T.C.
YEDİTEPE UNIVERSITY

ELECTRICAL & ELECTRONICS ENGINEERING DEPARTMENT

EE384-Lab Project

Control Systems

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1. Open-Loop Response

Get your transfer function from your lab instructor. Perform the following calculations and simulations:

□ **Analytical Approach: (2.5 pts)** Find step response of your transfer function by using inverse Laplace Transform. Plot your equation as a function of time (From "0" to 10 seconds with 1ms interval)

1.1

1

$T = \dfrac{500}{s^2+15s+500}$ Pole Location $= -5$

$R_1 = 5\,k\Omega$ $C_1 = 80\,nF$ $R_1 = 8M$ $C_1 = 25n$

$R_2 = 2\,k\Omega$ $C_2 = 100\,nF$ $R_2 = 1M$ $C_2 = 10n$

$s\left(\dfrac{R_2 . C_1 + R_1 . C_1}{R_2C_1 . R_1C_1}\right)$

$C(s) = R(s) \cdot \dfrac{500}{s^2+55s+500} = \dfrac{1}{s} \dfrac{500}{s^2+45s+500} = \dfrac{500}{s^3+45s^2+500s}$

$\mathcal{L}^{-1}(C(s)) = C(t)$

$C(s) = \dfrac{500}{s.(s+20)(s+25)}$

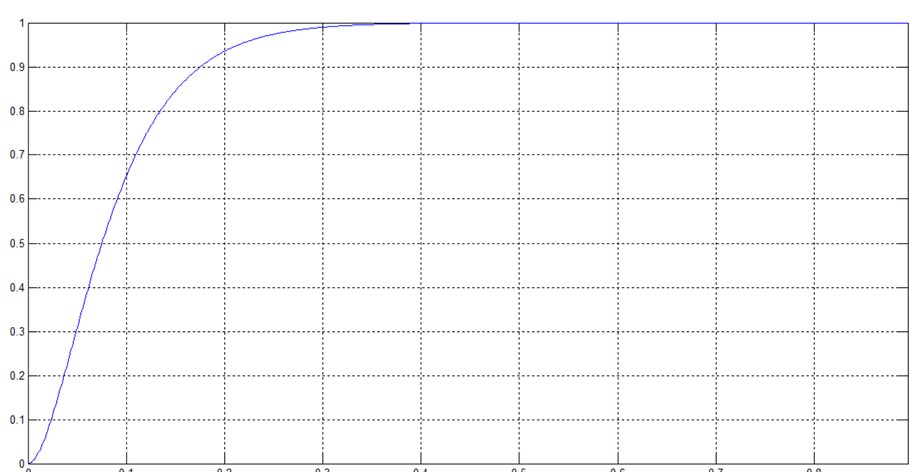
$\mathcal{L}^{-1}(C(s)) = -\mathcal{L}^{-1}\left\{\dfrac{5}{s+20}\right\} + \mathcal{L}^{-1}\left\{\dfrac{4}{s+25}\right\} + \mathcal{L}^{-1}\left\{\dfrac{1}{s}\right\}$

$\mathcal{L}^{-1}\left\{\dfrac{5}{s+20}\right\} = 5e^{-20t}$

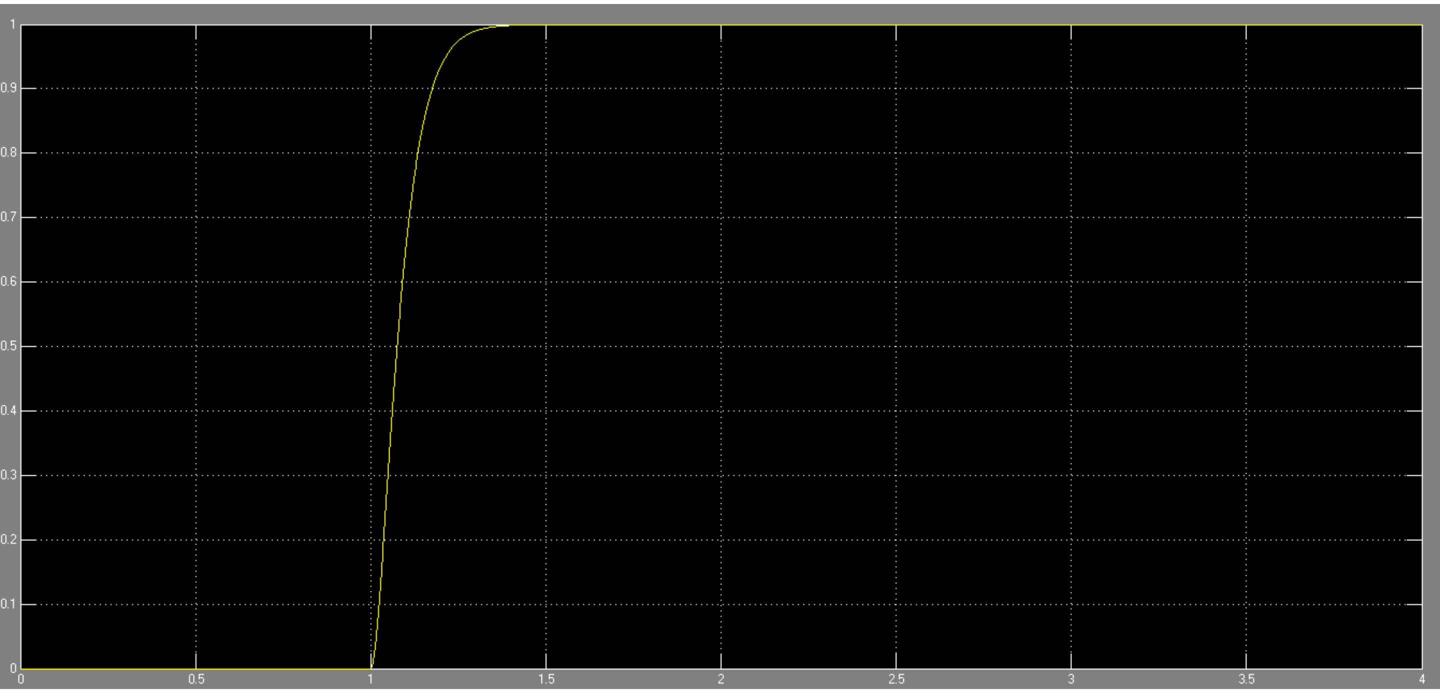
$\mathcal{L}^{-1}\left\{\dfrac{4}{s+25}\right\} = 4e^{-25t}$

$\mathcal{L}^{-1}\left\{\dfrac{1}{s}\right\} = 1$

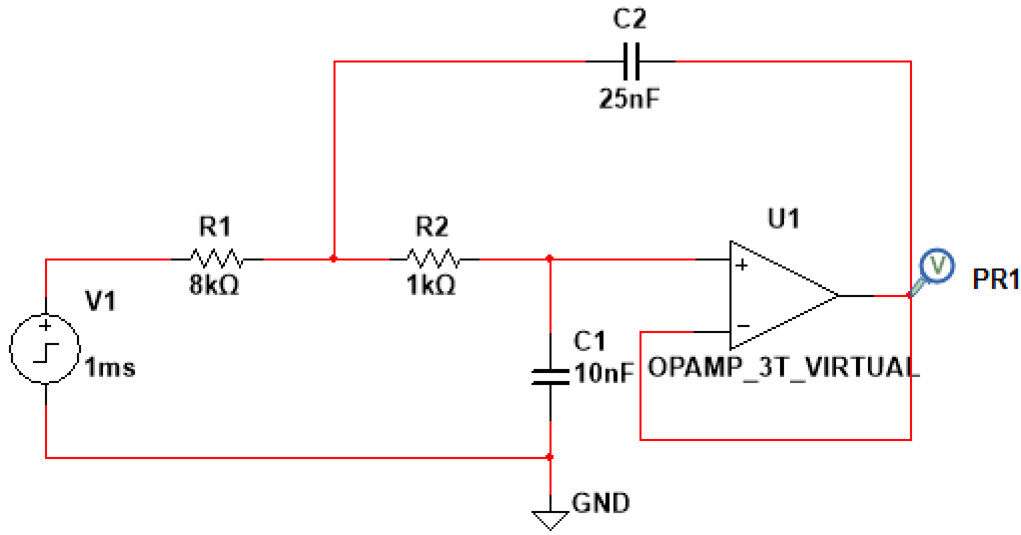
$\boxed{\mathcal{L}^{-1}\{c(t)\} = -5e^{-20t} + 4e^{-25t} + u(t) = y(t)}$

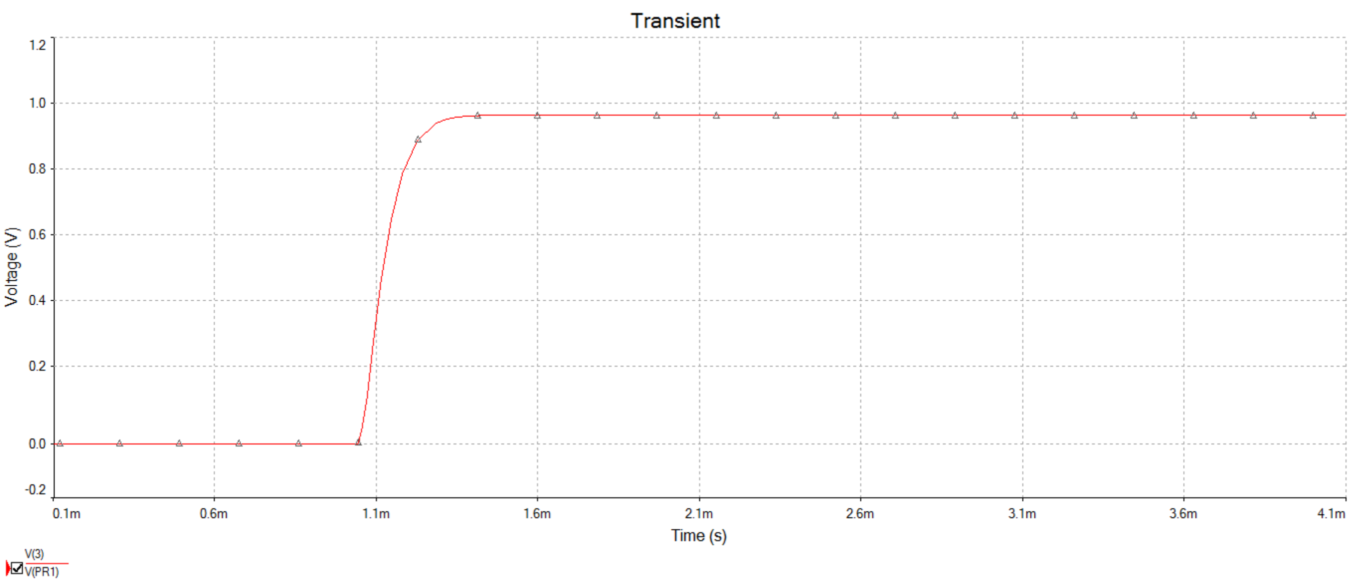


• **System Level Simulation: (2 pts)** Find step response of your transfer function using Simulink. Plot the step response in MATLAB. (You may prefer to perform this section on MATLAB with "`tf`") function.

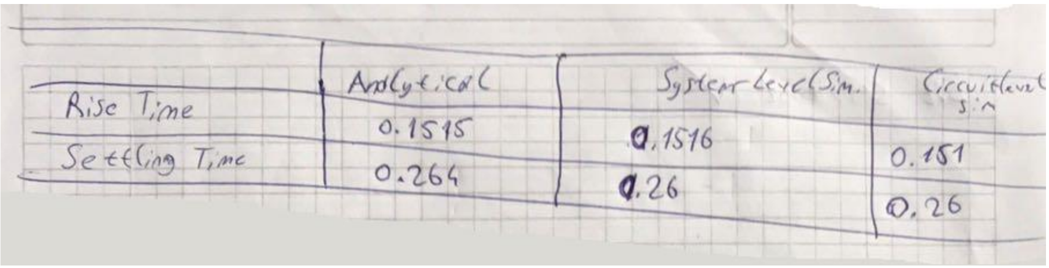


- **Circuit Level Simulation (3.5 pts)** Find an appropriate circuit topology for your transfer function and simulate using P-Spice.





	Analytical	System-Level Sim.	Circuit Level Sim.
Rise Time	0.1515	0.156	0.151
Settling Time	0.264	0.260	0.261



	Analytical	System Level Sim.	Circuit level Sim
Rise Time	0.1515	0.1516	0.151
Settling Time	0.264	0.26	0.26

2. Closed Loop Response

Get your pole location from your lab instructor and add the real pole to your transfer function and perform close loop analysis as shown in following block diagram.

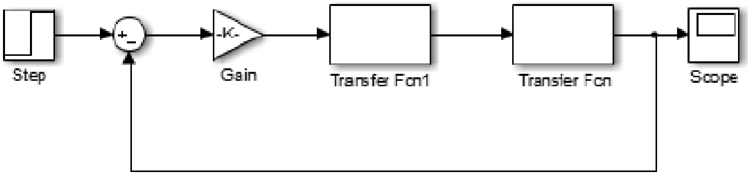


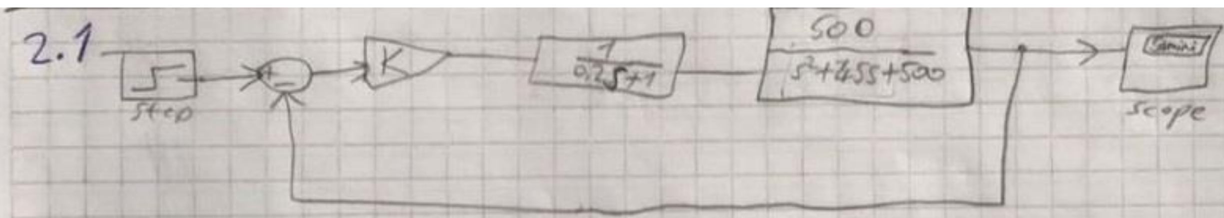
Fig 1. Close Loop Block Diagram

For close loop response please do the following:

- **Analytical Approach (2.5 pts)**

With the given transfer function & real pole location, please find the characteristic equation of overall transfer function and find "K" for marginally stable case using Routh- Hurwitz Criterion.

2.1



$$\frac{Y(s)}{R(s)} = \frac{\dfrac{500k}{0.2s^3+(0.2\times45)s^2+100s+s^2+45s+500}}{1+\dfrac{500k}{0.2s^3+(0.2\times45)s^2+100s+s^2+45s+500}} = \frac{500k}{0.2s^3+10s^2+145s+500+500k}$$

$$\boxed{q(s) = 0.2s^3+10s^2+145s+500+500k}$$

s^3	0.2	145
s^2	10	500+500k
s^1	b_1	0
s^0	c_1	0

$b_1 = 145 - 10 - 10k$

$c_1 = \frac{b_1 \, 500 + 500k \, b_1}{b_1} = 500+500k$

$b_1 = 135 - 10k > 0$ $\quad 13.5 - k > 0$ $\quad 13.5 > k$

$c_1 = 500+500k > 0$

$1+k > 0$

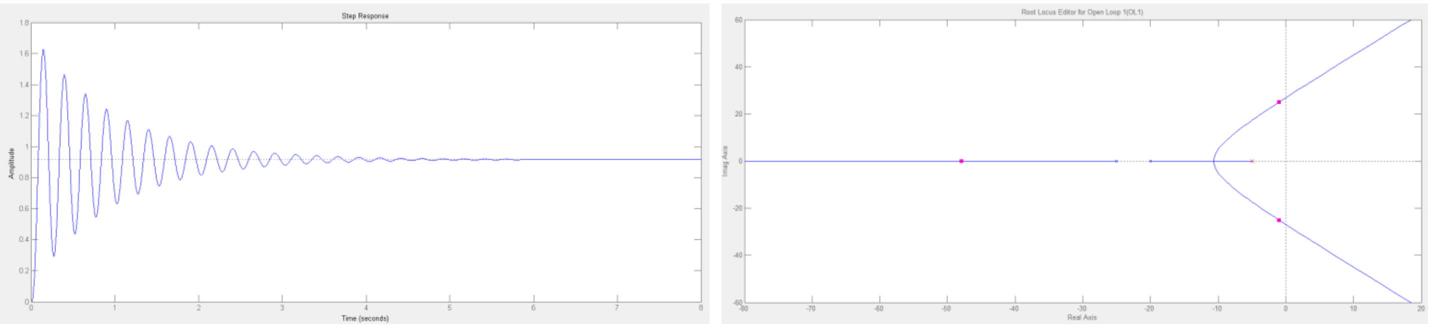
$k > -1$

$$\boxed{13.5 > k > -1}$$

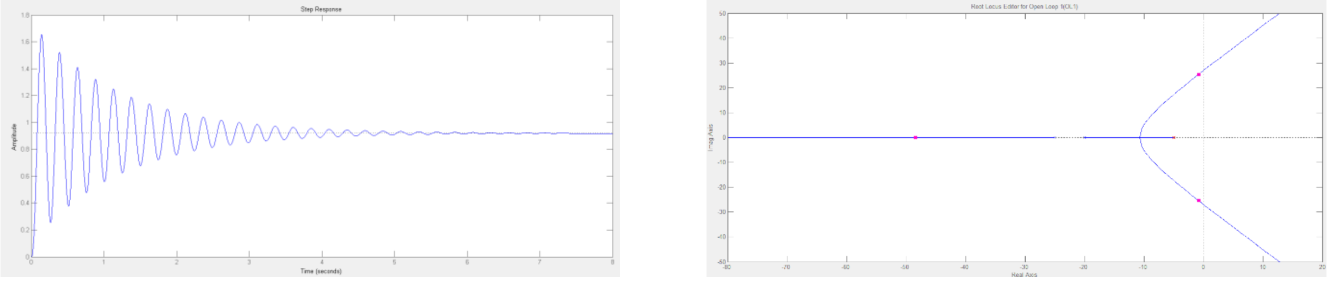
$\boxed{\text{Critical } K = 13.5}$

• **System Level Simulation (Sisotool) (2.5 pts)**

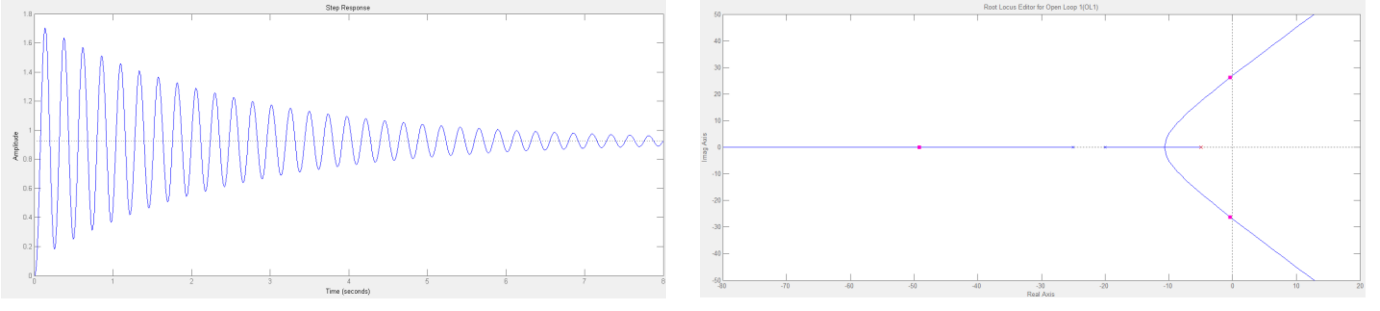
After finding the critical gain, implement your transfer function with a real pole in sisotool and verify that, critical gain causes an oscillating response.



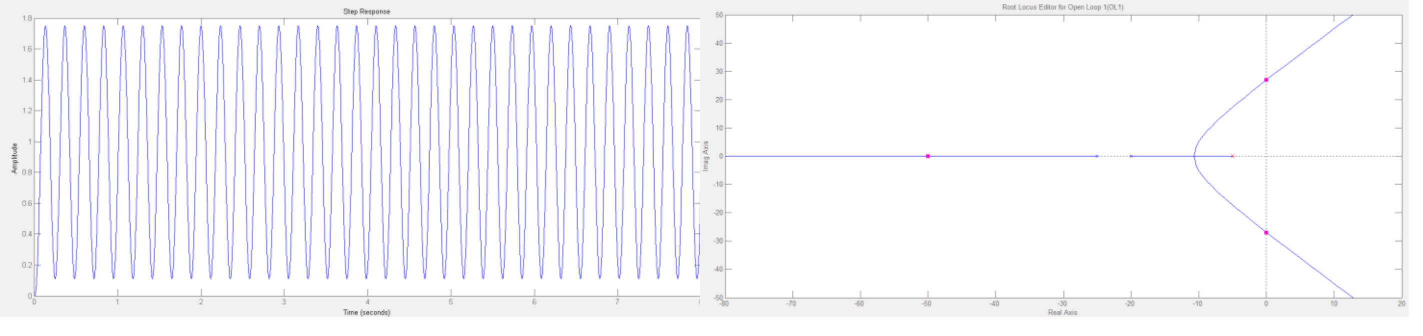
For K=11



For K=11.5

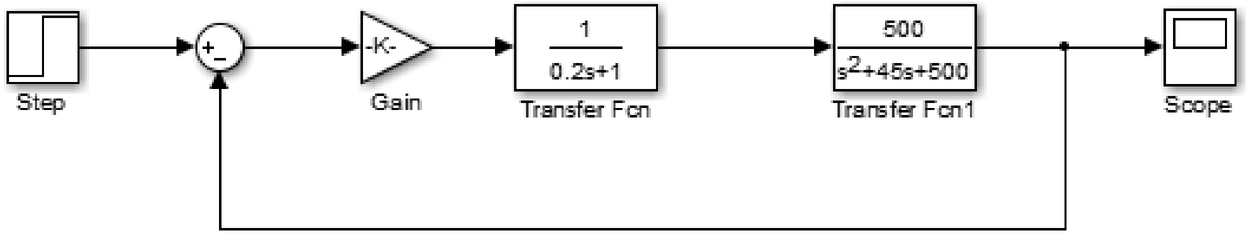


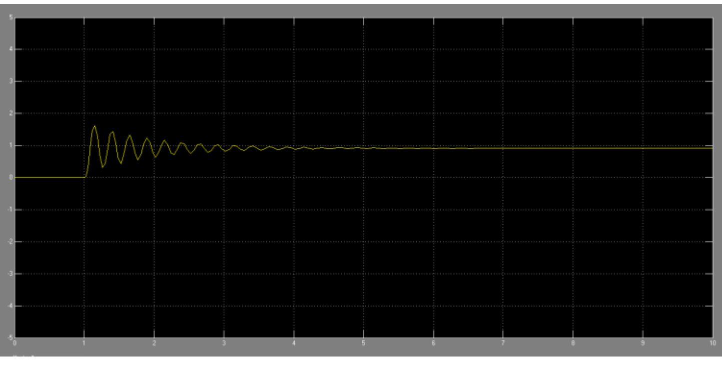
For K=12.5



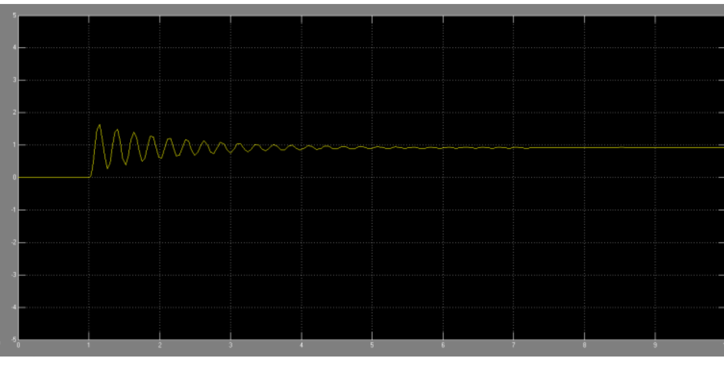
For Critical K=13.5

• **System Level Simulation (Simulink) (2.5 pts)** Build the block diagram in simulink and replace the value of "K" , Transfer Fcn1 & Transfer Fcn2 with appropriate values and verify that same oscillating response occurs in Simulink block diagram.

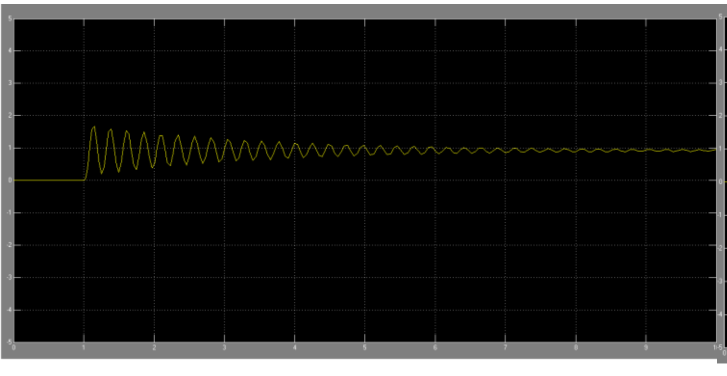




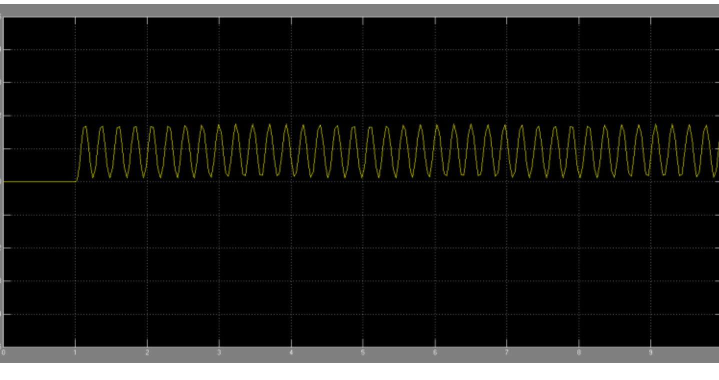
For K=11



For K=11.5



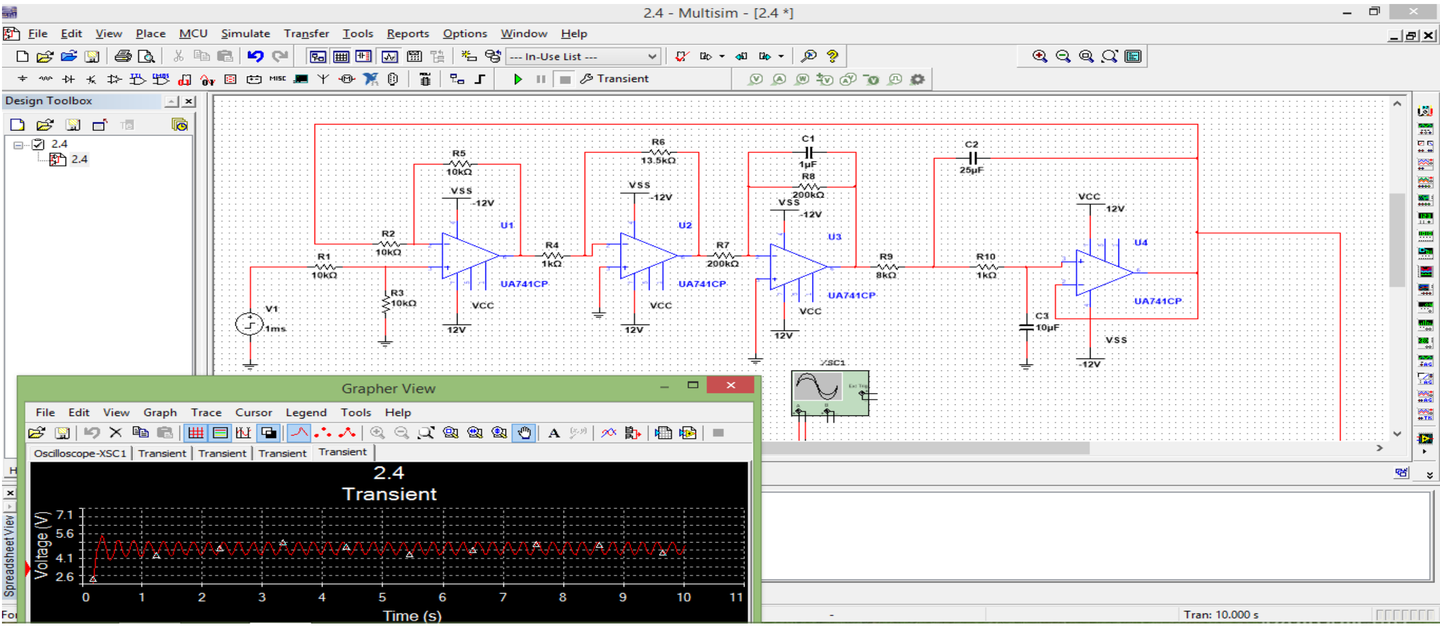
For K=12.5

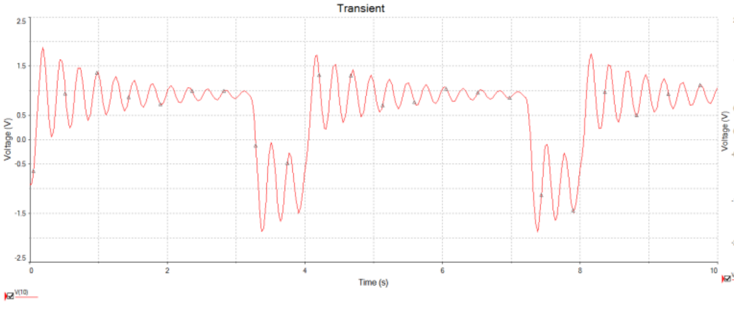


For Critical K=13.5

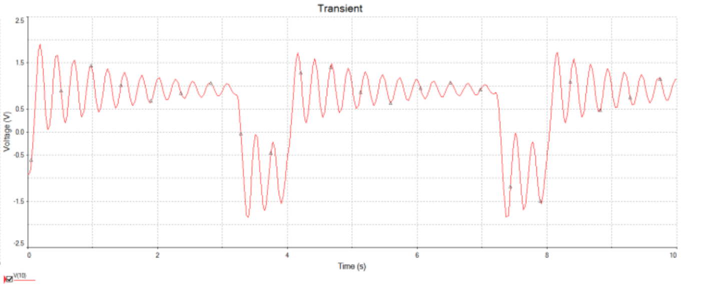
• Circuit Level Simulation (P-Spice) (3.5 pts)

Implement summing block, gain, real pole and transfer function block with appropriate circuit topologies and verify that same oscillating response occurs with selected critical gain.

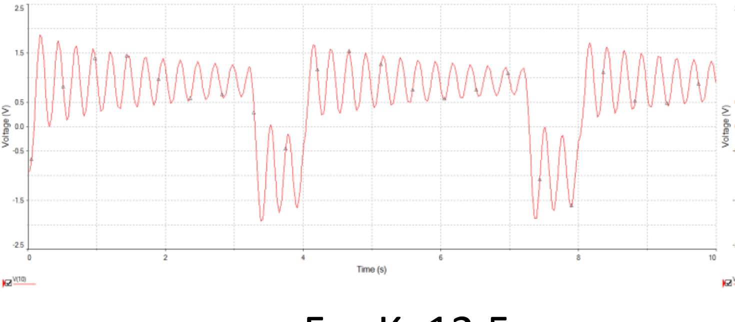




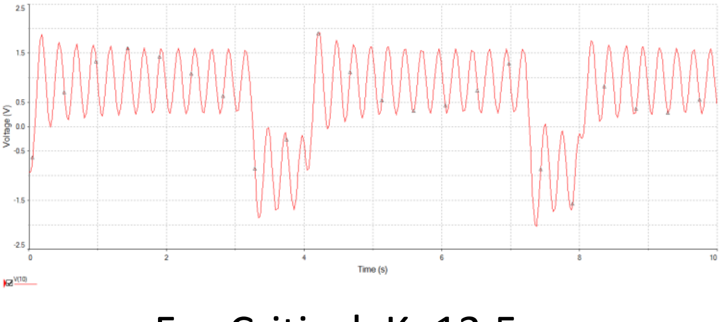
For K=11



For K=11.5



For K=12.5



For Critical K=13.5

● **Realization (6 pts)** Build the simulated circuit with real components and get measurement data. (For this section, contact with your lab assistant to make a schedule in the circuit lab).