Basic Electronic Circuits

Experiment 2 **Series and Parallel Resonance** **Spring 2008-09**

The objective of this experiment is to study series and parallel resonance in an LCR circuit. The capacitor used in this experiment is a **1000 pF** polyester capacitor, and can be represented by a pure capacitance **C**. The inductor used in this experiment is a coil with a ferrite core, normally used as the antenna coil of an AM radio receiver. Such a coil does not unfortunately behave like a pure inductance, but has to be represented by a series combination of an inductance **L** and a resistance **r**. This resistance is not just the d-c resistance of the coil; it also includes a resistance which represents the power loss in the coil. Hence the resistance r is always higher than the resistance of the coil as measured by a multimeter. Moreover, the nonlinear magnetisation characteristics of ferrite core makes the coil behave in a slightly nonlinear fashion, leading to some distortions in the waveforms, as you will observe in this experiment

As the measurements will be made at high frequencies near the radio-frequency range, one has to take into account the finite input impedance of the connecting wires and the CRO, which presents a 1MΩ resistance in parallel with a 30pF capacitance at each channel input. While 1MΩ is a very high resistance in comparison with other resistances in the circuit and can hence be treated as an open circuit, the capacitance of the connecting cable plus the input capacitance of the CRO can be quite significant in comparison with the actual capacitance used in the circuit. This capacitance (**C_c**) will therefore have to be determined and included in all calculations.

1. Check the values of the given capacitor and resistors from the colour code or printed code. Set up the circuit shown in **Fig. 2.1**, with **R_s = 0** and **R = 10Ω** , the L-r combination representing the coil. Apply a sinusoidal voltage v_s having frequency 100kHz and an amplitude of 1V. Verify that v_i (= v_s, as R_s = 0) and v_R (= iR) are both sinusoidal by observing them on the CRO, using v_i to trigger the CRO. Change the CRO display mode to the x-y mode, and note the elliptical display, indicating a phase difference between v_i and i. Increase the frequency gradually until the display becomes a straight line, indicating that v_i and i are in phase. Verify that **v_R is maximum** at this frequency, which is the **series resonant frequency** of the LCR circuit, given by **$f_0 = 1/2\pi\sqrt{(LC)}$**. Note down the value of this frequency f_0 and the slope of the straight line, which is given by **$v_R/v_i = R/(R + r)$**.

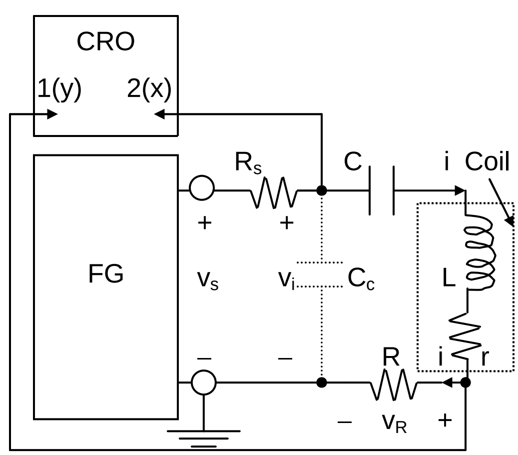

Fig. 2.1

2. Determine the value of **L** from the measured value of f_0, using the known value of C. Find the value of **r** from the measured value of v_R/v_i, using the known value of R. Measure the resistance of the coil with a multimeter and compare this value with that of **r**.

3. By changing the frequency on both sides of f_0, find the frequencies f_1 and f_2 giving a **phase difference of 45°** between v_i and v_R. Verify that v_R falls by a factor of $\sqrt{2}$ from its value at the resonant frequency f_0, i.e. **f_1** and **f_2** are the **half-power (3-dB) frequencies**.

4. Find the value of the bandwidth ($f_2 - f_1$) and hence **$Q = f_0 /(f_2 - f_1)$**. Compare this value with the expected value of **$Q = \sqrt{(L/C)}/(R+r)$.**

5. Insert R_s = **100 kΩ**, and connect v_i (instead of v_R) to channel 1(y), keeping v_s connected to channel 2(x), to obtain a display of v_i against v_s ($v_i \neq v_s$ now) with the CRO in the x-y mode. Starting with frequency 100 kHz, increase the frequency gradually until the display becomes a straight line again. Verify that v_i is minimum at this frequency, implying series resonance as observed in step 1, and note that this frequency is indeed the same as f_0 found in step 1.

6. Increase the frequency further to make the display become elliptic again, and keep increasing the frequency gradually until the display becomes a straight line again, with **v_i** attaining its **maximum** value, implying that this is the **parallel resonant frequency** of the entire circuit consisting of L, r, C, R and C_c: **$f_p = 1/ 2\pi\sqrt{(LC_{eq})}$**, where **$C_{eq} = CC_c/(C + C_c)$**. It is easy to see that **$(f_p/f_0)^2 = 1 + C/C_c$**. Use this relationship to determine the value of C_c from the measured values of f_p, f_0 and C. How does it compare with the CRO input capacitance?