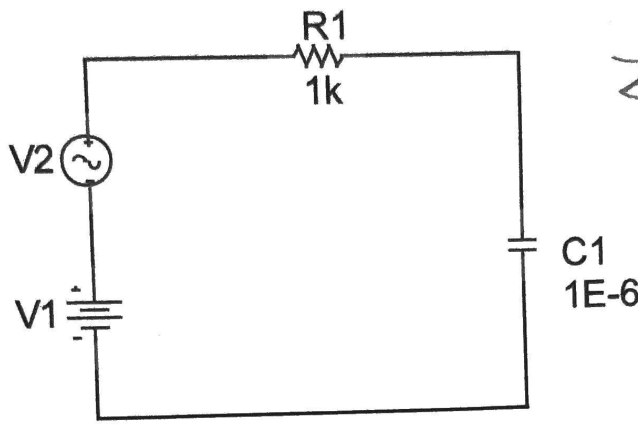
Homework 1

Reading: Circuits Review
Submission: Use Gradescope to upload your solution

1) Superposition



Z_C: $-1000j \rightarrow w = 1000$
$-10j \rightarrow w = 10^5$

In the above circuit, V1 is a DC source and V2 is a sinusoidal source, with voltages

V1 = 2V (assume the capacitor is at DC steady state for V1, ie. not a step function input)

V2 = 2sin(ωt) V – Assume AC steady state as well

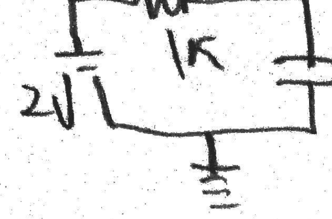
a)For ω=1000 [rad/s], use superposition to determine the time domain expression for the voltage across the capacitor, Vc.

  a. For several cycles of the sinusoidal signal, plot the voltage across the capacitor.
  b. What is the average voltage of the capacitor signal?
  c. What is the peak-to-peak voltage of the capacitor signal?

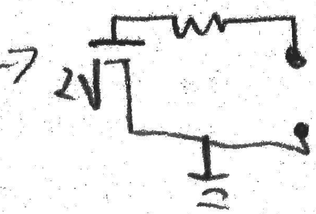
b)For ω=10^5 [rad/s], use superposition to determine the time domain expression for the voltage across the capacitor, Vc.

  a. For several cycles of the sinusoidal signal, plot the voltage across the capacitor.
  b. What is the average voltage of the capacitor signal?
  c. What is the peak-to-peak voltage of the capacitor signal?
  d. For this frequency, how would you compare the peak-to-peak voltage to the average voltage?

1 A: For V_1:

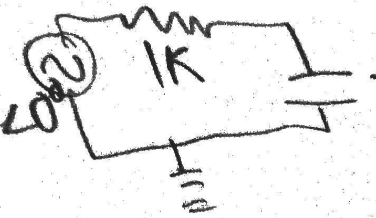


$\rightarrow$



For V_1: $V_c = 2V$

For V_2:



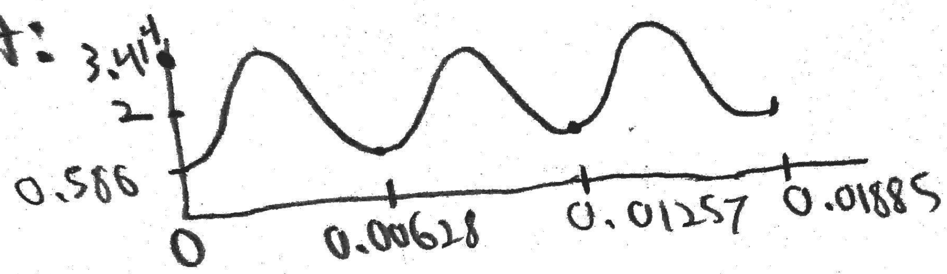
$-1000j$ $\quad V_C = \frac{2(-1000j)}{-1000j + 1000} = 1-j$

$V_C = \sqrt{2} \angle -90$

$V_c = \sqrt{2}\sin(-90'$

$V_{1c} + V_{2c} = \sqrt{2}\sin(\omega t + -90^\circ) + 2 = V_c(t)$

A:



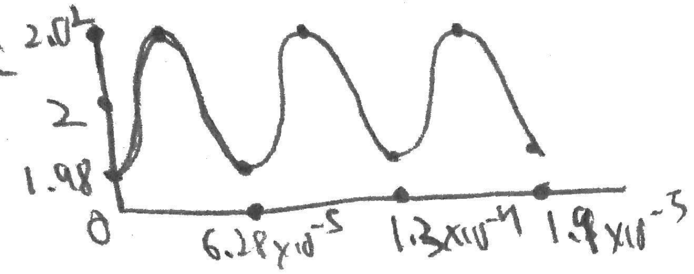
B: sine wave centered at 2V : avg = 2V

C: peak to peak = 2.828 V

1B: For V_1 : $V_C = 2V$ for $V_2 = 2V \frac{(-10j)}{1000 + -10j} = .002 - j.02$

$V_C(t) = .02\sin(\omega t + -90°) + 2$ $V_C = .02\sin(\omega t + -90°) + 2$

A:

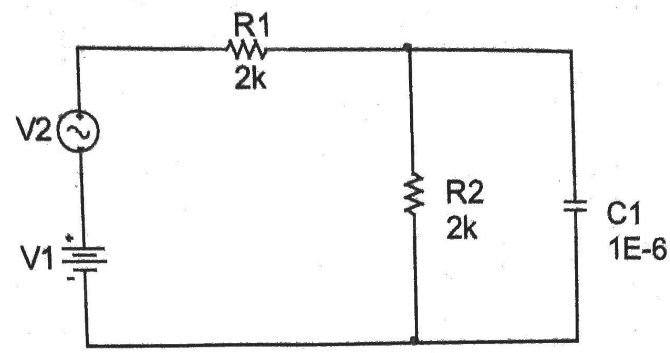


B: The average is 2V

C: The peak to peak is .04V

D: The peak to peak is much smaller than the average.

2) An important, familiar concept.



$Z_C = -1000j$

In the above circuit, V1 is a DC source and V2 is a sinusoidal source, with voltages

V1 = 4V (assume the capacitor is at DC steady state for V1, ie. not a step function input)

V2 = 4sin(ωt) V

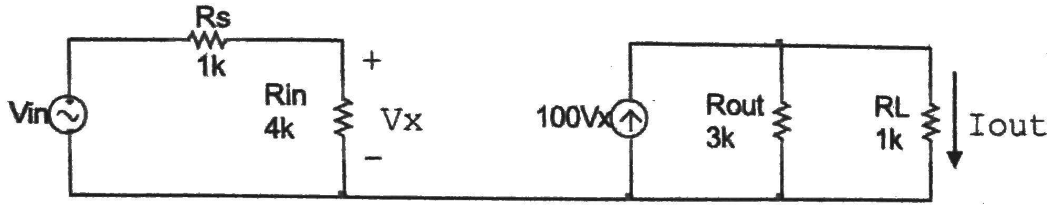
a)For ω=1000 [rad/s], determine the time domain expression for the voltage across the capacitor, Vc.

For V_1: $V_C = \frac{4(2k)}{4k} = 2V$ For V_2: $Z_{R_2 C_1} = \left(\frac{1}{-1000j} + \frac{1}{2000}\right)^{-1} = 400-800j$

$V_C = \frac{4(400-800j)}{2000+400-800j} = 1-j \rightarrow \sqrt{2}\sin(\omega t + -90°)$

A: $V_C(t) = \sqrt{2}\sin(\omega t + -90°) + 2V$

3) Dependent sources

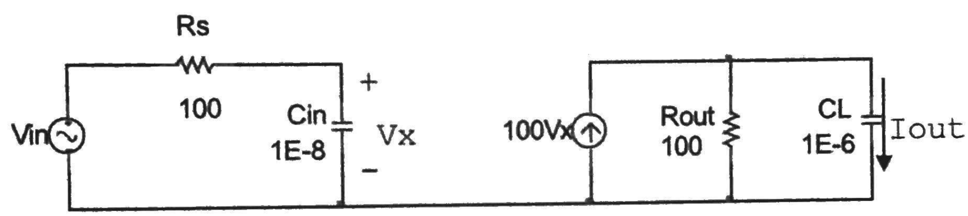


a) For the above circuit, symbolically determine the transfer function, H(s) = Iout(s)/Vin(s).

b) Symbolically, determine the Thevenin voltage, V_{Th}, for the indicated load.

c) Symbolically, determine the Norton current, I_N, for the indicated load.

d) Symbolically, using test voltage concepts, determine the Thevenin resistance, R_{Th}, for the indicated load.



e) For the above circuit, determine the transfer function, H(s) = Iout(s)/Vin(s).

f) Plot the Bode magnitude plot for the transfer function using the log-log plot (available on the last page). On the plot, identify the poles

3 A: $V_x = \frac{V_{in}(R_{in})}{R_{in}+R_s}$ $I_{out} = \frac{100V_x(R_{out})}{R_L+R_{out}} = \frac{100\,V_{in}(R_{in})}{R_{in}+R_s} \cdot \frac{R_{out}}{R_L+R_{out}}$

$$\boxed{\frac{I_{out}}{V_{in}} = \frac{100(R_{in})(R_{out})}{(R_{in}+R_s)(R_L+R_{out})} = H(s)}$$

B: Take off RL $V_{TH} = 100V_x \cdot R_{out} = \boxed{\frac{100V_{in}(R_{in})(R_{out})}{R_{in}+R_s} = V_{TH}}$

C: Short across RL $I_N = 100V_x = \boxed{\frac{100\,V_{in}(R_{in})}{R_{in}+R_s} = I_N}$

D:

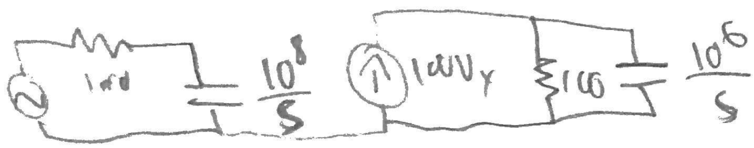
$V_{test} = 1V$ $\quad i_1 = 100V_x \quad i_2 = I_{test}$

$$0 = R_{out}\, i_2 + V_{test} - 100V_x$$

$$i_2 = \frac{100V_x - V_{test}}{R_{out}} \qquad \frac{V_{Test}}{i_2} = R_{TH} \qquad \frac{V_{test}\cdot R_{out}}{100V_x - V_{test}} = R_{TH}$$

$$R_{TH} = \frac{V_{Test}\cdot R_{out}}{\frac{100\,V_{in}}{R_{in}+R_s} - V_{test}} = \frac{R_{in}\cdot V_{Test}\cdot R_{out}\cdot R_s}{100\,V_{in} - R_{in}\cdot V_{Test}\cdot R_s}$$

E:



$$V_x = \frac{V_{in}\left(\frac{10^8}{s}\right)}{100 + \frac{10^8}{s}}$$

$$i_{out} = \frac{100V_x(100)}{100 + \frac{10^8}{s}} = \frac{\frac{V_{in}\cdot 100\left(\frac{10^8}{s}\right)(100)}{100 + \frac{10^8}{s}}}{100 + \frac{10^8}{s}}$$

$$H(s)\ \frac{i_{out}(s)}{V_{in}(s)} = \frac{100\left(\frac{10^8}{s}\right)(100)}{100 + \frac{10^8}{s}}\cdot\frac{1}{100 + \frac{10^8}{s}} = \frac{10^8 s}{(s+10^6)(s+10^4)}$$

Name

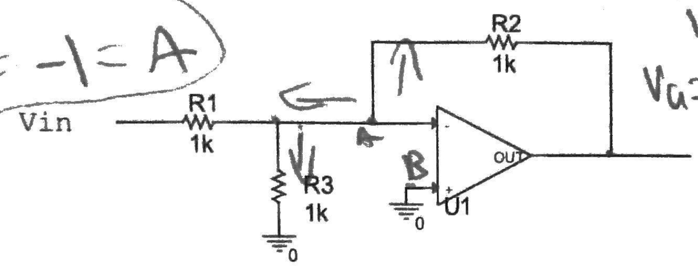
4) Amplifier Circuits

$\frac{V_a - V_{in}}{1k} + \frac{V_a}{1k} + \frac{V_a - V_{out}}{1k} = 0$

$V_a = V_B = 0$

$\frac{-V_{in}}{1k} = \frac{V_{out}}{1k}$

$\frac{V_{out}}{V_{in}} = \frac{-1k}{1k} = -1 = A$



a)Using op-amp 'rules' and circuit analysis, determine the gain, A = Vout/Vin, of the above amplifier circuit.

$\frac{V_a - V_{in}}{1k} = 0$ $V_a = V_{in}$

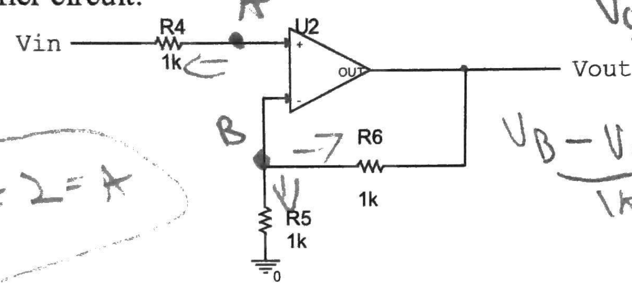
$V_a = V_B$

$\frac{V_B - V_{out}}{1k} + \frac{V_B}{1k} = 0$

$\frac{V_{in} - V_{out}}{1k} + \frac{V_{in}}{1k} = 0$

$\frac{2V_{in}}{1k} = \frac{V_{out}}{1k}$

$\frac{V_{out}}{V_{in}} = 2 = A$



b)Using op-amp 'rules' and circuit analysis, determine the gain, A = Vout/Vin, of the above amplifier circuit.

$\frac{V_a - V_{in}}{1k} + \frac{V_a}{1k} = 0$ $\frac{V_a}{1k} - \frac{V_{in}}{1k} + \frac{V_a}{1k} = 0$

$\frac{V_B - V_{out}}{1k} + \frac{V_B}{1k} = 0$

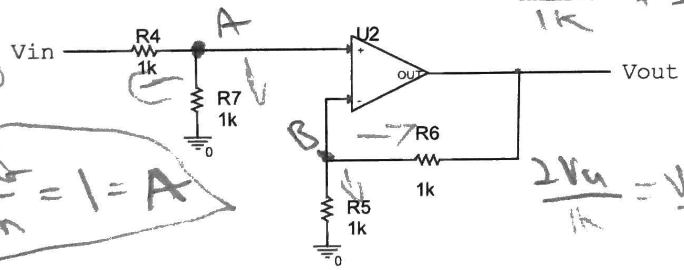
$\frac{2V_a}{1k} = \frac{V_{in}}{1k}$ $V_a = \frac{1}{2}V_{in}$

$V_a = V_B$

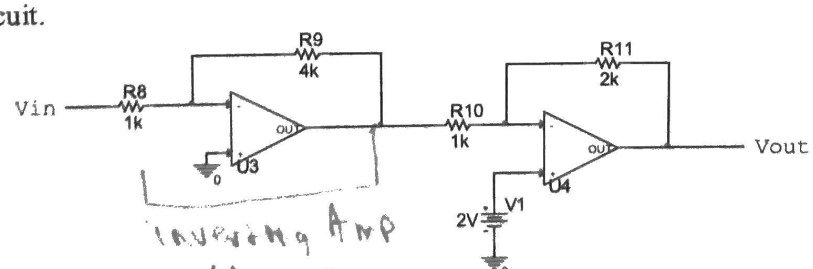
$\frac{V_{in}}{2k} - \frac{V_{out}}{1k} - \frac{V_{in}}{2k} = 0$

$\frac{2V_{in}}{2k} = \frac{V_{out}}{\cancel{1k}}$

$\frac{V_{out}}{V_{in}} = 1 = A$



c)Using op-amp 'rules' and circuit analysis, determine the gain of the above amplifier circuit.

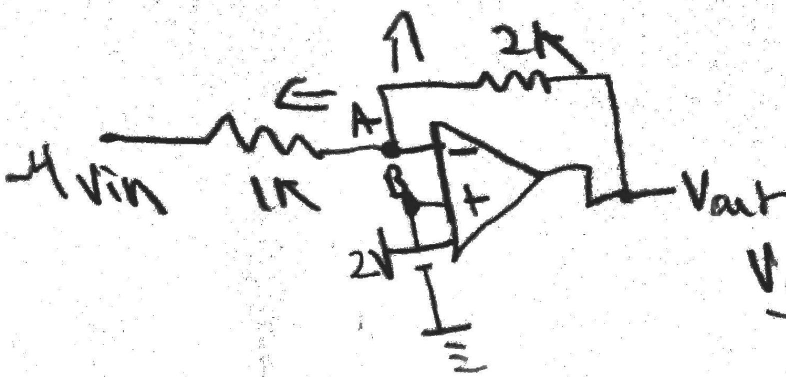


Inverting Amp

−4 gain

d)Using op-amp 'rules' and circuit analysis, determine the gain of the above amplifier circuit.

40:



$$\frac{V_a-(-4V_{in})}{1k}+\frac{V_a-V_{out}}{2k}=$$

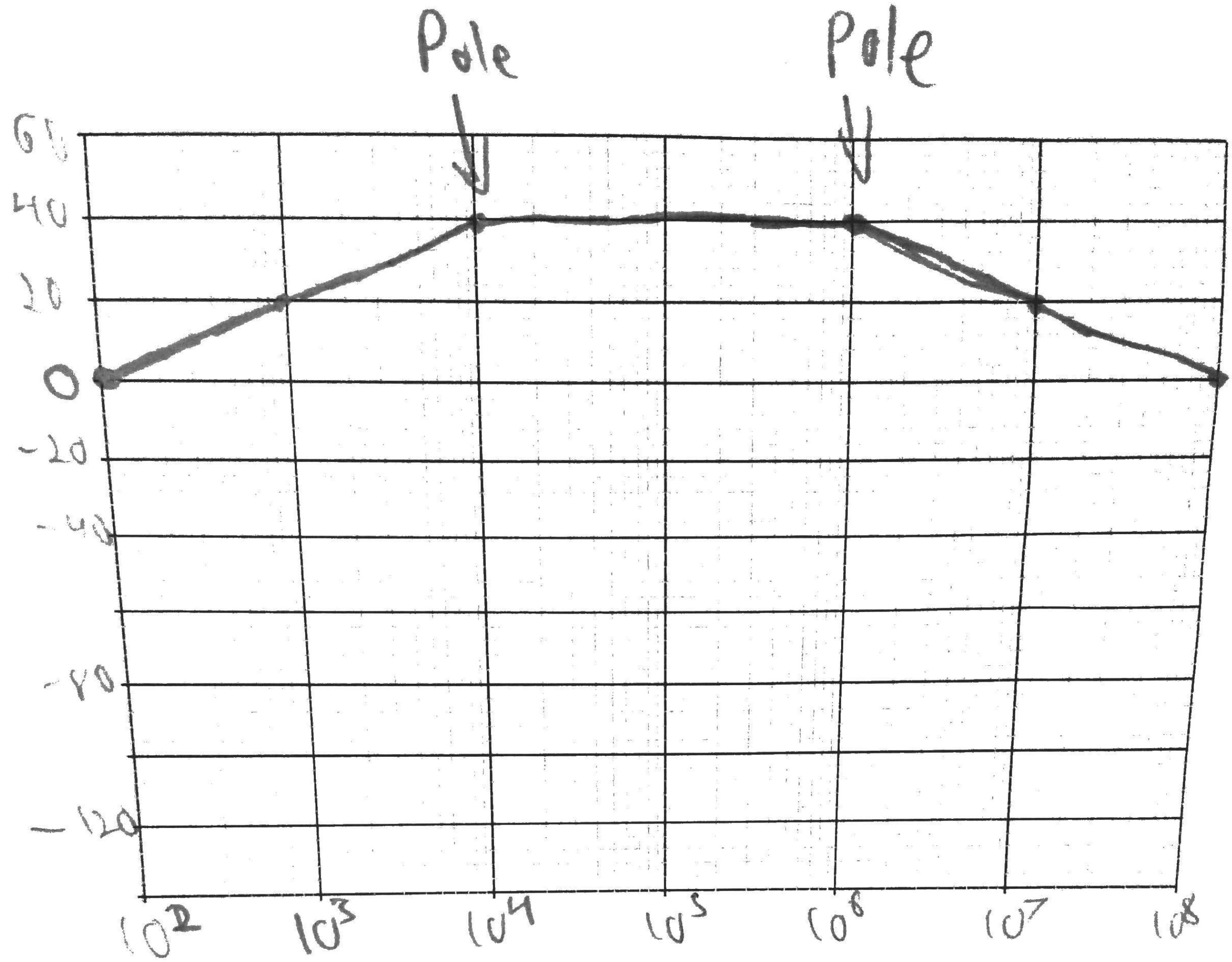
$V_B = 2V$ $\quad V_a = V_B$

$$\frac{2V+4V_{in}}{1k}+\frac{2V-V_{out}}{2k}=0$$

$$\frac{2V}{1k}+\frac{4V_{in}}{1k}+\frac{2V}{2k}-\frac{V_{out}}{2k}=0$$

$$\frac{6V}{2k}+\frac{4V_{in}}{1k}=\frac{V_{out}}{2k}$$

$$V_{out} = 6V + 8V_{in}$$



$20 \log(10^{-2}) = -40$ constant

poles at 10^6 and 10^4

0 = 20 dB/dec rise

10^4 = 0 then -20 dB decade

10^6 = 0 then -20 dB decade