Name PID

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Electrical and Computer Engineering Department

ECE 65 – Spring 2023

Components and Circuits lab

Midterm Exam#1 solutions

Closed books, one one-sided cheat sheet, and calculators are allowed

Electronic devices are not allowed.

Please put all answers in the provided sheets.

Be sure to write your name and PID.

Please do not begin until told.

Show your work.

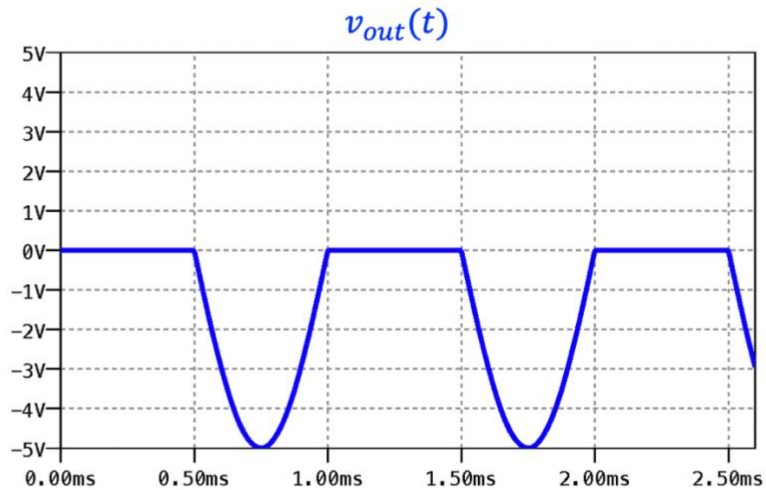
Good luck.

Name PID

Problem 1. (10 points)

a) Design a diode circuit that would generate the output waveform shown in the below graph when the input signal $v_i(t) = 5\sin(2\pi \times 1000\ t)\ V$ is applied to the circuit.

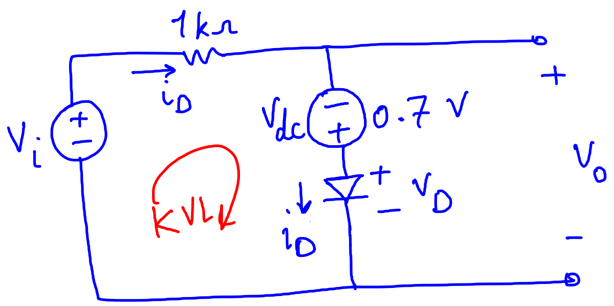
You can use regular PN junction diodes ($V_{D0} = 0.7\ V$), Zener diodes (any desired V_Z), resistor(s), and other circuit elements in your design. Make sure to label v_i and v_{out} on your circuit diagram.



a) Parametrically solve your designed circuit. That means find the relationship between v_i and v_{out}.

Show your work.

Name PID



Case 1: Diode ON

$i_D \geq 0$ and $V_D = V_{D_0}$

KVL: $V_i = i_D \times 1k\Omega - 0.7V + V_D$

$V_i = i_D \times 1k\Omega - 0.7 + 0.7$

$i_D = \frac{V_i}{1k\Omega} \geq 0 \rightarrow V_i \geq 0$

$V_o = -0.7 + V_{D_0} = 0$

Case 2: Diode Off

$i_D = 0$ and $V_D < V_{D_0}$

KVL: $V_i = i_D \times 1k\Omega - 0.7V + V_D$

$V_i = 0 - 0.7 + V_D$

$V_D = V_i + 0.7 < 0.7$

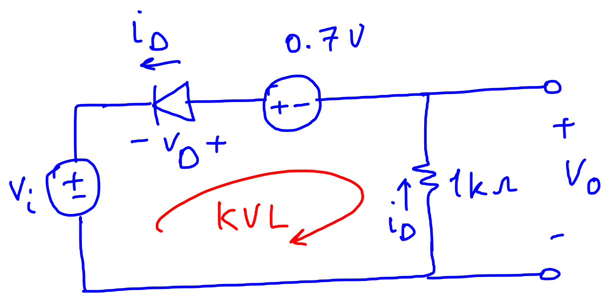
$\Rightarrow V_i < 0$

$V_o = V_i - i_D \times 1k\Omega = V_i$

$V_o = V_i$

Name PID

Another correct circuit:



Case 1: Diode ON

$i_D \geq 0$ and $V_D = V_{D_0}$

KVL: $V_i = -V_D + 0.7V - i_D \times 1k\Omega$

$V_i = -0.7 + 0.7 - i_D \times 1k\Omega$

$i_D = \dfrac{-V_i}{1k\Omega} \geq 0 \Rightarrow \boxed{V_i \leq 0}$

$V_o = V_i + V_D - 0.7V = V_i + 0.7 - 0.7$

$\boxed{V_o = V_i}$

Case 2: Diode Off

$i_D = 0$ and $V_D < V_{D_0}$

KVL: $V_i = -V_D + 0.7V - i_D \times 1k\Omega$

$V_i = -V_D + 0.7 - 0$

$V_D = -V_i + 0.7 < 0.7$

$\Rightarrow \boxed{V_i > 0}$

$V_o = -i_D \times 1k\Omega = 0$

$\boxed{V_o = 0}$

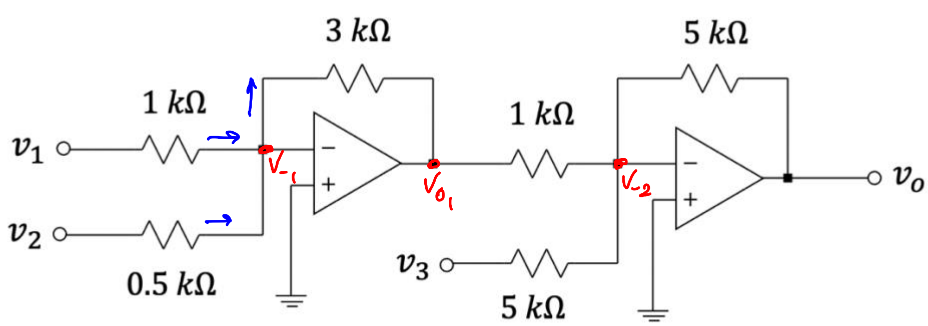
Name PID

Problem 2. (6 points)

Assuming ideal op-amps with $V_{sat} = \pm 15V$ in the below circuit,

a) find (derive) an expression relating v_o to v_1 , v_2 , and v_3.

b) Sketch the output waveform if $v_1 = 0.5\ V$, $v_2 = 0.5\ V$, and $v_3 = 1\sin(2 \times 1000t)\ V$. You do not need to label the time axis.



Show your work.

ideal op-amp $\rightarrow$ $i_+ = i_- = 0$: for both op-amps

negative feed back $\rightarrow$ $V_+ = V_-$

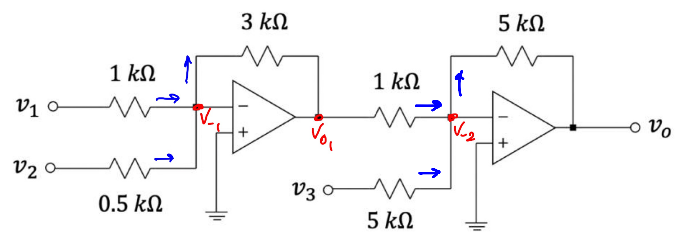
KCL :

$$\frac{V_1 - V_{-1}}{1k\Omega} + \frac{V_2 - V_{-2}}{0.5k\Omega} = \frac{V_- - V_{o_1}}{3k\Omega}$$

$V_{+_1} = 0 \rightarrow V_{-_1} = 0 \rightarrow \dfrac{V_1}{1k\Omega} + \dfrac{V_2}{0.5k\Omega} = \dfrac{-V_{o}}{3k\Omega}$

$\rightarrow V_{o_1} = -3V_1 - 6V_2$

Name PID



KCL:

$$\frac{V_{o_1} - V_{-2}}{1k\Omega} + \frac{V_3 - V_{-2}}{5k\Omega} = \frac{V_{-2} - V_o}{5k\Omega}$$

$V_{+2} = 0 \longrightarrow V_{-2} = 0$

$$\frac{V_{o_1}}{1k\Omega} + \frac{V_3}{5k\Omega} = \frac{-V_o}{5k\Omega} \longrightarrow V_o = -5\,V_{o_1} - V_3$$

$V_{o_1} = -3\,V_1 - 6\,V_2$

$V_1 = 0.5\ V$ and $V_2 = 0.5\ V \longrightarrow V_{o_1} = -1.5\ V - 3V = -4.5\ V < V_{sat-}$

$\longrightarrow V_{o_1} = -4.5V$

$V_o = -5\,V_{o_1} - V_3$

$V_{o_1} = -4.5V$ and $V_3 = 1\ \sin(\omega t) \longrightarrow V_o = 22.5 - 1\sin(\omega t) > V_{sat+}$

The output voltage will saturate and V_o will not exceed V_{sat^+}

$\Longrightarrow V_o = V_{sat^+} = 15\ V$