Basic Electronics Part 27
by
Thomas Atchison W5TV

We return to a circuit with resistance, R, inductance L, and an alternating voltage source. (Fig. 1)

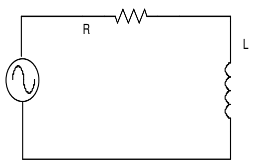


Fig. 1

Since this is a series circuit, the same current, I, flows through both R and L. Each component has its own series voltage drop. For the resistor, R, the voltage drop is $I R$. If the inductor has inductive reactance $X_L$ then the voltage drop across the inductance is $I X_L$.

Now, suppose $R=100\Omega$ and we measure the current as $I=1$ amp. Then the voltage drop across R is $V_R=I R$ so $V_R=100$ volts. Similarly, if the inductive reactance is $X_L=100\Omega$, then the voltage drop across L is $V_L=I X_L$. This means that $V_L=100$ volts. Following the same procedure as in Basic Electronics, Part 26, the total voltage, $V_T$, will be

$$\begin{aligned} V_T &= \sqrt{(I R)^2+(I X_L)^2} \\ &= \sqrt{100^2+100^2} \\ &= \sqrt{20000} \\ &= 141 \text{ volts.} \end{aligned}$$

The total opposition to current in a circuit is called the impedance. Impedance is denoted by $Z$. The relation connecting the impedance to the current and the total voltage is

$$V_T=I Z .$$

In this case, $V_T=141$ volts and $I=1$ amp, so $Z=141\Omega$.

Using the above equation for $V_T$, we have

$$I Z=\sqrt{(I R)^2+(I X_L)^2} .$$

This leads to

$$I\ Z=I\sqrt{R^2+X_L{}^2} .$$

We can divide out the common I to get

$$Z=\sqrt{R^2+X_L{}^2} .$$

Let's consider an example. Suppose we have $R = 30\,\Omega$ and $X_L = 40\,\Omega$ in a series circuit with an alternating voltage of 100 volts applied. In this case the circuit impedance, Z, is

$$Z = \sqrt{900 + 1600}.$$

So $Z = 50\,\Omega$.

The current, I, is given by

$$I = \frac{V_T}{Z}$$

so we have $I = 100/50 = 2$ amps.

The voltage across the resistor is given by

$$V_R = (2)(30) = 60 \text{ volts},$$

and the voltage across the inductance is given by

$$V_L = (2)(40) = 80 \text{ volts}.$$

The phase angle can be calculated using the reactance and the resistance as follows:

$$\tan\theta = \frac{X_L}{R}.$$

Here $\tan\theta = 40/30 = 1.333$ so we have $\theta = 53^o$. This means that $I$ lags $V_T$ by $53^o$.

Note that

$$\begin{aligned} V_T &= \sqrt{{V_R}^2 + {V_L}^2} \\ &= \sqrt{60^2 + 80^2} \\ &= \sqrt{3600 + 6400} \\ &= \sqrt{10000} \\ &= 100 \text{ volts}. \end{aligned}$$