P1 Determine $v_{out}(t)$:

707Ω

$v_{in}(t) = 5\cos(1000t)$

1μF 1μF 1.414kΩ $v_{out}(t)$ + −

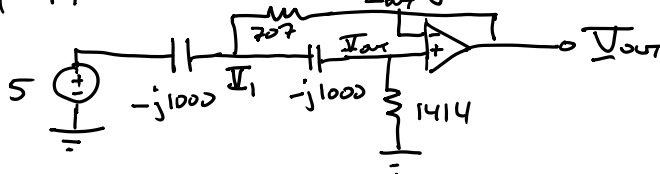Hint: Answer's phase should be close to 90°.

① Change to freq domain

707

$5\angle 0 = 5$

$\frac{1}{j\omega C} = -j1000$ $-j1000$ 1414 V_{out}
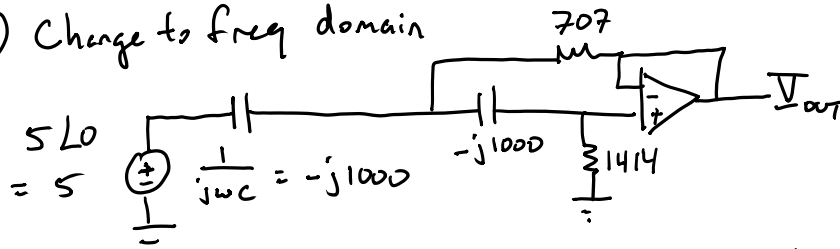
② Opamp, so use Nodal, noting $V^+ = V^-$ so only 1 variable there

707 I_{out} V_{out}

5 $-j1000$ V_1 $-j1000$ 1414 V_{out}

③ Op amp, so do not do a KCL @ output

$V_1: \dfrac{V_1 - 5}{-j1000} + \dfrac{V_1 - V_{out}}{-j1000} + \dfrac{V_1 - V_{out}}{707} = 0$ group variables on left, constants on right

$V_2: \dfrac{V_{out} - V_1}{-j1000} + \dfrac{V_{out}}{1414} = 0$

$V_1\left(\dfrac{1}{-j1000} + \dfrac{1}{-j1000} + \dfrac{1}{707}\right) + V_{out}\left(\dfrac{1}{j1000} - \dfrac{1}{707}\right) = -\dfrac{5}{j1000}$ put in a matrix

$V_1\left(\dfrac{1}{j1000}\right) + V_{out}\left(\dfrac{1}{-j1000} + \dfrac{1}{1414}\right) = 0$

$\begin{bmatrix} 0.00141 + j0.002 & -0.00141 - j0.001 \\ -j0.001 & 0.000707 + j0.001 \end{bmatrix}\begin{bmatrix} V_1 \\ V_{out} \end{bmatrix} = \begin{bmatrix} j0.005 \\ 0 \end{bmatrix}$ calc in polar, degrees

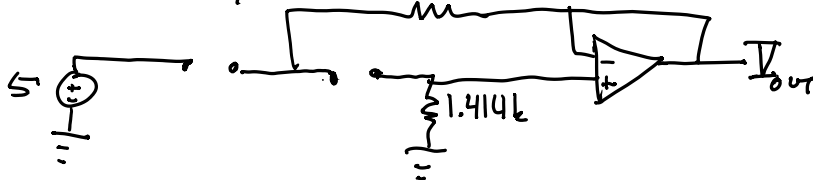$\Rightarrow \begin{bmatrix} V_1 \\ V_{out} \end{bmatrix} = \begin{bmatrix} 4.33\angle 54.7° \\ 3.54\angle 90° \end{bmatrix}$

④ Convert to time domain: $\boxed{V_{out}(t) = 3.54\cos(1000t + 90°)\ V}$

P2   What is $V_{out}(t)$ if we change $v_{in}(t)$ to 5V (i.e. a **DC** signal of $\omega = 0$ rad/s)

Here $\omega = 0$ so $Z_c = \frac{1}{j\omega C} = \infty =$ an open

① Redraw in freq domain

707

5 ⎓

1.414k

V_{out}

Could redo phasor analysis, but smarter to use intuition

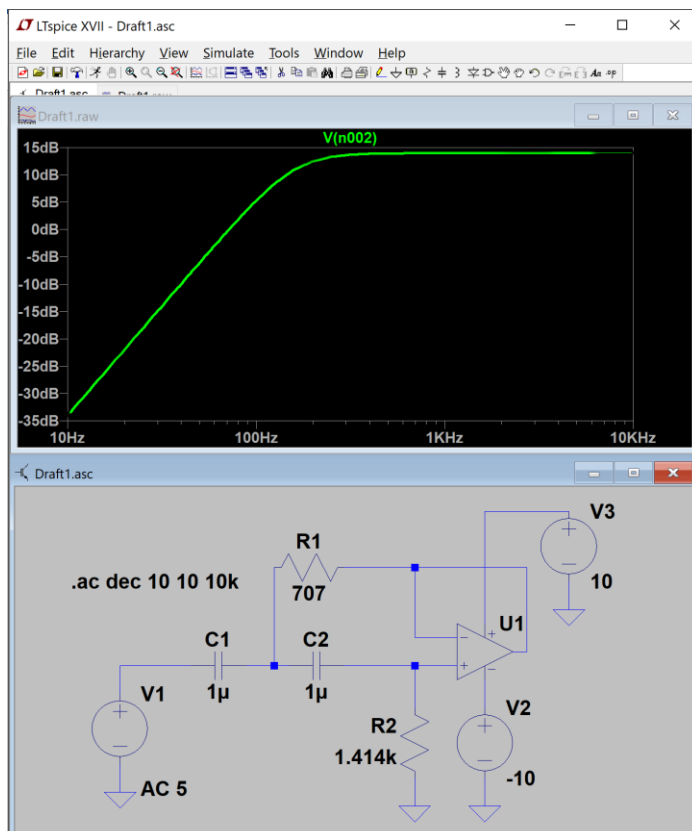a) $V^+ = 0$ by sight ($I=0$ so no voltage drop across R)

b) $V^- = V^+ = 0$ since opamp

c) $V_{out} = V^- = 0$ since connected by a wire

② $\boxed{V_{out}(t) = 5V}$

P3   Plot the magnitude of $v_{out}(t)$ as the input frequency changes from 10 to 10kHz using LTspice. This is an example of a *filter*. Does it pass low or high frequencies?

Use UniversalOpamp2
Passes high frequencies