Lab 9: Phasors

Report

Part 1: Capacitive Circuit

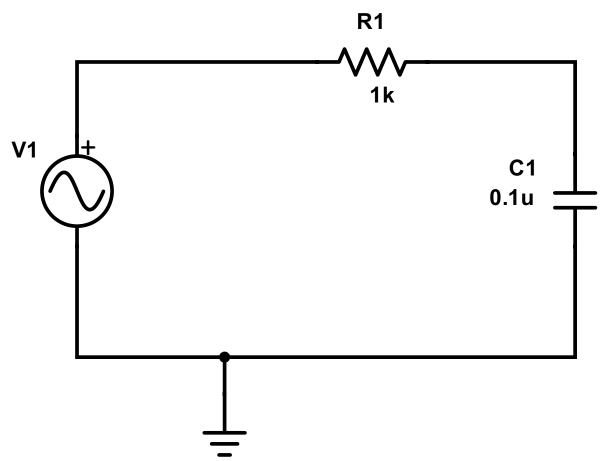


Figure 1: Series RC Circuit

Construct the circuit from Figure 1 on your breadboard.

1. Set the signal generator on the ADALM2000 to give a sinusoidal wave output with an amplitude of 1V ($2V_{pp}$), offset = 0V, and frequency = 500 Hz.
2. Connect channel 1 of the oscilloscope across V1 to measure V_{Source}.
3. Connect channel 2 of the oscilloscope across resistor R_1 to measure V_R.

Using cursors, measure the amplitude of the voltage across the resistor (not peak-peak) and the phase angle φ between V_R and V_{Source} (Hint: measure the time between a peak in V_R and V_{Source} and use that to calculate phase angle, and remember that sign matters). Write the measured V_R and φ_R in phasor notation below (include calculations).

$V_R\angle\varphi_R$:
$2\pi*500*400u = 72.5$ degrees

0.288 < 72.00

Using V_R, how can we calculate the current going through the circuit (in phasor notation)? Calculate it below:

$I\angle\varphi$:
I=V/R=0.288/1000=0.000288 A
Angle=72.5-0=72 degrees
Answer: 0.000288 < 72 degrees

Next, move channel 2 of the oscilloscope across C_1 to measure V_C (amplitude, not peak-peak). Find the amplitude and phase angle:

$V_C\angle\varphi_C$:

Vc = 0.961
Angle = $2\pi*500*-113u= -20.34$ degrees

V=0.961 < -20.7

Using the measured current and V_C, can you calculate and verify the complex impedance of the capacitor? Calculate Z_C using the measurements, and then calculate Z_C using the formula from the manual. Do they match up?

$Z_{C,\text{ measured}}$:

Zc=(V/I)=(0.961 < -20.7)/(0.000288 < 72 degrees)= 3336.8 < -92.7 degrees

$Z_{C,\text{ calculated}}$: 1/jwc=3189.099 <-90 degrees

CHECKPOINT 1: SHOW YOUR TA THE OSCILLOSCOPE RECORDING OF YOUR V_{SOURCE} AND V_C.

We have now verified the impedance of a capacitor using experimental measurements. Repeat this process now with the following frequencies: 1000, 2000, 4000, 8000 Hz. Fill Table 1 below. You do not need to show all your work.

Table 1: Measurements to verify a capacitor's complex impedance.

Freq. (Hz)	$Z_{C,calculated}(\Omega)$	V_R		I		V_C		$Z_{C,measured}(\Omega)$
		mag	phase	mag (mA)	phase	mag	phase	
500	3183 < -90	0.28	72	0.28	72	0.961	-20.7	3712.34<-92.7
1000	1592 < -90	0.53	26.8	0.45	26.8	0.805	-15.5	1428.84<-42.3
2000	795.79 < -90	0.809	12.37	0.703	12.37	0.652	-12.3	803.45<-24.67

4000	379.9 < -90	0.880	3.56	0.892	3.56	0.402	-7.77	420.20<-11.33
8000	198.944<-90	0.95	0.80	0.901	0.8	0.230	-3.5	164.23<-4.30

Part 2: Inductive Circuit

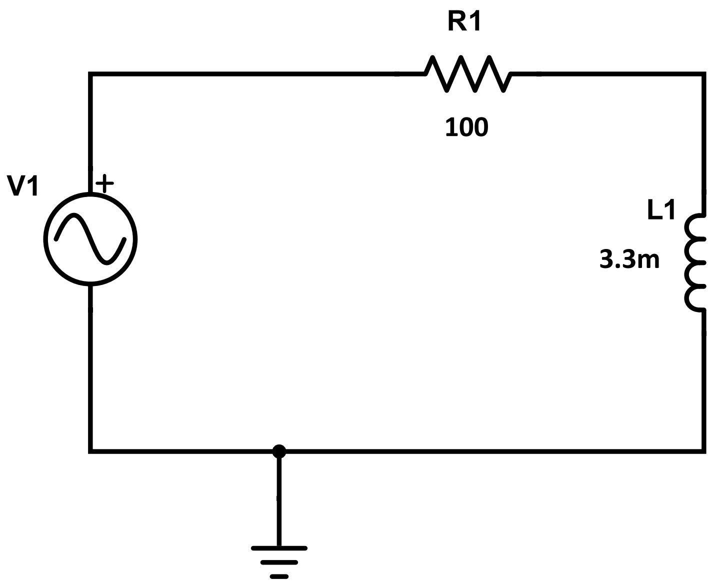


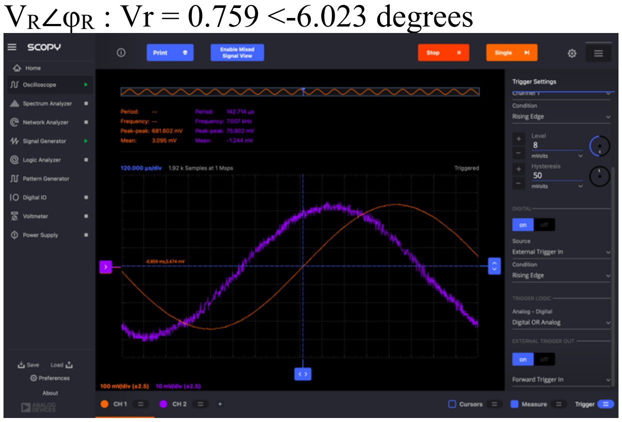
Figure 2: Series RL Circuit

We will now repeat the same experiments with an inductive circuit. Construct the circuit from Figure 2 on your breadboard.

1. Set the signal generator on the ADALM2000 to give a sinusoidal wave output with an amplitude of 1V ($2V_{pp}$), offset = 0V, and frequency = 500 Hz.
2. Connect channel 1 of the oscilloscope across V1 to measure V_{Source}.
3. Connect channel 2 of the oscilloscope across resistor R_1 to measure V_R.

Using cursors, measure the amplitude of the voltage across the resistor and the phase angle φ between V_R and V_{Source}.

$V_R\angle\varphi_R$: Vr = 0.759 <-6.023 degrees



Calculate current:

$I\angle\varphi$: 0.00759 <-6.023 degrees = (V/(100<0))

Next, move channel 2 of the oscilloscope across L_1 to measure V_L (amplitude, not peak-peak). Find the amplitude and phase angle:

$V_L\angle\varphi_L$: 0.077 < 60.3 degrees (V)

Using the measured current and V_L, calculate and verify the complex impedance of the inductor. Calculate Z_L using the measurements, and then calculate Z_L using the formula from the manual. Do they match up?

$Z_{L,\ measured}$: Z= (0.077<60.3)/ (0.00759 <-6.023) = 10.145<66.023 degrees $Z_{L,\ calculated}$: jwL=j*(500*2pi)*(3.3*10^-3)=10.367j=10.367<90 degrees

CHECKPOINT 2: SHOW YOUR TA THE OSCILLOSCOPE RECORDING OF YOUR V_{SOURCE} AND V_L.

Repeat this process now with the following frequencies: 1000, 2000, 4000, 8000 Hz. Fill Table 2 below. You do not need to show all your work.

Table 1: Measurements to verify a capacitor's complex impedance.

Freq. (Hz)	$Z_{L,calculated}(\Omega)$	V_R		I		V_L		$Z_{L,measured}(\Omega)$
		mag	phase	Mag(mA)	phase	mag	phase	
500	10.367 <90	0.731	-6.562	7.23	-6.562	0.076	62.37	10.36<57.3
1000	20.7325<90	0.630	-12.13	7.06	-12.13	0.153	71.25	20.67<85.43
2000	41.47<90	0.622	-24.32	6.52	-24.32	0.272	67.32	41.05<86.81
4000	82.938<90	0.604	-37.76	4.97	-37.76	0.531	50.52	100.54<83.15
8000	165.876<90	0.513	-57.10	4.35	-57.10	0.821	33.03	140.67<87.72

Does the voltage measured across the capacitor from Part 1 lead or lag behind V_{Source}? What about the voltage measured across the inductor in Part 2? Use the complex impedance equations from the formulas section on the first page of the manual to provide a mathematical explanation for this.

In the part we know that the voltage across the capacitor lags behind the voltage source sinch the capacitor has causes a negative reactive, more specifically though, the impedence is purely imaginary and thus the phase angle is -90 degrees.

$$Zc = -\frac{j}{\omega C} = \left(\frac{1}{\omega C}\right) < -90$$

$$Z_{eq} = R - \frac{1}{\omega C}j = A < -\phi \rightarrow where - \phi\ is\ in\ the\ fourth\ quadrant$$

$$Ic = \frac{Vs < 0}{A < -\phi} = B < \phi \rightarrow where\ B\ is\ \left(\frac{Vs}{A}\right)$$

Thus one can derive the voltage across the capacitor by:

Vc=$(Ic) * (Z_c) = (B < \phi)\left(\left(\frac{1}{\omega C}\right) < -90\right) = Vc < (\phi - 90)$

Since we know the ϕ is between 0 and 90 (by way of it being in the fourth quadrant), we know that the phase angle of Vc $(\phi - 90)$ is always less than, and thus Vc lags Vs.

(Note: additionally that the in-phase, $\phi = 90$ condition is not possible unless w or c are infinite)

We can apply the same principles to the inductive circuit:

$$ZL = jwL = (wL) < 90$$

$$Z_{eq} = R + (wL)j = A < \phi \rightarrow where\ \phi\ is\ in\ the\ first\ quadrant$$

$$Ic = \frac{Vs < 0}{A < \phi} = B < -\phi \rightarrow where\ B\ is\ \left(\frac{Vs}{A}\right)$$

Thus one can derive the voltage across the capacitor by:

Vc=$(Ic) * (Z_c) = (B < -\phi)(wL < 90) = Vc < (90 - \phi)$

Conversely to the capacitor calculations, by way of ϕ being in the first quadrant always, we can say that the phase angle $(90 - \phi)$ is always greater than or equal to 0

(Note: additionally that the in-phase, $\phi = 90$ condition is not possible unless w=0)