# Electrical Circuits Lab. 0903219

## Series RL Circuit Phasor Diagram

### - Simple steps to draw phasor diagram of a series RL circuit without memorizing:

* Start with the quantity (voltage or current) that is common for the resistor **R** and the inductor **L**, which is here the source current **I** (because it passes through both **R** and **L** without being divided).

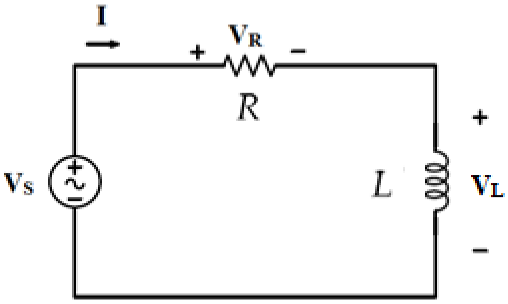
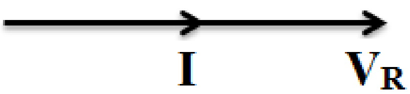



**Figure (1) Series RL circuit**

**Step1**

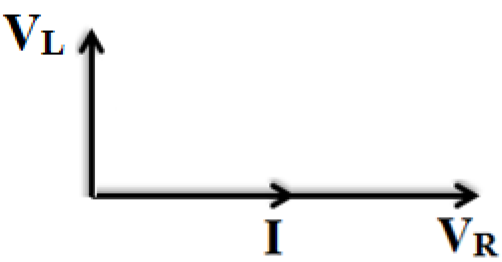

* Now we know that **I** and resistor voltage $\mathbf{V_R}$ are in phase or have the same phase angle (there zero crossings are the same on the time axis) and $\mathbf{V_R}$ is greater than **I** in magnitude.

**Step2**




* Since **I** equal the inductor current $\mathbf{I_L}$ and we know that $\mathbf{I_L}$ lags the inductor voltage $\mathbf{V_L}$ by 90 degrees, we will add $\mathbf{V_L}$ on the phasor diagram as follows:

**Step 3**




* Finally, the source voltage $\mathbf{V_S}$ equals the <u>vector summation</u> of $\mathbf{V_R}$ and $\mathbf{V_L}$:

**Step 4**

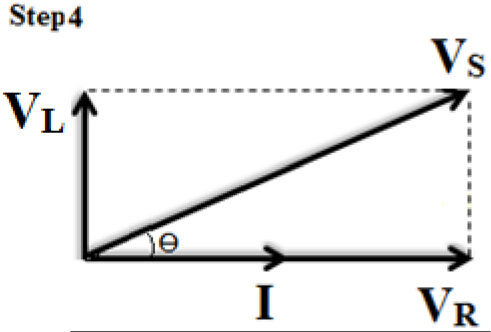



**Figure (2) Series RL circuit Phasor Diagram**

*Prepared by: Eng. Wiam Anabousi*

## - Important notes on the phasor diagram of series RL circuit shown in figure (2):

**A-** All the vectors are rotating in the same angular speed **ω**.

**B-** This circuit acts as an inductive circuit and **I** lags $\mathbf{V_S}$ by a phase shift of **Θ** (which is the current angle $\angle \mathbf{I}$ if the source voltage is the reference signal).

**Θ** ranges from 0° to 90° (0° < **Θ** <90°). If **Θ**=0° then this circuit becomes a resistive circuit and if **Θ**=90° then the circuit becomes a pure inductive circuit.

**C-** The phase shift between the source voltage and its current **Θ** is important and you have two ways to find its value:

**a-** $\Theta = \tan^{-1}\frac{V_L\,(imaginary\ part\ of\ V_S)}{V_R\,(real\ part\ of\ V_S)}$

**b-** $\Theta = \angle \mathbf{I} = -\angle \mathbf{Z} = -\tan^{-1}\frac{\omega L\,(imaginary\ part\ of\ Z)}{R\,(real\ part\ of\ Z)}$

**D-** Using the phasor diagram, you can find all needed quantities in the circuit like all the voltages magnitude and phase and all the currents magnitude and phase.

For a series **RL** circuit, if the magnitude of $\mathbf{V_L}$ and $\mathbf{V_R}$ was measured in Lab. (as a peak value from an oscilloscope or rms value from a digital multimeter), then we can find the magnitude of $\mathbf{V_S}$ as follows:

$|\boldsymbol{V_S}| = \sqrt{|\boldsymbol{V_L}|^2 + |\boldsymbol{V_R}|^2}$

**E-** You can find all leading or lagging quantities in this circuit with respect to a reference signal like the source voltage $\mathbf{V_S}$.

For example, it is clearly shown by the phasor diagram that **I** lags $\mathbf{V_S}$ by **Θ** degrees, $\mathbf{V_R}$ lags $\mathbf{V_S}$ by **Θ** degrees (since it is in phase with **I**) and $\mathbf{V_L}$ leads $\mathbf{V_S}$ by **90°- Θ**.

**F-** The phasor diagram helps in finding the change in current and voltage (magnitude and phase) with voltage source frequency ***f*** changing.

With frequency ***f*** increasing, the inductive reactance $\mathbf{X_L}$ will increase and $\mathbf{V_L}$ will increase too, the the resistor **R** will not be affected by the change of ***f***, then by voltage division rule $\mathbf{V_R}$ will decrease (to prevent $\mathbf{V_S}$ from changing since $\mathbf{V_S}$ is a voltage source). Since $\mathbf{X_L}$ increase and **R** is constant the total impedance **Z** will increase and the source current **I** will decrease. $\angle\mathbf{I}$ and $\angle\mathbf{Z}$ will increase because $\angle\mathbf{I} = -\angle\mathbf{Z} = \theta = \tan^{-1}\frac{V_L}{V_R} = -\tan^{-1}\frac{\omega L}{R}$ and the $\tan^{-1}$ function is increasing on the interval from 0 to $90^{o}$.

In a concise way:
$f\uparrow |\mathbf{X_L}|\uparrow |\mathbf{Z}|\uparrow |\mathbf{I}|\downarrow |\mathbf{V_R}|\downarrow |\mathbf{V_L}|\uparrow \Theta\uparrow$ .

**G-** Figure (3) below shows a time domain representation for all the vectors shown on the phasor diagram:

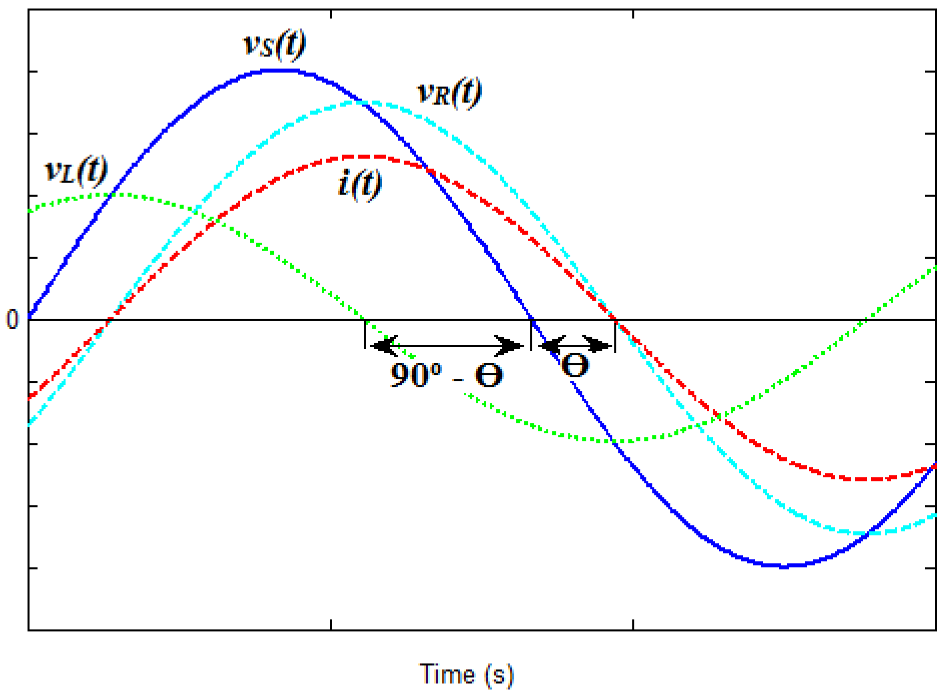



**Figure (3) Series RL Circuit Time Domain Representation**

# Electrical Circuits Lab. 0903219

# Parallel RL Circuit Phasor Diagram

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**- Simple steps to draw phasor diagram of a parallel RL circuit without memorizing:**

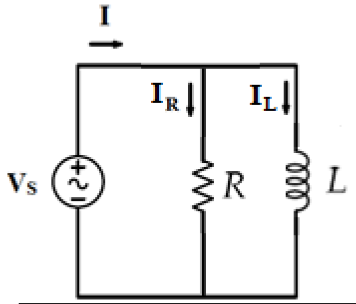



**Figure (1) Parallel RL**

* Start with the quantity (voltage or current) that is common for the resistor **R** and the inductor **L**, which is here the source Voltage $\mathbf{V_S}$ (because it is parallel with both **R** and **L** without being divided).

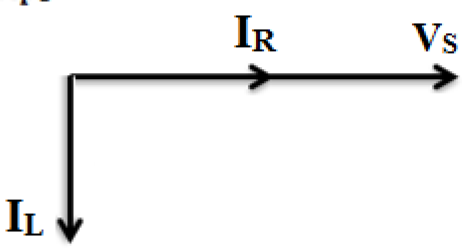
**Step1**


* Now we know that resistor current $\mathbf{I_R}$ and resistor voltage $\mathbf{V_R}$ (which equals $\mathbf{V_S}$) are in phase or have the same phase angle (there zero crossings are the same on the time axis) and $\mathbf{V_R}$ is greater than $\mathbf{I_R}$ in magnitude.

**Step2**


* Since $\mathbf{V_S}$ equal the voltage $\mathbf{V_L}$ and we know that $\mathbf{V_L}$ leads the inductor current $\mathbf{I_L}$ by 90 degrees, we will add $\mathbf{I_L}$ on the phasor diagram as follows:

**Step 3**




* Finally, the source current **I** equal the <u>vector summation</u> of $\mathbf{I_R}$ and $\mathbf{I_L}$:

**Step 4**

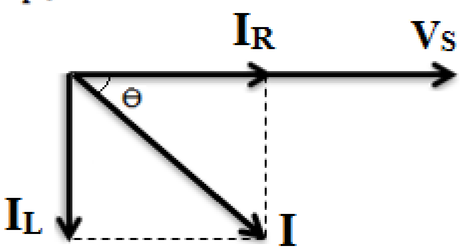



**Figure (2) Parallel RL circuit Phasor Diagram**

## - Important notes on the phasor diagram of Parallel RL circuit shown in figure (2):

**A-** All the vectors are rotating in the same angular speed **ω**.

**B-** This circuit acts as an inductive circuit and **I** lags $\mathbf{V_S}$ by a phase shift of **Ө** (which is the current angle $\angle\mathbf{I}$ if the source voltage is the reference signal).

**Ө** ranges from $0^o$ to $90^o$ ($0^o$ < **Ө** <$90^o$). If **Ө**=$0^o$ then this circuit becomes a resistive circuit and if **Ө**=$90^o$ then the circuit becomes a pure inductive circuit.

**C-** The phase shift between the source voltage and its current **Ө** is important and you have two ways to find its value:

$$\theta = \tan^{-1}\frac{I_L\ (imaginary\ part\ of\ V_S)}{I_R\ (real\ part\ of\ V_S)}$$

$$\theta = \angle\mathbf{I} = \angle\mathbf{Y} = \tan^{-1}\frac{B_L\ (imaginary\ part\ of\ Y)}{G\ (real\ part\ of\ Y)}$$

**D-** Using the phasor diagram, you can find all needed quantities in the circuit like all the voltages magnitude and phase and all the currents magnitude and phase.

For a parallel **RL** circuit, if the magnitude of $\mathbf{I_L}$ and $\mathbf{I_R}$ was measured in Lab. (as a peak value from an oscilloscope or rms value from a digital multimeter), then we can find the magnitude of **I** as follows:

$$|\mathbf{I}| = \sqrt{|\boldsymbol{I_L}|^2 + |\boldsymbol{I_R}|^2}$$

**E-** You can find all leading or lagging quantities in this circuit with respect to a reference signal like the source voltage $\mathbf{V_S}$.

For example, it is clearly shown by the phasor diagram that **I** lags $\mathbf{V_S}$ by **Ө** degrees, $\mathbf{I_R}$ leads **I** by **Ө** degrees and $\mathbf{I_L}$ lags **I** by $\mathbf{90^o}$**- Ө**.

**F-** The phasor diagram helps in finding the change in quantities (magnitude and phase) with voltage source frequency ***f*** changing.

With frequency $f$ increasing, the inductive reactance $\mathbf{X_L}$ will increase and so $\mathbf{I_L}$ will decrease, the the resistor **R** will not be affected by the change of $f$ and $\mathbf{I_R}$ will not change with frequency. Since $\mathbf{X_L}$ increase and **R** is constant the total impedance **Z** will increase, the source current **I** will decrease and the admittance **Y** will decrease. $\measuredangle\mathbf{I}$ and $\measuredangle\mathbf{Y}$ will decrease because $\measuredangle\mathbf{I} = \measuredangle\mathbf{Y} = \Theta = \tan^{-1}\frac{I_L}{I_R} = \tan^{-1}\frac{1/\omega L}{1/R}$ and the $\tan^{-1}$ function is increasing on the interval from 0 to 90°.

In a concise way:

$\boldsymbol{f}\uparrow |\mathbf{X_L}|\uparrow |\mathbf{Z}|\uparrow |\mathbf{Y}|\downarrow |\mathbf{I}|\downarrow |\mathbf{I_L}|\downarrow \boldsymbol{\Theta}\downarrow |\mathbf{I_R}|$**constant.**

**G-** Figure (3) below shows a time domain representation for all the vectors shown on the phasor diagram:

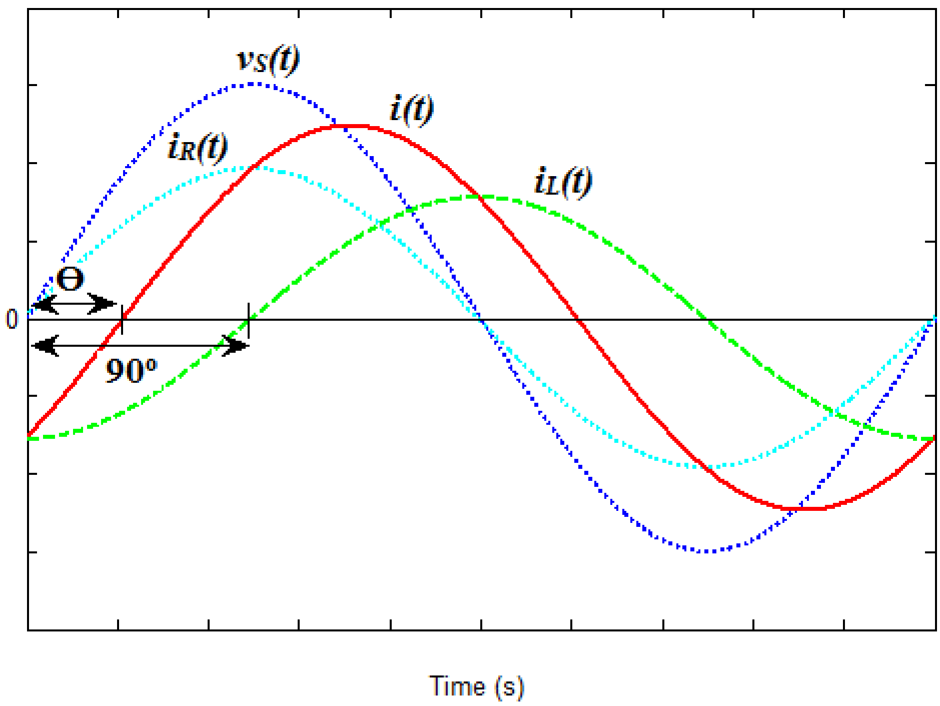



**Figure (3) Parallel RL Circuit Time Domain Representation**