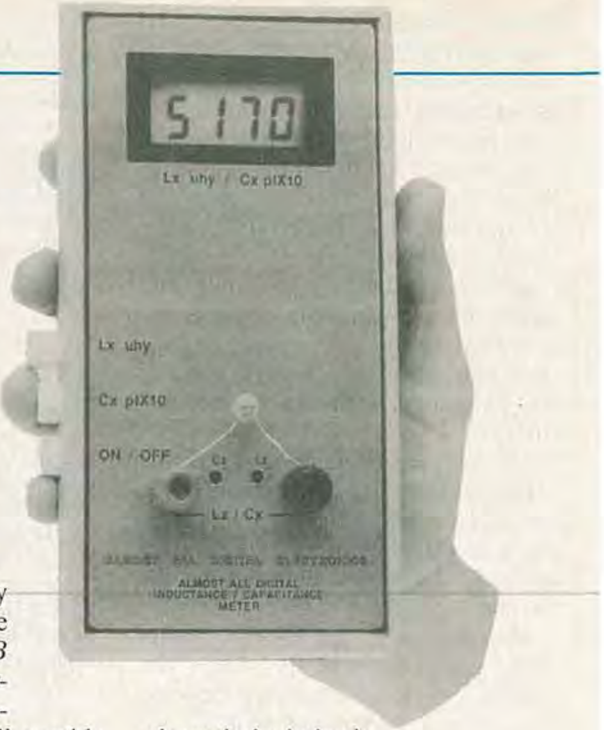
BUILD THIS

LC METER

This month we show you how to build the inductance/capacitance meter, and show you how to get the most out of using it.



NEIL W. HECKT

Part 2 LAST TIME WE EXplained the theory behind the LC meter. Now we build and align the meter so that you'll have a very accurate instrument to add to your lab.

Construction

The instrument is assembled on a double-sided printed-circuit board for which templates are provided in PC Service. Alternately, a PC board having plated-through holes is available from the source given in the Parts List.

The component placement is shown in Fig. 3. Note that the four display drivers, IC8–IC11, are mounted under the liquid-crystal display (DSP1). The display must be mounted about ½ inch off the PC board if it is to be reasonably close to the front panel of the specified Pactec *HPL-9VB* cabinet. Three layers of low-profile 40 pin IC socket-halves plugged together will provide the clearance. On the other hand, both the kit and the finished unit specified in the Parts List contain some Samtec 0.56-inch sockets.

If S1, S2, and S3 are ITT's Cannon-type switches, they mount directly on the PC board. However, the switches supplied with the kit are from a different manufacturer and it is necessary to mount them off the PC board in such a manner that less than 1/32-inch of the longer leads protrude through the board on the solder side. In either case, the correct mounting so the push-button switches will fit through the holes in the cabinet is for the center line of the switch shafts to be 11/32 inch above the component side of the PC board. (Note: The switches in the kit are supplied pre-installed.)

The PC board provides for two 4-pole double-throw switches and one 2-pole double-throw switch. The extra contacts aren't used.

The LM7805 voltage regulator, IC12, lies flat on the board and must have a small piece of plastic electrical tape between it and the PC board to prevent shorting the case of the regulator to the circuit traces. Of course a standard mica insulator can also be used. Heat is not a problem as the unit draws only 17 mA.

Binding posts BP1 and BP2 are mounted in a somewhat unusual way directly to the PC board. Drill clearance holes for two 8-32 screws at the two binding-post locations shown in Fig. 3. Pass the screws through from the bottom of the board and secure ¾-inch 8-32 metal spacers at each location. When the cabinet is assembled, BP1 and BP2 are passed through the cabinet cover into the spacers, making the electrical connections and securing the cabinet.

The completed unit, with the cover removed, is shown in Fig. 4. Notice that no binding posts are shown. Instead, there are threaded spacers in the binding-post locations on the PC board. When the cover is installed the

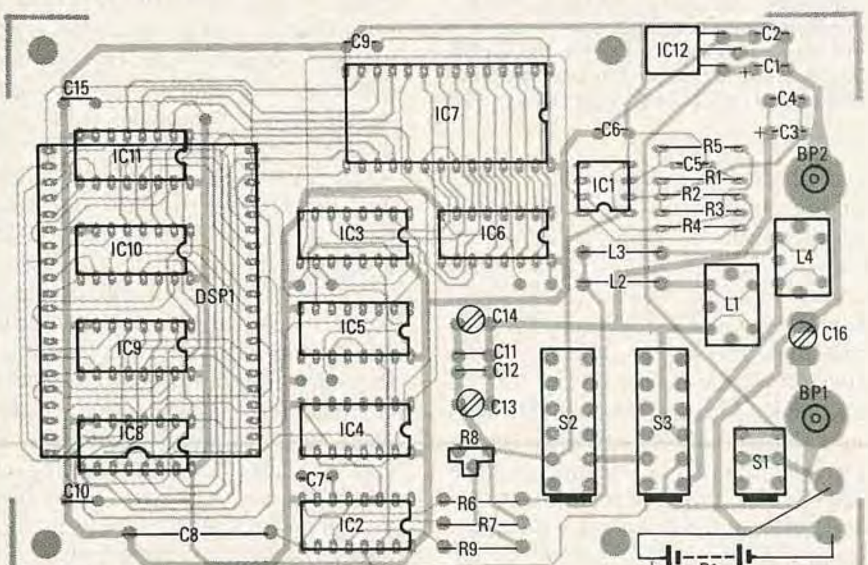


FIG. 3—THE PARTS LAYOUT for the PC board. Four integrated circuits, IC8–IC11, are located directly under the display module (DSP1). Binding posts BP1 and BP2 mount through the enclosure to spacers on the PC board.

binding posts pass through the cover and are screwed into the spacers; thereby securing the cover while providing electrical connections to the meter.

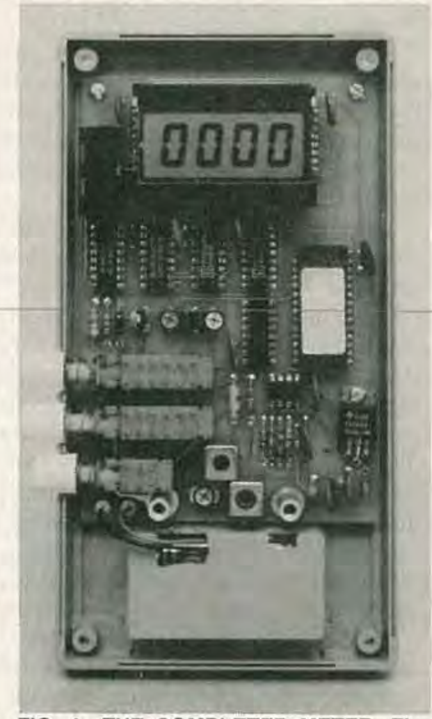


FIG. 4—THE COMPLETED METER. Five IC's are installed on the PC board directly under the display module, which is raised off the board approximately ½ inch so it will be flush with the enclosure's window. The battery is in a separate compartment that is moulded into the bottom of the enclosure.

PARTS LIST

All resistors ¼-watt, 5%, unless otherwise noted.
R1, R2, R7—100,000 ohms
R3, R5—47,000 ohms
R4—1000 ohms
R6—1 Megohm
R8—25,000 ohms, trimmer potentiometer, 0.1" × .2" spacing
R9—4700 ohms

Capacitors
C1, C3—10 μF, 10 volts, tantalum
C2, C4, C5, C9, C10, C15—0.1 μF, 50 volt, ceramic disc
C6—not used
C7—1500 pF, 100 volt, Mylar
C8—2.2 μF, polystyrene (Panasonic *ECQ-1225KZ*)
C11, C12—330 pF, polystyrene or propolyne
*C13—12–70 pF, trimmer capacitor (Mouser *ME242-1270*)
*C14, C16—3–10 pF, trimmer capacitor (Mouser *ME242-2710*)

Semiconductors
IC1—LM311N
IC2—CD4046
IC3—CD4520
IC4—CD4020
IC5—CD4022
IC6—CD4040
IC7—27C256 special programmed EPROM (see ordering note below)
IC8—CD4054
IC9–IC11—CD4056
IC12—LM7805CT
†DSP1—four digit LCD display, AND *FE0202*

Inductors
*L1—39 μH, variable inductor (Toko *154ANS-T1016Z*)
*L2—33 μH (J. W. Miller *8230-56*)
*L3—0.39 μH (J. W. Miller *8230-10*)
*L4—0.33 μH, variable inductor (Toko *BTKXNS-T1047Z*)

Other components
B1—9-volt battery
*BP1, BP2—5-way binding post with 8-32 thread
*S1, S2, S3—DPDT alternate action switch (ITT Schadow *51281*)
*3—pushbuttons for S1–S3
†2—LCD sockets
*2—8-32 × ¾-inch threaded spacer with mounting hardware
*2—8-32 screws and star washers
*1—battery terminal clip !1—socket for DSP1, Samtec *ESQ-120-12-T-S*
1—enclosure, Pactec *HPL-9VB*

Note: The following parts and kits are available from Almost All Digital Electronics, 5211 117th St. SE, Bellevue, WA 98006.
A complete kit containing all components in the parts list with the exception of the EPROM, display kit, enclosure, and the PC board: $69.95. A kit of hard-to-locate parts consisting of those indicated in the parts list with the * symbol: $29.95. The programmed EPROM: $19.95. The display kit consisting of those parts indicated in the parts list with a † symbol: $14.95. The enclosure, with all holes machined and a front panel decal: $19.95. The PC board with plated-through holes: $19.95
A complete semi-kit (the switches are mounted and soldered) consisting of all of the above and a "standard" capacitor for calibration: $149.95.
The completely assembled, tested, and calibrated unit: $169.95. Add $5 for shipping and handling per total order. Washington residents must add 8% sales tax.

Alignment

All that's needed to align the unit is a frequency counter and a capacitor of approximately 68,000 pF who's value is known to an accuracy of at least 1%. That capacitor is much larger than the 705-pF standard capacitor in the tank circuit, making the standard capacitor insignificant when adjusting the standard 70.5-μH inductor.

Ignore the display during the initial alignment because it might be doing some pretty wild things if the PLL is not in lock. (That particular adjustment will be made after the oscillator alignment.) Connect the frequency counter to pin 14 of IC3. The frequency at that location is the oscillator frequency/16.

First calculate the oscillator frequency when your known capacitor will be in the circuit:

$$f2=1/(2 \times \pi \times \sqrt{(70.5E\text{-}6 \times (C_K + 705)E\text{-}12)})/16$$

where C_K is your known capacitor in pF. ($f2$ should be about 4500 Hz.)

Connect C_K across the test jacks, depress C_X switch S3, and adjust L1 to obtain the calculated frequency ±10 Hz. Release S3 and set coarse-adjustment C13 (12–70 pF) and fine-adjustment C14 (3–10 pF) to obtain a frequency of 44,582Hz ±100 Hz. You may want to repeat the entire procedure several times because there is some interaction between the adjustment of L1 and the capacitors.

Finally, set R8 to the center of the adjustment range that produces 0000 on the display. The lock range is fairly large so the adjustment isn't critical. The center of the range will provide the best long-term stability rather than any immediate benefit.

The 9-volt battery-terminal clip cannot be installed until the PC board is installed in the cabinet because the clip cannot fit through the opening to the cabinet's battery compartment. Alternately, you can cut away part of the battery compartment's wall so the clip can then slide through into the compartment.

Final adjustment

After final assembly, the only remaining operation is to adjust the zero-trimmers for the binding posts. Use a non-metallic alignment tool for the adjustments.

With nothing connected to the binding posts, depress switch S3 and adjust C16 for a 0.00 pF reading. The adjustment will be somewhat tricky because the 3–10 pF trimmer capacitor is very tiny and has only a ½-turn range.

Next, place a piece of braided solder wick (which is about as close to zero inductance as you can get) across the binding posts and depress switch S2. Adjust inductor L4 for a reading of 0.00.

Note: The C16-adjustment reading is hard to maintain because the effect of your hand's capacitance is well within the range of the instrument. Rather than habitually make the zero adjustment, or when using test leads, we suggest you measure the open circuit capacitance and/or short-circuit inductance as described above— including test leads if any, and subtract those values from the final reading. The range of the zero adjustments is too small to compensate for test leads anyway.

The offset drift of the zero adjustments is usually only $\pm$0.01–0.02 µH, and therefore becomes insignificant (1% to 2%) when measuring components with values greater than 1 µH or 10 pF.

Accuracy

Using 31 inductors ranging in value from 0.1 µH to 6800 µH, and 35 capacitors ranging from 2.7 pF to 0.1 µF, the average error for inductance measurements, compared to the measurements of a 1-MHz digital *HP4275A* laboratory-type LCR bridge was 1.58%. Percentages for values below 0.1 µH lose meaning because the 0.01-µH resolution would cause a minimum percentage error of 10%, degrading to 100% at 0.01 µH.

The average error for capacitors was 0.78%. Percentages for values below 1.0 pF lose meaning because the 0.10-pF resolution would cause a minimum percentage error of 10%, degrading to 100% at 0.10 pF

When the same components were measured on an *HP4274A* digital LCR bridge, at 100 kHz the average error between the two laboratory instruments was 10.17% for inductors and 7.12% for capacitors. **R-E**