Newcomers' Notebook

They always ring true
Resonant circuits

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An important element of any radio communications equipment is the LC circuit. The **L** stands for *inductance*, quoted in Henries (H) and named after the scientist Joseph Henry (1797–1878). The symbol L for inductance was chosen to honour the physicist Heinrich Lenz (1804–1865), who pioneered work in electromagnetic induction. The **C** of LC stands for *capacitance*, quoted in Farads (F) and named after the English physicist Michael Faraday (1791-1867).

As the symbolism implies, the components in a resonant circuit are an inductor and a capacitor. Depending on how the components are connected dictates how the circuit operates. Simple explanation without complex mathematics.

In RF circuits, the values of L are generally specified in very small fractions – microhenries (uH) and millihenries (mH); occasionally, in nanohenries (nH). Likewise with the values of C – generally, picofarads (pF – million-millionths) and nanofarads (nF – 1000-millionths). You'll get used to it.

A quick rehash

A capacitor is a component with two plates separated by a dielectric (an insulator). The capacitor will block DC and can store energy. The governing factors for capacitance are the size of the plates, the distance between them and the type of dielectric.

Inductors generally comprise a coil of wire that may be wound onto a 'former' that serves to hold it conveniently (often a cylinder), which attracts the generic name – *solenoid*. If wire of a sufficiently heavy gauge is use, the coil can be self-supporting; the simplest is just a single-turn loop.

Inductors also store energy and can block AC signals. Inductance is determined largely by the number of turns on the coil. A rod of special material (e.g, ferrite) may be placed in the coil centre, or used as the coil former, to increase the inductance by interacting with the magnetic field. Ferrite toroids enable high-value inductors to be made in a small volume; they have very low interaction with other material or coils nearby because the magnetic field is 'closed.'

Figure 1: Various capacitors encountered in resonant circuits used in radiocommunications equipment.

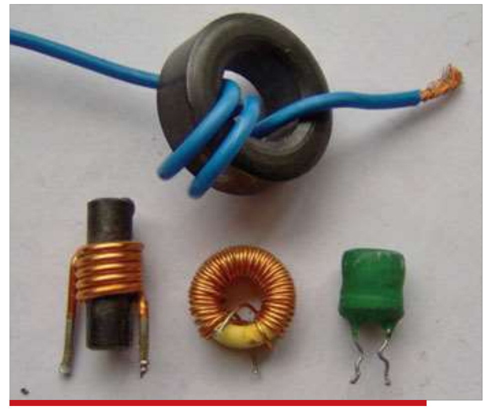

Figure 2: Various inductors that may be seen used in resonant circuits. The toroid at the top, with a few turns of heavy wire wound on it, may be used as a 'choke' to block RF current above a certain frequency.

Impedance

Every electrical and electronic component has a direct current resistance value measured in Ohms. The opposition to alternating current by inductors or capacitors is called *reactance*. The reactance value, also measured in Ohms, is dependent on the types and makeup of the components used, and the frequency.

Reactance is designated with the letter **X**, so capacitive reactance is $\mathbf{X_c}$, indicated with a negative number, while inductive reactance is $\mathbf{X_L}$, indicated with a positive number. Where you have inductance and capacitance in the circuit, the total reactance is the difference between the inductive reactance and capacitive reactance.

The total opposition (resistance and reactance) to alternating current in a circuit of two or more components, is called *impedance* (**Z**) and is also measured in Ohms. This is graphically shown in **Figure 3** as a triangle.

Series or Parallel

The components for an LC circuit can be connected in series or in parallel. An uncomplicated way to identify if the components are in series or parallel, is to

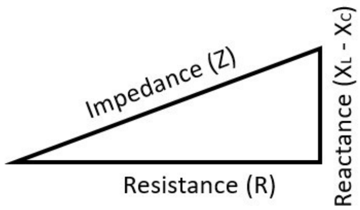

Figure 3: The 'impedance triangle'.

look at the current path. If the current in the circuit splits and goes through the inductor and capacitor separately, this is a parallel circuit, as illustrated in **Figure 4**. If all the current goes through one component then the other, then it's a series circuit, as seen in **Figure 5**.

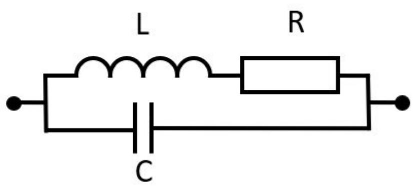

Figure 4: A parallel LC circuit. You'll often see them referred to as a 'tuned circuit', or occasionally a 'tank circuit'.

Figure 5: A series LC circuit.

Resonant frequency

The useful thing about LC circuits is that, with any combination of the values of C value and the L, they will have a *resonant frequency*. At this frequency, the circuits act differently than the components individually. The formula for these values is available on the internet – look for "LC resonant frequency".

A parallel LC circuit, such as **Figure 4**, will block any signal that is operating on the resonant frequency. In a parallel LC circuit at resonance, the time taken for the capacitor to charge and discharge, is the same time taken for the inductor to charge and discharge.

The energy in the circuit will charge the capacitor and, as the capacitor discharges, the energy will charge the inductor. As the inductor discharges, the energy recharges the capacitor. So, at the resonant frequency, the LC circuit will oscillate. The combined reactance is high, increasing the impedance as illustrated in **Figure 3**. So, at resonance, the parallel tuned circuit has a high impedance. A signal at any other frequency will pass through the parallel LC circuit.

In a series LC circuit, **Figure 5**, the energy goes through one component then the next. Any signal below the resonant frequency will be blocked by the capacitor. Signals above the resonant frequency will be blocked by the inductor. Signals at the resonant frequency are not blocked by the capacitor or the inductor.

At resonance in the series tuned circuit, the reactances cancel each other, leaving only resistance in the circuit. So, this circuit has a low impedance to the alternating signal.

About 'Q'

In an operational circuit, the ratio of the reactance to the resistance is called the **Q** (Quality Factor) of the circuit. If the current in the circuit is plotted against frequency, either side of the resonant frequency, the result will be a Q plot resembling a bell curve. The base of the bell and the height of the bell indicate the *bandwidth* of the circuit.

A sample Q plot of a series tuned circuit is shown in **Figure 6**. As the frequency drops, the capacitive reactance Xc is predominant, while the inductive reactance XL, is predominant in the higher frequencies.

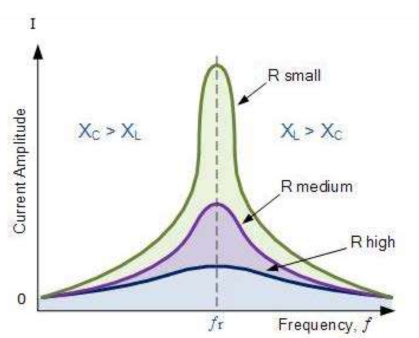

Figure 6: Sample Q plot – frequency versus current for a series tuned circuit.

Applications

These LC circuits are an essential building block in communications equipment. They can function as filters, tuning circuits for a receiver, or the basis of an oscillator. **Figure 7** shows a parallel tuned circuit – L1 and C1 – used to set the frequency of an oscillator. The smaller coil, L2, provides regenerative feedback for the circuit to maintain the tuned circuit oscillations. Sometimes, L2 is referred to as the 'tickler' coil.

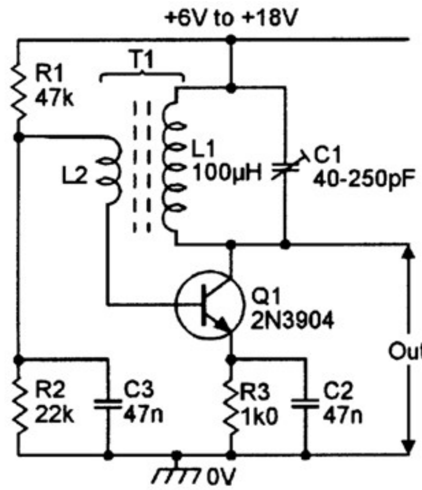

Figure 7: A parallel tuned circuit oscillator application.

Similarly, **Figure 8** shows a series tuned circuit – L1-C3 – in an oscillator circuit. At the resonant frequency, the tuned circuit is a very low impedance, allowing feedback between the transistor's collector and base, thus enabling oscillation. At frequencies away from resonance, the tuned circuit is a high impedance and C1-C2 will shunt signals to earth.

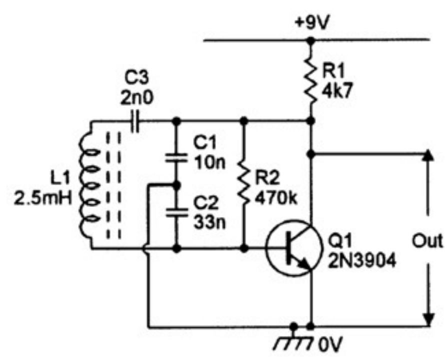

Figure 8: A series tuned circuit oscillator application.

If you have a topic you would like to be covered in a future instalment of Newcomers' Notebook, email Jules at jp.bqt@bigpond.net.au

Have fun and stay safe.