EE4312 Analog Electronic Circuits Notes

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CONTENTS

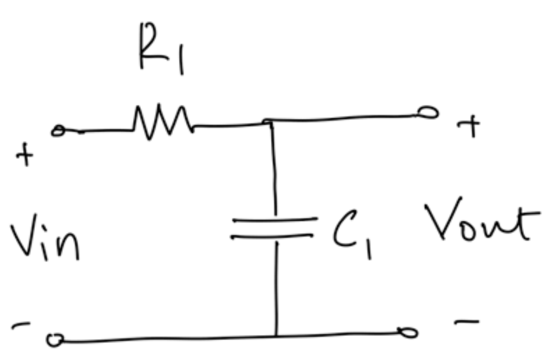
PRE-REQUISITES TEST FOR ANALOG ELECTRONIC CIRCUITS

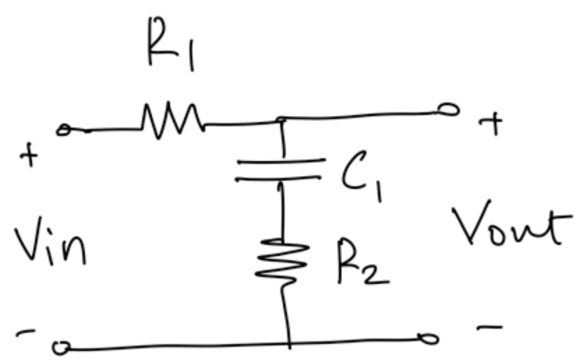
1.1 Assumed Preparation

- EE3201 Circuit Analysis
- EE3106 Solid-State Devices and Materials
- EE3331 Electronic Circuits I
- EE3081 Signals and Systems

1.2 Circuit Analysis

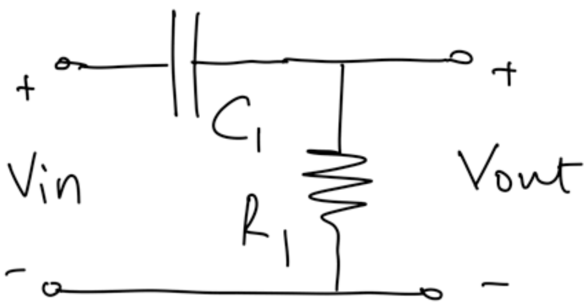
1. Analyze the following circuits:

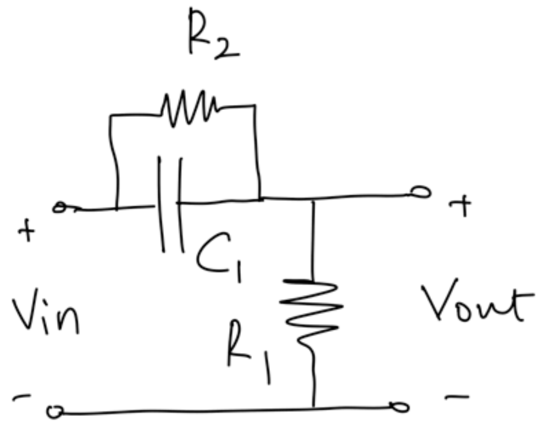




- Derive the expression for the transfer function $H(s) = V_{out}(s)/V_{in}(s)$.
  - What are the poles and zeros of $H(s)$?
  - Plot the Bode diagram for $H(s)$ assuming $R_1 = 10K\Omega, C_1 = 160pF, R_2 = 1K\Omega$.
- Assume $V_{in}(t) = \sin(2\pi f t)$ with f = 100kHz; plot $V_{in}(t)$ and $V_{out}(t)$ in steady state.
- What type of filter is the network on the left?
- The network on the right is called a *lag* network; can you explain why?

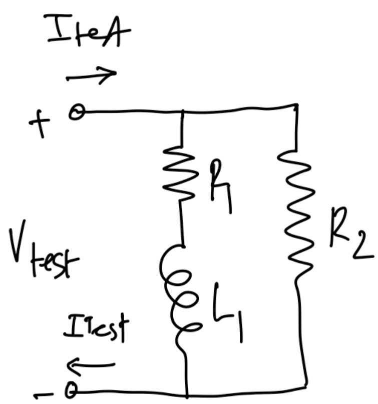
2. Repeat the same analysis for the following circuits:

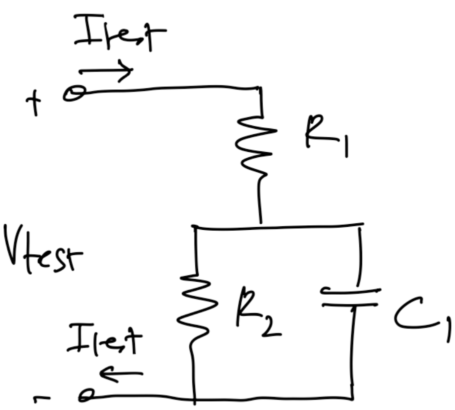




- Now assume $R_1 = 10K\Omega, C_1 = 160pF, R_2 = 100K\Omega$.
- The network on the right is called a *lead* network; can you explain why?

3. Determine the impedance $Z(s) = V_{test}(s)/I_{test}(s)$ for the following networks:





- Plot the magnitude $|Z(j\omega)|$ vs the angular frequency ω on a *log-log* plot and the phase $\angle Z(j\omega)$ vs the angular frequency ω on *semilogx* plot over the relevant frequency range.
  - Assume R_1 = 10Ω, R_2 = $1K\Omega$, and L_1 = $160\mu H$ for the left network
  - Assume R_1 = 10Ω, R_2 = $1K\Omega$, and C_1 = $1.6nF$ for the right network

4. Use a spice-type simulator to verify your results. Carefully consider which simulation analyses to use for the various parts of the questions.

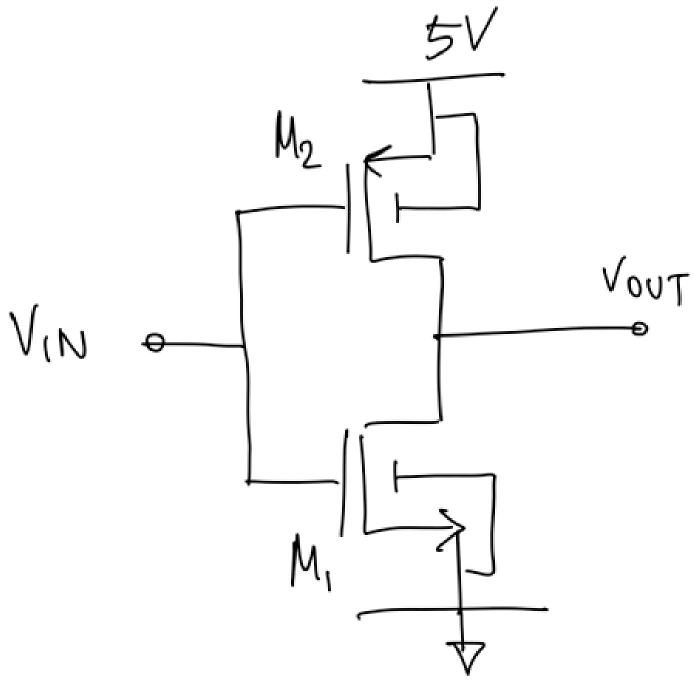
1.3 Systems Analysis

1. For the following transfer functions, are the poles and zeros in the left or right half of the complex plane? Draw their impulse response and step response:
   - $H(s) = \frac{A}{1+s/\omega_p}$
     - with $\omega_p = 1/(2\pi 1\mu s)$
   - $H(s) = \frac{A}{1+s/\omega_p}$
     - with $\omega_p = -1/(2\pi 1\mu s)$
   - $H(s) = \frac{A}{(1+s/s_1)(1+s/s_2)}$
     - with $s_1 = \alpha + j\omega_p$, $s_2 = \alpha - j\omega_p$, $\alpha = 1/(10\mu s)$, $\omega_p = 1/(2\pi 1\mu s)$
   - $H(s) = \frac{A}{(1+s/s_1)(1+s/s_2)}$
     - with $s_1 = \alpha + j\omega_p$, $s_2 = \alpha - j\omega_p$, $\alpha = -1/(10\mu s)$, $\omega_p = 1/(2\pi 1\mu s)$
2. (*more advanced*) Derive the expression for the impulse and step response for the circuits above and plot them.
3. (*more advanced*) Use a toolbox in a mathematical tool like Matlab or NumPy (with the Control Systems Library) to check your results

1.4 MOS Devices and Basic Electronics Circuits

You can assume a 5V CMOS technology with transistor threshold voltages $V_{Tn} = |V_{Tp}| = 0.7$V; the transistors have ideal square-law behavior.

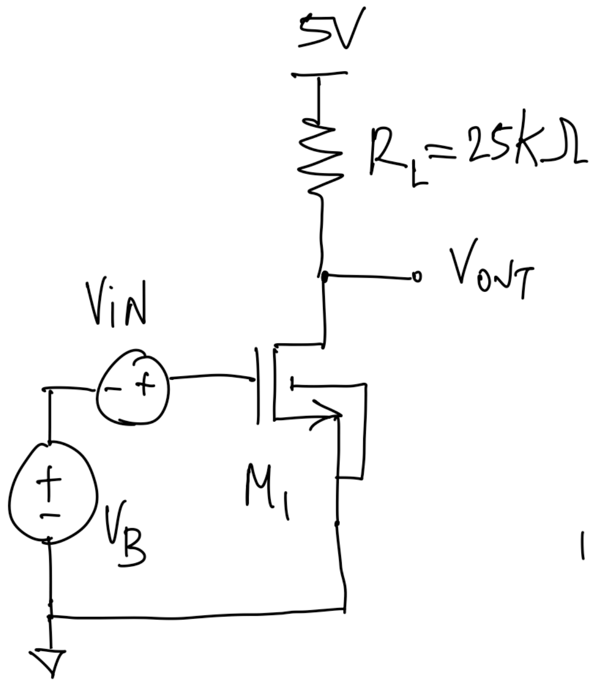
1. Given the following two-transistor circuit:

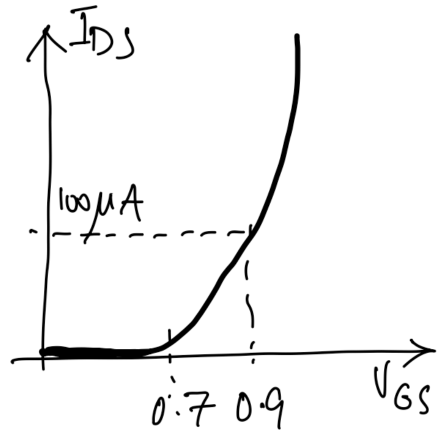


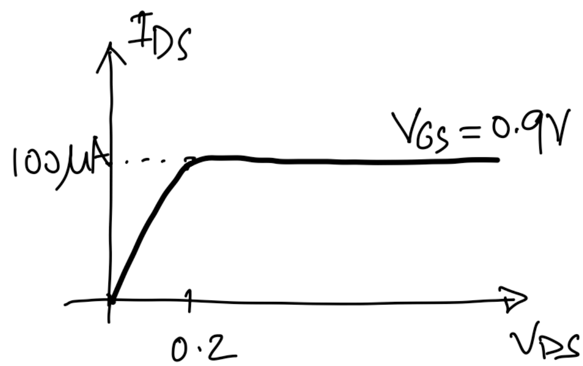
- Plot the V_{OUT}-V_{IN} characteristic for V_{IN} going from 0 to 5V.
- What the region of operation of M_1 and M_2, when V_{IN} is 0, 2.5 and 5V; explain your reasoning.

2. Given the following one-transistor amplifier[1] $V_B = 0.9$V, and the nMOS transistor characteristics shown:

[1] In practical circuits we would never bias this amplifier with a fixed voltage; this is done here to keep the schematic simpler.







- Assuming $V_{IN} = 0$,
  - determine the bias current through M1
  - determine the DC bias of V_{OUT}
  - what is the gate-overdrive voltage of M1
  - what is the transconductance g_m of M1; if you cannot find the g_m, use 2mS for the remainder of this question.
- Assuming $V_{IN} = 10mV$,
  - what are the current through M1 and V_{OUT} now?
  - based on this calculation, what is the small-signal gain of the amplifier?

CHAPTER

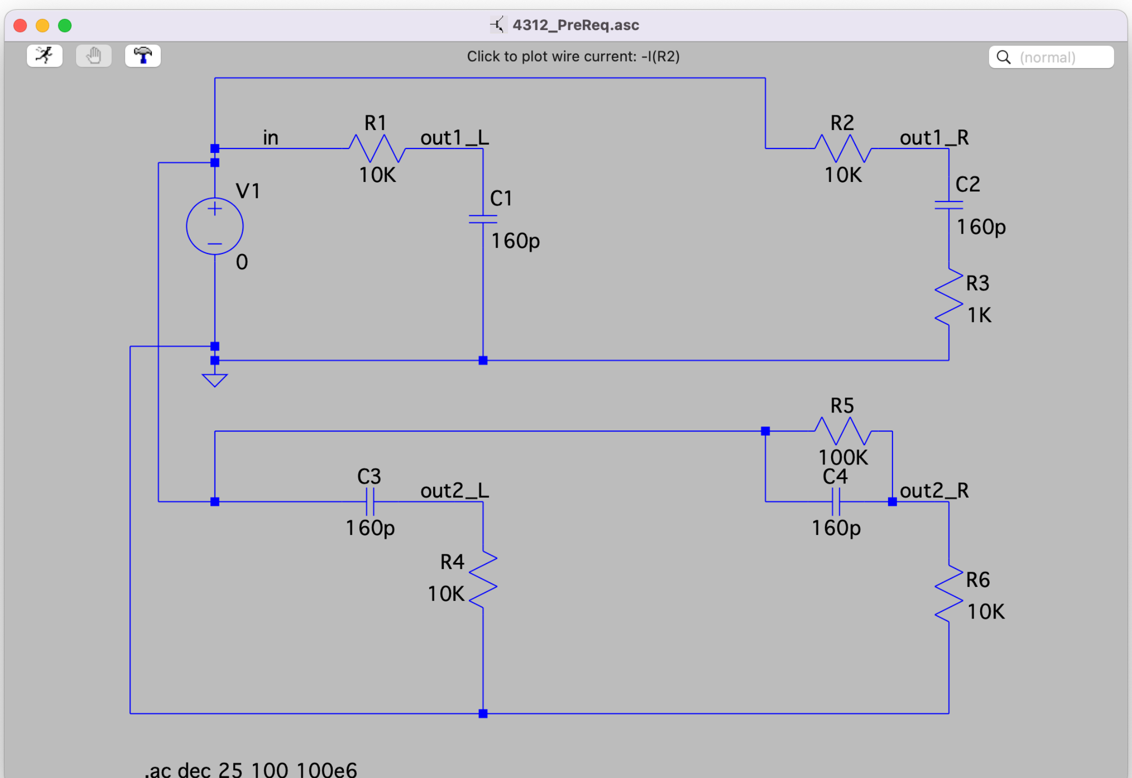
TWO

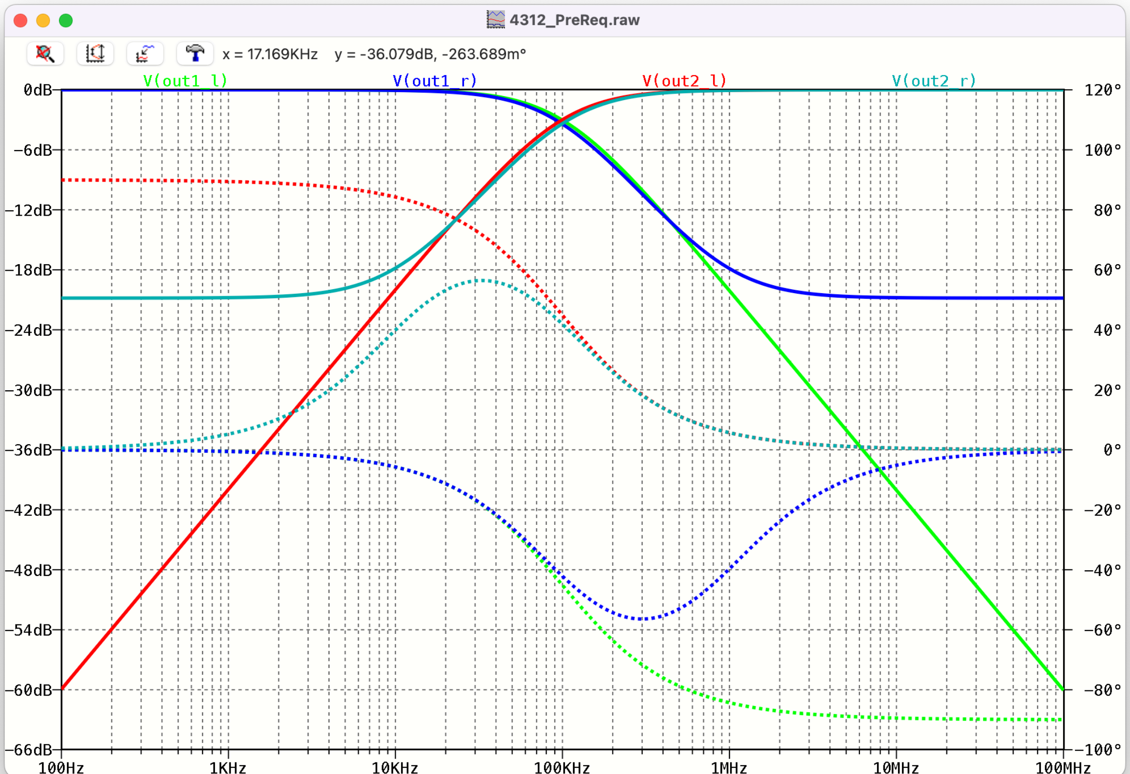
SOLUTION: PRE-REQUISITES TEST FOR ANALOG ELECTRONIC CIRCUITS

2.1 Circuit Analysis

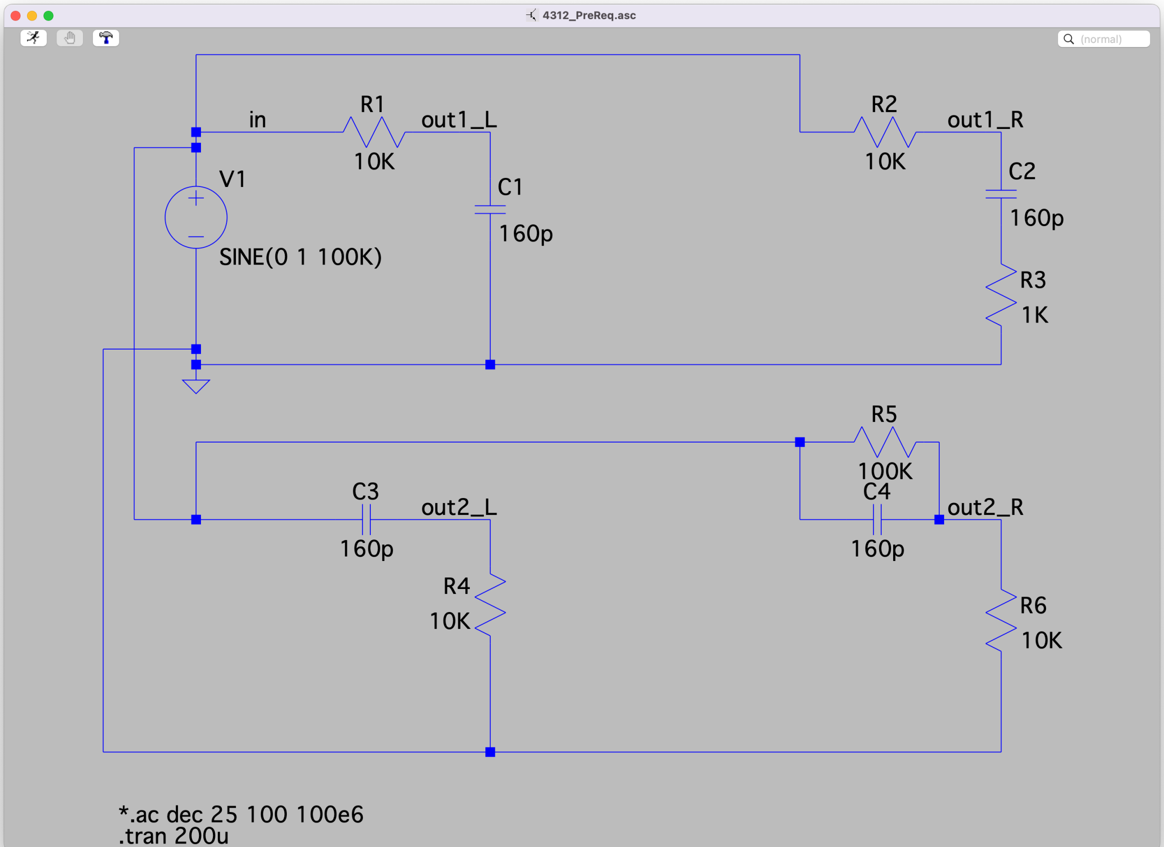
1. Analysis of RC Networks

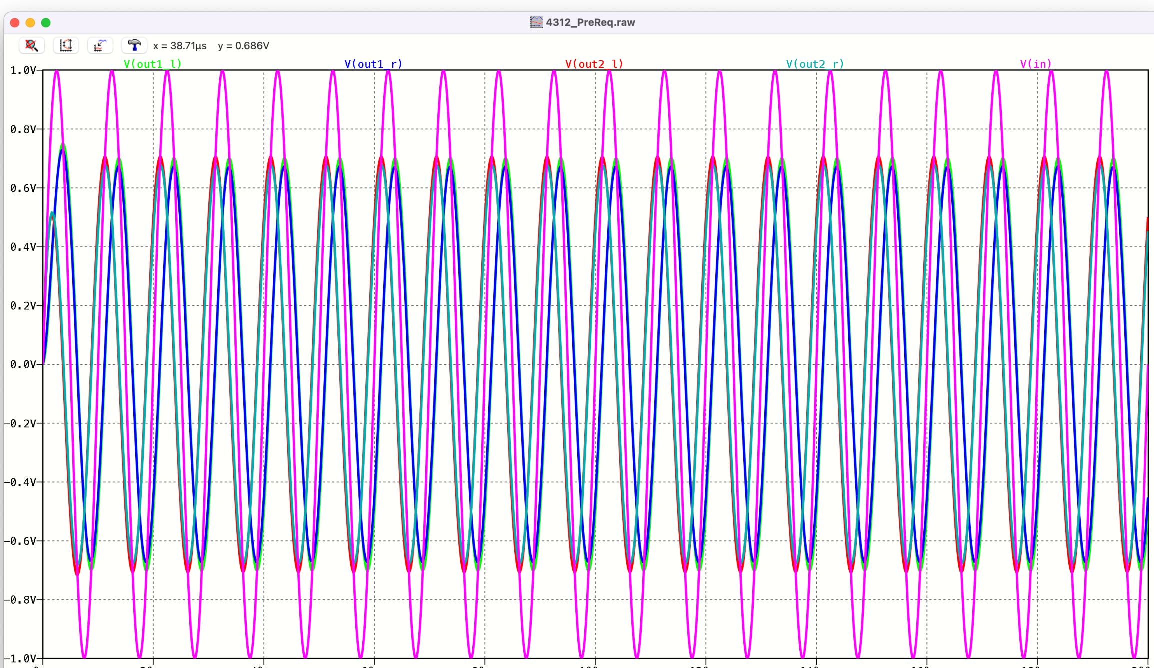
- Bode Plots of transfer function $H(j2\pi f)$
  - Small Signal AC analysis `.ac`

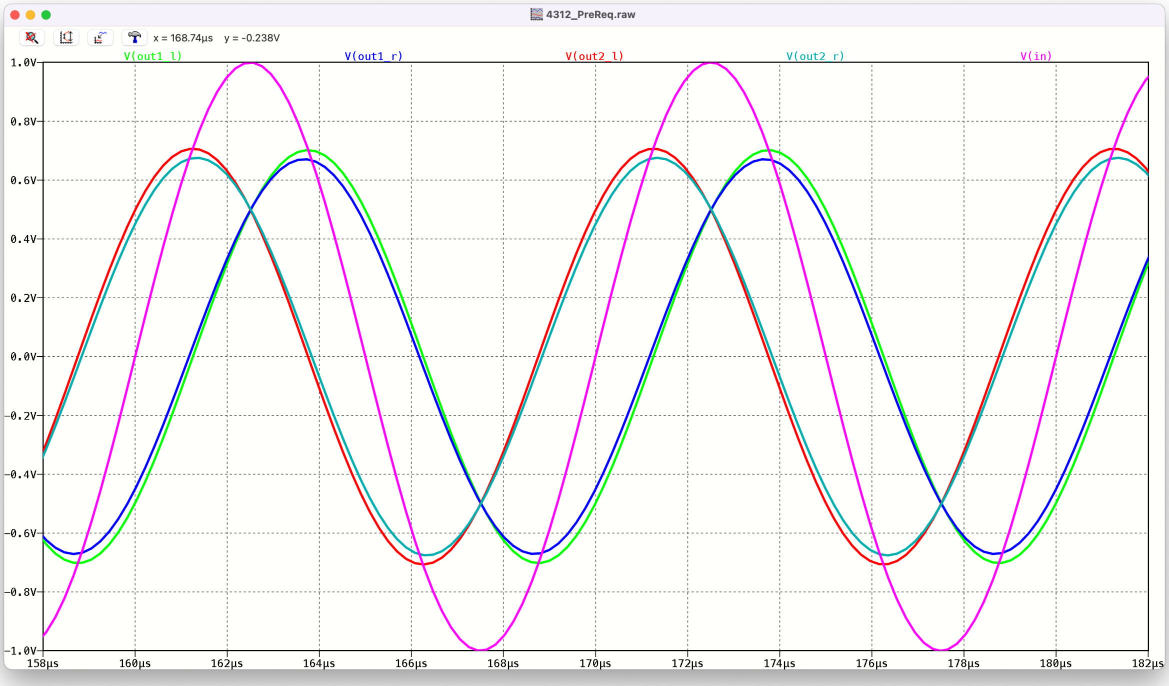




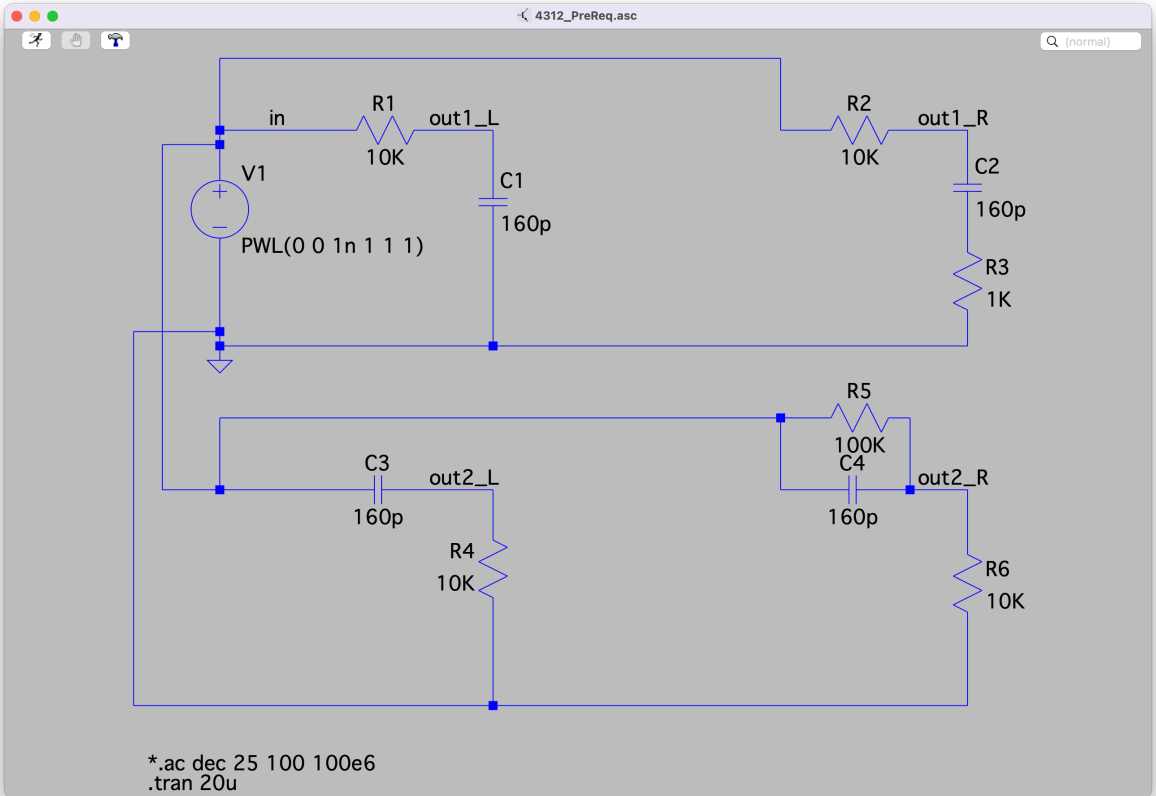
- Response to a Sine Wave
  - Transient simulation `.tran` with a sinusoidal input signal

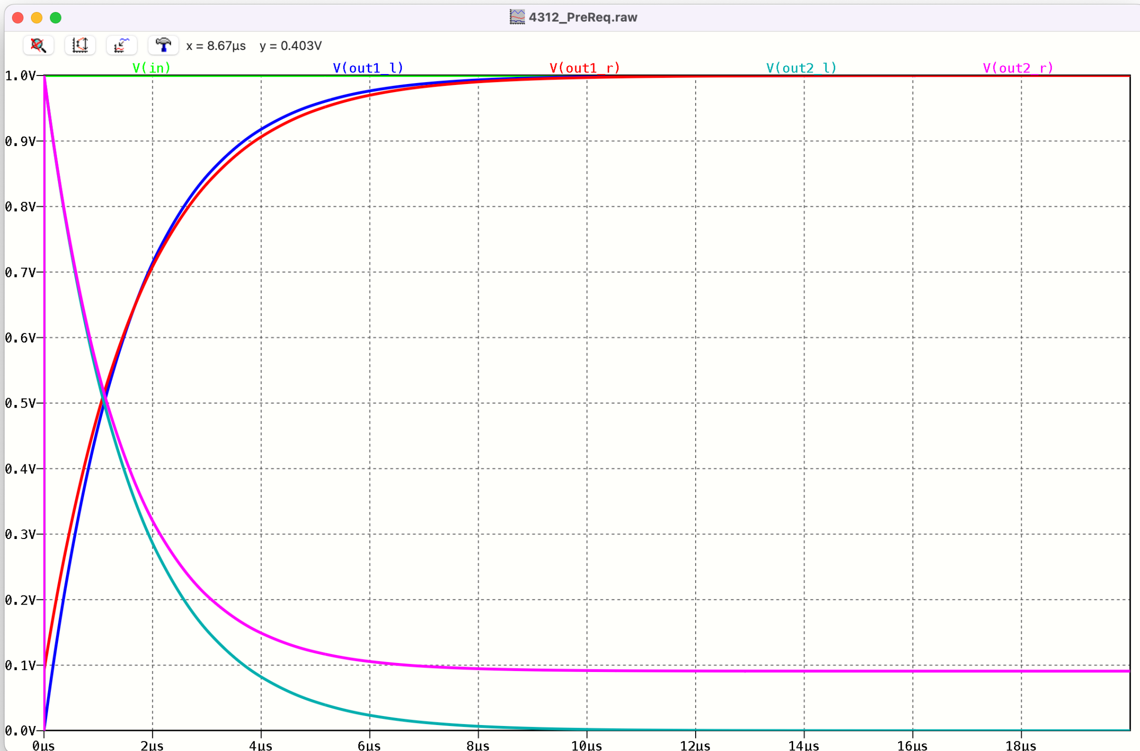

4312_PreReq.asc
in
R1
10K
out1_L
C1
160p
V1
SINE(0 1 100K)
R2
10K
out1_R
C2
160p
R3
1K
R5
100K
C4
160p
C3
160p
out2_L
out2_R
R4
10K
R6
10K
*.ac dec 25 100 100e6
.tran 200u


4312_PreReq.raw
x = 38.71µs y = 0.686V
V(out1_l)
V(out1_r)
V(out2_l)
V(out2_r)
V(in)
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
-0.2V
-0.4V
-0.6V
-0.8V
-1.0V
0µs
20µs
40µs
60µs
80µs
100µs
120µs
140µs
160µs
180µs
200µs



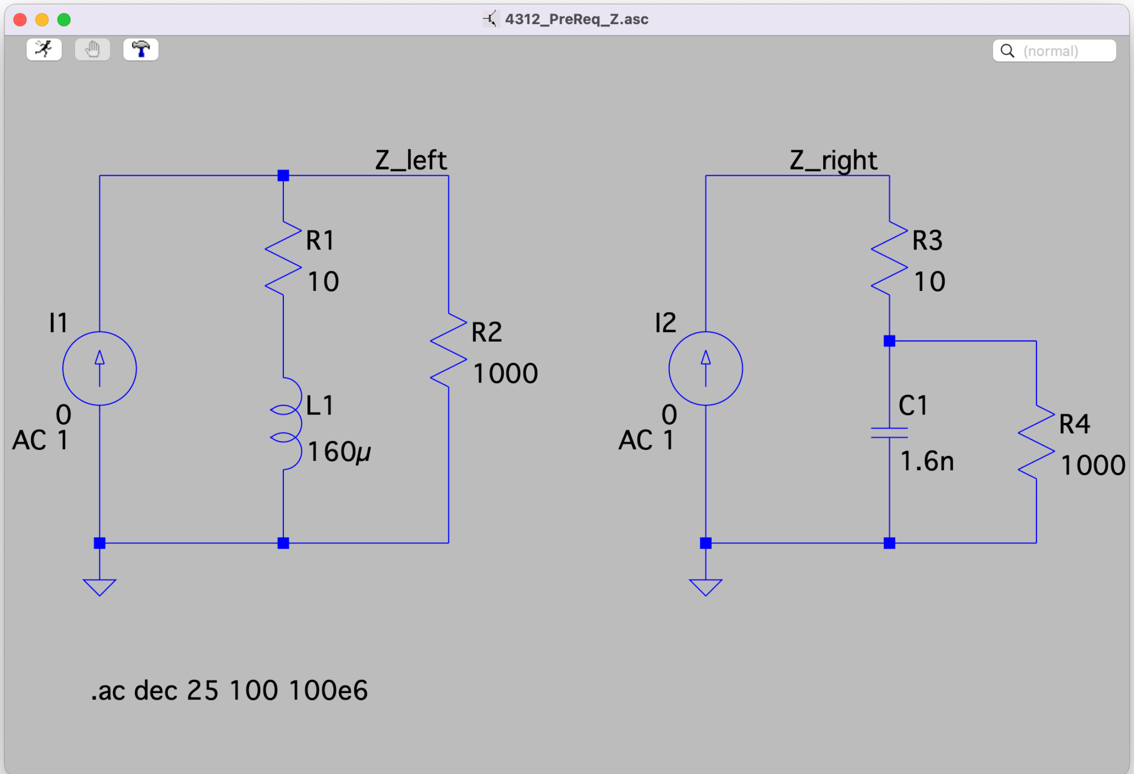
- Extra: Impulse Response
  - Transient simulation `.tran` with a step input created with a PWL source

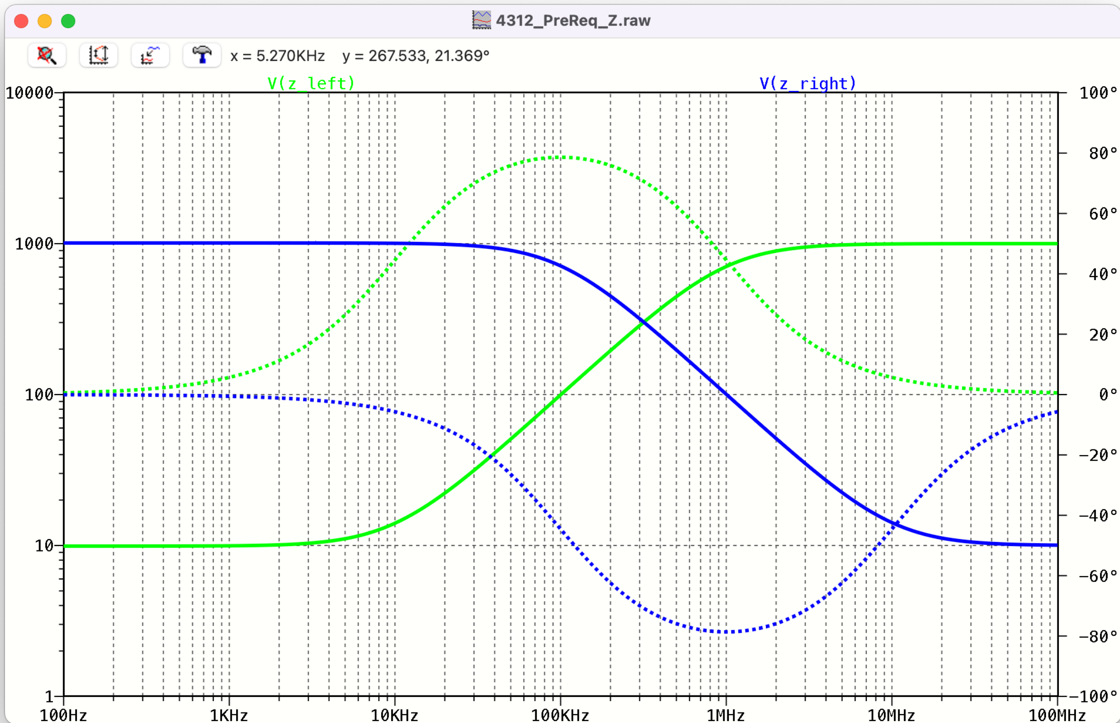

4312_PreReq.asc
in
R1
10K
out1_L
C1
160p
V1
PWL(0 0 1n 1 1 1)
R2
10K
out1_R
C2
160p
R3
1K
R5
100K
C4
160p
out2_R
C3
160p
out2_L
R4
10K
R6
10K
*.ac dec 25 100 100e6
.tran 20u



3. Analysis of Impedance

- Bode Plots of transfer function $Z(j2\pi f)$
  - Small Signal AC analysis `.ac`


4312_PreReq_Z.asc
(normal)
Z_left
R1
10
I1
0
AC 1
L1
160μ
R2
1000
Z_right
R3
10
I2
0
AC 1
C1
1.6n
R4
1000
.ac dec 25 100 100e6


4312_PreReq_Z.raw
x = 5.270KHz y = 267.533, 21.369°
V(z_left)
V(z_right)
10000
1000
100
10
1
100°
80°
60°
40°
20°
0°
−20°
−40°
−60°
−80°
−100°
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz