CLARA

(C) and (L) Automatic Reading Apparatus

Information Manual   Version 1.0.3

This manual refers to CLARA PCB version 1.0

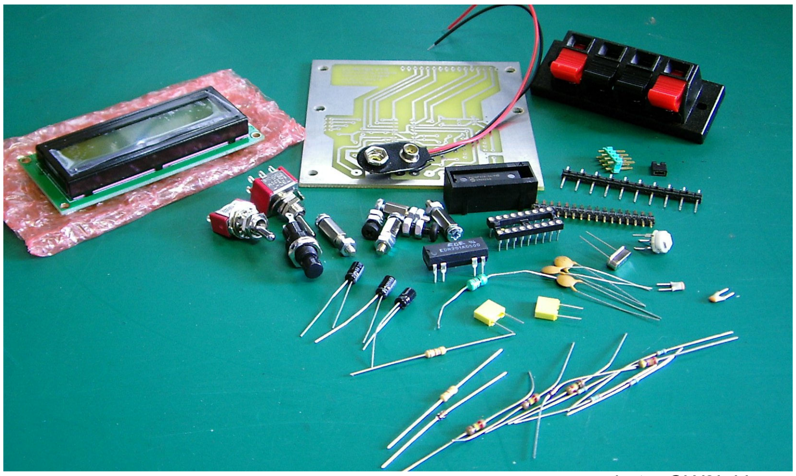

photo GW8LJJ

The kit of parts

This is a fully supported project.

Please contact gw4gte@s9plus.com or eric@ericedwards.co.uk with any questions, problems or comments before, during or after construction.

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1. Introduction

CLARA (C) and (L) (A)utomatic (R)eading (A)pparatus is an automatic inductance and capacitance meter with a digital readout. Accuracy is claimed as better than 2% over the range 0.0pF to >100nF and 0.0uH to >10mH.

CLARA is a reworked version of a design by Phil VK3BHR who has approved this project. VK3BHR cites work by Neil at AADE [www.aade.com] as his inspiration for the design although the PIC used and its source code is unique to VK3BHR's version. CLARA uses the same circuit and software as Phil's LC Meter although the PCB has been laid out differently.

PCB manufacturing and kitting/distribution is handled by Eric GW8LJJ. This project would not have appeared without Eric's assistance.

Figure 1.1 Example of CLARA fully dressed (enclosure not provided)

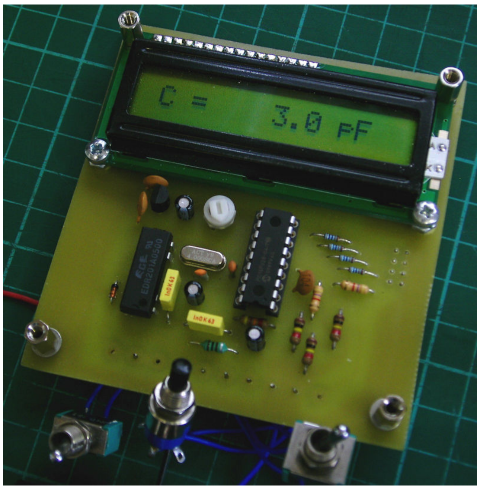

Figure 1.2 CLARA unclothed

2. Principle of Operation

There are various ways of measuring inductance and capacitance; all involving detecting a change of some sort or other that is proportional to the value of the component under test. For instance you could measure the charge time of a capacitor, where the charge time would increase for larger values. Or you could apply an AC voltage to a network that includes the component under test and measure the change that produces. Many commercial LC meters work this way, offering a range of fixed test frequencies.

How CLARA does it
Another method, and the one used in CLARA is to create an LC oscillator where the values of L and C are known. Any additional L or C applied to the oscillator will alter its frequency. If the new frequency can be measured, the value of the added L or C can be calculated.

CLARA operates at a variable frequency depending on the DUT (device under test).The internal 50kHz oscillator is reduced in frequency by an amount dependent on the magnitude of the L or C being measured.

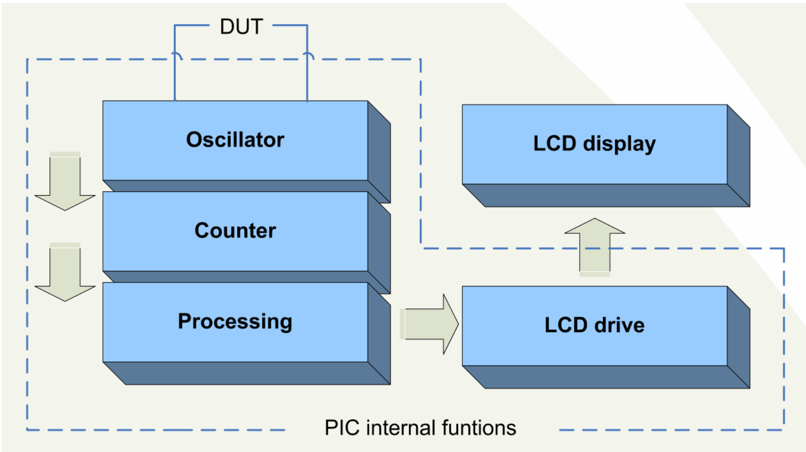

Figure 2.1 CLARA block diagram

The block diagram above breaks CLARA down into functional parts. An oscillator drives a counter which counts cycles over a gate period to produce a frequency with a resolution proportional to the gate period. This count is compared to the stored count of the internal oscillator and the stored values of the internal L and C which were determined during calibration.

Reactances are never purely inductive or purely capacitive. There will be a small resistive component and an opposite reactive component as well. Because of this, inductors and capacitors can behave unexpectedly at certain frequencies when they self-resonate. This is very unlikely to happen at the frequencies used, although the original notes do mention the possibility of self-resonance in L1. This has not been observed so far.

Ideally L and C measurement should take place at the intended operating frequency of the component. For exacting work a VNA (vector network analyser) is a better choice for plotting reactance against frequency though for most amateur work the accuracy of CLARA (stated in the original design as better than 2% when calibrated) is quite sufficient.

3. Circuit Description

U1 is a 16F628 PIC microcontroller, which is clocked at 4MHz, determined by XL1, C5 and C6. The PIC's internal functions include a counter and two comparator stages. Comparator 1 (pins 1, 2, and 17) are wired to produce an oscillator using R3 as feedback. C3 provides DC isolation for L1, which together with C1 determines the frequency of oscillation. C2 is switched in circuit by RL1 for calibration. This lowers the frequency of the oscillator and provides enough data for the values of the original L and C to be calculated. In other similar designs C2 cannot be determined and the value must be known. Accuracy depended on the accuracy of C2. In this version links are provided to calibrate the unit by using a known value capacitor as the DUT in parallel with C2 allowing the readout of capacitor value to be adjusted. Inductance is automatically calibrated at the same time as the effect is the same.

SW2 selects L or C. Inductors are placed in series with L1, capacitors are placed in parallel with L1. Hence the oscillator frequency drops for either type of component. A connection back to U1 pin 12 tells the PIC whether L or C is selected otherwise it has no means of determining which is selected.

U1 directly drives LCD1, a 16 x 1 LCD display. The display provided can be backlit but this is not required in daytime lighting and would only serve to drain the battery. RV1 sets the contrast of the display and is a one-time setting for best visibility.

Links 1 to 4 are used for calibration and test.

- LK1: raises C readout
- LK2: lowers C readout
- LK3: displays F1 on LCD (basic oscillator frequency)
- LK4: displays F2 on LCD (calibration frequency with C2 in circuit)

CLARA can be powered by any voltage from 7.5V to VR1's upper limit of 35V but the intention is for a 9V PP3 battery to be built into the box. With the occasional use these sorts of devices are put to the battery will probably last years.

CLARA Version 1

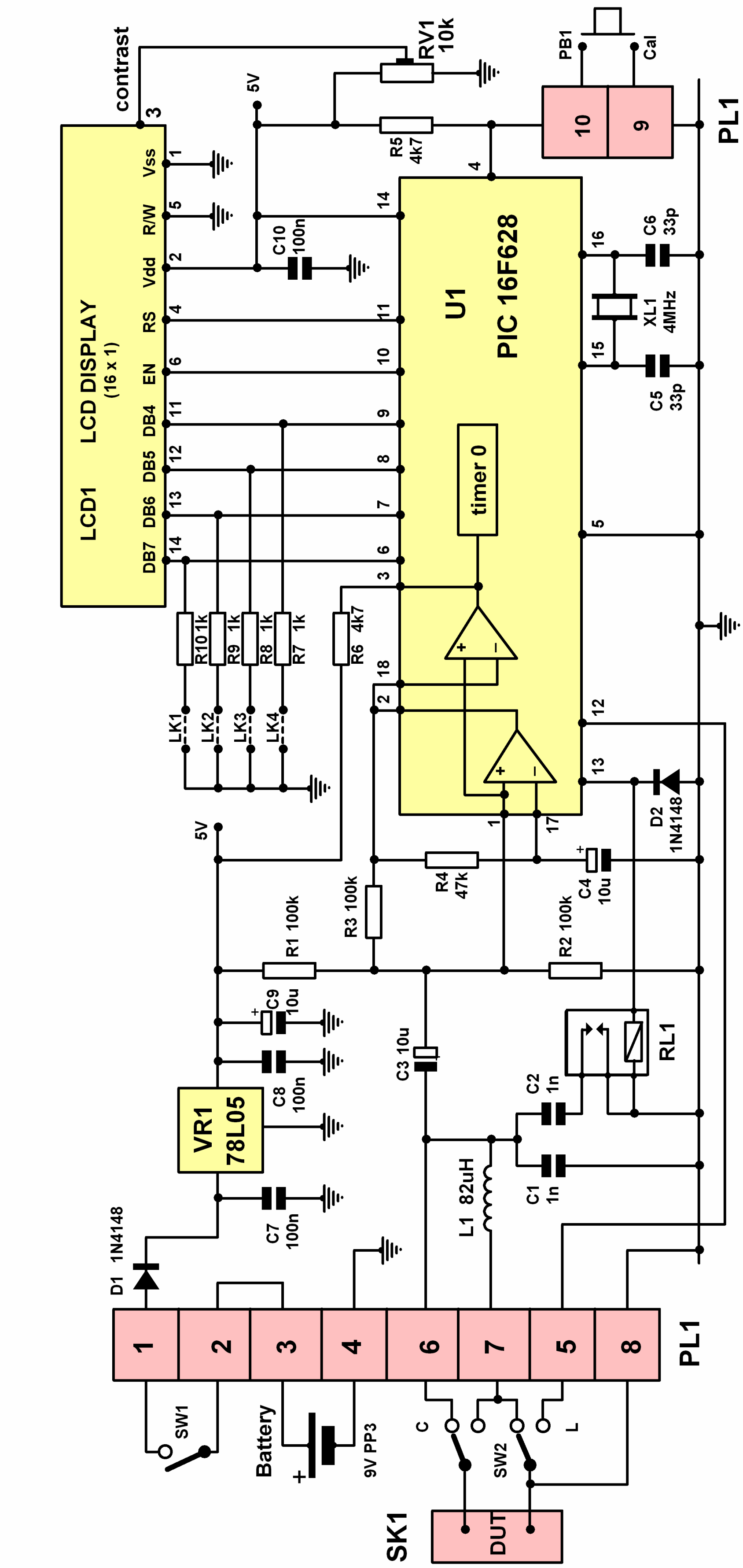

Figure 3.1 CLARA circuit diagram

4. Construction and initial testing

Before starting

The PCB is hand made so although it will have been checked please take a few seconds to check the track for any signs of etching problems before you start. In the unlikely event you find a fault that isn't simple to rectify please notify us and a replacement board will be sent out to you free of charge. Please let us know anyway so we can track any re-occurring issues. Also check all holes have been drilled.

Build order

There are no positional dependencies so the PCB can be populated in any order the builder chooses. However it is suggested the IC sockets are installed first followed by all other components, leaving the crystal and the LCD display until last. Don't plug U1 in until you have done some basic checks – see below. C3, C4 and C9 are polarised electrolytics – double check for correct orientation before soldering.

Attaching the LCD Display

The LCD display is soldered to the main PCB via a header strip as shown in figure 4.1. Before soldering, mechanically attach and align the display with the main PCB. The pins on the header strip are longer on one side of the plastic support than the other. Push the longer pins on the header strip through the LCD module and through the corresponding holes on the PCB, starting from the top of the LCD module. Solder the header strip to the track side of the main PCB making sure to leave enough pin length protruding on the top side of the LCD module for soldering. Cut off the excess header pin length on the top of the LCD module just below the plastic support (removing the support to leave just the pins) then solder the pins to the LCD module to complete the procedure.

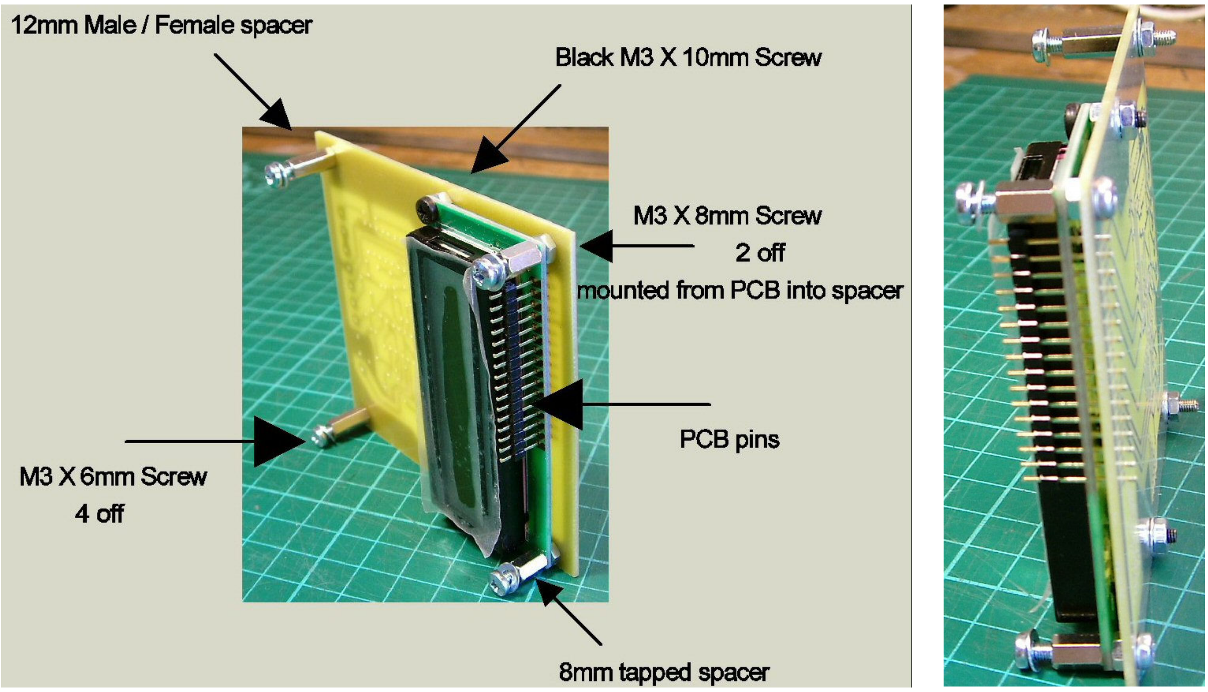

Figure 4.1a/b Attaching the LCD

Mounting the PCB/LCD assembly in a case

Figure 4.1b above shows how the PCB mounting pillars are attached. Pillar lengths are chosen for suspending the entire unit under a box lid with holes cut out for the display, switches etc. Alternatively builders may wish to attach the PCB from the track side by inverting the pillars or using other screws to suit.

External components
All components external to the PCB are connected via PL1 (refer to figure 4.6). A 10 pin 0.2" spacing header strip is supplied (made from a 0.1" spacing strip with alternate pins removed). This should be soldered to the PCB before wires are attached. The battery connector, switches and button are all provided in the kit as is the DUT connector which should be mounted on the outside of the chosen enclosure. A battery (PP3 recommended) is not supplied. The cheapest PP3 you can find will probably last ages.

DUT connector block
The DUT connector block (see figure 4.2 below) will be recognisable as a loudspeaker connector block. Similar colour terminals should be wired together. The four terminal version offers two different connector spacings depending on the terminals used. Twin connectors also offer an easy means of matching capacitors by leaving one in situ. Figure 4.5 shows how 4mm posts can be used instead (not supplied).

Attaching the L/C switch and DUT connector
The DUT connector SK1 is wired in conjunction with the L/C selector switch SW2. Connect the two black terminals together and the two red terminals together.

Figures 4.2 and 4.3 below show how the L/C switch SW2 and the DUT connector SK1 are connected.

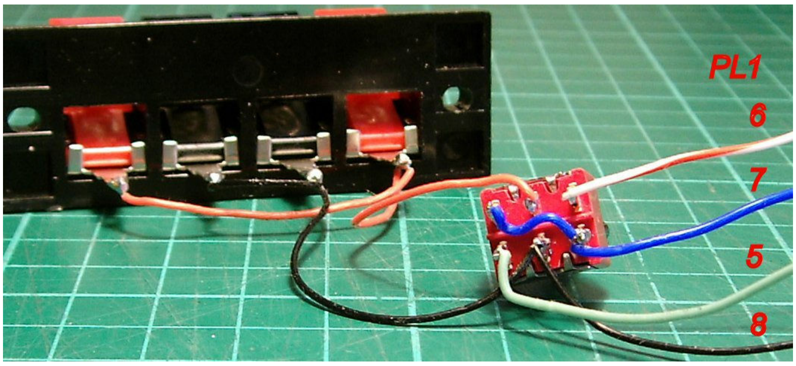

Figure 4.2 Attaching the L/C switch and DUT connector block

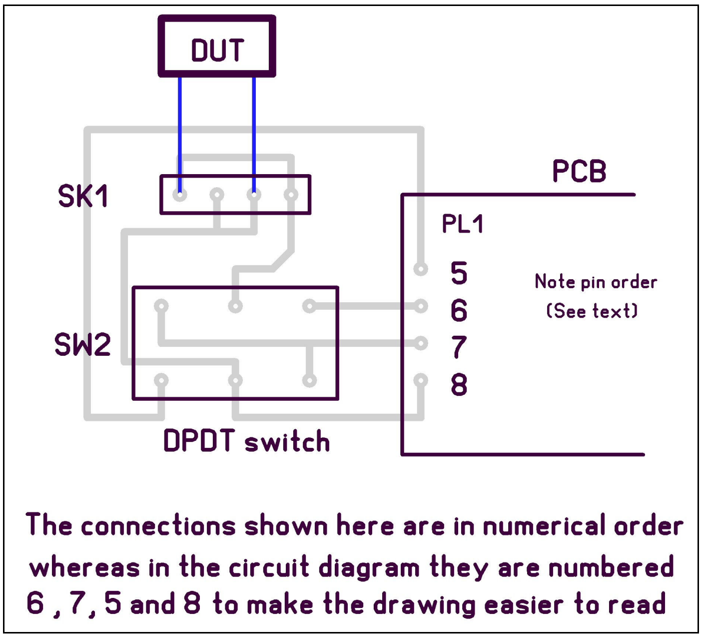

Figure 4.3 L/C switch wiring detail

First checks
Visually inspect your soldering for any bridges. Also double check D1 and D2 are the right way round. Check RL1 is the right way round – pin 1 markings are the same as any DIL IC.

You will be eager to power up the board on the bench, but before inserting U1 apply power and check 5V is present between U1 pin 14 and pin 5. Now insert U1 if all is ok.

You need to connect PL1/7 to PL1/8 to connect L1 into circuit otherwise the oscillator will not function. It's best of course to be patient and connect SW2 correctly but a quick power-up to get a display is fine.

Power consumption
Current drain should be of the order of 10mA. Check this by connecting a milliammeter across PL1/1 and 2 with SW1 off.

Adjusting the display contrast
RV1 adjusts the LCD display contrast. If the display is blank on power-up don't panic – try adjusting RV1. Set the position for personal preference.

Expected LCD reading at power-up
The display sequence depends on the position of SW2.

Assuming no test component is attached:

> **SW2 in 'C' position**
> LCD initially displays 'Calibrating' for one second then displays a low capacitance value or 0.0pF
> **SW2 in 'L' position**
> LCD initially displays 'Calibrating' for one second then displays 'Over Range'

Choice of enclosure
A metallic enclosure will minimise hand capacitance effects when measuring small value components, although this is not a big problem. Plastic boxes are much cheaper and do the job perfectly well. Maplin have a number of reasonably priced plastic boxes to suit.

Figure 4.4 Enclosure example

The photo opposite shows CLARA housed in a plastic enclosure Farnell 495-2650. Note also the use of 4mm terminal in place of the spring loaded connector block supplied with the kit. This box is a little long but it does have a PP3 battery compartment.

Other potentially suitable enclosures are Maplin AB10/LF11 (aluminium £3.69), Maplin N21GC (plastic £4.79) and Maplin N90BQ (diecast box £5.49). These have not been verified but the dimensions look ok.

Making holes in your chosen enclosure.
Figure 4.5 below shows a drilling template. Print this page on A4 (which should scale the image properly), cut out the template and offer it up to the PCB, then punch through the four corner holes using the actual holes on the PCB itself as a guide. Use the four LCD window corner marks to mark out the oblong LCD window. There is some work involved now and unless you have a jigsaw, drill out the window with a number of large holes then file out the remainder. Don't assume the template print is correct without checking against the PCB.

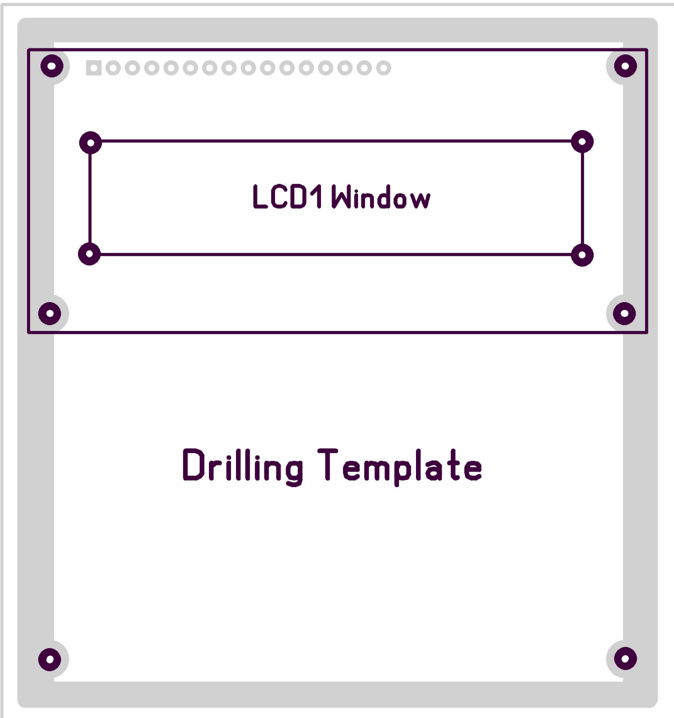

Figure 4.5 Drilling Template
(This should print to size in A4 but check first against actual PCB)

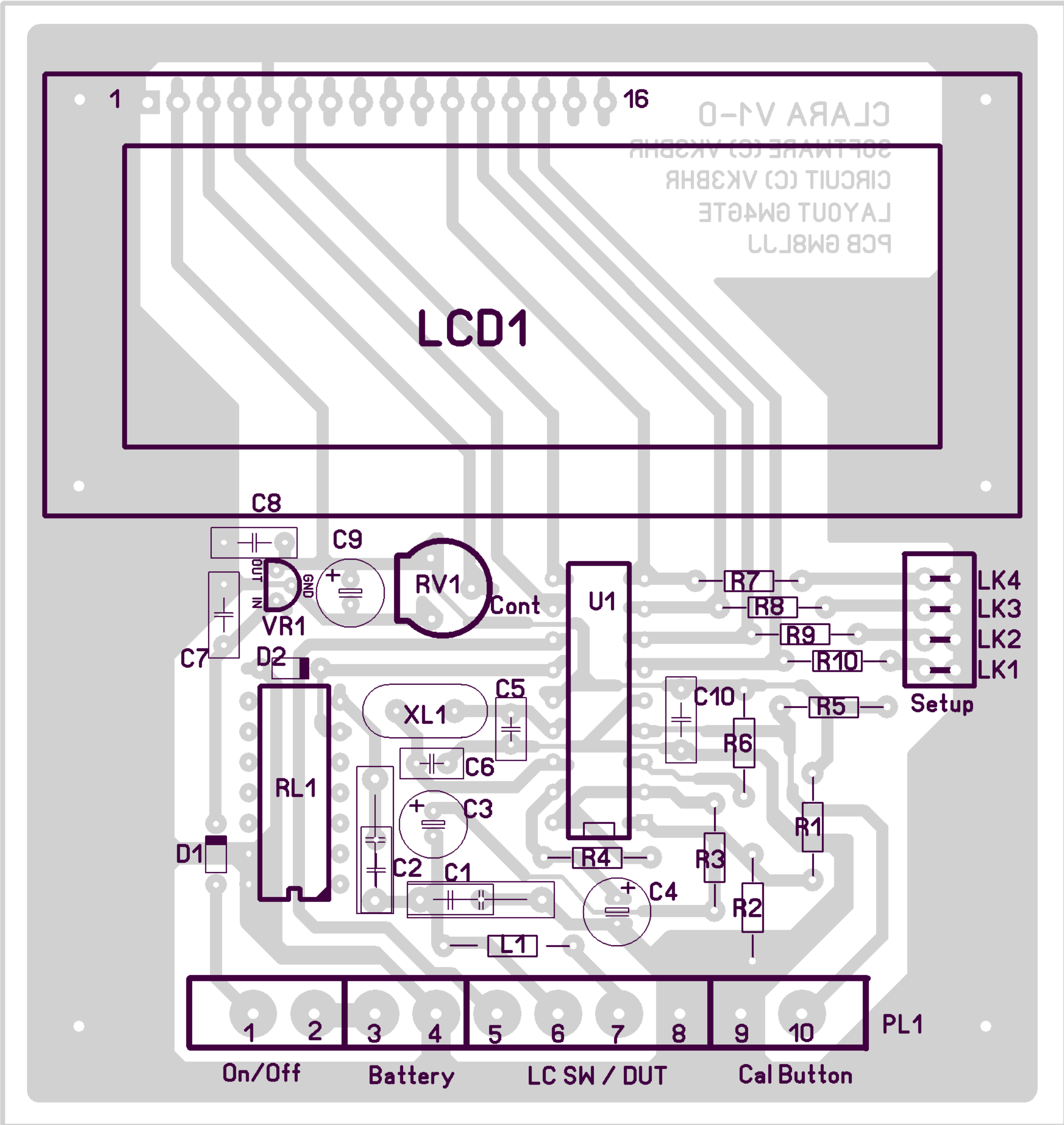

Figure 4.6 CLARA PCB layout

CLARA - Parts List

Component	Value	Notes
R1	100k ¼ W carbon film, 5% or better supplied	Or metal film as available
R2	100k ¼ W carbon film, 5% or better supplied	Or metal film as available
R3	100k ¼ W carbon film, 5% or better supplied	Or metal film as available
R4	47k ¼ W carbon film, 5% or better supplied	Or metal film as available
R5	4k7 ¼ W carbon film, 5% or better supplied	Or metal film as available
R6	4k7 ¼ W carbon film, 5% or better supplied	Or metal film as available
R7	1k0 ¼ W carbon film, 5% or better supplied	Or metal film as available
R8	1k0 ¼ W carbon film, 5% or better supplied	Or metal film as available
R9	1k0 ¼ W carbon film, 5% or better supplied	Or metal film as available
R10	1k0 ¼ W carbon film, 5% or better supplied	Or metal film as available
RV1	10K lin 5mm pitch LCD contrast	Cermet single turn horizontal
C1	1n 5mm or 10mm pitch polyester	Polystyrene or mica pref
C2	1n 5mm or 10mm pitch polyester	Polystyrene or mica pref
C3	10uF radial electrolytic 2.5mm pitch	
C4	10uF radial electrolytic 2.5mm pitch	
C5	33p NP0 ceramic 2.5mm pitch	
C6	33p NP0 ceramic 2.5mm pitch	
C7	100n ceramic 5mm pitch	
C8	100n ceramic 5mm pitch	
C9	10uF radial electrolytic 2.5mm pitch	
C10	100n ceramic 5mm pitch	
C(cal)	Calibration capacitor supplied with kit	See calibration notes
D1	1N4148	
D2	1N4148	
L1	82uH inductor	
VR1	78L05 low power 5V regulator	
XL1	4.00MHz HC49 low profile	20ppm recc. 50ppm ok.
U1	PIC 16F628 or 628A	18 pin DIL pre-programmed
RL1	5V reed relay 14pin DIL	Rapid # 60-2400
LCD1	LCD display 16 x 1 HD44780 compatible	
PL1	10 pin 5.08mm pitch header strip	Optional / direct solder
PL2	Battery connector for PP3	e.g. Maplin HF28F
LK1-4	2 x 4 pin 2.54mm pitch header strip	Plus single handbag link
SKT1	18 pin DIL socket for U1	
SKT2	14 pin DIL socket for RL1	
PL1	4-way sprung L/S connector for DUT conn.	Maplin BW71N
PB1	Push to make single pole push button	Chassis mounting, threaded
SW1	Single pole toggle on/off	Chassis mounting, threaded
SW2	Double pole double throw L/C select	Chassis mounting, threaded
PCB1	Etched /tinned/ drilled PCB	Manufactured by GW8LJJ
Case	User supplied	
PP3	9V battery – user supplied	
misc	Header pin strip for LK1-4 and LCD1	See section 4
M3 screws	10mm, black, qty 2	Lower LCD mounting
M3 screws	6mm, qty 4	Case attachment
M3 screws	8mm, qty 2	LCD corners
M3 nuts	qty 8	
M3 washers	qty 10	
M3 spacers	12mm, male/female, qty 2	Non LCD corners
M3 spacers	8mm, female/female, qty 2	LCD corners

Table 4.1 Parts list

5. Calibration / Normal Use

[Adapted from the original notes by VK3BHR)

1. Switch CLARA on with SW2 set to ‘C’. The display should briefly show the word ‘Calibrating’, then C=0.0pF (or some other capacitance up to +/- 10pF).
2. Allow several minutes "warm-up", then press button PB1 to force a re-calibration. The display should now show C=0.0pF.
3. CLARA should have been supplied with a test capacitor. An enclosed test sheet will indicate the actual measured value. This has been checked on a professional LC meter with a stated accuracy of 0.1%. Connect your test capacitor. The LC meter should read somewhere near its value (with up to +/- 10% error).
4. Attach the ‘handbag’ link provided to LK1 to raise the indicated capacitance or to LK2 to lower the indicated capacitance. When the indicated value is as close as possible to the required value, remove the link. The PIC will remember the calibration. You can repeat this as many times as required. The calibration is done in approximately 0.1% increments so the actual step value increase with capacitance – this is normal and is a characteristic of the design. Thus resolution decreases at higher capacitance / inductance values. See test results below.
5. If the meter misbehaves, you can use LK3 an LK4 to check the oscillator frequency. Apply link LK3 to check the free running frequency "F1" of the oscillator. This should be shown as 00050000 +/- 10%. If this reading is too high (near 00065535), the meter may go into "numerical overflow" and give you an error message. If the reading is too low (say below 00040000), you will lose some accuracy. Apply link LK4 to check the calibration frequency "F2" (C2 connected via RL1). This should be near 71% +/- 5% of the "F1" reading.
6. If the meter shows near 00000000 for F1 and or F2, then recheck the wiring around the L/C switch SW2.
7. The Inductance measuring function is automatically calibrated when you calibrate the capacitance function as the effect on the oscillator is the same – i.e. the frequency is reduced.

Normal Use

Measuring Capacitance
Set SW2 to the C position and switch on. For best results, allow CLARA to settle herself down for a few minutes then press the cal button to zero the display before making a measurement. Connect the component to be measured (the DUT – device under test) and note the reading. The display may take a few moments to stabilise for higher values of capacitor.

Measuring Inductance
Set SW2 to the L position and switch on. When L is selected with no inductance attached the display will show “Over Range”. Calibration can be performed by switching to the C position of SW2, pressing reset, then re-selecting L. Alternatively you may choose to short our the DUT connections and press reset to calibrate in the L position. This may help to offset wiring reactance when measuring low inductances.

6. Test Results

The tables below give a comparison between CLARA and a selection of professional LCR meters. The Tonghul TH2811D uses several fixed test frequencies including 100Hz, 1kHz and 10kHz and has a stated basic accuracy of 0.1%.

In table 1 CLARA was calibrated to read 100.2pF using the nominal 100pF test capacitor, measured as 100.21pF at 10kHz on the TH2811D.

Accuracy is very good (well within 2%) up to the 1800pF test capacitor after which CLARA appears to over-read somewhat. Inductance accuracy has not been checked although a similar level of accuracy can be expected as circuit operation is the same.

	TONGHUL TH2811D			CLARA	
Component	**100Hz**	**1kHz**	**10kHz**		
1pF	*	1pF	0.65pF	1.0pF	
3.3pF	*	3.1pF	3.27pF	3.7pF	
10pF	*	9.4pF	9.64pF	9.8pF	
27pF	27pF	27.1pF	27.08pF	27.5pF	
47pF	46pF	46.0pF	45.86pF	46.3pF	
100pF	100pF	100.4pF	100.21pF	100.2pF	CAL
470pF	470pF	469.4pF	468.51pF	468.8pF	
1200pF	1195pF	1193.2pF	1190.2pF	1195pF	
1800PF	1814pF	1804pF	1797pF	1809pF	
8200pF	8219pF	8213pF	8203pF	8420pF	
20nF	19.89n	19.91n	19.91n	20.78n	
47nF	46.41n	46.25n	45.82n	49.85n	
100nF	101.15n	100.8n	99.94n	110.9n	

Table 6.1 Test results

Component	HP4261A 1KHz	HP4285A 100KHz	CLARA
1pF	1.4pF	0.9pF	1.2pF
3.3pF	4.0pF	3.5pF	3.7pF
10pF	10.5pF	9.9pF	10.2pF
27pF	28.1pF	27.2pF	27.5pF
47pF	47.1pF	46.1pF	46.3pF
100pF	101.4pF	100.5pF	100.2pF
470pF	470pF	468.7pF	467.8pF
1200pF	1194pF	1.19nF	1.193nF
1.8nF	1.81nF	1.79nF	1.806nF
8.2nF	8.21nF	8.20nF	8.40nF
20nF	19.9nF	19.9nF	20.70nF
47nF	46.3nF	45.1nF	49.1nF
100nF	100.9nF	97.5nF	109.9nF

Table 6.2 More test results

7. Specification

[Edited from VK3BHR's original text]

Supply Voltage
7.5V to 35V. 9V PP3 cell (not supplied) recommended for battery-powered operation

Supply current
10mA nominal. Slight peak when calibrating.

Measurement Range

Capacitors - 0.0pF to about 100nF. The upper limit is set by the "quality" of the comparators and by the "Q" of the capacitor being measured and by the inductor "Q". The amplitude of the oscillator gets pretty low for "big Cs". This may lead to erratic oscillation.

Inductors - 0.0uH to somewhere over 10mH. The upper limit here seems to be set by stray capacitance in the inductor being measured. The meter cannot compensate for this.

Claimed Accuracy - At best, +/- 1% or reading +/- "one least significant digit". More likely accuracy +/- 2% or reading +/- "one least significant digit".

The test results in section 6 show CLARA to be very accurate for values up to several thousand pF which is the range where the best accuracy is required. The same accuracy results can be expected with inductors as the circuit effect is the same.

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