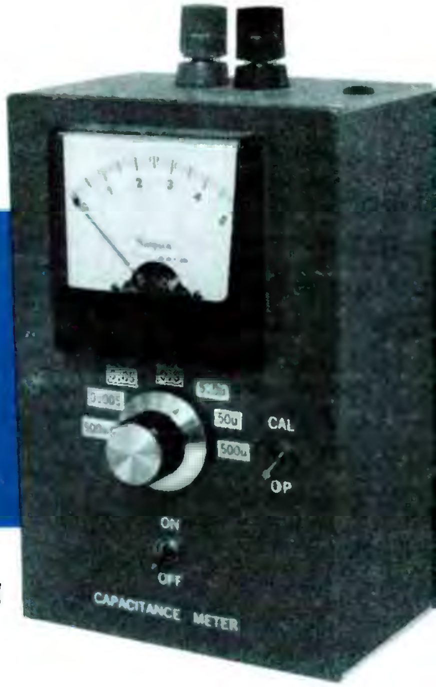


CAPACITANCE METER

Now you can identify the rating of those unmarked capacitors in the bottom of your junkbox that you could never use before!

By Joe Horner

NEARLY EVERY HOBBYIST HAS A BOX-FULL OF UNUSED capacitors which sit there, year after year, because he doesn't know what value of capacity they have. Color codes have faded or worn off. Even when they are marked, you can't always be sure—for instance, does "510J" mean 51.0-picoFarads or 510-picoFarads? From the capacitor's physical size you can usually tell if it is pico- or microfarads, but that's about all.

Here is an easy-to-understand, easy-to-build project using one integrated-circuit chip that can measure about 95 percent of the capacitors you will ever use in projects and servicing of consumer-electronics devices. It measures full scale from 500-pF to 500-µF in six decades, requires no calibration, or no zeroing—just a full-scale potentiometer adjustment. On the lowest scale (500-pF) you can measure down to about 10-pF, giving the instrument a *dynamic range* (ratio of highest to lowest value) of nearly 8 powers or 100 million). Not bad for a one-chip gadget that we call the Capacitance Meter.

How it Works

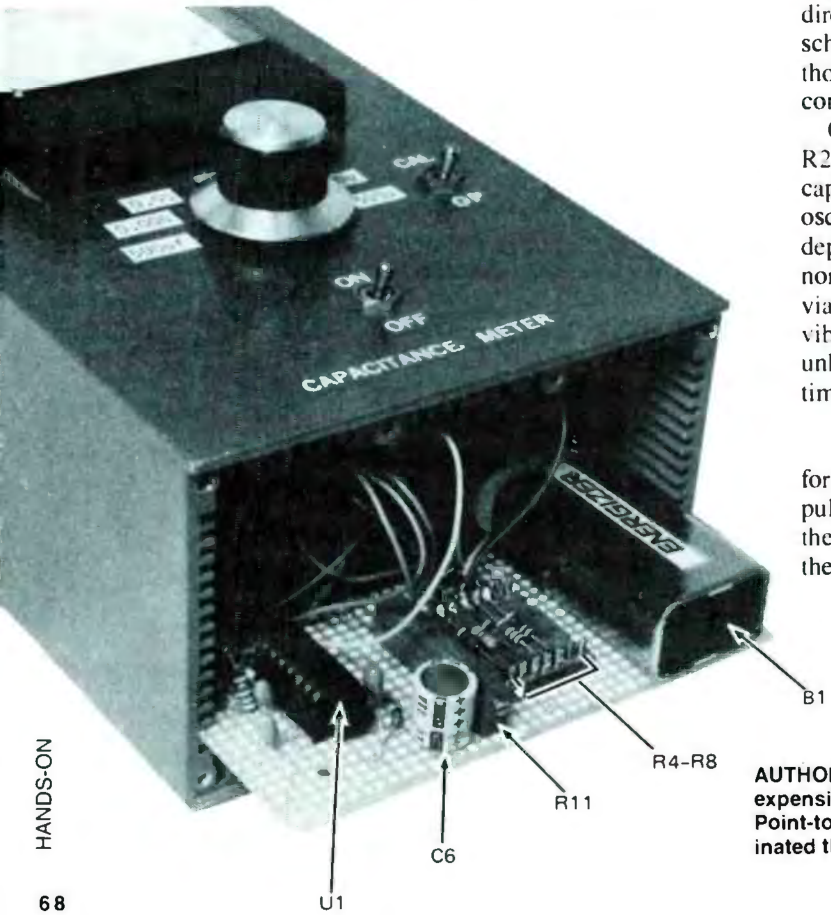
The heart of the unit is the popular 555 timer integrated-circuit, in its dual-package version, the 556. The first stage, U1-a, is an oscillator, and the second, U1-b, the measurement part of the circuit. It converts unknown capacity into a pulse-width modulated signal the same way an automotive dwell meter works. It does that in a very linear fashion, so that the fraction or percent of the time that the output is high is directly proportional to the unknown capacitance (C_x in the schematic). Meter M1 effectively reads the average voltage of those pulses since its mechanical frequency response is low compared to the oscillator frequency of U1-a. See Fig. 1.

Oscillator U1-a's frequency is determined by C1 and R1, R2, or R3 selected by range switch S1-a. Use a high-quality capacitor for C1 such as a mylar or polystyrene type. The oscillator frequency of U1-a is either 5.5, 55 or 550 Hz depending on the setting of S1. The output, at pin 5, is normally positive, and very briefly goes low, triggering U1-b via capacitor C5. Chip U1-b is wired as a non-stable multivibrator. When triggered, its output (pin 9) goes high, and the unknown capacitor starts charging up. It takes a period of time

$$t = 1.1RC_X$$

for C_X to charge up. Pin 9 then goes low until the next trigger pulse from the oscillator, and the whole cycle repeats. If T is the time between the drive pulses out of U1-a, that portion of the on time at the output is

$$t/T = 1.1RC_Xf.$$



AUTHOR'S CONSTRUCTION TECHNIQUE is a bit classier and expensive than that required for home-workshop purposes. Point-to-point, wire-wrap, wiring on the perfboard eliminated the need for a printed-circuit board.

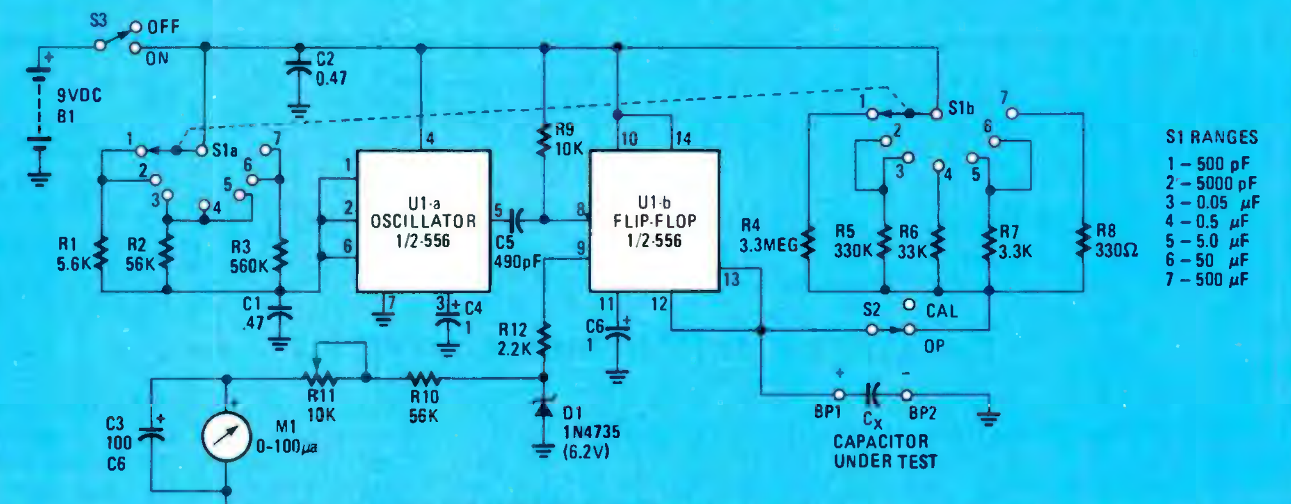


FIG. 1—A ONE-CHIP PROJECT, the Capacitance Meter circuit parts fit neatly onto a small circuit board. Switches S1, S2, and S3, meter M1, and binding posts BP1 and BP2 mount on the chassis box.

PARTS LIST FOR CAPACITANCE METER

SEMICONDUCTORS
D1—1N4733 Zener diode, 6.2-volt
U1—556 dual timer integrated circuit

CAPACITORS
—.47-μF, mylar or polystyrene
C2—.47-μF, disk
C3—100-μF, 15-WVDC, electrolytic
C4, C6—1-μF, 15-WVDC, electrolytic
C5—490-pF, disk

RESISTORS
(All fixed resistors are ¼-watt, 5% units unless otherwise noted)
R1—5600-ohm
R2, R10—56,000-ohm
R3—560,000-ohm
R4—3.3-Megohm
R5—330,000-ohm
R6—33,000-ohm
R7—3300-ohm
R8—330-ohm
R9—10,000-ohm
R11—10,000-ohm, linear-taper, trimmer potentiometer
R12—2200-ohm

ADDITIONAL PARTS AND MATERIALS
B1—9-volt DC transistor-radio battery
BP1, BP2—Multi-way binding post; one red, one black
M1—0-100-μA, 2- to 3-in., DC meter
S1—2-pole, 8-position or 2-pole, 12-position, non-shorting, rotary switch, use only 7 positions
S2, S3—SPDT, miniature, toggle switch
Perfboard, IC socket (optional), flea clips, knob with index, stranded wire, decals, solder, battery holder (optional), hardware, etc.

where f is the frequency (f = 1/T). Full-scale reading occurs for t/T = 1.00, so the design equation becomes

$$C_X \text{ (full scale)} = 1/1.1Rf.$$

For example, to measure an unknown capacitor of 500 μF (full scale) with a trigger frequency of 5.5 Hz requires a charging resistor of:

$$R = 1 \div [1.1 \times .0005(f) \times 5.5 \text{ Hz}] = 330 \text{ ohms}$$

That points out why the upper range of the instrument is 500μF. We can't go lower with the oscillator frequency, or the meter needle visibly vibrates and is hard to read. Applying Ohm's law, with 330 ohms being the resistance, the peak charging and discharging currents is approximately

$$V \div R = A$$
$$9 \div 330 = 27 \text{ mA}.$$

To increase the Capacitance Meter range another decade (5000 μF and 33 ohms) would result in charging current of 270 mA—far too much for the battery and the internal transistor in U1-b which discharges the capacitor.

The output voltage is held constant at 6.2 volts by the Zener diode D1. Resistors R10 and R11, and capacitor C2 form a low-pass filter to smooth out the low frequency ripple, slightly visible at the highest full-scale range.

Construction

The circuit shown in Fig. 1 is all that there is to wire. Layout and placement of parts is not critical, because of the low frequencies used. I built mine in a 2½- × 4- × 6-inch aluminum box with lots of room to spare. You could fit the Capacitance Meter into a smaller enclosure for a more compact unit—that's up to you.

The integrated circuit and various components are mounted on a perfboard as shown in the photo. Be sure to use multi-way, color-coded binding posts for the terminals BP1, BP2) of the test capacitor, C_X, since one side is ground and one side is positive. Trimmer potentiometer R11 is so infrequently adjusted that I mounted it on the circuit board. It is accessible through a small hole in the bottom of the case.

After wiring is completed and checked, turn the unit on. With no unknown capacitor connected, switch S2 to the CAL

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position, turn R11 until the meter pointer indicates full scale. Return switch S2 to the OP position. Precaution: Always start with the range switch, S1, in the highest position and work your way down range until you obtain a reasonable reading. The reason for that is that if the unknown capacitor is larger than the meter's full-scale value, a mid-scale value on the meter will be observed. That is because the charging cycle of C_x doesn't finish before the next trigger pulse, and runs into the next cycle.

Here's a trick you can use to extend the meter's range effectively. If you have two identical capacitors (or any number N for that matter) put them in series (observing polarity, plus to minus) and connect them to the C_X terminals, BP1 and BP2. An individual capacitor will be N times the measured value.

The number of otherwise useless capacitors in your junkbox will now be able identified and usable—that will more than make up for the few dollars you may have to spend for parts. ■