ECE 2101L
Electrical Circuit Analysis II Laboratory

Lab 11
Transfer Function of AC Circuits

Report

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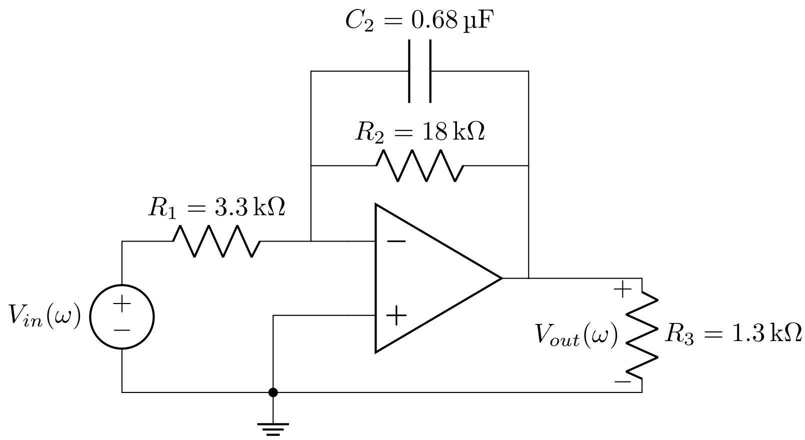
1 Circuit gain and phase shift for different frequencies



Procedure

The above circuit was simulated with LTSpice XVII.

Result

f	$\lvert H(\omega)\rvert$ calculated	$arg(H(\omega))$ calculated	$\lvert V_{out}\rvert$ calculated	$arg(V_{out})$ calculated	$\lvert V_{out}\rvert$ measured	$arg(V_{out})$ measured	$\lvert V_{out}\rvert$ error	$arg(V_{out})$ error
20 Hz	2.973123	123.0296°	4.459 684 V	123.0296°	4.459 54 V	123.031°	0.00%	0.00%
80 Hz	0.8750748	99.23188°	1.312 612 V	99.23188°	1.312 59 V	99.2319°	0.00%	0.00%
160 Hz	0.4418225	94.64609°	0.662 733 8 V	94.64609°	0.662 722 V	94.6454°	0.00%	0.00%
320 Hz	0.2214568	92.32687°	0.332 185 2 V	92.32687°	0.332 18 V	92.3251°	0.00%	0.00%
640 Hz	0.1107969	91.16392°	0.166 195 4 V	91.16392°	0.166 193 V	91.1603°	0.00%	0.00%

Analysis

At $f = 80\,\text{Hz}$,

$$H(2\pi 80) = 0.8750748\underline{/99.23188}$$

$$V_{in} = 1.5cos(2\pi 80t + 0)$$

$$V_{out} = 1.312612cos(2\pi 80t + 99.23188°)$$

It can be observed that the amplitude of V_{out} is the amplitude of V_{out} multiplied by the magnitude of $H(\omega)$ and the phase of V_{out} is the phase of V_{out} added by the phase of $H(\omega)$.

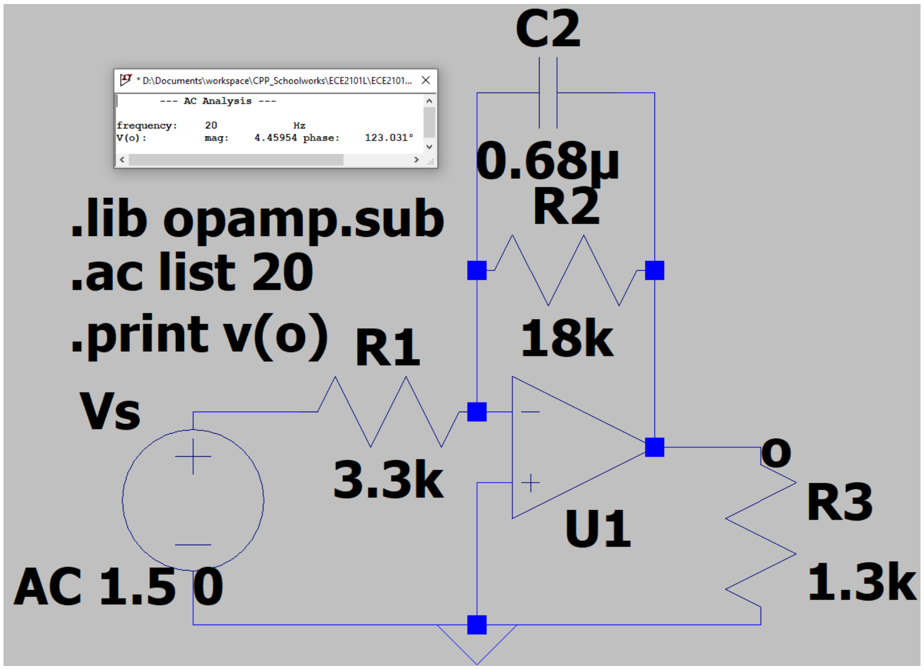


Figure 1: Simulation of the circuit with LTSpice XVII at $f = 20\,\text{Hz}$

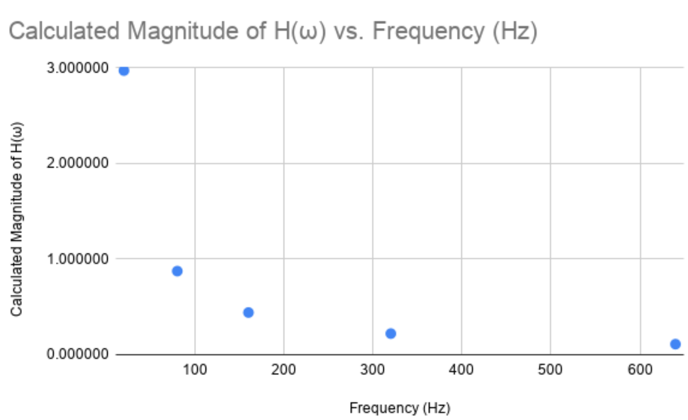


Figure 2: Calculated Magnitude of $H(\omega)$ vs. Frequency (Hz)

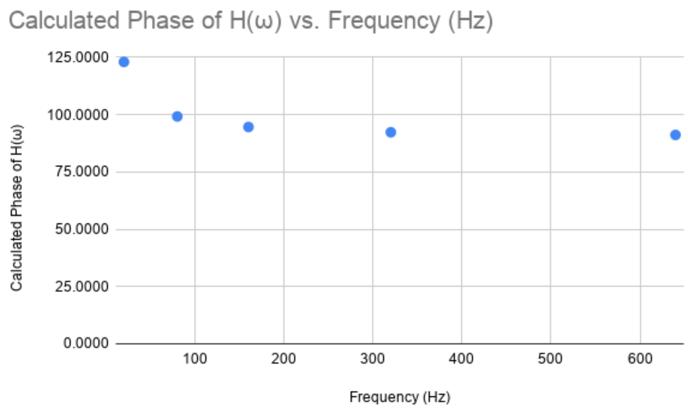


Figure 3: Calculated Phase of $H(\omega)$ (°) vs. Frequency (Hz)

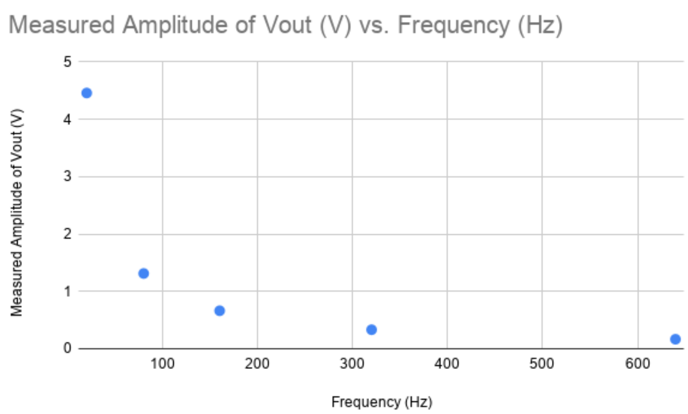


Figure 4: Measured Amplitude of V_{out} (V) vs. Frequency (Hz)

2 Circuit maximum gain and phase shift

Result

Frequency	Gain		Phase shift	
Hz	maximum	minimum	maximum	minimum
0	8.181 29 V		180°	
$+\infty$		0 V		90°

Analysis

$$H(\omega) = \frac{1}{\sqrt{(\frac{R_1}{R_2})^2 + (R_1(2\pi f)C_2)^2}} \angle tan^{-1}\left(-R_2(2\pi f)C_2\right)$$

From the equation above we can determine that the gain is maximized when the denominator is minimized, which is when the frequency goes to zero. Also, the gain minimizes when the denominator is maximized, which is when frequency approaches positive infinity.

Assuming the range of $tan^{-1}(x)$ is $[90°, 180°]$ when x is not positive, the maximum and minimum phase shift can also be determined from the above equation; $tan^{-1}(x)$ is at its maximum $= 180°$ when $x = -R_2(2\pi f)C_2$ goes to zero, which is when f goes to zero. Also, $tan^{-1}(x)$ is at its minimum $= 90°$ when $x = -R_2(2\pi f)C_2$ approaches positive infinity, which is when f approaches positive infinity.