G4HUP

Inductance and Capacitance Meter

Technical Manual

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Contents

Unit Specifications

Model Ref Inductance and Capacitance Meter

Performance

Measurement Range	Min	Max
Capacitance	0	>0.1µF
Inductance	0	>10mH

Accuracy	±1%	C and L
Resolution	±0.1pF	
	±10nH	

Performance data is taken from
http://ironbark.bendigo.latrobe.edu.au/~rice/lc/index2.html

Supply Requirements

Internal Battery – PP3, 9v; current typically <10mA at switch on, then decreasing

External DC supply – 9v to 15v max 9v recommended - 200mA minimum

Scope of Document

This document is intended to provide all necessary information to guide users in the construction and installation of the G4HUP Inductance and Capacitance Meter Model LC V2 in normal operation.

This document is relevant for units constructed on Issue V2_c PCB's.

Reference data can be found on the LC Meter pages of the DFS web-site, including any identified issues or problems – http://g4hup.com/LCM/LCMeter.htm.

LC Meter Description

The LC Meter is a combination of VK3BHR's excellent PIC software and its associated hardware, engineered into a simple to construct mechanical design. The completed unit forms a piece of test equipment useful in any electronics workshop. In addition to the basic hardware design, some extra features have been included :

- The option has been provided for both internal battery supply and external DC supply from, for example, a 'wall-wart' type of plug-in transformer/rectifier
- Both standard and backlit LCD options are available. The meter itself is normally powered by a 9v PP3 battery, but due to the very the high current demands of LED backlights used for LCD's (150 - 200mA), an external supply must be used with the backlight. The circuitry has been arranged so that the backlight will only operate when the meter has an exernal supply - ie it will operate as a non-backlit model from the internal battery.
- Due to the layout of the PCB to fit the case, the PIC must be installed without the use of a socket. To avoid any problems should an updated version of the software be made available, the Microchip ICSP (In Circuit Serial Programming) interface circuitry has been added to the hardware, so that the PIC can be re-programmed without de-soldering from the PCB.

A full description of how the software works can be found on VK3BHR's website, http://ironbark.bendigo.latrobe.edu.au/~rice/lc/index2.html

Physical Description

The LC Meter is housed in a Hammond type 1455 extruded aluminium case, measuring 120 x 103 x 30.5mm. The PCB assembly is secured to the panel by the two DPDT switches and the test terminals in the standard model, but is only located by the button of the Cal switch in the backlit version. Optionally, the external DC input can be provided through an end wall of the case. Note that due to the non-standard nature of the DC power plugs supplied on wall mounted transformer supplies, the parts for establishing this connection are not supplied with the kit – you should source these if you wish to use this option. The necessary on-board diodes to isolate the internal battery from the external DC, and therefore prevent any risk of attempting to charge the internal battery, are provided as standard with the kit.

A single row, 1 x 16 character, LCD is used for the display – it is mounted on 7mm stand-off insulators to allow component placement beneath the LCD itself, and to bring the display up against the back surface of the instrument panel.

The PCB is designed to slide into the internal slots in the edge of the Hammond box, therefore no securing holes are required in the case – with the PP3 battery, the PCB takes up the available length of the case. If there is any slack, one or two small pieces of foam can be inserted to hold everything in place.

Options

ICSP – In Circuit Serial Programming Interface

The PIC used in this circuit needs to be mounted directly to the PCB, without the use of a socket. In the unlikely event that an upgraded version of the software becomes available, then it will either need to be removed from the PCB for re-programming, or updated in situ. The necessary circuitry for this has been incorporated in the PCB layout, and JP2 provides a connector to access this without disturbing the circuit.

Fig shows the 5 connections on JP2, as viewed from the underside of the PCB. Fig 2 shows how the connector is installed from above the PCB, so that it can be soldered on the underside – be careful not to allow the solder to run too far up the connector pins.

To facilitate the ICSP circuitry you will need to provide R12, 13 and 14, and D4, plus the PCB bridges marked P in Fig 1. This can be done as you construct the meter, or can be done later, when you need to use the ICSP facility. You will also need to make up a suitable connection to the PC – it is recommended that you consult the Microchip website for further details on ICSP -
http://ww1.microchip.com/downloads/en/DeviceDoc/31028a.pdf

Note – R12 is in series with the relay, and will therefore restrict the current available to operate the relay. If you fit the ICSP components, you must also solder a link across R12, on the track side of the PCB, for normal operation. Remove the link temporarily when programming is required.

If you do not fit the ICSP components, **R12 must be replaced by a short circuit link. See Table 2 for further clarification**

External DC supply

By fitting a suitable connector into the end wall of the case, an external DC supply can be used to power the meter. In this case, the positive side of the external supply should be connected to TP1, and the negative to TP3, along with the battery negative.

Any external DC supply that can provide between 9 and 15v should be suitable – the current drawn by the meter circuit is very small. If you are using the external supply to power the backlit version, it is recommended that you use 9 or 12v, rather than 15v, to keep the dissipation of R15 as low as possible - see below.

Backlighting of the LCD

The standard LCD provided with the kit does not have an inbuilt backlight. However, should you prefer that then a suitable 1 x 16 character display with backlighting is available as an alternative to the one supplied. In this case, provide R15 and the PCB bridge marked B in Fig 1, then whenever the meter is powered from an external DC supply, the backlight will be on. The value of R15 supplied with the backlit versions when requested assumes a 9V external (or battery) supply only - **for other supply voltages see the Table 1 below** - the backlight supplied draws approx 150mA at 4.2v.

External Voltage (DC)	R15 value (3W)
9	33R
12	56R
15	82R

Table 1 - R15 values for external supply voltages

It is recommended that the external supply voltage is kept as low as possible, since the case is not ventilated, and over long periods of use, the excess heat from R15 will build up inside the case. Twice as much heat (1.4W) is dissipated when using 15v as compared to using 9v (0.7W).

Alternatively, it would not be difficult to implement a push switch to allow short term use of the back light from battery power, but be aware that the backlight draws almost 150mA, and a PP3 will not supply that for long!

Front Panel Power LED

An option that can be added, without drawing extra power from the battery has been sent to me by ZS2PG – this trick can be used in any battery powered circuit that uses a voltage regulator to some advantage.

The LED and its series resistor are wired from the S1 +ve common side to the regulator output. For the LC Meter, the series resistor should be 680R. With these values, the LED will be on when the meter is on, and will gradually decrease in brightness as the battery discharges. Since the circuit will draw its current primarily through the LED, there is no significant overhead in current drawn from the battery.

LC Meter Construction

Construction is straightforward, although some comments on the sequence and methods are appropriate. If you are building a backlit version, please see the separate comments below, in addition to the main details.

PCB Preparation

Minimal preparation is required, but there are a couple of bridges that need to be installed on the PCB before component assembly commences. Fig 1 shows graphically which vias on the PCB must be connected for the LC meter to function correctly, and also identifies the connections that are needed if the ICSP circuitry is implemented – note the extra components for ICSP are not provided with the kit.

PCB's V2_b and later are marked with the link positions.

Component Assembly

Install the low-profile passive components and the diodes first, including the relay and the crystal. Save the wire spills that you cut from the resistors and capacitors, as these can be used for the connections from the PCB to the LCD. Note that the 100uH inductor, L1, looks very much like a resistor!

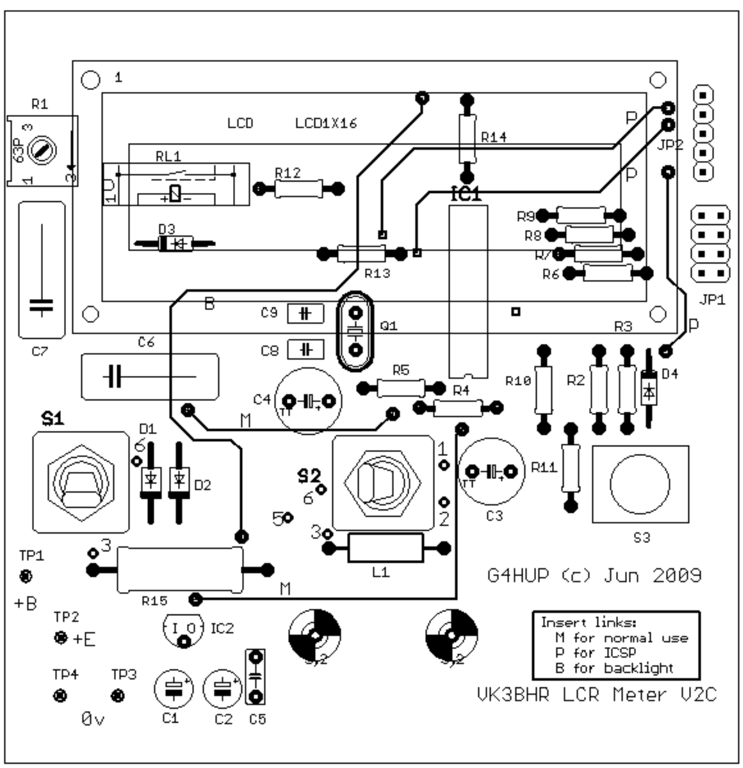

Fig 1 – Position of bridges.

Links marked M <u>must</u> be installed for normal operation, P for ICSP, and B for backlighting

Note that R12, R13, R14 and D4 are only required for ICSP operation. If you are not providing this facility, then R14 can be omitted, and R12, R13 and D4 should be replaced by wire links. Table 2 below should help to clarify this.

Component	Non-ICSP	ICSP
R12	s/c	1k*
R13	s/c	1k
R14	o/c	1k
D4	s/c	1N4148

Table 2 - ICSP option details

*R12 must be bridged under the board for meter operation - remove bridge for ICSP update only

Also, R15 is only required for backlit LCD displays. For the optional backlit display provided with the kit, R15 is also supplied - 33R 2W.   Mount this resistor with some air-space (1 or 2mm) underneath it, since there will be almost 1W dissipated in it.

Once all the passive components are in, mount the regulator (IC2) and the PIC directly to the PCB (ie no socket), but do not add the switches yet. Also mount the header for JP1 – this mounts from the top side of the PCB, so that its pins are accessible once the LCD is in place and the PCB is assembled into the case – see Fig 2

Mount the LCD on its spacers and bolts. As you can see in Fig 2 above, the head of the bolt should be on the LCD PCB, a spacer is between the LCD and the PCB, and a washer and nut are used on the underside of the PCB.

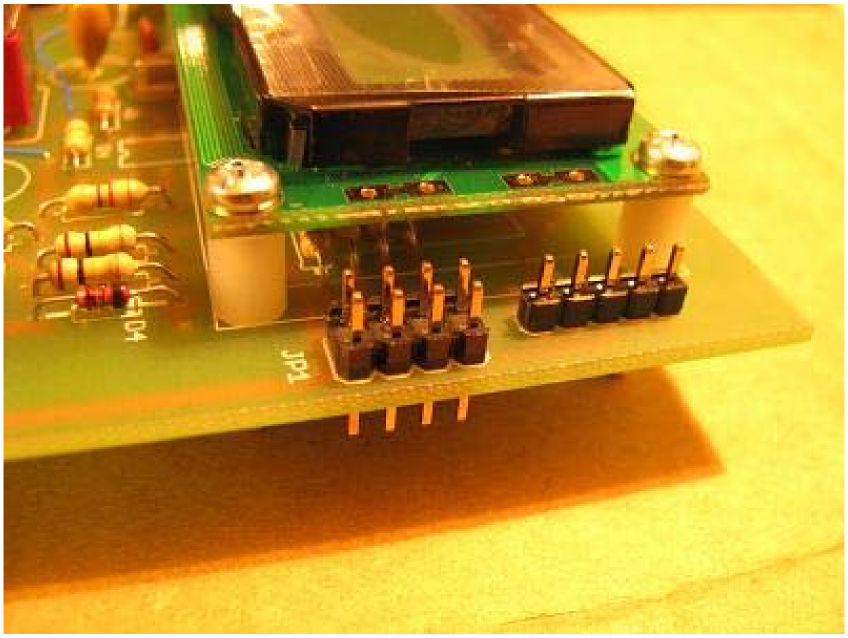

Fig 2 – View of partially constructed LC Meter, showing how JP1 and JP2 are installed, and mounting of LCD above PCB

Then pass wires (end clippings from the resistors are ideal) through the PCB and the LCD and solder each in place. Not all the connections are required – make sure that you have wires in pins 1-6, and 11 – 14. No other pins are used in this design – unless you have decided to use a backlit display, in which case you will also need wires in pins 15 and 16 (in addition to providing R15).

Standard Version

Finally install the switches, but do not attach the two terminal posts yet. Make sure that you solder the switch pins very well – a lot of solder is needed to ensure a reliable connection. At this stage, you can test to confirm that the circuit is operating correctly, before installing it in the case. Attach a 9v PP3 battery, with the positive to TP1, and the negative to TP3. Adjust the trimpot, R1, to set the display contrast. If your module does not show any signs of life, see the Troubleshooting section, below.

Backlit Version

The backlit LCD is thicker than the standard one, due to the LED panel behind the display itself. This means there are one or two changes to the mounting details. The two SPDT switches will have to be connected to the PCB using short wires, and the two terminal posts will also need the same treatment. Switch S3 (Cal) is supplied with a longer button, so that it will reach the panel.

On the V2_c PCB, several connecting points have been provided around the switches for the wires to solder through. Fortunately, not all 6 connections of each switch require wiring!

SPDT Switch Connections

Fig 3 shows the numbering of the connections to the SDT switches, giving both a front view (as you look from above the PCB) and the underside view (as you will see it when you are wiring it)

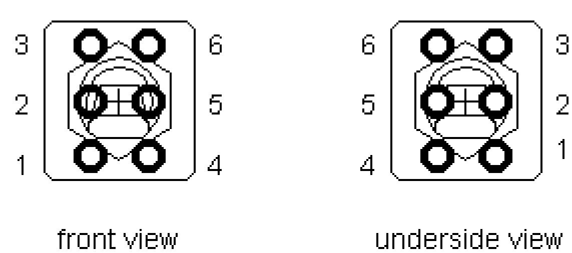

Fig 3 - SPDT Connection Numbering

Switch S1 - On/Off

Figs 4 and 5 below show how S1 must be wired. In Fig 4 you can see two vias on the PCB, numbered 3 and 6. Using the information from Fig 3 above, prepare two short wires and solder them onto pins 3 and 6 of the switch. Also connect the battery positive lead directly to pin 5, and the external DC supply positive to pin 2 of the switch respectively. Connect the 0v side of both supply sources to TP3 and 4 on the PCB. Finally, solder the wire from the switch pin 3 into the via marked 3 on the PCB, and repeat this for the wire on pin 6 of the switch.

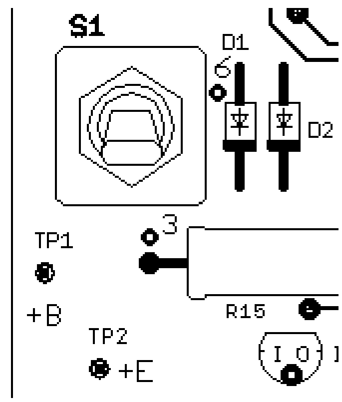

Fig 4 - S1 physical connections to PCB

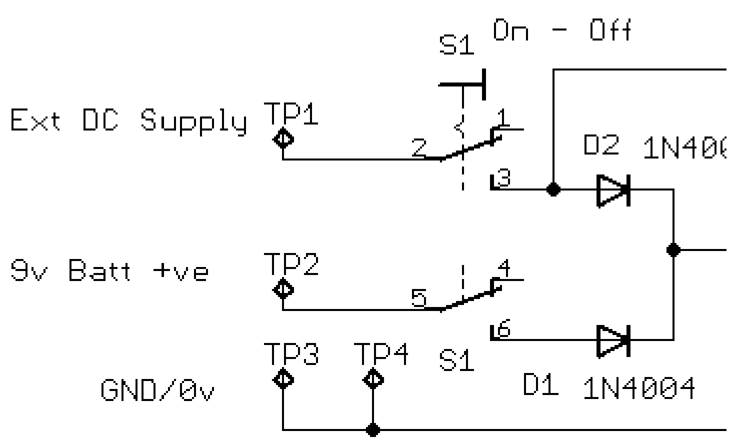

Fig 5 - S1 schematic connections

Switch S2 - C/L

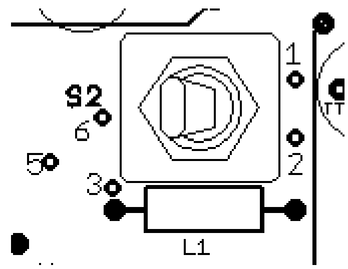

Fig 6 - S2 physical connections to PCB

As with S1, there are vias around the switch location showing where each wire must be connected. 5 wires are needed for S2 - but note that pin 4 must be connected to pin 3 via a short bridge wire on the back of the switch, and does not need a separate connection to the PCB. Referring to Fig 6 above, the locations are numbered, to show where the wire from each pin must be connected. Fig 7 shows the related part of the schematic diagram for reference.

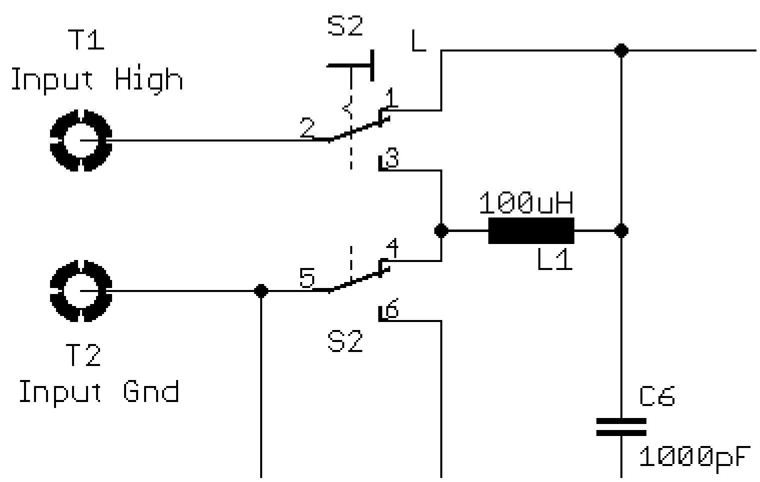

Fig 7 - S2 schematic connections

Case Preparation

Use the downloaded paper template for drilling the case panel. Remove the sliding panel from the box and using a glue stick, attach the template accurately in place. You can centre punch the circular holes and also use the template as a guide to cutting the aperture for the LCD. The paper will come away from the panel easily once the cutting work is completed.

A second inclusion with the kit is a prepared front panel, already laminated and cut to size. You will need to use a scalpel or similar to cut out the holes for the switches and terminals.

If you are providing an external DC power capability, mount the socket in the end panel of the box so that it does not foul the battery.

Final Assembly

Remove the protective plastic cover from the LCD face.

Standard version

Mount the two terminals through the front panel and the metal panel and do the nuts up finger tight. Offer the PCB up from the back of the panel and adjust the position of the nuts on the barrels of S1 and S2 so that the PCB is parallel to the panel when viewed from the end. Check also the alignment with the slots in the lower part of the case, and adjust the height of the PCB if necessary. The Cal switch, S3, should be just beneath the panel front line, so it cannot be operated accidentally.

Place the outer nuts on the switches and tighten up. Solder the two terminals to the PCB, tighten the back nuts of the terminals fully and construction is complete.

Backlit version

The case assembly is similar to the standard version, except that the switches and terminals are attached to the panel, but have short wires to the PCB. In this version none of the components are used to fix the panel to the PCB - only the operating button of the Cal switch locates the correct relationship between the two.

Because of the thicker LCD assembly, the PCB will locate into slots lower down the case than the standard version - you will need to reduce the length of the four screws which secure the LCD in place so that they clear the back of the case. Slide the PCB and front panel into place together.

You may find it helps to use some pieces of foam to space the PCB away from the end panels of the case in use, although the battery (if installed) will help to provide some stability for the PCB

Assemble the LC meter by sliding the front panel and PCB into the case, and attaching the end panels with the screws provided. The adhesive feet can also be attached to the rear of the case.

The edges of the laminated panel can be held down onto the aluminium panel by a bead of cyano-acrylate (Superglue) carefully run round just inside the edge of the panel.

Operation

The LC meter is easy to use. At switch on, S2 should be set in the 'C' position, and after a few seconds the display will rest at a small positive capacitance – typically around 1pF. Pressing the Cal switch should zero this reading. Before trying to measure any components accurately, the Meter needs to be calibrated.

Troubleshooting

If your LC Meter does not show any signs of operating at switch on, then try the following:

1. make sure that you have inserted the two essential PCB bridges marked M in Fig 1
2. make sure that you have tried the full range of adjustment on the LCD contrast pot, R1. The correct contrast setting is very near to one end of the rotation, but the trimmer pots as supplied are in the centre of their travel.
3. make sure that R12 is either a wire link (if ICSP not installed) or is bridged by a link (if ICSP has been installed), and that the full ICSP detail on p7 has been followed.
4. make sure that there are no solder bridges on the PCB, and that you have soldered all connections.
5. carefully check the placement (and in some cases the orientation) of components
6. make sure that you have the battery and external supply connections correct (+ to TP1 or TP2, - to TP3/4)
7. For backlit versions, make sure you have the switches wired correctly, and that you linked pins 3 and 4 of S2 on the back of the switch.
8. If the backlight does not work off the external supply, then check that the link marked B was installed on the PCB. Also see the Errata section.

If your meter continually displays 'Over Range' at switch on, regardless of the position of the C/L switch, this is due to either:

- incomplete soldering of the connections of the C/L switch to the PCB. Use plenty of solder and fill up the available space.
- The M link between C6 and S2 is not in place, or is broken.

If your meter displays the leftmost 8 characters with all pixels black, then:

- The M link between +5v and the PIC is not in place, or is broken
- The Cal switch is short circuit at switch on

If your meter does have a display, but is unstable in operation, then referring to Fig 8 (below) check the oscillator operation.

Bridge the pins of JP1/2 and check that the display shows 00050000 (within ±10%) – this is the free running frequency. Now move the link to JP1/1 and check the calibration frequency – this should show approx 71% (±5%) of the value you read previously.

If the meter displays 00000000 on the two checks above, then this indicates that the oscillator is not running, and the fault is likely to be around the connection of S2 and its associated components.

If both of these checks are successful, then it is likely that either:

- a you have a construction error or bad joint
- b you have a faulty component in the circuit.

It has been pointed out that when the meter is in the C measurement position, then input RB6 (pin 12) of the PIC is left floating. No problems have been identified for which this has been the cure, however, if you are concerned that it may contribute to a problem you are seeing, this can be eliminated by placing a 100k resistor between the junction of R13 and pin 12 and the +5v supply.

Further information regarding troubleshooting (and modifications) and an FAQ file can be found on Phil's site: http://ironbark.bendigo.latrobe.edu.au/~rice/lc/faq2.html

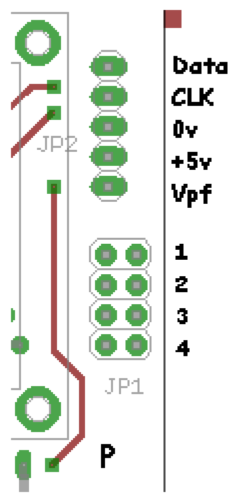

Fig 8 – JP1 and JP2 connections (viewed from topside of PCB)
JP1 – Oscillator check and Calibration test points
JP2 – In Circuit Serial Programming (ICSP) Interface for 16F628A

Calibration

The calibration of the meter is good enough for most purposes without any further adjustment, thanks to the excellent software. However, if you have a close tolerance capacitor (1% or better) available, then you can trim the display using the following steps:

- Once the display is stable after the initialization sequence, then press Cal to force a re-calibration – the display should then rest at 0.0pF.
- Connect your 'reference' capacitor to the terminals and note the display.
- If you need to increase the displayed frequency, then bridge JP1/4 until the display is correct – remove the bridge at this point.

- Similarly, to lower the displayed value, bridge JP1/3, and remove it when the display is correct.
- In each of the above steps, the new calibration is automatically stored to the EEPROM memory of the PIC
- No separate calibration is required for inductance measurement – it is implicit with the capacitance calibration. Just short the terminals, make sure the C/L switch is in the L position and press Cal.

For further comment and guidance on the use of the links for troubleshooting and calibration see VK3BHR's site:
http://ironbark.bendigo.latrobe.edu.au/~rice/lc/index2.html

Measurement

You can now attach your unknown C to the terminals, and immediately the display will show you the value.

To measure inductors, allow the unit to stabilize as above, move the C/L switch to the L position then short circuit the terminals and press Cal. Now attach your unknown L and measure.

You can also calibrate out the effects of any test connection you need to make. For example, if you need to use some wires to attach the unknown component (C or L) the effect of these can be removed from your measurement, so the reading you see on the display is the true value of the unknown component. Simply attach your test wires, in as close as possible to the position they will be in during the measurement, and press Cal – the display will zero, and once you attach your component, you will see its value. This technique can also be used to take differential readings – for example to confirm the range of a variable capacitor. Attach the capacitor, and set it to one end of its travel. Now press Cal, then move the capacitor to the other end of its range – the display will directly show you the range difference from one end to the other of its travel.

For measuring SMD components a test jig or cable is required, and the above comments apply to this as well – perform a Cal with the test jig/cable connected, but without the component in place. See http://g4hup.com/LCM/LCMeter.htm for details of a suitable set of test tweezers for SMD components.

Errata and Addenda

This section contains information about components that have been changed or added compared with the original PCB design.

1 There is a legend error on the Version 2_c PCB's - the connection points for the battery and external supply are reversed. If you are not using a backlit version, this is does not matter, but for backlit versions, the connections for these must be reversed.

2 It has been noted that the two radial 10uF capacitors, C1 and C2, stand very close to the inside of the case when the meter is assembled. It is recommended that on installation, those components are inclined slightly towards the centre of the PCB to avoid any possible abrasion.

See http://g4hup.com/LCM/LCMerrata.html for full details, versions impacted and resolution guidance, including pictorial support.

Component Locations

Figs 9 and 10 respectively show the circuit schematic and the locations of components on the top side of the PCB. Following these is a list of the components that should be provided in your kit - if any items are not present, please contact me! Note that the 100uH inductor supplied looks very similar to a resistor!

Maintenance

Construction Practices

Kits are not supplied with any solder, but it is recommended that a small diameter, good quality flux cored solder is used, to ensure minimum flux residues on the PCB after assembly. The PCB will accept lead-free solder, and components used are generally ROHS compliant, and should therefore also accept lead-free solder if you prefer.

It is recommended that lead based solder is used for maximum reliability of soldered joints.

Copyright

Acknowledgements

Phil Rice VK3BHR, for an excellent design, that is well supported via the website – thanks!
Paul Galpin, ZS2PG, for expanded troubleshooting comments and the front panel LED option.
Giles Read, G1MFG, of the RSGB, for useful comments following kit review (published in July 2009 Radcom)

Change History

Date	Iss No	Comment	Author
24 Sep 2008	0.A	First Draft version	G4HUP
4 Oct 2008	0.B	Minor corrections, R12 warning added	G4HUP
17 Nov 2008	1.0	Minor corrections, extended Troubleshooting section	G4HUP
26 Nov 2008	1.01	Comment re C/L switch soldering added to Troubleshooting	G4HUP
21 Jan 2009	1.02	Expanded troubleshooting, Front Panel LED option	G4HUP
25 Apr 2009	1.03	Updated troubleshooting information	G4HUP
15 May 2009	1.04	Updated troubleshooting section, PCB overlay diagram	G4HUP
21 Jun 09	1.05	Minor typographical correction, ICSP and Backlight updates	G4HUP
13 Jul 09	2.0	Backlight version construction details added	G4HUP
14 Jan 2010	2.01	Table reference corrected	G4HUP

End of text – Diagrams follow

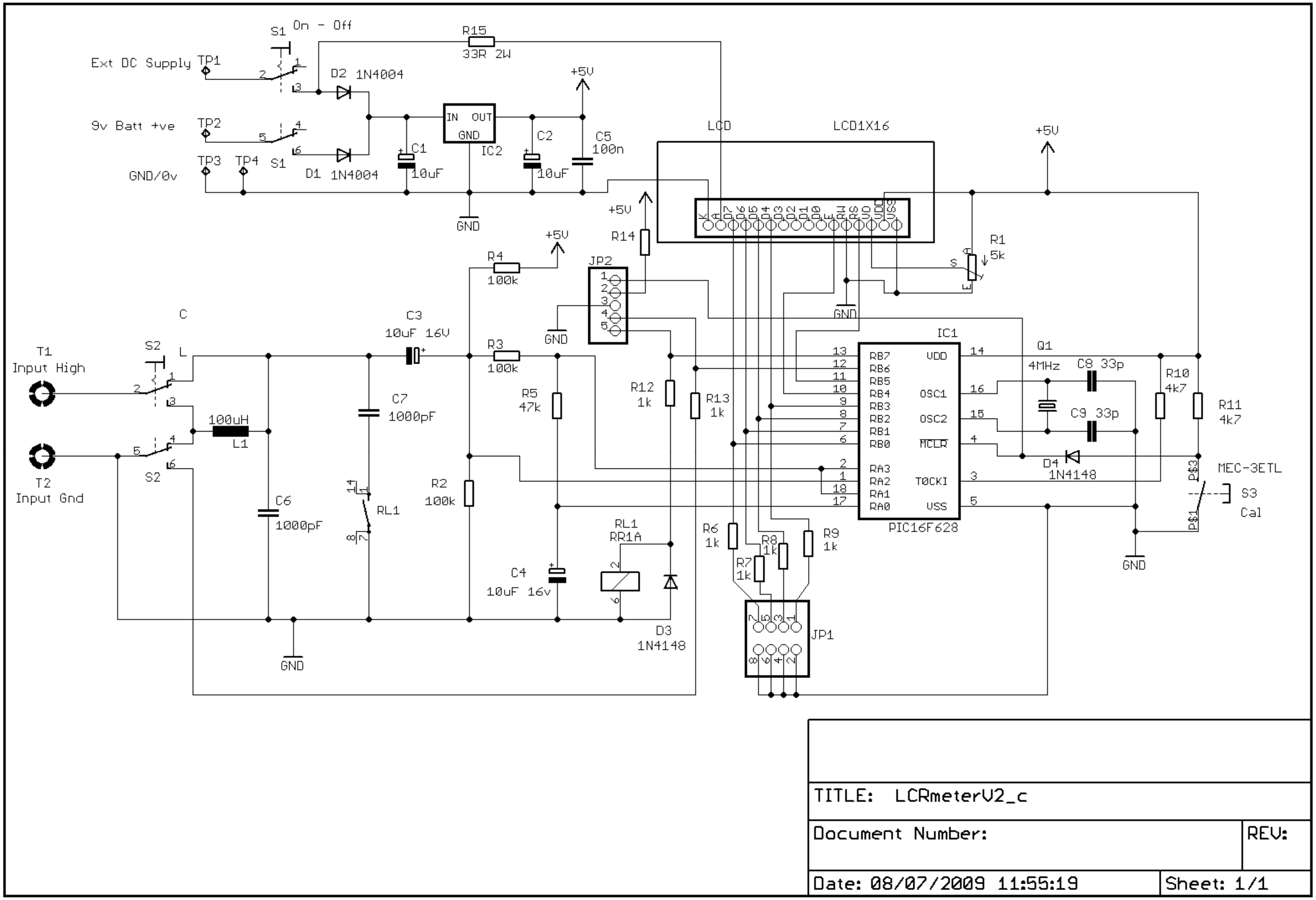

Fig 9 – LC Meter V2_0 circuit schematic diagram

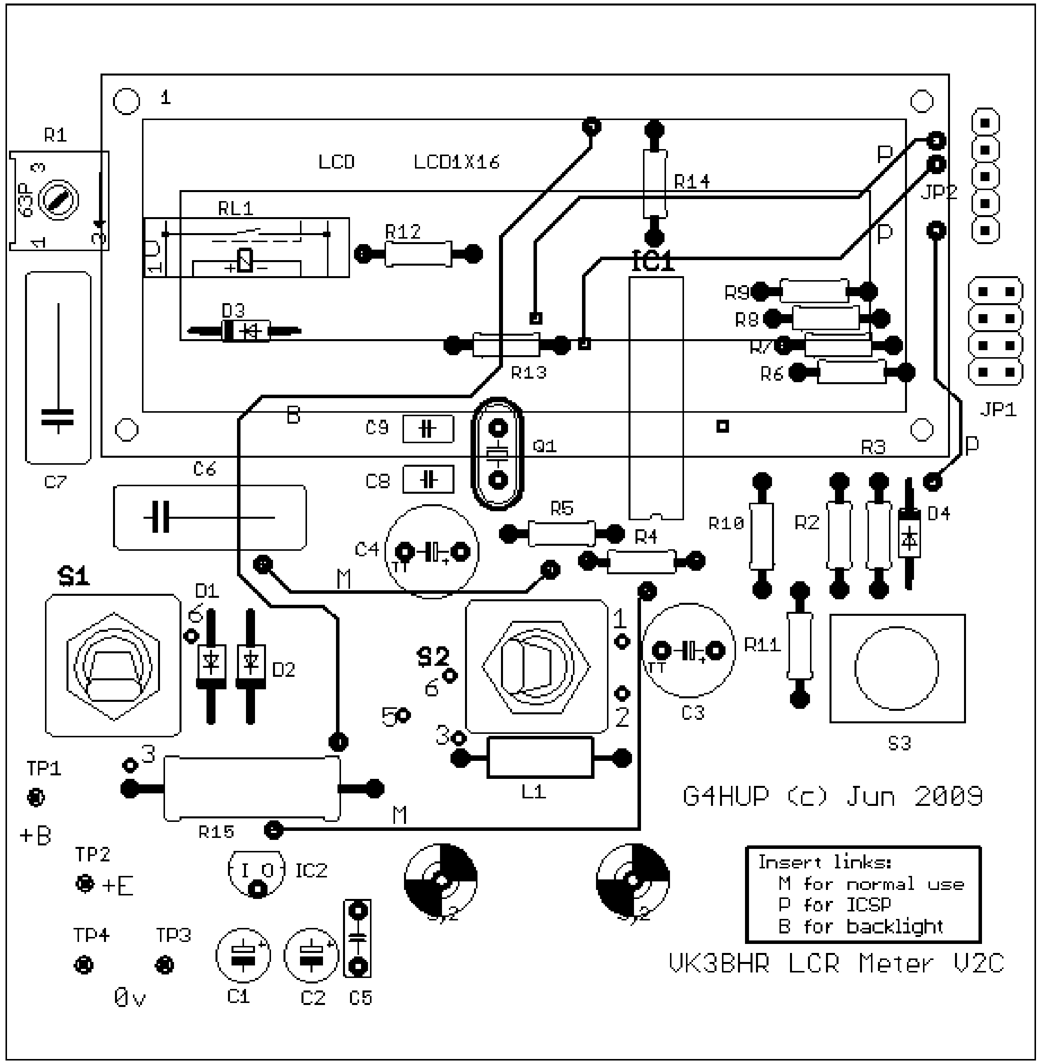

Fig 10 – PCB Component side Locations

Component List

Ref ID	Value	Tolerance	Comment
C1, 2	10uF 25v		radial
C3, 4	10uF 16v		tantalum bead
C5	100n		5mm box poly
C6, 7	1000pF	±2.5%	polystyrene
C8, 9	33pf		ceramic plate
L1	100uH		moulded choke
R1	5k		3/8" trim pot
R2, 3, 4	100k	5%	0.25W MF
R5	47k	5%	0.25W MF
R6, 7, 8, 9	1k	5%	0.25W MF
R10, 11	4k7	5%	0.25W MF
R12, 13, 14	1k		ICSP only
R15	33R	2W	Backlight only – 9v DC
D1, 2	1N4001		
D3	1N4148		
D4	1N4148		ICSP only
IC1	16F628A		Pre-programmed
IC2	78L05		TO92
Q1	4.00 MHz	±20ppm	HC49/S low profile
RL1	DIL Relay		5V SPNO
S1, 2	DPDT		ON-ON min toggle
S3	Press switch		15mm high
LCD	1601ARS		1x16 character
JP1	4 x 2 Header		
JP2	5 x 1 Header		ICSP only
PCB	VK3BHR V2_c		©G4HUP 2009
Case	1455		Hammond
Terminals	4mm binding post		1 red, 1 green
PP3 Battery clip			
Mounting screws	Set of 4		Screws, nuts washers and spacers
Drilling template			©G4HUP 2009
Panel overlay			©G4HUP 2009

Notes – components for ICSP are not supplied in the kit
Backlit LCD and R15 supplied as optional alternative