ECE2101L
Electrical Circuit Analysis II Laboratory

Lab 8
Op Amp in AC Circuits

Report

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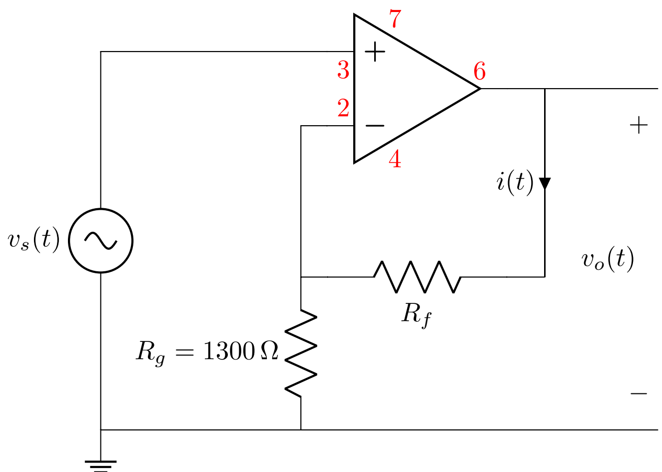
1 Basic characteristics of non-inverting positive-gain op amp circuit



Theory

Assuming ideal op amp, no current is flowing into inverting input and there is no voltage difference between inverting and non-inverting input, therefore i is both the current flowing across R_f and across R_g and voltage at inverting input is v_s. Then:

$$i = \frac{v_s}{R_g}$$

$$v_o = iR = \frac{v_s}{R_g}(R_f + R_g) = (\frac{R_f}{R_g} + 1)v_s$$

$$G = \frac{v_o}{v_s} = (\frac{R_f}{R_g} + 1)\frac{v_s}{v_s} = \frac{R_f}{R_g} + 1$$

For sinusoidals:

$$v_{rms} = \frac{v_{peak}}{\sqrt{2}} \quad i_{rms} = \frac{i_{peak}}{\sqrt{2}}$$

Procedure

The above circuit was simulated with LTspice XVI as follow. The obtained measurements of voltage and current are then divided by $\sqrt{2}$ to obtain the below results.

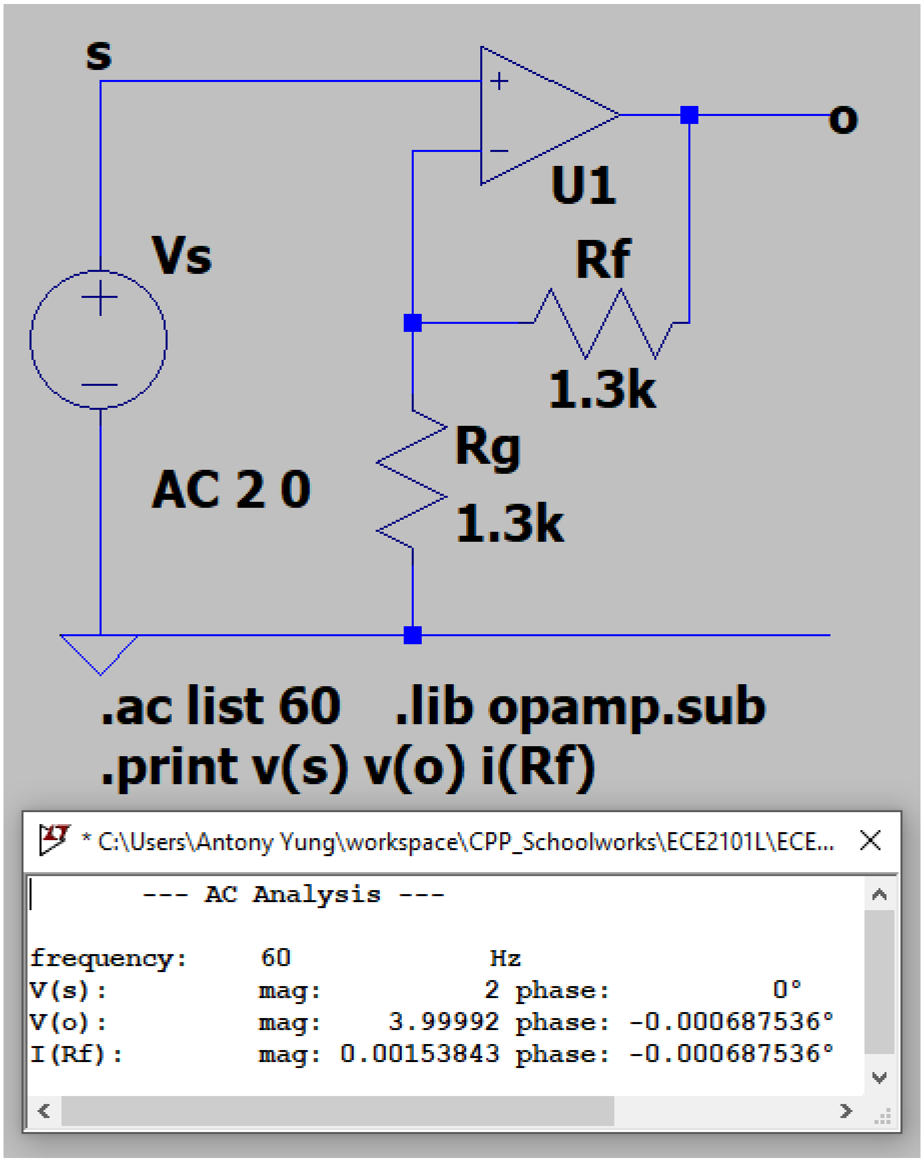


Figure 1: Screenshot of circuit description used and the simulation result with $R_f = 1.3\,\mathrm{k\Omega}$

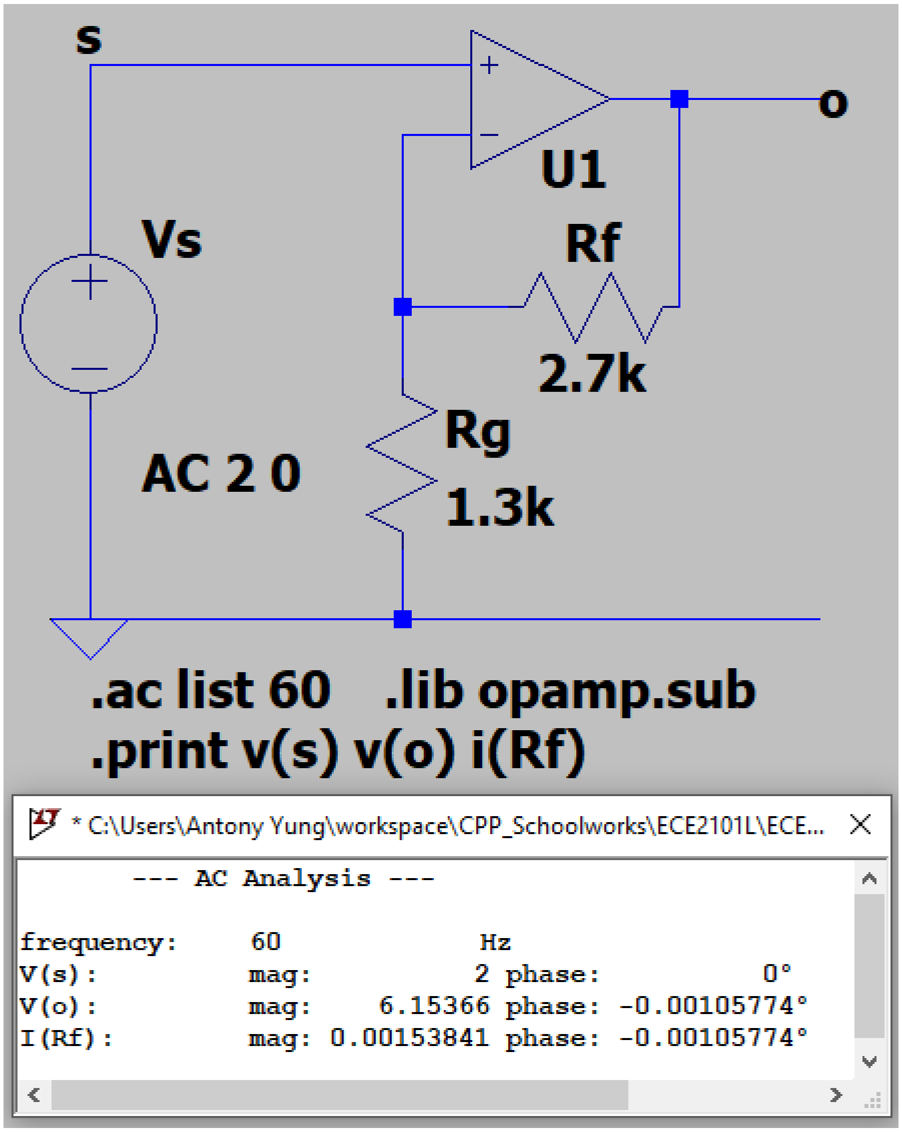


Figure 2: Screenshot of circuit description used and the simulation result with $R_f = 2.7\,\mathrm{k}\Omega$

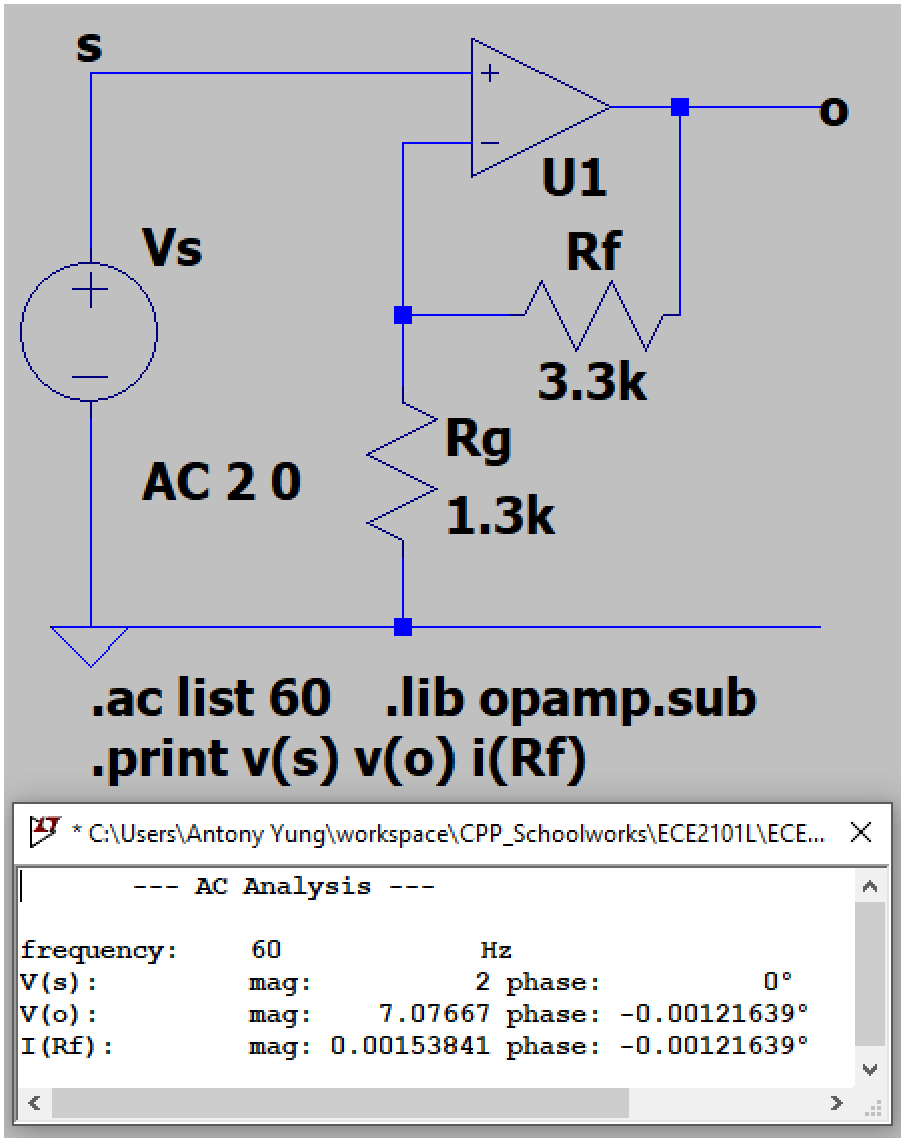


Figure 3: Screenshot of circuit description used and the simulation result with $R_f = 3.3\,\mathrm{k\Omega}$

Result

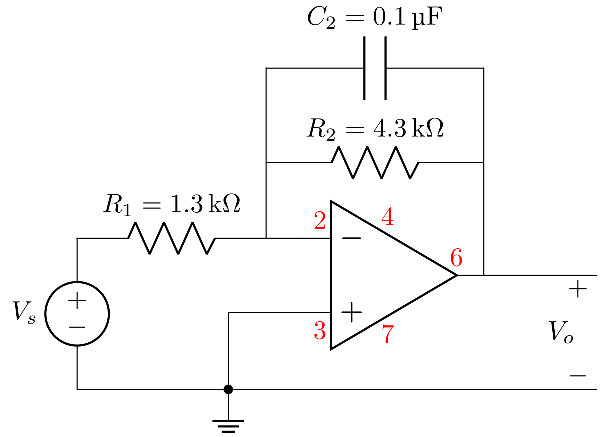
R_f	V_o RMS calculated	G calculated	V_s RMS measured	V_o RMS measured	I RMS measured	G measured	G error
1300 Ω	2.828 43 V	2.00000	1.414 21 V	2.828 37 V	0.001 087 83 A	1.99996	0.00%
2700 Ω	4.351 43 V	3.07692	1.414 21 V	4.351 30 V	0.001 087 82 A	3.07683	0.00%
3300 Ω	5.004 14 V	3.53846	1.414 21 V	5.003 96 V	0.001 087 82 A	3.53834	0.00%

Analysis

As the circuit was simulated instead of built physically, the error demostrated by the simulation is close to zero. The non-zero error could be due to the methodology of which the simulator simulates the circuit. If this is a physical circuit, non-ideal components and imprecise measurements can contributes to error.

Assuming ideal op amp, no current flow into the inverting input of op amp, and therefore current flowing across R_g must be the same as I, current flowing across R_f, by KCL. As the current flowing across R_g is $\frac{V_-}{R_g} = \frac{V_s}{R_g}$ which does not depend on the value of R_f, I must remain constant as well.

2 Complex gain of inverting op amp circuit



Theory

The complex gain can be determined as follow:

$$G = \frac{V_o}{V_s} = -\frac{Z_2}{Z_1} = -\frac{R_2||Z_{C_2}}{R_1} = -\frac{\frac{1}{\frac{1}{R_2}+Z_{C_2}}}{R_1} = -\frac{1}{\frac{R_1}{R_2} + R_1 Z_{C_2}} = \frac{-\frac{R_1}{R_2} + R_1\omega C_2 j}{(\frac{R_1}{R_2})^2 + (R_1\omega C_2)^2}$$

$$G = -\frac{1}{\frac{1300}{4300} + (1300)(2\pi 120)(0.1)(10^{-6})j} = -2.993 + 0.9704j = 3.1465\underline{/162.0367^\circ}$$

Result

Partner	G calculated	V_o RMS calculated	V_o RMS measured	V_o error
3	$3.1465\ \underline{/162.0367^\circ}$	$4.44976\ \underline{/162.0367^\circ}$V	$4.44953\ \underline{/162.034^\circ}$V	0.00%

3 Changing phase shift using op amp circuit

$$G = \frac{-\frac{R_1}{R_2} + R_1\omega\frac{C_2}{10}j}{(\frac{R_1}{R_2})^2 + (R_1\omega\frac{C_2}{10})^2} = 3.3060\underline{/178.1431^\circ}$$

Currently the op amp applys a 162.034° phase shift to the source voltage. As the gain phasor is in the second quadrant, as we decrease the positive reactance, the phase of gain phasor will increase. As seen in the above calculation, reducing C_2 by a factor of 10 will increase the phase shift the op amp applys to the source voltage from 162.0367° to 178.1431°, an increase larger than 10°. This is verified by the below simulation shown in figure 5.

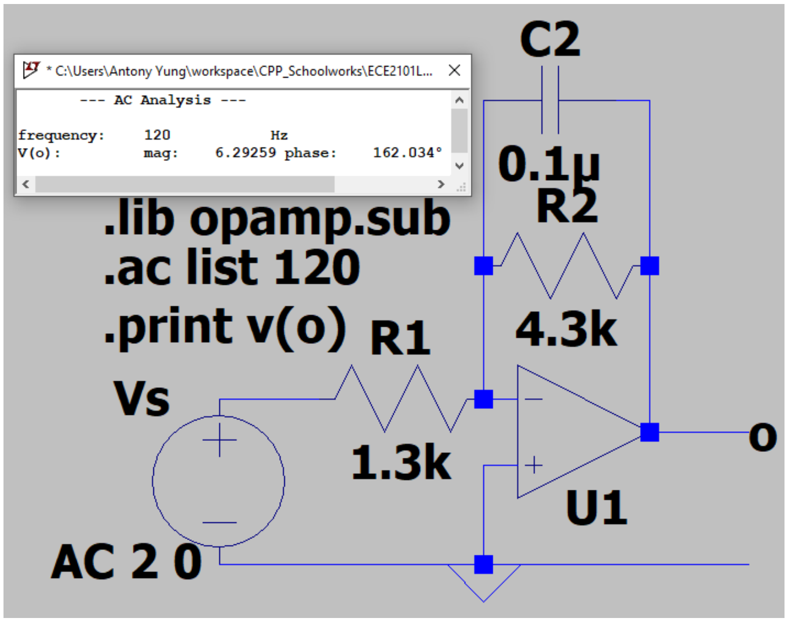


Figure 4: Screenshot of circuit description used and the simulation result

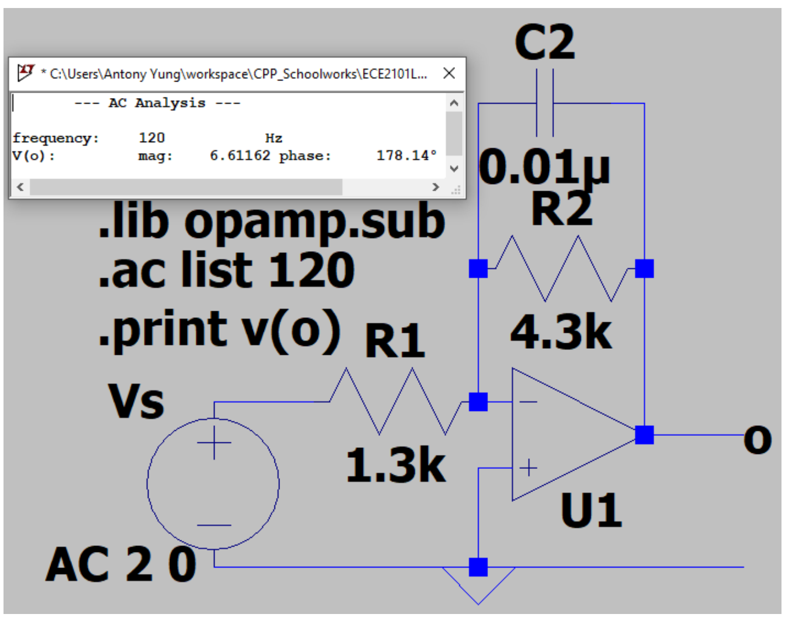


Figure 5: Screenshot of circuit description used and the simulation result