Autoranging Capacitance Meter

wide-range, PIC-controlled

Design by Flemming Jensen

Most commercial digital Capacitance meters can measure capacitors from a few pFs (picofarads) up to 2,000 μF (microfarads). A few are able to measure up to 20 mF. Circuits like audio power amplifiers, switched-mode power supplies, printers and photocopiers often incorporate really large capacitors in the hundreds of mF range (1 mF = 1,000 μF). With this cheap circuit, you'll be able to measure any capacitors of almost any 'size', from picos to Farads.

Main Features

– Low cost, direct reading,
– Wide range, (from a few pFs up to several Farads)
– Auto-ranging, (no range switches)
– Auto-zeroing, (nulls stray capacitance of connected test leads or test jig on power up)
– Low-Battery indication
– Simple setup

Although the specifications of the Autoranging Capacitance Meter are pretty impressive, the circuit diagram is uncluttered and free from surprises — see **Figure 1**. Using connector K1, the capacitor to be tested, C_x, is connected into a circuit based on the CMOS version of the good old 555 timer IC. Here, the TLC555 is configured as a monostable multivibrator (MMV). The real workhorse in the circuit is a PIC16F84 microcontroller running at 20 MHz. Using two output port lines, the PIC controls the 555's R
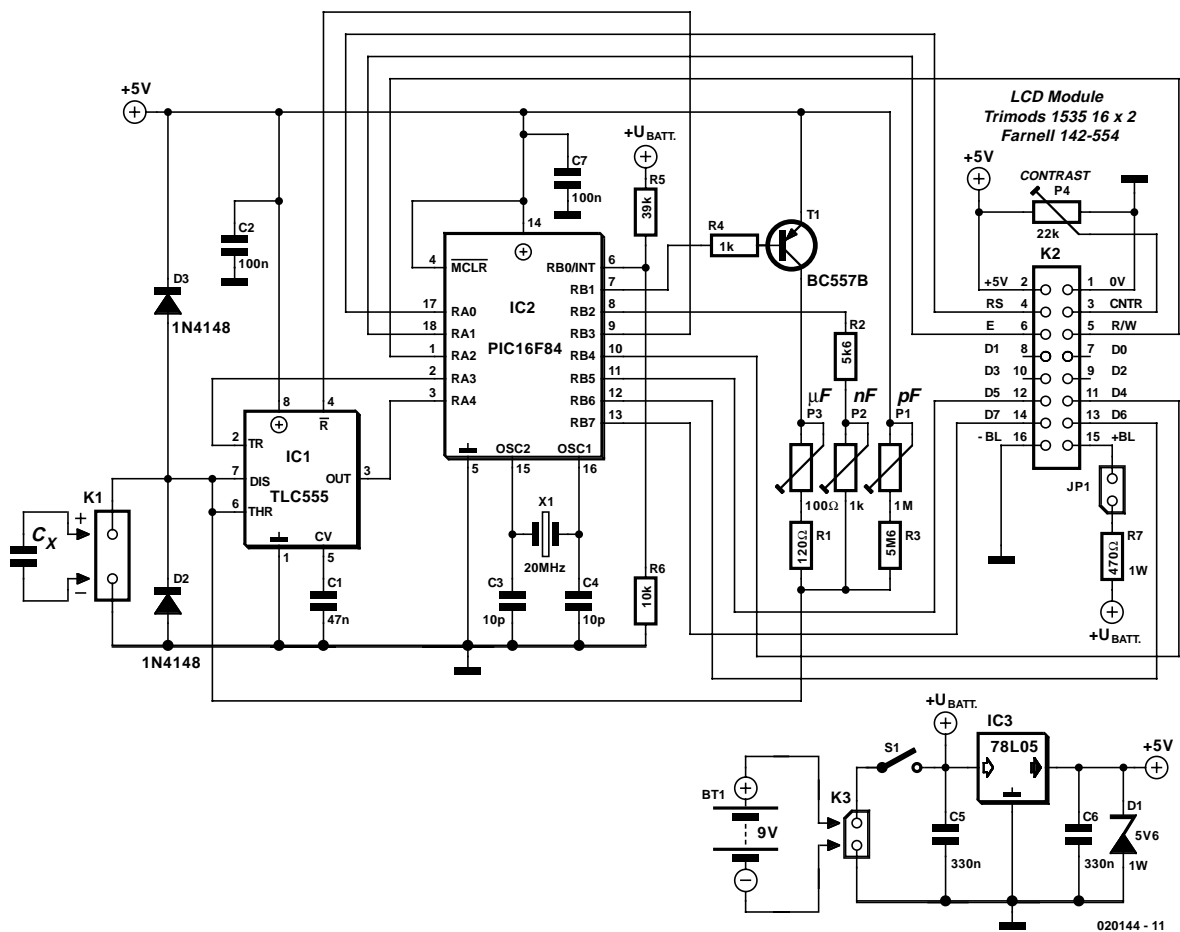
Figure 1. Circuit diagram of the Autoranging Capacitance Meter.

(reset) and TR (trigger) inputs and at the same time senses the logic level at the 555's OUT (output) pin. The larger the capacitance of the capacitor under test, the longer the High time of the pulse at the 555's output. As long as this output is high, the PIC increments a software counter (i.e., a variable). When the 555's output drops Low again the result is processed and sent to the readout. The PIC handles the necessary range switching and controls the LCD module as well.

The meter has three capacitance ranges:

pF   used for capacitors from 1 pF to 9,999 pF
nF   which covers 10 nF to 9999 nF
μF/mF which covers 10 μF and up.

For your convenience, the read-out is modified so the meter will show 1 pF to 999 pF, and 1.00 nF to 9.99 nF. The same goes for the μF range.

The MMV oscillator frequency and hence the calibration for each range is determined by capacitor C_x and the resistance between the parallel-connected DIS (discharge) and THR (threshold) pins of the TLC555 chip. The resistance is range-dependent and is derived from resistor/preset combinations which can be switched into the circuit by the PIC using its RB1 and RB2 port lines.

The LCD, a 2-line, 16-character type is controlled in 4-bit mode. Its backlight may be switched on optionally using jumper JP1.

The power supply is totally standard and based on the 78L05 three-pin fixed voltage regulator. An extra zener diode, D1, is included to prevent any risk of damage to the circuit when the input is overloaded with a direct voltage in excess of the supply voltage (5 V).

The circuit is powered by a 9-volt PP3 battery. Current consumption is in the region of 7 mA with the LCD backlight left off.

Auto-zeroing and auto-ranging

At power-up, the PIC runs a routine that checks the stray capacitance at the input caused by test leads. and puts the result in a variable. This result is later subtracted from the result obtained from the capacitor measurement. Note, however, that this is only true in the pF range. It is therefore important that no capacitor is connected when the instrument is switched on, unless, of course, you intend to cancel a certain amount of stray capacitance. In all other ranges than the pF range, the capacitor may be connected at power-up.

After the zeroing routine, the meter enters the pF range. At this point, any measured capacitance will be recorded and placed in a variable. The auto-ranging functions like this: if the capacitor is too large for the pF range, the count will overflow, and the PIC will select the nF range, i.e., select a lower value charging resistor, and then continue by performing a new measurement. If the capacitance value is still too large, the μF range is selected, and so on. The result is displayed on the two line alphanumeric LCD module.
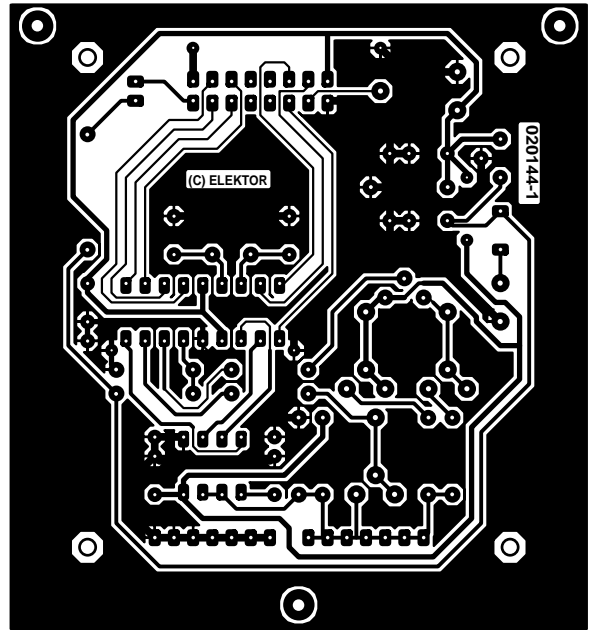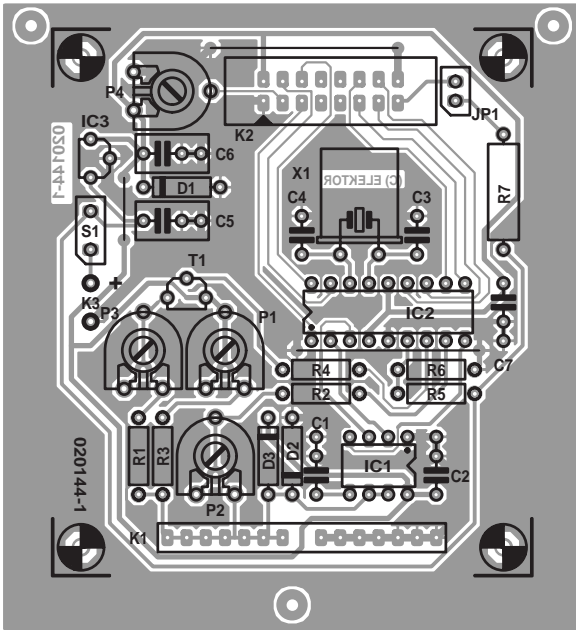
Figure 2. PCB design for the project (board available ready-made).

Hum and noise cancellation

In the pF range, the input represents a very high impedance. In this range the capacitor is charged via a 5 to 6 Megohm resistor and therefore the meter is sensitive to hum and noise picked up via the capacitor leads and the test leads, if used. When measuring capacitors near the low end of the pF range it is essential for the meter to be kept well removed from transformers etc., otherwise a unsteady readout may be the result. To reduce hum and noise pickup even further, the measurement in the pF range is performed twice, with a 10-ms interval. The mean value of the two results is calculated and the result is sent to the readout. This method is sure to give a steadier reading. In the nF and μF ranges, the resistor values in the MMV are relatively low and no special precautions are called for, allowing every single measurement to be read out.

Mode change when measuring large capacitors

Capacitors below 10 mF are measured continuously, i.e., the meter faithfully starts in the pF range. If the count overflows, the nF routine is run. If the count still overflows then the μF routine is run, and so on. Once the proper range is reached, the result is sent to the readout. Next, the whole thing starts all over again: pF routine → overflow → nF routine, → and so on.

Larger capacitors, in excess of 10 mF (10,000 μF = 10×10^{-3} F), are not measured

continuously but four times. A message 'wait' is displayed on the LCD until all four measurements have completed. The result of the fourth measurement is then read out, a message 'ready' is displayed and the result is valid. This method ensures

COMPONENTS LIST

Resistors:
R1 = 120Ω
R2 = 5kΩ6
R3 = 5MΩ6
R4 = 1kΩ
R5 = 39kΩ
R6 = 10kΩ
R7 = 470Ω 1W (see text)
P1 = 1MΩ 10-turn multiturn preset, vertical mounting
P2 = 1kΩ 10-turn multiturn preset, vertical mounting
P3 = 100Ω 10-turn multiturn preset, vertical mounting
P4 = 22kΩ

Capacitors:
C1 = 47nF
C2,C7 = 100nF
C3,C4 = 4pF7
C5,C6 = 330nF

Semiconductors:
D1 = zener diode 5V6 1W
D2,D3 = 1N4148
IC1 = TLC555 (Texas Instruments), 3V555 or TS555 (Thomson)
IC2 = PIC16F84A-20/P, programmed, order code **020144-41**
IC3 = 78L05
T1 = BC559B

Miscellaneous:
BT1 = 9V PP3 (6F22) battery with clip-on connector
JP1 = 2-way pinheader with jumper
K1 = two 7-way socket strips, lead pitch 0.1 inch
K2 = 16-way boxheader
K3 = PCB solder terminals
S1 = on/off switch
X1 = 20MHz quartz crystal
LCD display, 2x16 characters, e.g., Trimods 1536, Farnell # 142-554
Length of 16-way flat cable with IDC socket
Enclosure: e.g., Pactec HPS and HPLS series, type HPS-9VB (28x53x91x146 mm), Farnell # 736-351, see also www.pactecenclosures.com
PCB, order code **020144-1** (see Readers Services page)
Disk, source code and hex files, order code **020144-11** or Free Download

that the capacitor has been fully discharged and charged, gives a reliable reading and guarantees a low current consumption.

To prepare for a new measurement the on/off switch has to be operated.

Figure 3. Close-up view of our prototype board.

Construction
and Troubleshooting

Populating the printed circuit board shown in **Figure 2** should not present problems if you follow the component overlay printed on the ready-made board (or else gleaned from Figure 2) and the information in the parts list. Connector K1 consists of two socket strips that allow capacitors with different pin spacings to be easily connected without introducing too much stray capacitance. Wander (banana) sockets in the traditional colours red and black are used for the test leads.

Depending on the exact LCD type you intend to use you may need to establish a suitable value for resistor R7 in accordance with the current drawn by the backlight lamp inside the LCD. Here, a value of 470 Ω, 1 watt, is given for initial guidance.

The three wire links on the board should be installed first so they are not forgotten later.

Carefully inspect the board for solder blobs, short circuits, dry joints and the orientation of all polarised components. Our working prototype board is shown in **Figure 3**.

Before fitting IC1 and IC2 on the board, check the presence of the +5-volt supply volt-
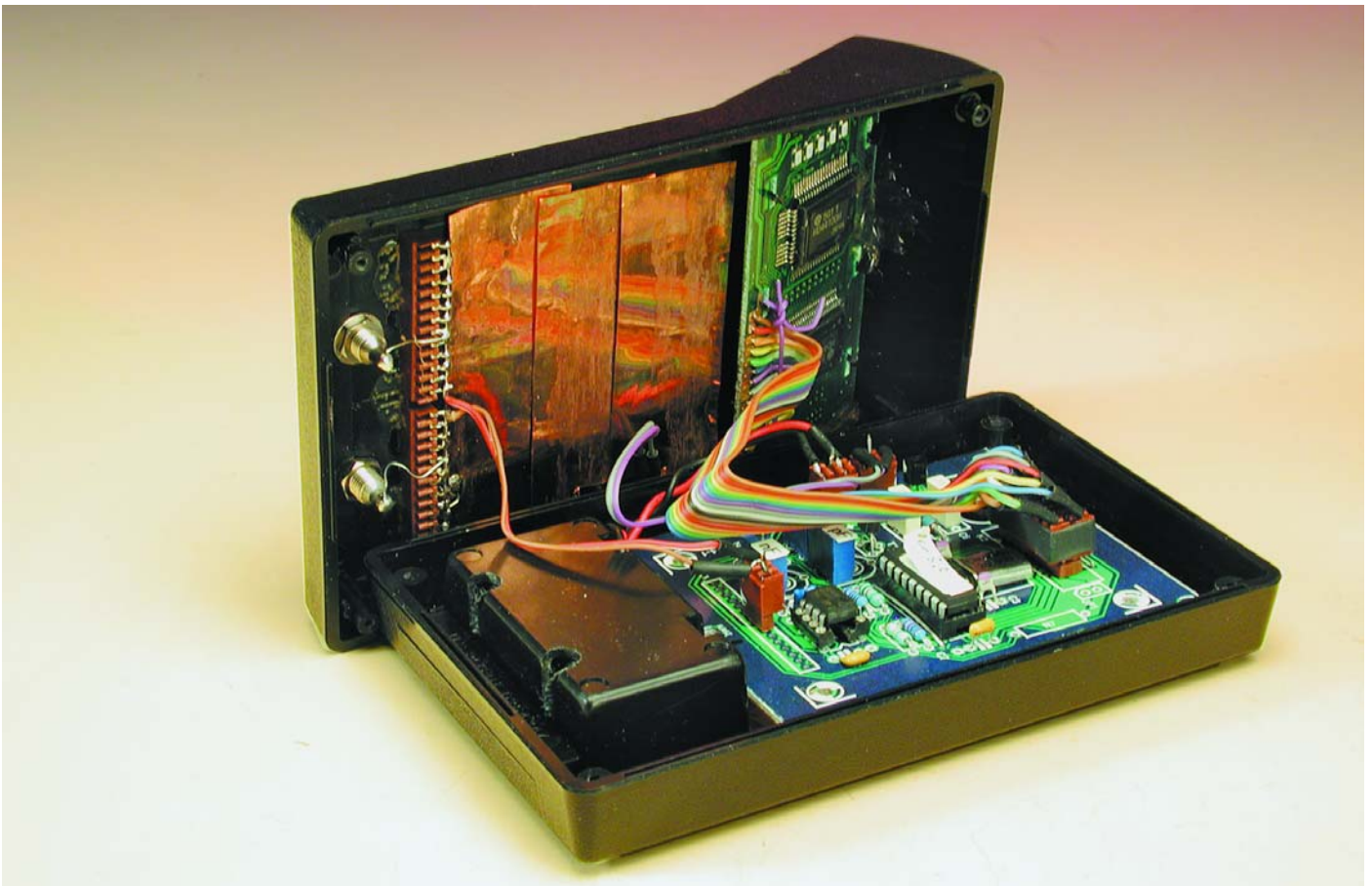

Figure 4. A look inside the case. The copper foil shielding is optional, and only necessary if interference from external sources is a problem.

Things to Remember

Discharge capacitors before testing.

In the pF range: first power up the meter, then connect the capacitor.

Capacitors larger than 10 mF: 4 measurements are performed. When meter signals 'ready' the result is valid. Turn the meter off and back on for a new measurement.

Large capacitors: don't get impatient. A 370-mF cap will take about 10 minutes to test.

age at a few relevant points in the circuit (use the circuit diagram for reference). If everything checks out okay, switch off and install the ICs.

The LCD is connected to the circuit via a boxheader and a short length of flatcable. A suggested mounting method in the Pactec case may be gleaned from the photograph in **Figure 4**.

The board fits exactly on the three moulded bosses in the Pactec case, and is secured using small self-tapping screws. The LCD will have to be secured in the sloping part of the enclosure using glue or a similar substance, but only if its connections to the circuit are known to be correct.

If you don't see anything on the display, turn P4 fully anticlockwise. If this result in a dark upper line, but no text, you probably have a short-circuit between some of the tracks going to the display connector, or you may have some of the display wires mixed up. Check and repair before proceeding.

Figure 4 shows pieces of copper laminate or foil fixed to the inside of the case. A few pieces are also present under the board. This method of screening the sensitive circuit helps to avoid interference. The laminate should be connected to the PCB ground plane.

The suggested Pactec HPS-9VB enclosure has an internal battery compartment and requires a minimum amount of mechanical work. However, you'll have to carefully file away about 1 mm of each side of the LCD module board. This shouldn't be too difficult. There's no need to make any clearance for the LCD module, because the enclosure comes with a loose display panel.

Setting up the instrument using a DMM

Turn the contrast preset P4 fully anticlockwise and then slightly clockwise until a usable contrast is reached. The production

tolerance on a number of makes of the CMOS 555 IC has been examined. In conclusion. we prefer the genuine Texas Instruments TLC55, Thomson TS555 or 3V555IN. If you decide to use other brands it may be necessary to alter the range resistors slightly.

Using close tolerance capacitors as reference devices, and the Thomson 555 ICs it proved possible to set up the next Capacitance Meter and achieve repeatable results by using nothing more than an ordinary multimeter. The only requirement is that the DMM is capable of reliably measuring resistance values in excess of 6 MΩ. This way it should be possible for *Elektor Electronics* readers to avoid special reference capacitors when setting up the instrument.

Remove IC1 and IC2 from their sockets. For the *µF* range: measure the resistance between pin6/7 of IC1 and the collector of T1, and adjust P3 for a 190 Ohm reading. For the nF range: measure the resistance between pin 6/7 of IC1 and pin 8 of IC2, then adjust P2 for a 5.94 kΩ reading. Finally, for pF range: unsolder one end of R3 (the end nearest the K1 connector), then measure the resistance between this end and pin 8 of IC1. Adjust preset P1 for a 6.0 MΩ reading.

Setting up the instrument using reference caps

Turn the contrast preset P4 fully anticlockwise and then slightly clockwise until a usable contrast is reached. To adjust the Capacitance Meter you should get hold of one precision capacitor whose value falls in the pF range, e.g., 470 pF and one that falls in the nF range e.g., 220 nF. These values can be obtained as 1% tolerance from Farnell, among others. A value like 1,000pF is not advisable because it will cause the meter to switch back and forth between a 999 pF and a 1.00 nF reading during adjustment.

Keep the instrument well away from any mains transformers. Be aware that your soldering iron or halogen light source may generate a strong magnetic 50 Hz field. Switch on the instrument and connect the 470-pF precision cap. Adjust P1 for a 470-pF reading. Remove the capaci-

tor and connect the 220-nF cap, then adjust P2 for a 220-nF reading. For the *µF* range it will probably not be possible to get hold of a low-tolerance capacitor and if you do not have access to a commercial capacitance meter you may use an ohmmeter to adjust the series combination R1-P3 for a total resistance of 190 Ω.

SMD and trimming capacitors

If you construct a simple test jig (fixture) to hold SMD capacitors, the auto-zero function will cancel out the capacitance of the jig and make it very easy to test pF-range SMD caps. The same goes for trimmer and tuning capacitors (ceramic, PTFE or air types). Make a simple, mechanically stable jig that allows the capacitor to be soldered to (or into).

Switch on the instrument with the test jig connected up. The stray capacitance of the jig will be cancelled out. Next, solder the trimmer to the jig and measure. Adjust the trimmer and observe the varying capacitance. Make a note of its lowest and highest capacitance.

Burn your own

Assembly-code lovers, as well as those with access to a PIC programmer and blank 16F84 chips will be pleased to know that the author's source and hex code files for this project are available free of charge from the Free Downloads page at www.elektor-electronics.co.uk. The file number is **020144-11** under month of publication.

Final notes

Be sure to discharge any capacitor before testing it. Sure, the Capacitance Meter is equipped with a simple diode input protection, but you would not like to stress it into actual operation, would you? Various other, more advanced, protective circuits have been tested but they all seemed to degrade either the wide range or the accuracy of the meter. Still, the Capacitance Meter is rather robust if you just keep in mind that all capacitors should be fully discharged before testing.

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