Capacitance Meter

using a CMOS timer

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As demonstrated in this article, a simple test instrument is sufficient to unravel the mysteries of the cryptic and impossibly small print often found on capacitors.

Besides the obvious advantages of space savings, the miniaturisation of electronic components has a couple of dark sides too. Until about ten years ago, there used to be plenty of room on capacitor bodies to print the capacitance value, the tolerance, operating voltage, manufacturer code and other salient information. Today's capacitors, being much smaller in size, have illegible, incredibly small and cryptic print on them and before fitting such a capacitor you are well advised to measure the actual capacitance! Rocket science? Well, no. The good news is that this article describes a low-cost and extremely simple instrument to do just that.

Two timers

The circuit diagram shown in **Figure 1** indicates that two ICs type 555C are used. These are standard timer ICs that are largely pin and functionally compatible with the good old NE555 or LM555. The truth table of the IC is given in **Table 1**. These essential difference is the suffix 'C' — the current consumption of the inputs labels THRESHOLD, RESET and $\overline{\text{TRIGGER}}$ is just a few pico-amperes and so low that it has no noticeable effect on the capacitor's charging process.

The two timer ICs — internal architecture shown in **Figure 2** — operate in different 'modes'. IC1 is configured as an astable multivibrator; IC2, as a monostable one. IC1 generates short negative pulses of about 25 μs and spaced 65 ms apart at its output (pin 3). These pulses serve to trigger the second timer, IC2, in order to start a measurement cycle.

Timer IC2 handles the actual measurement of the unknown capacitor. Initially, the Discharge pin, number 7, can be considered as having ground potential, hence discharges the capacitor under examination. The measurement starts when the trigger signal arrives at the Trigger input pin 2. The internal Discharge FET is then switched off and the unknown capacitor is charged via resistors R2-R7 connected into the circuit by rotary switch S1 (see Table 2). The end of the trigger pulse has no effect since the states of the output and the Discharge FET remain unchanged as long as the voltage on the capacitor stays under 2/3rd of the supply voltage. This voltage is monitored at the Threshold input.

However, after a time

$$T_H = 1.1\,R\,C_x$$

that condition is ended and the IC output toggles to Low. Consequently, the Discharge output goes low again, discharging the capacitor. No more changes occur until the next trigger pulse arrives. This cycle is repeated until you switch off the instrument. The mark/space (= on/off) ratio of the output signal is a measure of the capacitance between the test inputs.

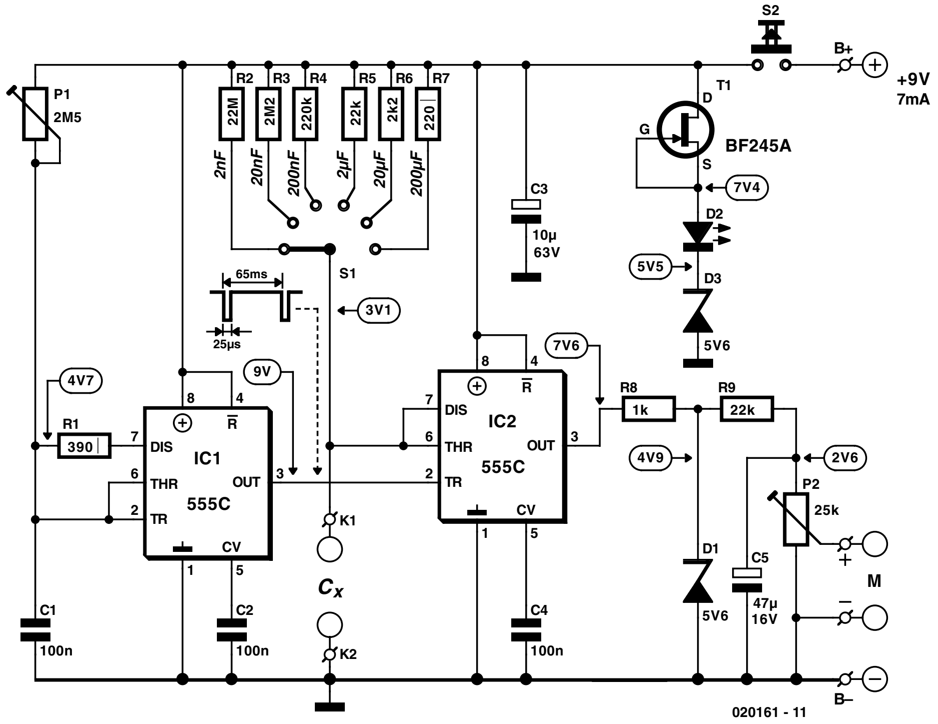


Figure 1. Circuit diagram of the capacitance meter based on the 555 — it's a classic!

Table 1. 555 Truth Table

THRESHOLD (Pin 6)	TRIGGER (Pin 2)	RESET (Pin 4)	OUTPUT (Pin 3)	DISCHARGE SWITCH (Pin 7)
don´t care	don´t care	Low	Low	On
>2/3·V+	>1/3·V+	High	Low	On
<2/3·V+	<1/3·V+	High	Stable	Stable
don´t care	<1/3·V+	High	High	Off

Table 2. Measurement Ranges

S1	R_{Meas}	Range*
1	22 MΩ	1 nF
2	2,2 MΩ	10 nF
3	220 kΩ	100 nF
4	22 kΩ	1μF
5	2.2 kΩ	10 μF
6	220 Ω	100 μF

* Double value on DVM readout

The rest of the circuit will require a less elaborate explanation. For simplicity's sake, a 100-μA moving-coil meter is used for the readout. Alternatively, you may want to use a DVM set to the 2-volts range. Resistor R9 ad capacitor C5 smooth the output signal to prevent an unsteady meter indication caused by the mark/space ratio of the output signal. A direct voltage proportional to the mark/space ratio is taken from the wiper of potentiometer P2. Diode D1 stabilizes the voltage to make it independent (within limits) of the battery voltage. That concludes our discussion of the measurement principle. To arrive at capacitance readings that are reliable as well as sensible, some conditions need to be fulfilled.

The period time of the measurement (here, 65 ms) may not be too long because the average output voltage and consequently the meter deflection would become too small.

Much worse results are obtained, however, by a too short period time because then a new trigger pulse arrives before the measurement is finished. This causes pulse loss and erroneous measurement results. You can actually see this happening by turning P1 and so raising the oscillator frequency — the readout will suddenly drop by half the value.

With period time and measurement time at the right ratio, but too long (for example, of the order of tens of seconds), the smoothing action of R9 and C5 will no longer suffice to keep the needle from quivering.

A simple battery indicator is built around T1, D2 and D3. The 'on' voltage of the LED has been 'raised' to about 7.4 V by zener diode D3. When the battery voltage drops below that level, the LED will go out. FET T1 acts as a simple current source.

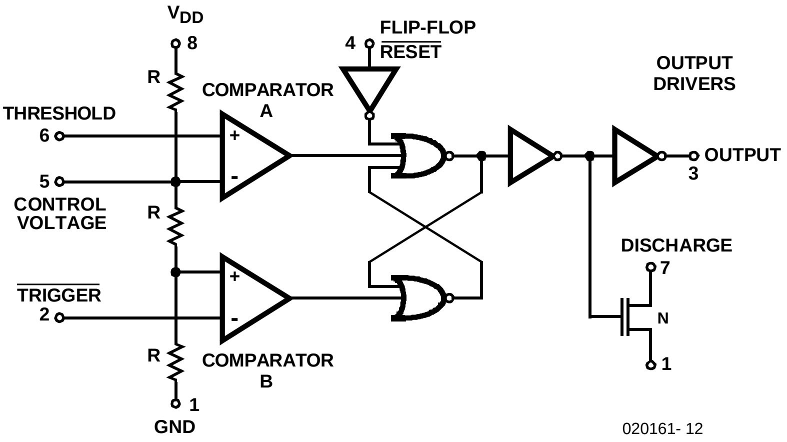


Figure 2. What's inside the 555 timer IC.

Construction, adjustment and practical use

The PCB designed for this month's Mini Project is shown in **Figure 3**. Unfortunately, it is not available

COMPONENTS LIST

Resistors:
R1 = 390Ω
R2 = 22MΩ
R3 = 2MΩ2
R4 = 220kΩ
R5,R9 = 22kΩ
R6 = 2kΩ2
R7 = 220Ω
R8 = 1kΩ
P1 = 2MΩ5 preset
P2 = 25kΩ preset

Capacitors:
C1,C2,C4 = 100nF
C3 = 10µF 63V radial
C5 = 47µF 16V radial

Semiconductors:
D1,D3 = zener diode 5V6, 500mW
D2 = LED, red, high-efficiency (2mA)
T1 = BF245A or BF256A
IC1,IC2 = 555C or TLC555 (CMOS 555)

Miscellaneous:
S1 = rotary switch, 2 poles, 6 positions
S2 = pushbutton, 1 make contact
K1,K2 = 4-way SIL socket for IC pins, turned pins
Case, 60 x 10 x 126 mm with battery compartment
Knob
Moving coil meter, f.s.d.100 µA

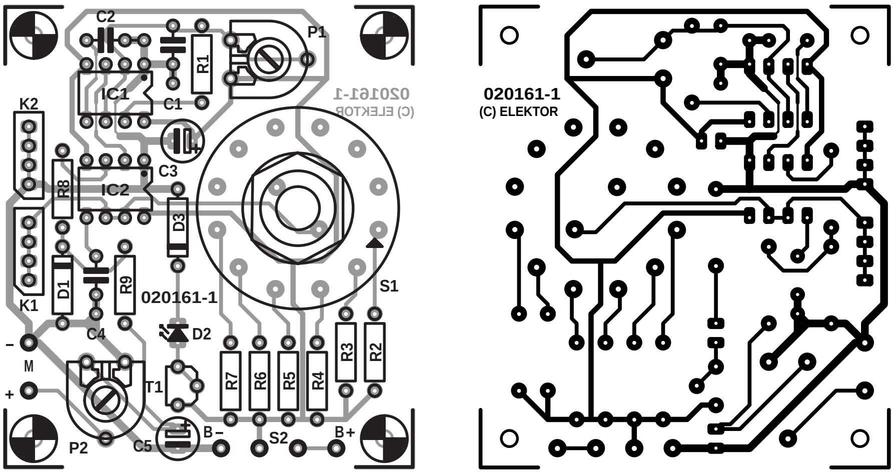
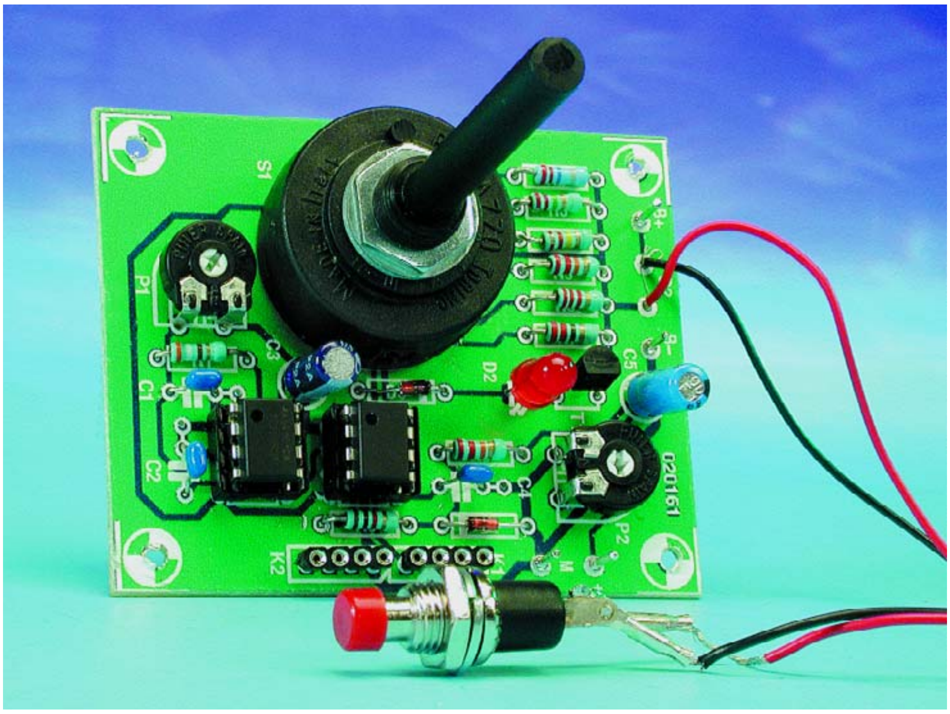


Figure 3. PCB layout, component mounting plan and the way the peripherals are connected up.



ready-made. All components not accommodated on the board (push-button, battery and meter) are connected up via solder pins and short wires. Because long wires represent considerable stray capacitance, the capacitor under test should be plugged straight onto the board. This is made easy by K1 and K2, two ordinary SIL sockets with good-quality (i.e., turned or gold-plated) contacts. The farthest removed contacts allow capacitors with a lead pitch of 20.32 mm to be inserted. If that is not sufficient, there's more room on the board for a longer version of K2.

The circuit has to be adjusted before it is fitted into an enclosure. A suggested front panel layout is shown in **Figure 4**.

The two adjustment points are P1 and P2. P1 determines the measurement frequency and is initially turned fully counter-clockwise. P2 is set to mid-travel. Connect the moving-coil meter or the DVM (set to the 2-volts range), connect a 'known-good' 0.1-microfarad (100nF) high stability capacitor to the test socket, and finally turn S1 to the 200 nF range. Next, connect the battery (watch the polarity) and press S2. The meter may show some deflection at this point. Carefully turn P1 until the meter value suddenly drops by 50% (we know why, don't we?). Next, slowly turn P1 back until the about 90% of the previously noted vale is indicated again. Then adjust P2 for full-scale deflection (100 μA on the moving-coil meter or 1.00 volts on the DVM). That completes the adjustment procedure.

As already noted, we are not discussing a high-precision instrument here, so a measurement error of a few percent should be accepted. Using high-precision resistors in positions R2-R7 will not improve the accuracy — 1% tolerance types are sufficient in all cases. After all, the instrument is aimed at identifying capacitors from the E6 range, which is marked by factors 1, 1.5, 2.2, 3.3, 4.7 and 6.8. Each value is therefore about one and half times that of the previous one ($\sqrt[6]{10}$ or 1.47 to be accurate…). This should allow the present instrument to unerringly identify E6 series capacitors.

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