Basic Electronics Part 16
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When real components are connected in a circuit, the circuit can exhibit different behavior than what we have described in the past. For example, wire is used to connect various components and wire has some resistance, some capacitance, and some inductance, therefore, these quantities are introduced into a circuit. The wire used to construct an inductor or a capacitor has resistance; therefore, an inductor or capacitor added to a circuit will introduce some additional resistance. These may be small but they need to be considered if we are to understand how a circuit operates. We usually want the resistance in such components to be much smaller than the reactance of the capacitor or inductor.

We assign a number to a capacitor or an inductor to indicate that component's relative merits. The number represents a quality factor or Q for the component. The Q of a capacitor or an inductor is the ratio of the reactance to the resistance. The Q of a real capacitor, C, is equal to the capacitive reactance divided by the resistance. That is

$$Q = X_C / R.$$

The Q of a real inductor, L, is equal to the inductive reactance divided by the resistance. That is

$$Q = X_L / R.$$

Notice in both of these cases, the smaller the resistance, R, the larger the value of Q. Larger Q values indicate better quality components. We also recall that reactance varies with frequency. Capacitive reactance is largest at low frequencies and decreases as the frequency increases. Inductive reactance is smallest at low frequencies and increases as the frequency increases. To see how this will affect Q we consider several examples.

Consider the circuit in Fig. 1.

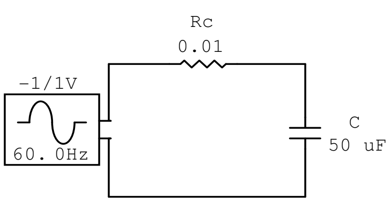

Fig. 1

If the signal generator applies an ac signal of 60 Hz into a 50 μF capacitor, C, that has 0.01 ohm of lead resistance, Rc, what is the capacitor's Q? Here

$$X_C = 1 / 2 \pi f C = 1 / (6.28)(60)(50)(10^{-6})$$

$$X_C = 1 / (18.85)(10^{-3}) = 53 \text{ ohms}.$$

The Q is given by

$$Q = 53 / 0.01 = 5300.$$

If the signal generator is changed to a 600 Hz signal, then we have

$$X_C = 1 / (6.28)(600)(50)(10^{-6})$$

$$X_C = 1 / (188.5)(10^{-3}) = 5.3 \text{ ohms.}$$

The Q is given by

$$Q = 5.3 / 0.01 = 530.$$

We see that the reactance at the higher frequency is 10 times smaller, so the Q at that frequency is also 10 times smaller. Thus, a higher frequency applied to a capacitor causes the reactance and the Q to become smaller.

Now look at the circuit in Fig. 2.

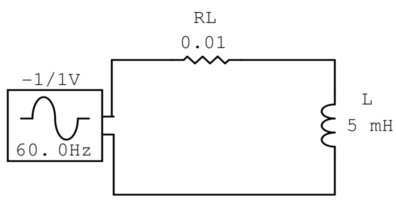

Fig. 2

If the signal generator applies an ac signal of 60 Hz into a 5 mH inductor, L, with a 0.01 ohm resistance in the wire, RL, we want to calculate the inductor's Q. Here

$$X_L = 2 \pi f L = (6.28)(60)(5)(10^{-3}) = 1.885 \text{ ohms.}$$

The Q is given by

$$Q = 1.885 / 0.01 = 188.5.$$

What is the inductor's Q at 600 Hz? To get this we calculate

$$X_L = (6.28)(600)(5)(10^{-3}) = 18.85 \text{ ohms.}$$

The Q is given by

$$Q = 18.85 / 0.01 = 1885.$$

Here the reactance at the higher frequency is 10 times higher than the reactance at the lower frequency, so the Q at that frequency is also 10 times higher. The higher frequency applied to an inductor causes the reactance and the Q to become higher.

In the next part we will talk about the trade-offs to consider when selecting components. These deal with the circuit function, the purpose a component serves in the circuit, and the frequency of signals applied to the component.