Almost All Digital Electronics

L/C Meter IIB
Neil Heckt

Please read, or at least scan, the instructions all the way through before beginning assembly. Will save you a lot of time later. Only takes a minute.

• Specifications

Range

- **.001 µHy (1 nHy) to 100 mHy (most units measure to 150 mHy)**
- **.010 pF to 1 µFd (most units measure to 1.5 uFd)**
- **(Capacitors must be non-polarized)**
- **AUTOMATIC RANGING**

Accuracy 1% of reading Typical

- **Typical means the average error for 60 inductance calibration standards:**
  - **20 HP 16470A standard calibration inductors**
  - **16 Booton type 103A standard calibration inductors**
  - **6 Booton type 62-2A standard calibration inductors**
  - **18 Marconi type TM 4520 standard calibration inductors**
- **and 83 capacitance calibration standards**
  - **7 Heathkit 0.25% capacitance calibration standards**
  - **37 Vero 0.1% capacitance calibration standards**
  - **39 0.5% decade capacitance calibration standard**
  - **10 2% high value capacitance calibration standards**
- **See http://www.aade.com/lcm2binst/HP.html for detailed results.**
- **SELF-CALIBRATING**

Display

16 Char intelligent LCD
Four Digit Resolution
Direct display in engineering units, ie: Lx= 1.234 µHy / Cx= 123.4 pF

Sampling Rate:

Approximately 5 samples / second. (will track while adjusting adjustable components)

The unit displays values in one of two modes which can be changed during operation. The "micro mode" displays values in uHy, mHy, pF, and uF when applicable. In this mode, for example, 10.00 nano-Farads displays as .01000 micro-Farads and 1 nano-Henry displays as .001 micro-Hy. It is for old timers like me and is the way many parts are marked. The "nano mode" is for those more metrically inclined. Table 1 shows how each range is displayed in each mode.

INDUCTANCE nano mode	INDUCTANCE micro mode	CAPACITANCE nano mode	CAPACITANCE micro mode
000-999 nHy	0.000 - 0.999 µHy	0.00 - 0.99 pF	0.00 - 0.99 pF
1.000 - 9.999 µHy	1.000 - 9.999 µHy	1.00 - 9.99 pF	1.00 - 9.99 pF
10.00 - 99.99 µHy	10.00 - 99.99 µHy	10.00 - 99.99 pF	10.00 - 99.99 pF
100.0 - 999.9 µHy	100.0 - 999.9 µHy	100.0 - 999.9 pF	100.0 - 999.9 pF
1.000 - 1.999 mHy	1.000 - 1.999 mHy	1.000 - 9.999 nF	1000 - 9999 pF
10.00 - 99.99 mHy	10.00 - 99.99 mHy	10.00 - 99.99 nF	.01000 - .09999 µF
100.0 - 150.0 mHy *	100.0 - 150.0 mHy *	100.0 - 999.9 nF	.1000 - .9999 µFd
		1.000 - 1.500 µFd *	1.000 - 1.500 µFd *

TABLE 1. Display Options (* Some values may be out of range).

Operating Modes

When the **Lx** and **Cx** switches are off pressing the **ZERO** button sequences L/C Meter IIB through five different operating modes.

READY MEASURE n measures Lx or Cx and displays the result in "nano mode"
ie: Lx = 99 nHy, Cx = 12.34 nF

READY MEASURE u measures Lx or Cx and displays the result in "micro mode"
id: Lx = .099 uHy, Cx = .01234 uF

READY MATCHnMODE first measures a reference component Lz or Cz and displays the value in "nano mode". When the **ZERO** button is pressed this value is stored in RAM and the difference between it and subsequent components is displayed in "nano mode"
ie: Lx - Lz = 99 nHy, Cx - Cz = 12.34 nF

READY MATCHuMODE first measures a reference component Lz or Cz and displays the value in "micro mode". When the **ZERO** button is pressed this value is stored in RAM and the difference between it and subsequent components is displayed in "micro mode"
ie: Lx - Lz = .099 uHy, Cx - Cz = .01234 uF

READY MATCH%MODE first measures a reference component Lz or Cz and displays the value in "nano mode". When the **ZERO** button is pressed this value is stored in RAM and the ratio of the difference between it and subsequent components is displayed in percent.
ie: (Lx - Lz)/Lz*100 =12.34%, (Cx - Cz)/Cz*100 = 12.34%

Note that a positive reading in the matching modes means Lx is greater than Lz or Cx is greater than Cz and vice versa.

L/C Meter II is intended to measure inductors and capacitors "out of the circuit". Inductors must have a reasonable Q for their value and negligible distributed capacitance for their value. I have tested it using commercially available RF chokes ranging from 0.1 micro-Henry to 1000 mico-Henry, Hash chokes up to 100 mico-Henry wound on ferrite rods, on Pi-wound RF chokes up to 7.5 milli-Henry, on toroid wound inductors up to 150 milli-Henry (such as the HI-Q series obtainable from Mouser Electronics), and on several slug tuned inductors from a Coilcraft Slot-10 designers kit (similar to the TOKO line of tunable inductors).

Stray Inductance and Capacitance

The circuit traces on the PCB, the switches, and the test leads all contribute a small amount of "Stray" inductance (Ls) and capacitance (Cs). These stray values add to the values of Lx or Cx. The unit is zeroed by pressing the ZERO switch which causes the unit to store the values of stray inductance or capacitance and subtracts them from the measured values.

To zero Ls the operator must short circuit the test leads, press Lx and then press the ZERO button. **For small values of inductance maximum accuracy is obtained if you short the test leads before you turn the unit on.**

Similarly, for capacitors, the operator open circuits the test leads, presses Cx and then presses ZERO.

The stored values of Ls and Cs are saved until the operating mode is changed. When measuring components, it is not necessary to re-ZERO between components. When the operating mode is changed from MEASURE to MATCH these values are reset to zero.

If an inductor is inserted when the Cx switch is depressed it will display "NOT A CAPACITOR". This does not work for very large values of Lx and the unit may display an erroneous reading.

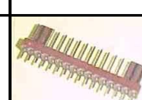
Putting a capacitor in when the Lx switch is pressed displays "NOT AN INDUCTOR". This is not true for very large values of Cx in which case the unit may display an erroneous reading.

L/C Meter IIB can zero out ANY value in its range. If a value is inserted and ZERO'd the unit will display the difference between it and subsequent components similar to the MATCHnMODE and MATCHuMODEs. The difference in the MATCHxMODEs is that the range is frozen to the resolution of the initial component. This limits the minimum difference in values to be 1 part in 10,000 or .01%. The reason for this may not be obvious. The maximum resolution of the unit is four digits **at the value of the components being measured**. Consider two components, one with an exact value of 5000 pF and the other with an exact value of 5010.25 pF. The difference would be 10.25 pF, however the unit cannot resolve less than 1 pF at this range and it would be misleading to display the fractional portion of the difference.

About winding toroid inductors

The inductance obtained winding toroid inductors depends on several things. Winding diameter, length, number of turns etc. (similar to air wound but on a higher permeability core). Just as in airwound, inductance can be varied by varying the length of the winding. **AL values are normally specified for windings spaced over at least 80% of the core circumference and wound tightly to maximize magnetic coupling**.

As a test I *close wound* 10 turns #20 wire on a T-50-6, AL = 40 uHy/100 turns
The calculated L was 0.4uHy
Measured value was 0.7uHy
I then spread the turns evenly over at least 80% of the core.
Measured value was 0.45uHy.
Clearly winding method has large influence on inductance.
A wealth of information can be found at http://www.micrometals.com/ and http://www.bytemark.com/

Parts List	Not a complete inventory! To help you identify parts	Suggest sort your parts alongside their pictures
R1, R2, R3	100K ohm 1/4 watt	 brown / black / yellow
R4	47K ohm 1/4 watt	 yellow / violet / orange
R5	1000 ohm 1/4 watt	 brown / black / red
R6	Contrast Potentiometer **(value not critical)**	
C1	680pF **(disc ceramic marked 681 in very tiny print)** with short leads	
C2a	1000pf 2% **(C2a and b are packed in a little brown envelope)**	 or 
C2b	1pf to 39pf NPO as required to make exact total.	
C5,C6	0.1 µFd film **(Yellow marked 100n)**	
C3	10 µFd /10v Tantalum **(tan tear drop shaped, observe polarity)**	
C4,C9,C10	10 µFd /10v electrolytic **Actually, these are bipolar, non-polorized**	
C7,C8	22 pF ceramic **(brown monolythic marked 22J)(value may vary from 20 to 27pF)**	
C11	2.2pF **(Brown disc with black top labeled 2.2C)**	
X1	8.0 MHz crystal	
L1	68µHy	
U1	LM311N voltage comparitor	
U2	PIC16C622 microcomputer	
U3	LT1121CZ-5 low drop-out voltage regulator	
RLY1	SPST N.O. reed relay (has internal diode, observe install orientation) May be Black or Silver	
DISP	LM-16151 or equiv'	
J1	16 pin **female** square post socket **See important note in the instructions about installing this**	 **(install on display)**
P1	16 pin **male** square post plug	 **(install on PCB)**
Lx, Cx, PWR	DPDT **alternate action** SW **make sure you put them in the PWR, Lx and Cx positions**	 3 are alternate action push on / push off
ZERO	DPDT **momentary** SW Make sure you get it in the ZERO button position	 one is momentary
Test Jacks	binding posts	

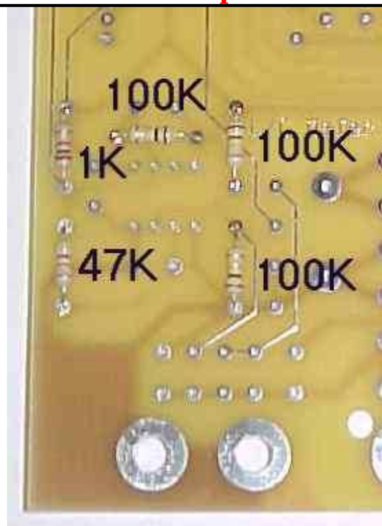
If you receive some extra resistors or capacitors ignore them. I dropped them in by mistake and it was not worth the effort to fish them out of the bag.

Color of parts may vary, refer to parts list for current production.

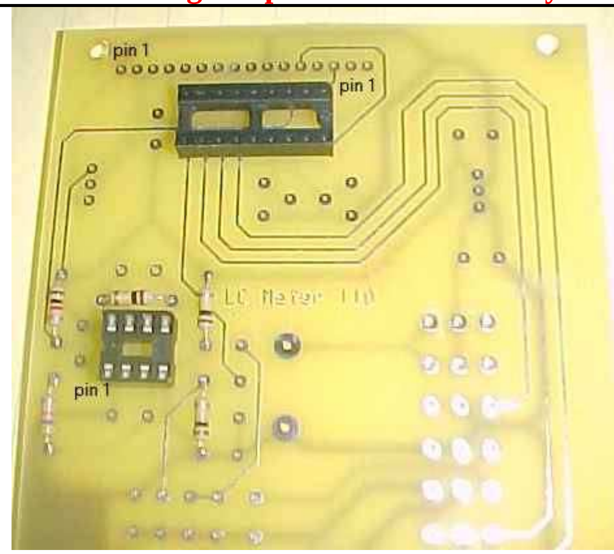
Construction (There is a layout drawing on last page for you to check your work)

NOTE: there is only 3/8 inch space under the display, leave enough lead length to tip regulator and two electrolytics at an angle so that the vertical dimension does not exceed 3/8 inch.

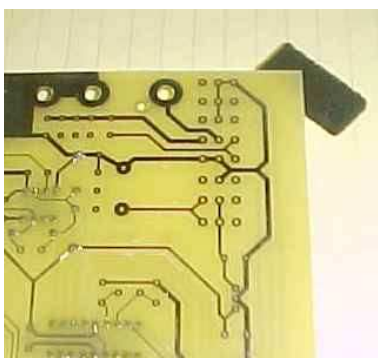
Current production uses components small enough to fit without having to tip them out of the way.



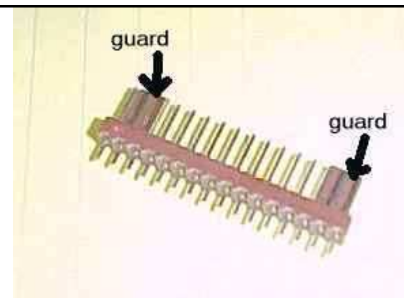
Begin by installing the resistors.



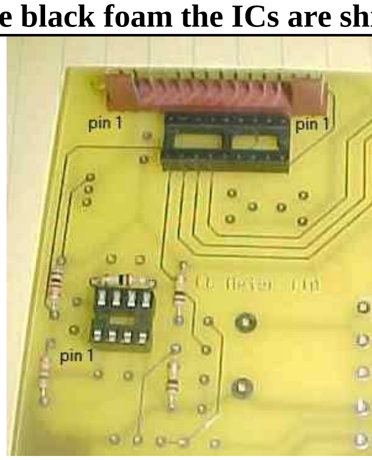
Then the IC sockets



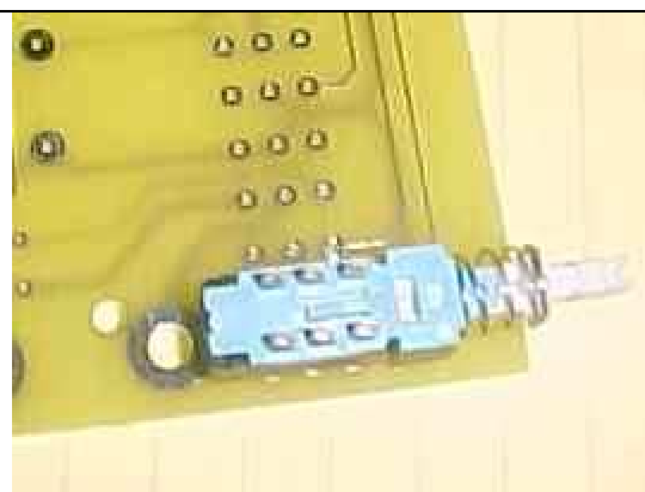
When soldering the sockets, support the corner Using the black foam the ICs are shipped on.



If you received a 14 pin connector install it in pins 1-14 of the PCB. Current production is the 16 pin connector shown.

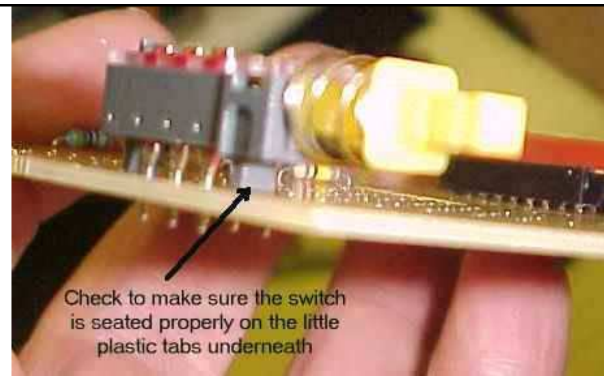


Install the connector with the guard toward the bottom of the PCB. Might require some pushing to get it seated all the way down.

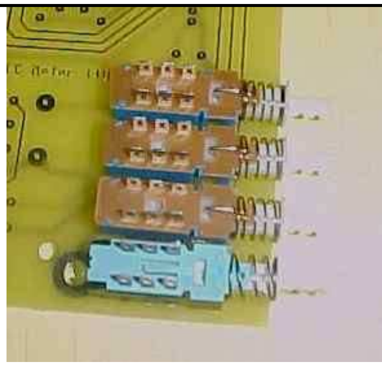


Install the *momentary action* ZERO switch.

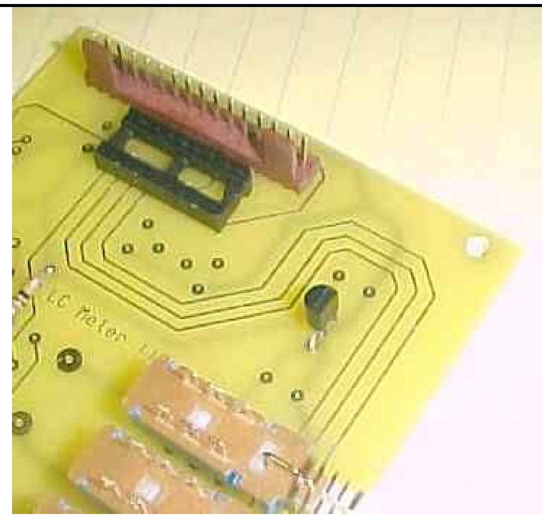
Solder just one pin



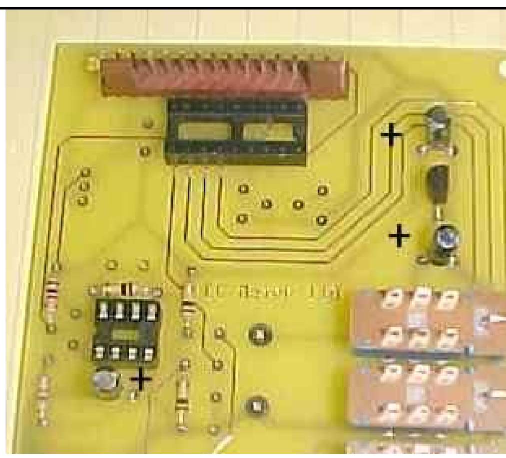
Check to make sure the switch is seated squarely on the plastic tabs then solder remaining pins.



Install the remaining three *alternate action* switches. Solder only one pin on each switch then make sure They are all aligned with each other and seated squarely on the plastic tabs then solder the rest.



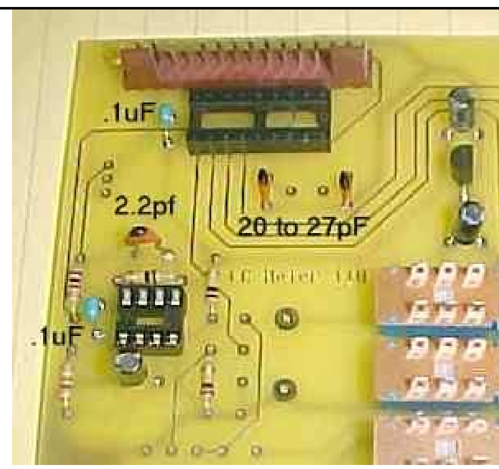
Install the voltage regulator flat side toward right



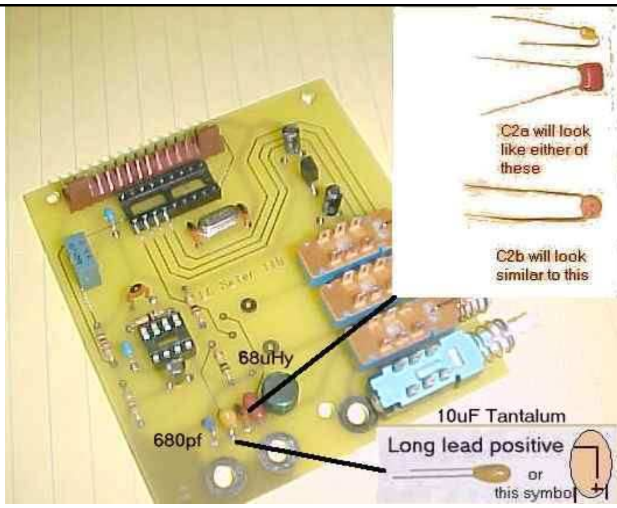
Install the three 10uF electrolytics with polarity as shown above.

(These are non-polorized)

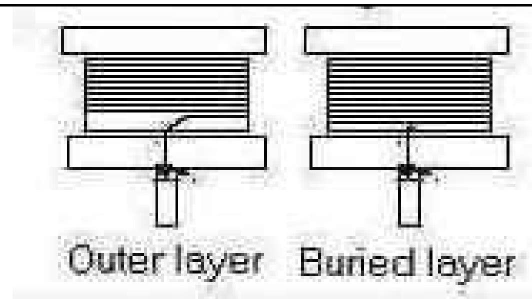
install them in either direction



Install the two 0.1uF ceramics, the 2.2pF ceramic and the two 20 to 27pF (value not critical) ceramics .1uF caps are yellow in current production.

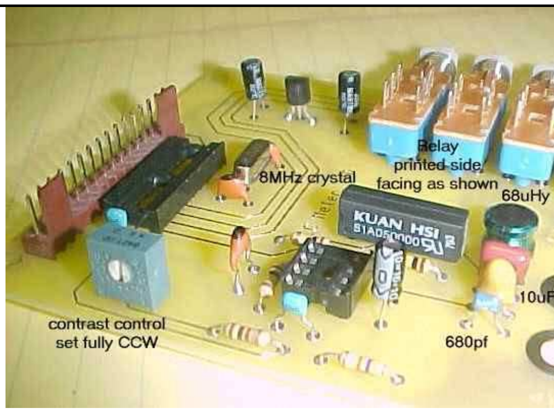


Install the 680pF ceramic, 10uF tantalum (positive toward 8 pin dip socket). Then install C2a and b which are in a little brown envelope.



L1 installation.

I don't know why but best results are obtained if the terminal connected to the outer layer is toward the bottom of the pcb.
Careful inspection will reveal that the other lead clearly goes to a buried layer.



Install L1 (68uHy) Install contrast control and initially set fully CCW. (It may have to be fully CW)
Install the crystal between the two 22pf caps.
Install the relay with printing toward the LM311 socket as shown left. The relay has an internal diode so it has a polarity

Install the two spacers using #8 washer and screw from the bottom of the pcb.

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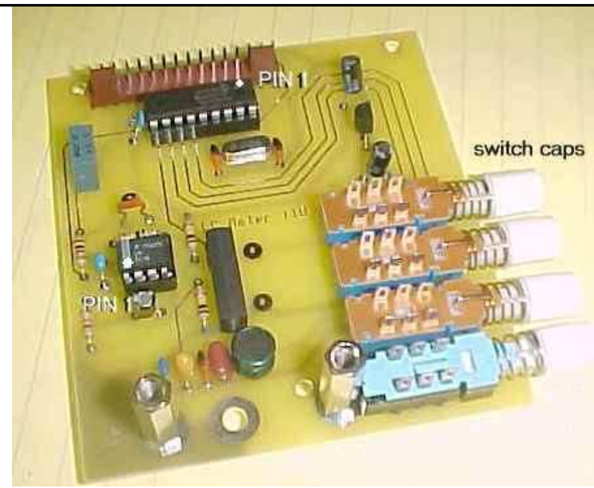
Install the female header connector on the display. If the connector is missing a pin make sure it is over position 16 and not position 1. Pins 15 and 16 are not used by the meter.
Remove the thin scratch protection film from the front of the display.

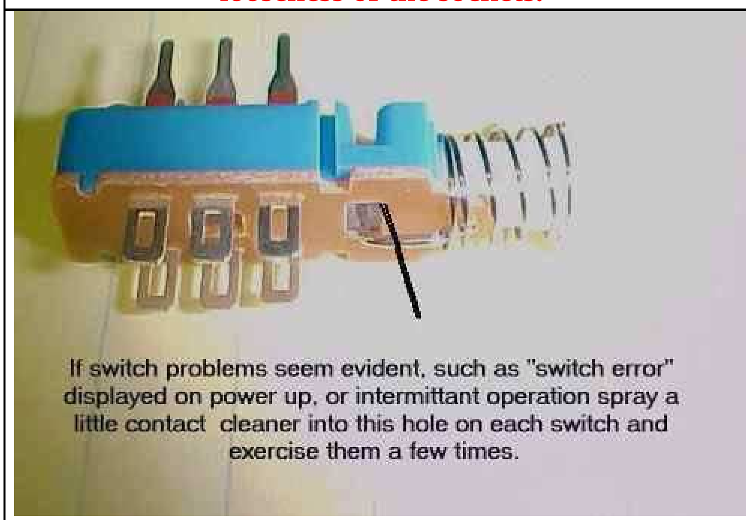
For a 14 pin connector use pads 1-14,
For 16 pin connector use all pads

Solder only one pin, check to make sure connector is at right angle then solder remaining pins.

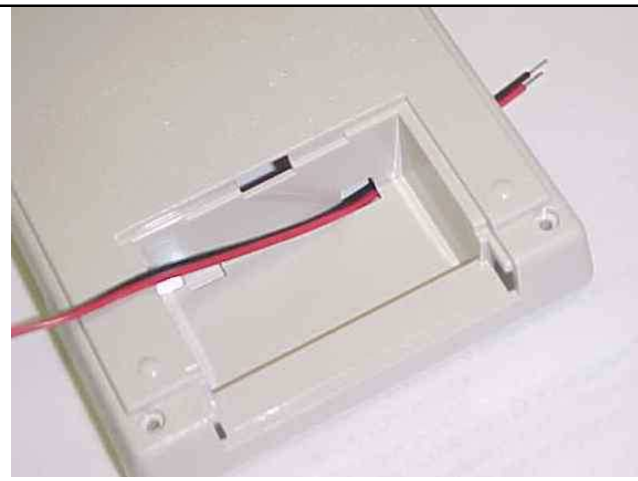
Actually, an angle of about 100 degrees is even better since it will be more parallel to the window due to looseness of the sockets.



Install the PIC16C622 and LM311 as shown above with white dot indicating pin 1.
Install the switch caps by pushing them onto the square Switch posts. They snap all the way to the spring
They go on hard

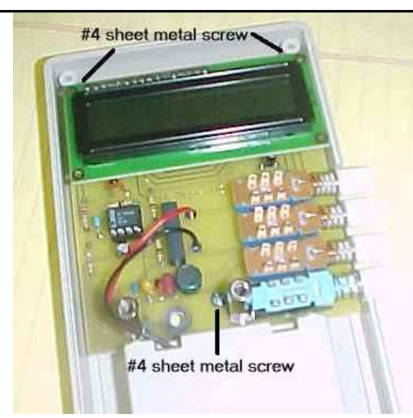


Recommend Radio Shack 640-4345 contact cleaner
Or
From Lowes Hardware, CRC QD contact cleaner



Take the cover off the enclosure battery box and thread the battery wires through the cutout as shown above.

Insert those wires into the PCB as shown above and solder on the back side. At this point you can test the unit by attaching a 9 volt battery and turning the unit on. You should see the power up sequence described in the text below and can adjust the contrast control if needed.



Install the unit in the enclosure using the three #4 sheet metal screws.

Put the front cover on the enclosure. Disassemble the test jacks as shown above and discard the parts circled.

Reassemble the remaining parts and screw them into the threaded spacers visible through the holes in the enclosure. **Then put on the knurled parts but do not over tighten.**

Assembling the optional SMD probe is a bit of a no brainer. Just remember to clip the plastic part at the tips even with the metal part using a finger nail clipper as shown above upper right.

The kit of parts is shown on the top and the finished product and how to use it on the bottom.

Put the four #2 sheet metal screws into the back to secure the enclosure.
Turn the unit on and enjoy the fruits of your labor.

The unit will display "L/C Meter IIB" for 10 seconds followed by "CALIBRATING" for two seconds followed by "READY MEASURE x". If so, you're up and running. Adjust the contrast control so the background is just barely visible.

Troubleshooting

It is very unlikely you will have any problems, however, if you just can't seem to get it to work I will try to fix it free except for a $6.00 return postage and handling fee.

If it did not work, remove the PCB and carefully inspect to see you have soldered everything that should be soldered and have not soldered anything that should not be (look for solder bridges). Bad soldering accounts for most units that fail to work immediately. Here are some hints on where to look.

1) **Blank display, contrast control not adjusted correctly. Start with it fully counter clockwise. This is the number one problem I get calls on.**

2) **On rare occasions a through-hole plating may not have gone through from the bottom to the top of the PCB. Check those few pads on the top side that have circuit traces and solder the component lead on the top side of the PCB as well as the bottom. This has only occurred once in 6000 units so unlikely.**

3) **Blank display, check 5V power to CPU and display. If you ever applied reverse voltage, even for a moment, or if you installed the PIC16C622 in backwards you have blown the voltage regulator. Surprisingly, the PIC usually survives.**

4) **Displays 8 black squares, CPU not communicating with display. Check solder around CPU and display. CPU crystal not oscillating. Check with oscilloscope if possible.**

5) **Displays only the first 8 characters. Crystal frequency too high because crystal is mis-marked. This has only happened once in over 6000 units so not too probable. Call me for replacement.**

6) **Displays WAIT, then CALIBRATING and sticks in CALIBRATING. Oscillator (LM311) is not oscillating. Check soldering around LM311, LM311 properly installed, parts properly installed. C3 in backwards? .**

7) **Also the ZERO button may be stuck in or not soldered. Check continuity to ground from pin 13 of the CPU. Switches intermittent, See item 10)**

8) **Seems to work but readings appear way off from components marked value. Relay in backwards (relay should be installed with its part number opposite the switches and towards the LM311). Calibration capacitors not correctly installed (you put some other part where they are supposed to go), C3 installed backward (+ terminal should be toward top, display end of the PCB)**

9) **Does not measure values above about .1 to .2 uF (should measure to 1 uF) . Measure directly across test jacks or use shorter test leads (about 3"). I absolutely do not have a clue why this may be necessary.**

10) **Switches seem noisy, nonfunctional or intermittent (may power up with "Switch Error"). Spray a little contact cleaner into the openings on the top of the switches and exercise them a few times (See instructions for details).**

11) **Does not measure polarized capacitors, capacitors over 1.5uF or inductors over 150mHy. These values exceed the units specifications. It is for measuring the small values found in radio frequency circuits. It does not measure polarized capacitors such as electrolytics.**

12) **When measuring capacitors the value may change rapidly at first finally settling to a stable value.** Some capacitors make excellent temperature sensors. The meter puts a small amount of current thru the cap being measured and changes its temperature. The temperature must stabilize before the capacitance will. You can determine if temperature is the cause by squeezing the cap between your fingers to heat it up and watch the meter. The cap will change value rapidly and when you let go will slowly go back to a stable reading.

13) **Display shows badly misspelled words.** You have a solder bridge between two of the data lines to the display. (See schematic for details).

Operation

The unit is intended to measure components designed to be inductors or capacitors, not items which may happen to have inductance or capacitance such as motors, power transformers, solenoids, relays, metal detector coils etc. These need to be measured at very low frequencies due to huge core losses at higher frequencies. Results may vary when measuring such items.

The typical stray inductance is .04 to .06 µHy's and the typical stray capacitance is 5 to 7 pF's. When measuring inductors less than 5 µHy's or capacitance's less than 50 pF's it is advisable to ZERO the unit first. . For larger values the strays are insignificant to the result. It is difficult to retain a reading of 0.000 pF's because of the extreme sensitivity of the unit. Your body capacitance influences the reading. Try ZEROing the capacitance and then move your hands around the test leads without touching them. You will find your can adjust the reading a few hundredths of a pF.
To measure inductance place the unknown across the test leads and depress Lx. To measure capacitance place the unknown across the test leads and press Cx.
The oscillator tends to drift a few Hertz during the first few minutes of operation. When measuring very small values the unit should be allowed to warm up for about five minutes. With a resolution of 5 Hz, thermal drift will always occur as evidenced by a slowly drifting reading. The first readings after pressing Lx or Cx are the most accurate.
Accuracy and Resolution
L/C Meter IIB has four digit resolution which for small values of L and C are 1 nHy and .01 pF. You cannot accurately measure values this small. The resolution greatly exceeds the accuracy. You can measure values as small as .01µHy and .1 pF with about 15% accuracy. You generally won't find components this small. For example a piece of wire less than one inch long is .01 µHy. The resolution is, however, relative and can be used for sorting a batch of similar components as it truly does indicate which are slightly larger of smaller than others. Also, for small values of inductance, the leads will contribute quite a bit to the value. Measuring from the ends of the leads instead of next to the body of the component can add up to .025µHy.
For small values the frequency of operation (test frequency) is about 750 KHz decreasing to about 60 KHz at .1 µFd's or 10 mHy's and about 20 KHz at 1 µFd or 100 mHy's.

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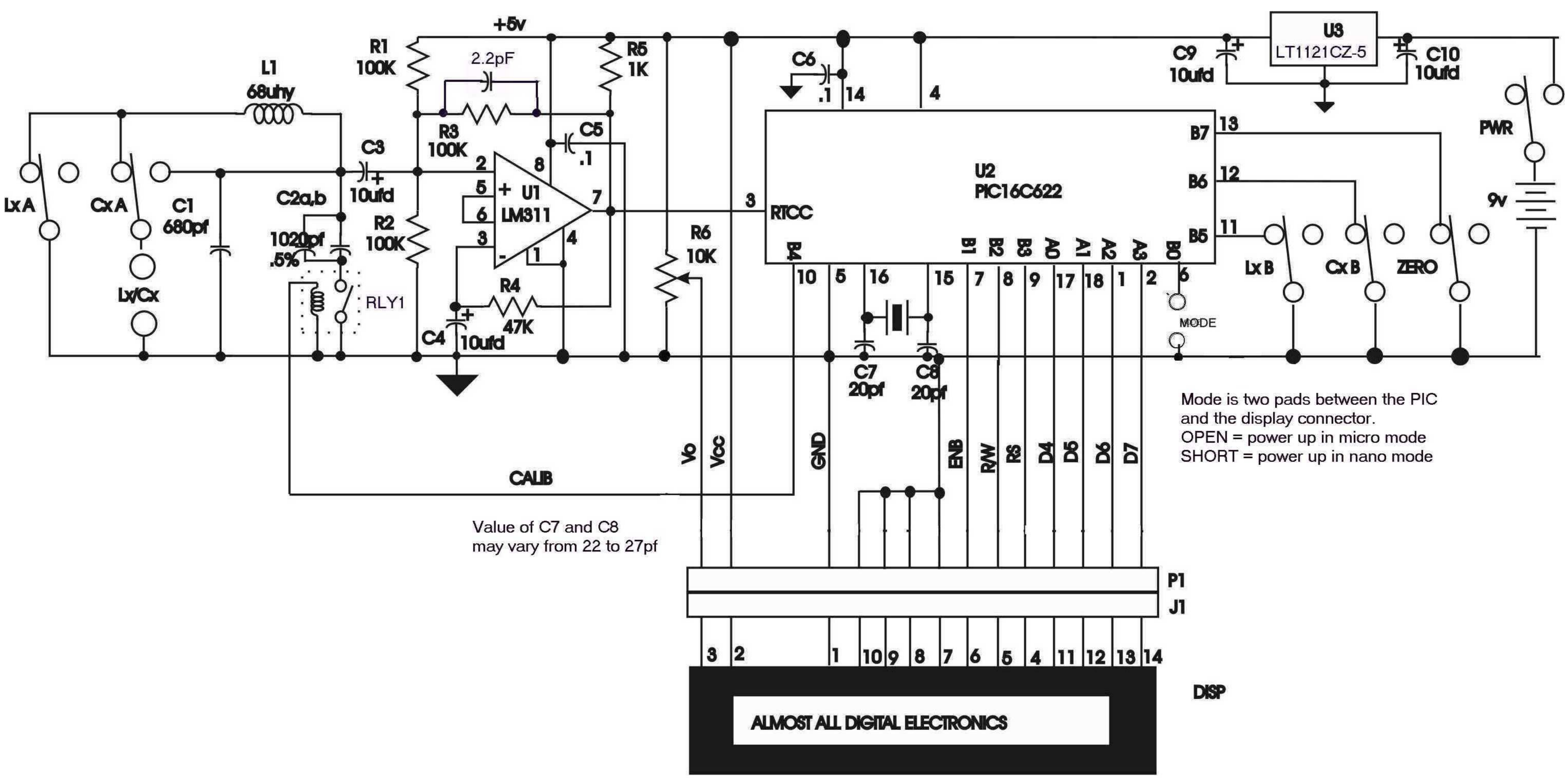
TECHNICAL SUPPORT
Voice 253-351-9316 9AM-9PM (usually available on weekends)
FAX 253-931-1940
e-mail neil@aade.com

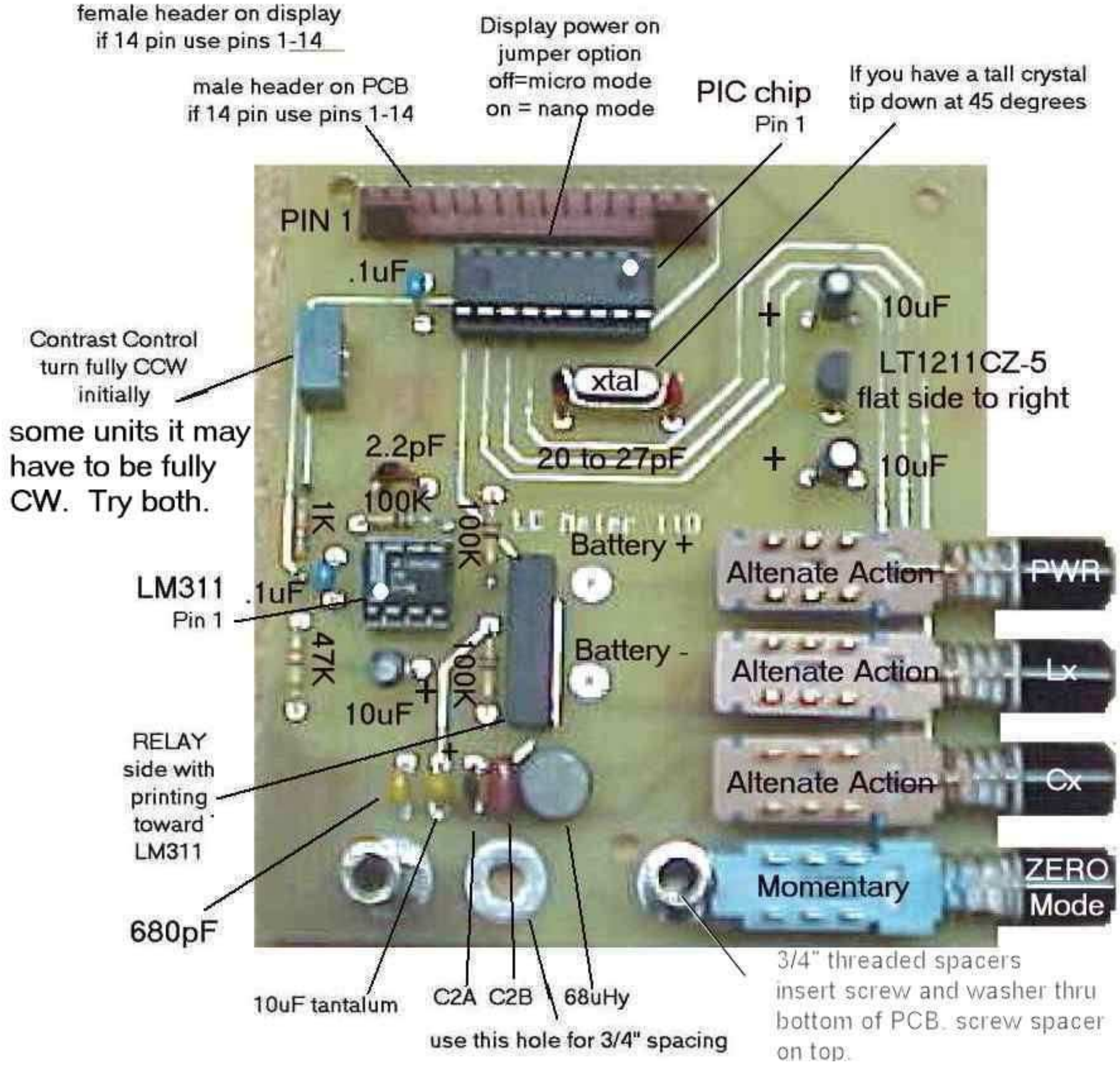


Mode is two pads between the PIC and the display connector.
OPEN = power up in micro mode
SHORT = power up in nano mode

Value of C7 and C8
may vary from 22 to 27pf

L/C METER IIB SCHEMATIC

Assembling the unit using only this drawing is not a good idea. A better idea is to take a few minutes to read the instructions (and even follow the step by step procedure) then use this drawing to check your work.



The LCMeterIID/E marking on the PCB is a version number of PCB <u>not a newer version of LC Meter IIB.</u>