; the



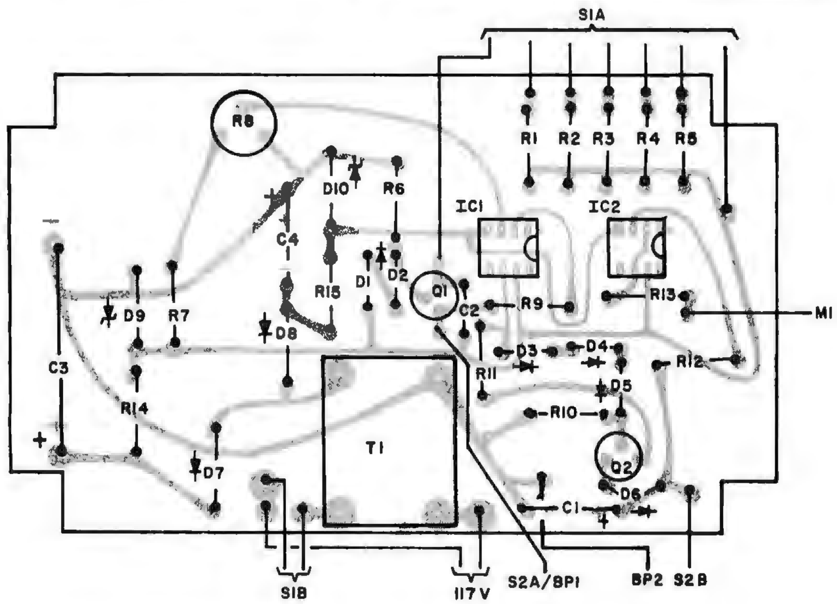


Fig. 3. Actual-size etching and drilling guide is above, component layout at left.

basic accuracy of the meter movement used and the accuracy of resistors *R1* through *R5*. In most cases, the meter accuracy will be 3%, and experience has shown that, with 5% tolerance resistors, the overall accuracy is about 3%. Although this may sound strange, it is due to the fact that most 5% resistors made by the same company tend to be off tolerance by the same percentage, thus reducing the effective percent error between the resistors. Using 10% resistors yields about 6% accuracy.

Calibration. Before applying power to the capacitance meter, use a small screwdriver to set the meter pointer exactly to the zero mark.

Select a capacitor between 0.5 and 1.0 µF at 5% or better. This will be the "calibration standard." Connect this capacitor between *BP1* and *BP2* (positive side to *BP1*). Set range switch *S1* to the "1" position (meter indicates 1-µF full scale). Operate *S2* to remove the ground lead from the two circuits (*Q1* collector and *C1*). The meter should start upscale and stop at some value. Reversing *S2* should cause the meter to drop to zero volts. Flip *S2* again and note the upscale value of the meter. Alternately flip *S2* and adjust *R8* until the meter indicates the exact value of the 5% calabration capacitor. The one calabration will suffice for all the other ranges. ◈

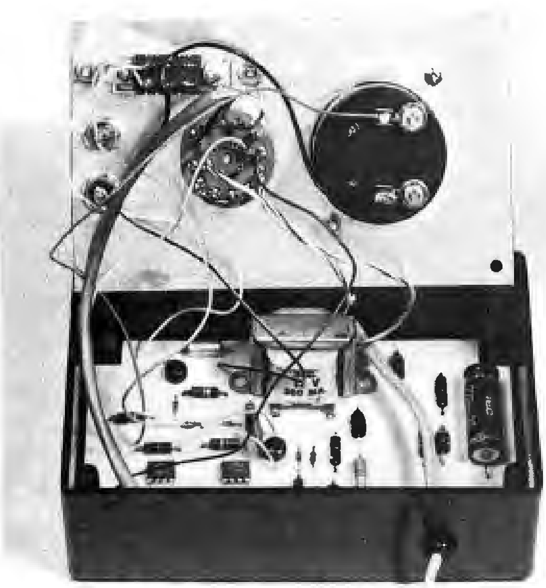


Photo shows how author's prototype was assembled in box.