

LC meter notes 1 by G4KGP

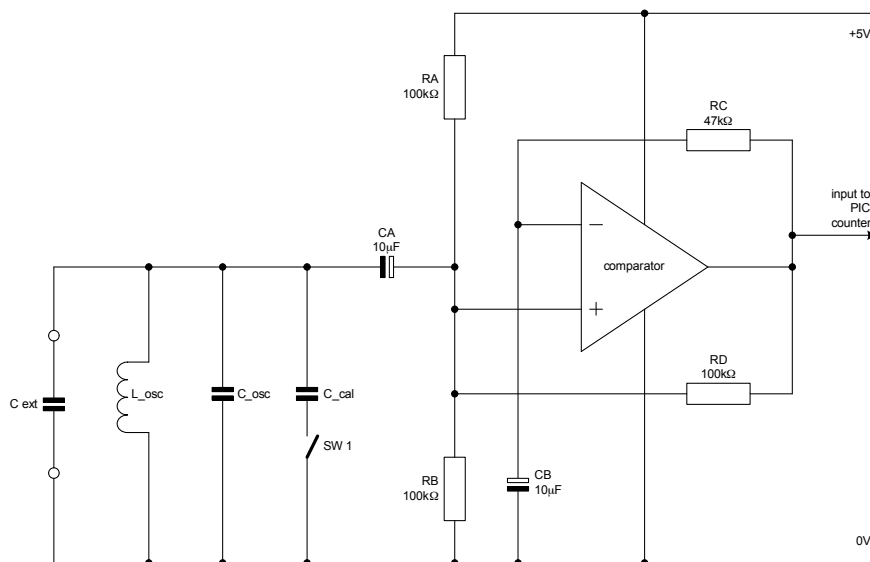
References

1. Inductance and Capacitance Meter Technical Manual by G4HUP
2. A Surprisingly Accurate Digital LC Meter by Phil Rice VK3BHR
3. Digital LC Meter Version 2 by Phil Rice VK3BHR
4. LC Meter Project and Kit by Neil Heckt of AADE (Almost All Digital Electronics)

These notes deal exclusively with the 'front end' of the LC meter – the part that responds to the L or C to be measured and discusses various aspects of this front end design. The information herein is based upon data derived from the above references and then thinking about it.

The LC meter's operational method is as follows;

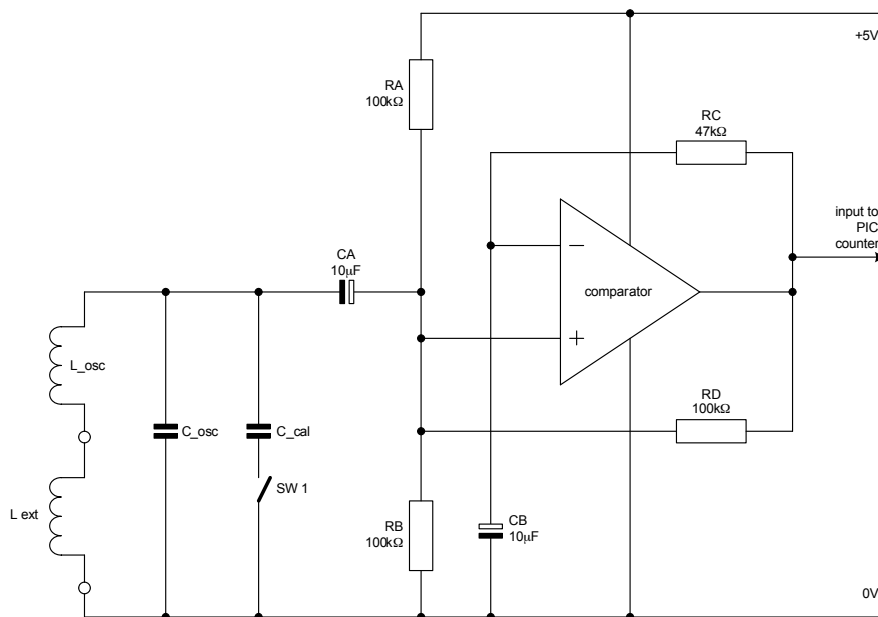
The front end circuit, which is based on a Voltage Comparator, is an oscillator whose oscillation frequency is initially set by an inductor (L_{osc}) and a capacitor (C_{osc}) as shown in the diagrams below. The first diagram shows the configuration for Capacitance measurement and the second diagram the configuration for Inductance measurement. S2 in the circuit diagrams presented in Reference 1 switches the circuit configurations (to those shown below) for C and L measurement.



CAPACITANCE MEASUREMENT

Note, the comparator circuit shown in references 2 and 4, which were the earlier versions of this LC meter, used a LM311 device as the Voltage comparator, whilst the later versions of the LC meter, which are discussed in References 1 and 3, use a Voltage comparator which is embedded within the PIC chip. Both versions of the circuit work in the same manner (though the LM311 circuit needs a 1kΩ pull up resistor on the comparator output and the PIC version does not need this resistor).

Imagine, for a moment, that the circuitry to the left of the 10μF capacitor CA connected to the comparator's + input is not connected (so all the components to the left of CA are not in the comparator circuit).



INDUCTANCE MEASUREMENT

Then the comparator circuit will act as a low frequency square wave oscillator whose frequency is set by the ratios of the 100kΩ resistors RA, RB & RD and the 47kΩ/10μF network RC & CB.

When the comparator's output is low then RD is effectively in parallel with RB, so causing the voltage at the comparator + input to be $\frac{1}{3} V_{cc}$, i.e. $0.3333 \times 5V = 1.667V$.

When the comparator's output is high then RD is effectively in parallel with RA, so causing the voltage at the comparator + input to be $\frac{2}{3} V_{cc}$, i.e. $0.6667 \times 5V = 3.333V$.

The average of these two values is $\frac{1}{2}V_{cc}$, i.e. 2.5V, which is the voltage that will be present on C8 when the circuit is oscillating at high frequency (see later below).

This then means that the time for one half cycle of oscillation will be $\log_e 0.5 \times RD \times CB$

$= 0.693 \times 47k\Omega \times 10\mu F = 0.3257$ seconds, so 2 of these $\frac{1}{2}$ cycles = 0.6514s, a frequency of 1.535Hz.

But now with the circuitry to the left of CA connected, these components form a parallel connected tuned circuit which is 'kicked' when the comparator's output stage changes from low to high. The tuned circuit rings when it is kicked and this ringing causes the comparator's output to change between high and low states at the same frequency of the ringing parallel tuned circuit, i.e. the whole circuit produces an output square wave whose frequency is determined by the tuned circuit to the left of CA. The frequency of oscillation has to be much greater than the low frequency (1.535Hz) calculated above for this oscillator to work properly.

Now looking at the tuned circuit components C_osc, L_osc, C_cal, C_ext and L_ext, the circuit functions as follows. C_ext or L_ext represent the C or L that will eventually be measured.

Firstly looking at the capacitance measurement circuit configuration, imagine that SW1 is open. This condition represents the highest frequency of oscillation since only C_osc and L_ext are in circuit.

Then imagine that SW1 is closed, so bringing C_cal into the circuit, which must then cause a lower oscillation frequency.

So, when the LC meter is self calibrating firstly the PIC measures its input frequency F1 with only C_osc and L_ext in circuit. Then, it measures the lower frequency F2 when C_cal is added into the

circuit. This arrangement means that the actual frequency F1 is not particularly important (but see more below about F1) but the change in frequency between F1 and F2 (which the PIC can measure very accurately) is important. Provided that the value of C_cal is accurately known then the PIC has sufficient 'information' to perform the mathematical calculations to subsequently determine the values of the externally added C_ext or L_ext. **This subsequently means that the accuracy of the measurement of the C or L you are measuring (C_ext or L_ext) is set only by the accuracy of C_cal and the PIC clock frequency (4MHz crystal oscillator).**

(all the versions of this LC meter in References 1 to 4 above use a 1000pF capacitor for C_cal, though Reference 4 also discusses a further 20pF capacitor added in parallel with the 1000pF capacitor to make 1020pF. 1000pF plus circuit stray capacitance could total 1024pF and 1024 just happens to be 2^{10} , which is a very convenient number for a digital counter – I do wonder if this is relevant within the PIC's programme).

Reference 2 includes the information that if the input frequency to the PIC counter is over 655.350kHz then the counter will overflow, and states, "for best accuracy, the free running frequency [F1] should be 10% to 15% below 655kHz. If it is too close, it may accidentally overflow the PIC's internal 16 bit count. You may need to adjust the inductance [L_osc] to get the frequency right."

For the club's LC meter kit, jumper connector 2 checks F1 and jumper connector 1 checks F2, which causes the PIC to measure and then display the oscillation frequency as measured over a 0.1s period.

Reference 1 and Reference 3 use L_osc = 100μH, C_osc = 1000pF and C_cal = 1000pF. These result in F1 being nominally 503.3kHz (i.e. a display of 00050330) and F2 being nominally 355.9kHz (i.e. a display of 000355900).

With L_osc changed to 82μH and with C_osc = 1000pF and C_cal = 1000pF, (as is presented in Reference 2) these result in F1 being nominally 555.8kHz (i.e. a display of 00055580) and F2 being nominally 393.0kHz (i.e. a display of 00039300).

Reference 4 uses L_osc = 68μH, C_osc = 680pF and C_cal = 1000pF. These result in F1 being nominally 740.1kHz (i.e. a display overflow because above 655.350kHz) and F2 being nominally 470.9kHz (i.e. a display of 00047090). If C_osc were to be 1000pF, with L_osc = 68μH and C_cal = 1000pF, then these values result in F1 being nominally 610.3kHz (i.e. a display of 00061030) and F2 being nominally 431.6kHz (i.e. a display of 00043160).

Then, when measuring capacitance (see first diagram) or inductance (see second diagram) these added components further reduce the comparator's oscillation frequency, which the PIC processes to display the component's value.

Conclusions – the calculations above show what the display should nominally indicate for various value combinations of L_osc, C_osc and C_cal.

The likely best combination (which will yield the optimum accuracy of measurement) is C_osc = 1000pF, L_osc = 68μH and C_cal = 1000pF. However, with these values be careful that F1 does not cause an overflow due to tolerance variations of C_osc and L_osc.