Name PID

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Electrical and Computer Engineering Department

ECE 65 – Fall 2022

Components and Circuits lab

Midterm Exam 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 on **all pages**.

Please do not begin until told.

Show your work.

Good luck.

Name PID

Problem 1. (12 points)

You will use the last digit of your PID to answer this question.

$V_1 = -1 \times$ the last digit of your PID. (The unit is Volts)

$V_2 = -2 \times$ the last digit of your PID. (The unit is Volts)

For example, if your PID is A14126523, solve this problem with $V_1 = -3\ V$, and $V_2 = -6\ V$.

If the last digit of your PID is zero, solve this problem with $V_1 = -2\ V$, and $V_2 = -4\ V$.

a) Design a diode waveform shaping circuit such that the amplitude of its output voltage signal is always between V_1 and V_2. This means

$$V_2 \leq amplitude\ of\ output\ voltage \leq V_1$$

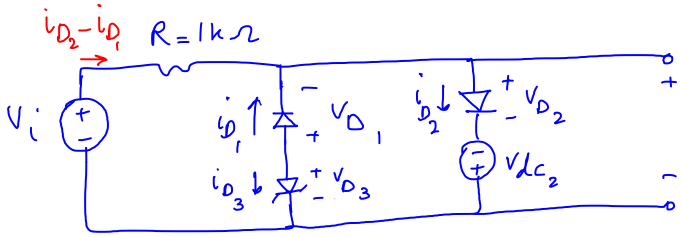
b) Parametrically solve your designed circuit.
   - Find the transfer function of the circuit.
   - Draw the transfer function graph.

Assume you have access to regular PN junction diodes ($V_{D0} = 0.7\ V$), Zener diodes (any desired V_Z), and other circuit elements.

You must use Zener diode(s) in your design.

Show your work.

Name PID



$V_1 = -1\,V, \; V_2 = -2\,V$

$$V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega - V_{D_1} + V_{D_3}$$

$$V_o = -V_{D_1} + V_{D_3}$$

Also, $V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega + V_{D_2} - V_{dc_2}$

Also, $V_o = V_{D_2} - V_{dc_2}$

Case 1: D_1 is ON and D_2 off and D_3 in Zener

$V_{D_1} = V_{D_0} = 0.7\,V$, $\quad i_{D_1} \geq 0$, $\quad V_{D_2} < V_{D_0}$, $\quad i_{D_2} = 0$

$V_{D_3} = -V_Z$, $\quad i_{D_3} \leq 0$

We want $V_o = -2\,V$ when D_1 conducts.

$$V_o = -0.7\,V - V_{Z_1} = -2 \rightarrow V_{Z_1} = 1.3\,V$$

$$V_i = -i_{D_1} \times 1k\Omega - 0.7\,V - 1.3$$

$$i_{D_1} = \frac{-V_i - 0.7 - 1.3}{1k\Omega} \geq 0 \rightarrow V_i \leq -2\,V$$

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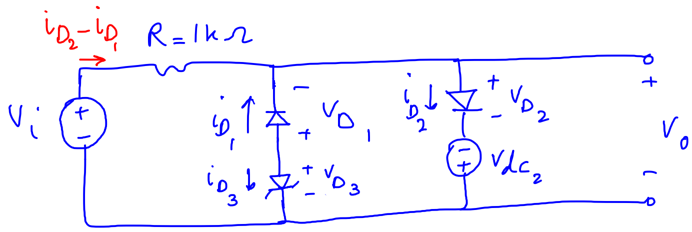


$$V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega - V_{D_1} + V_{D_3}$$

$$V_o = -V_{D_1} + V_{D_3}$$

Also, $V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega + V_{D_2} - V_{dc_2}$

Also, $V_o = V_{D_2} - V_{dc_2}$

Case 2 D_1 and D_3 are off and D_2 is ON

$V_{D_2} = V_{D_o} = 0.7V$, $i_{D_2} \geq 0$, $V_{D_1} < V_{D_o}$, $i_{D_1} = 0$

$-V_2 < V_{D_3} < V_{D_o}$, $i_{D_3} = 0$

We want $V_o = -1$ when D_2 conducts.

$$V_o = V_{D_o} - V_{dc_2} = 0.7 - V_{dc_2} = -1 \text{ V}$$

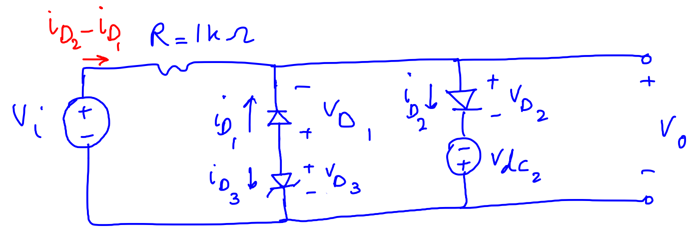
$$\Rightarrow V_{dc_2} = 1.7 \text{ V}$$

$$V_i = 1k\Omega \times i_{D_2} + V_{D_2} - V_{dc_2}$$

$$V_i = 1k\Omega \times i_{D_2} + 0.7V - 1.7 \text{ V}$$

$$i_{D_2} = \frac{V_i + 1V}{1k\Omega} \geq 0 \rightarrow V_i \geq -1 \text{ V}$$

Name PID



$V_1 = -1\ V, \quad V_2 = -2\ V$

$$V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega - V_{D_1} + V_{D_3}$$

$$V_o = -V_{D_1} + V_{D_3}$$

Also, $V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega + V_{D_2} - V_{dc_2}$

Also, $V_o = V_{D_2} - V_{dc_2}$

Case 3 D_1 and D_2 and D_3 are off

$V_{D_2} < 0.7V$, $i_{D_2} = 0$, $V_{D_1} < V_{D_o}$, $i_{D_1} = 0$, $-V_Z < V_{D_3} < V_{D_o}$, $i_{D_3} = 0$

$$V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega - V_{D_1} + V_{D_3} = -V_{D_1} + V_{D_3}$$

$-\infty < V_{D_1} < 0.7 \longrightarrow \quad -0.7 < -V_{D_1} < \infty$

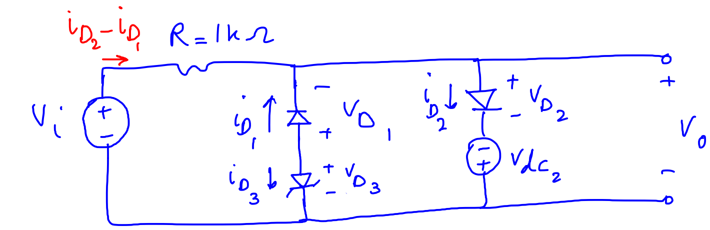
$$-V_Z < V_{D_3} < 0.7$$

$-V_Z - 0.7 < V_{D_3} - V_{D_1} < \infty \quad \longrightarrow \quad V_i = V_{D_3} - V_{D_1} > -V_Z - 0.7V$

we need $V_i > -2\ V$ for this case $\Longrightarrow$

$-V_Z - 0.7 = -2 \longrightarrow V_Z = 1.3\ V$

Name PID



$V_1 = -1\ V, \quad V_2 = -2\ V$

Case 3

$V_i > -2\ V$ and

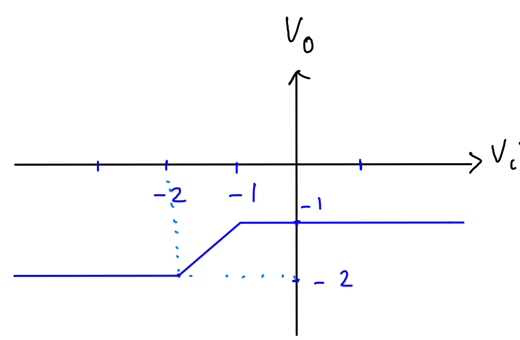
$$V_i = (i_{D_2} - i_{D_1}) \times 1k\Omega + V_{D_2} - V_{dc_2} = V_{D_2} - 1.7\ V$$

$$V_{D_2} = V_i + 1.7\ V < 0.7 \rightarrow V_i < -1\ V$$

$V_i < -1\ V$ and $V_i > -2\ V \longrightarrow -2 < V_i < -1$

$$V_o = V_i$$

$$\begin{cases} V_i \geq -1\ V & V_o = -1 \\ -2 < V_i < -1 & V_o = V_i \\ V_i \leq -2\ V & V_o = -2\ V \end{cases}$$



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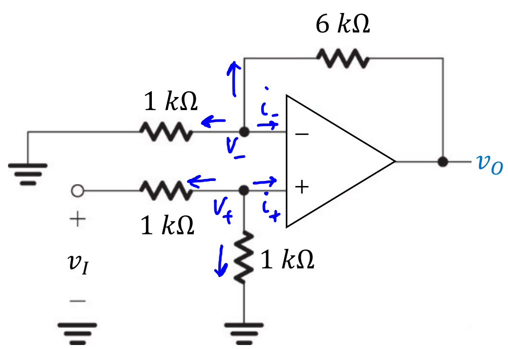
Problem 2. (5 points)

Assuming an ideal op-amp with $V_{sat} = \pm 15V$ in the below circuit, find (derive) an expression for the voltage gain.



Show your work.

ideal op-amp and negative feedback : $V_+ = V_-$

also $i_+ = i_- = 0$

KCL at the + input terminal:

$$\frac{V_+}{1k\Omega} + \frac{V_+ - V_I}{1k\Omega} + i_+ = 0 \rightarrow \frac{2\,V_+}{1k\Omega} = \frac{V_I}{1k\Omega} \rightarrow V_+ = \frac{1}{2} V_I$$

KCL at the − input terminal:

$$\frac{V_-}{1k\Omega} + \frac{V_- - V_o}{6k\Omega} + i_- = 0 \rightarrow \frac{V_-}{1k\Omega} + \frac{V_-}{6k\Omega} - \frac{V_o}{6k\Omega} = 0$$

$$6V_- + V_- = V_0 \rightarrow 7\,V_- = V_0$$

$$\rightarrow V_- = \frac{1}{7} V_0$$

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$$\begin{cases} V_+ = V_- \\ V_+ = \frac{1}{2} V_I \\ V_- = \frac{1}{7} V_0 \end{cases}$$

$$\Rightarrow \frac{1}{7} V_0 = \frac{1}{2} V_I \Longrightarrow V_0 = \frac{7}{2} V_I$$

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