In the lab, the nominal AC circuit was set up with $v_S(t) = 8\cos(1000t)$ V and the component values shown.

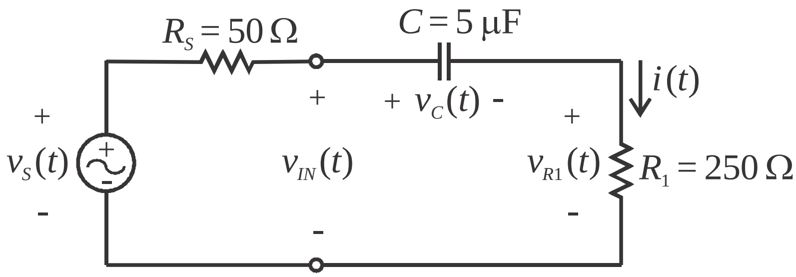


Figure 1 Nominal time-domain circuit

We will use experimental measurements to determine the values for the following phasor equivalent circuit and later the 'real' time-domain circuit.

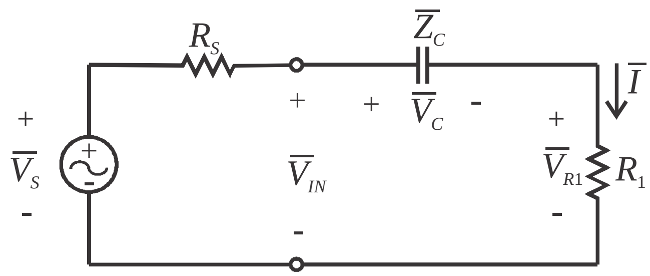
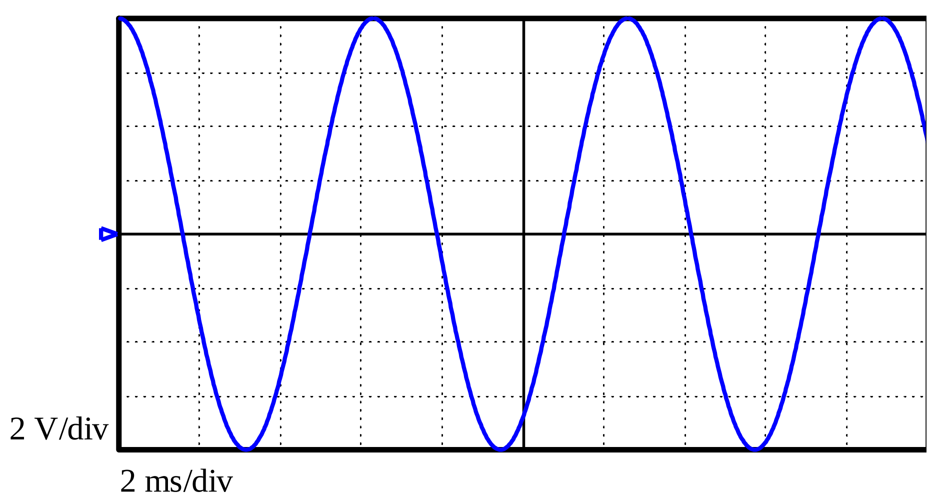


Figure 2 Phasor equivalent circuit

1) Assume that $\underline{\boldsymbol{R_S = 50\ \Omega}}$ as specified by function generator specifications.
2) Use a digital multimeter to measure $\underline{\boldsymbol{R_1 = 251.48\ \Omega}}$.
3) Use an oscilloscope connected directly to the function generator to set up $v_S(t)$ with the screen display shown below.

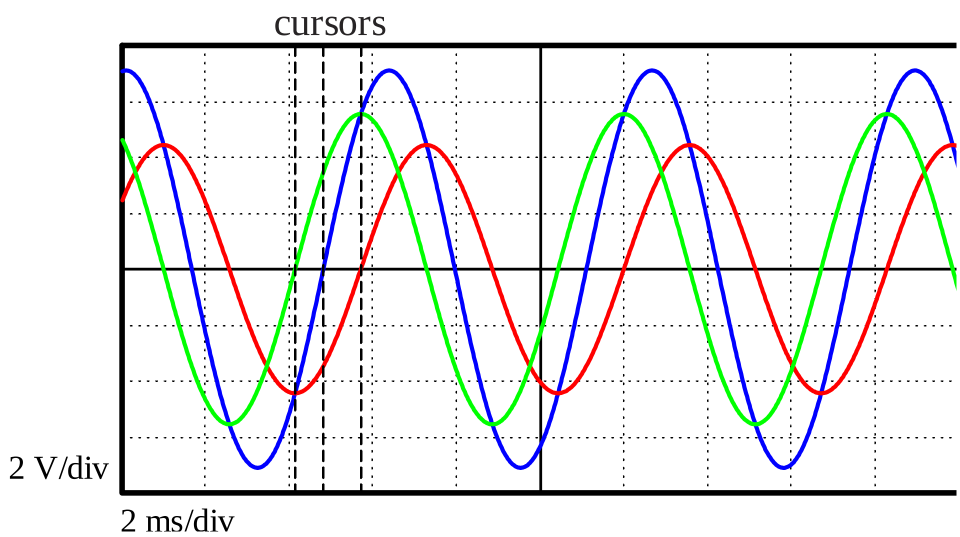


Using the oscilloscope measurements menu, determine:

the peak-to-peak voltage is $\underline{15.98\text{ V}} \Rightarrow \underline{\boldsymbol{V_{S,m} = 7.99\text{ V}}}$, and

the period is $\underline{\boldsymbol{T = 6.283\text{ ms}}}$.

4) Connect the circuit shown in Figure 1. Then, set up and connect the oscilloscope to measure $v_{IN}(t)$ [ch 1- blue line], $v_{R1}(t)$ [ch 2- green line], & $v_C(t)$ [math- red line] with the screen display shown below.



Using the oscilloscope measurements menu, determine:

the peak-to-peak voltage for $v_{IN}(t)$ is 14.38 V ⇒ $\mathbf{V_{IN,m} = 7.19\ V}$,

the peak-to-peak voltage for $v_{R1}(t)$ is 11.22 V ⇒ $\mathbf{V_{R1,m} = 5.61\ V}$, and

the period is $\mathbf{T = 6.283\ ms}$ (no change).

Using the oscilloscope cursors menu, determine:

the peak-to-peak voltage for $v_C(t)$ is 8.98 V ⇒ $\mathbf{V_{C,m} = 4.49\ V}$,

the time offset between $v_{IN}(t)$ & $v_{R1}(t)$ is +673 µs

now calculate ⇒ $\boldsymbol{\theta_{R1}} \mathbf{= 0.673/6.283*360° = 38.56°}$,

the time offset between $v_{IN}(t)$ & $v_C(t)$ is -900 µs

now calculate ⇒ $\boldsymbol{\theta_{C}} \mathbf{= -0.900/6.283*360° = -51.57°}$,

Hints:

- To determine the magnitude of sinusoidal signals, measure the peak-to-peak voltage V_{pp}. Then, the sinusoidal voltage magnitude $V_m = V_{pp}/2$.
- To calculate the phase angle of sinusoidal voltages relative to our reference signal $v_{\mathrm{IN}}(t)$:
  a) Measure period T of the sinusoidal voltages. Remember one period T is equivalent to 360° of phase.
  b) Measure time offset Δt_{off} (positive number) between the sinusoidal voltage with respect to $v_{\mathrm{IN}}(t)$. The magnitude of the offset angle is $\theta_{\mathrm{off}} = (\Delta t_{\mathrm{off}} / T) * 360°$.
  c) Comparing similar points on the sinusoidal voltages (e.g., zero crossings with positive slopes), if the voltage is shifted to the left of $v_{\mathrm{IN}}(t)$, θ_{off} is leading (positive angle). If the voltage is shifted to the right of $v_{\mathrm{IN}}(t)$, θ_{off} is lagging (negative angle).

5) Assuming $v_{IN}(t)$ to be the reference voltage, determine the phasors $\bar{V}_{IN}$, $\bar{V}_{R1}$, & $\bar{V}_C$ from the oscilloscope data:

$$\bar{V}_{IN} = V_{IN,\text{m}}\angle 0^\circ \quad \Rightarrow \quad \underline{\bar{V}_{IN} = 7.19\angle 0^\circ \text{ V}}$$

$$\bar{V}_{R1} = V_{R1,\text{m}}\angle\theta_{R1} \quad \Rightarrow \quad \underline{\bar{V}_{R1} = 5.61\angle 38.56^\circ \text{ V}}$$

$$\bar{V}_C = V_{C,\text{m}}\angle\theta_C \quad \Rightarrow \quad \underline{\bar{V}_C = 4.49\angle -51.57^\circ \text{ V}}$$

6) Using Ohm's Law, $\bar{V}_{R1}$, & the measured R_1, determine the phasor current $\bar{I}$ when $v_{IN}(t)$ is the reference:

$$\bar{I} = \bar{V}_{R1} / R_1 = 5.61\angle 38.56^\circ / 251.48 \quad \Rightarrow \quad \underline{\bar{I} = 22.308\angle 38.56^\circ \text{ mA}}$$

7) Using KVL, $\bar{V}_{IN}$, $\bar{I}$, R_1, and Ohm's Law, determine the phasor source voltage $\bar{V}_S$ when $v_{IN}(t)$ is the reference:

$$\bar{V}_S = \bar{I}\,R_S + \bar{V}_{IN} = (0.0223\angle 38.56^\circ)50 + 7.19\angle 0^\circ = 8.09\angle 4.93^\circ \text{ V}$$

However, we earlier measured $V_{S,\text{m}}$ = 7.99 V. So, adjusting the magnitude while keeping the phase angle, yields

$$\Rightarrow \quad \underline{\bar{V}_S = 7.99\angle 4.93^\circ \text{ V}}$$

8) Make $v_S(t)$ the reference signal by subtracting 4.93° from all the phasor angles

$$\bar{V}_S = 7.99\angle(4.93 - 4.93)^\circ \text{ V} \quad \Rightarrow \quad \underline{\bar{V}_S = 7.99\angle 0^\circ \text{ V}}$$

$$\bar{V}_{IN} = 7.19\angle(0 - 4.93)^\circ \quad \Rightarrow \quad \underline{\bar{V}_{IN} = 7.19\angle -4.93^\circ \text{ V}}$$

$$\bar{V}_{R1} = 5.61\angle(38.56 - 4.93)^\circ \quad \Rightarrow \quad \underline{\bar{V}_{R1} = 5.61\angle 33.63^\circ \text{ V}}$$

$$\bar{V}_C = 4.49\angle(-51.57 - 4.93)^\circ \quad \Rightarrow \quad \underline{\bar{V}_C = 4.49\angle -56.50^\circ \text{ V}}$$

$$\bar{I} = 22.308\angle(38.56 - 4.93)^\circ \quad \Rightarrow \quad \underline{\bar{I} = 22.308\angle 33.63^\circ \text{ mA}}$$

9) Using $\bar{V}_C$, $\bar{I}$, and Ohm's Law, determine the impedance $\bar{Z}_C$ and the measured phasor equivalent circuit:

$$\bar{Z}_C = \bar{V}_C / \bar{I} = (4.49\angle -56.50^\circ)/(0.02231\angle 33.63^\circ) \approx -0.46 - j201.25\Omega$$

Neglect small real part to get $\quad \Rightarrow \quad \underline{\bar{Z}_C = -j201.25\ \Omega}$

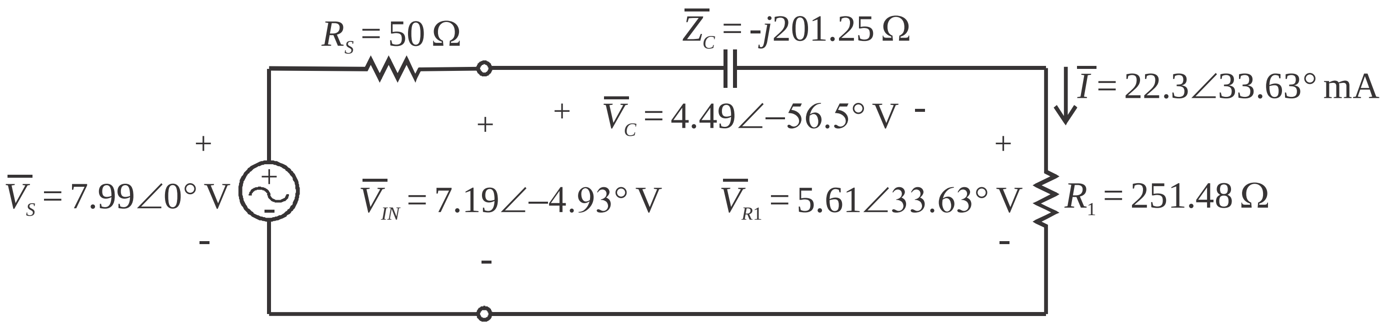


Figure 3 Measured phasor equivalent circuit

10) Using $\bar{Z}_C$, ω = 2π/*T*, and the definition of the impedance of a capacitor, determine the measured capacitance *C*:

$$\bar{Z}_C = -j201.25\ \Omega = \frac{-j}{\omega C} = \frac{-j}{(2\pi / T)C} = \frac{-j}{(2\pi / 0.006283)C}$$

Solving for *C*, we get $\Rightarrow \quad \underline{C = 4.969\,\mu\text{F}}$

11) Using the phasors, ω = 2π/*T*, and Euler's identity, determine the measured time-domain circuit:

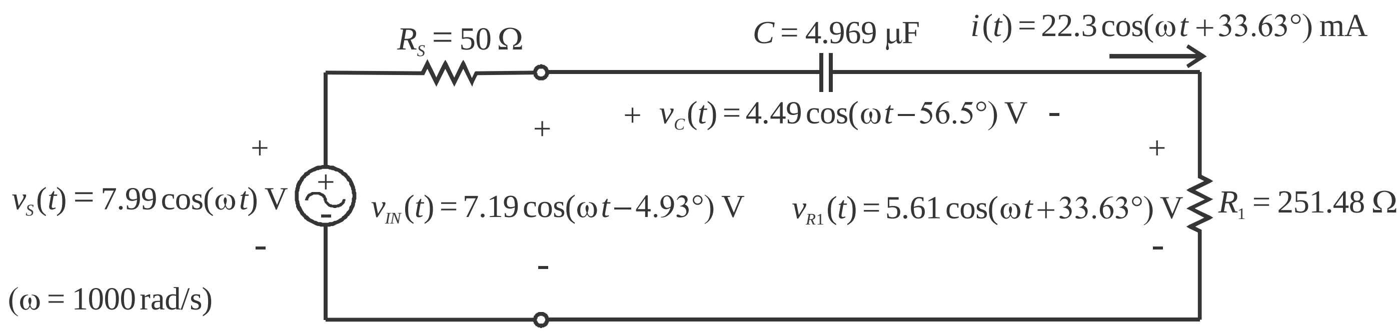


Figure 4 Measured time-domain circuit