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ECE 65 Fall 2018 Midterm Exam Answer Sheet

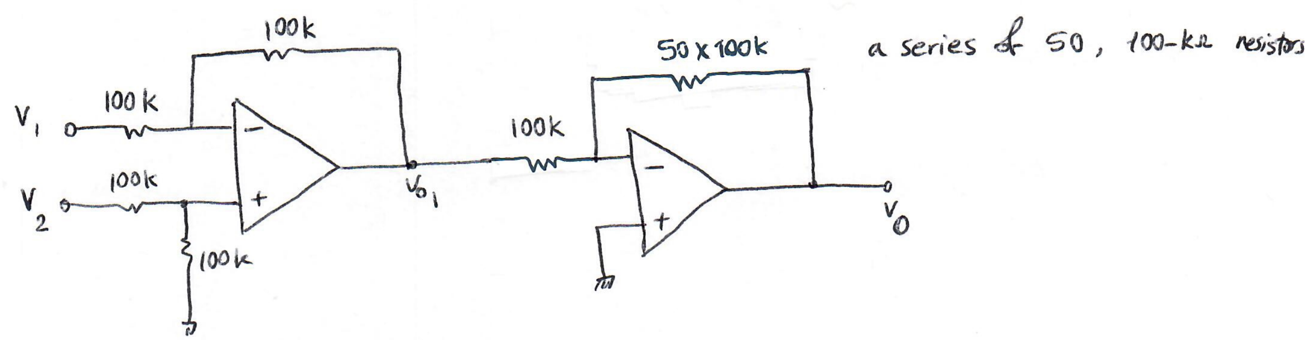
Problem 1. (10 points)

In a system, it is required to take the difference between two signals,

$$v_1 = 4\sin(2\pi \times 50t) + 0.01\sin(2\pi \times 2000t)$$
$$v_2 = 4\sin(2\pi \times 50t) - 0.01\sin(2\pi \times 2000t)$$

such that the 50-Hz component is eliminated and the 2000-Hz component is amplified with a gain of 40 dB. <u>Design</u> the circuit using **two** ideal op-amps and 100 $k\Omega$ resistors. Assume opamps have $V_{sat} = \pm 10V$.

One possible design is as following



$$V_{o1} = \frac{100k}{100k}(V_2 - V_1) = -0.02\sin(2\pi \times 2000t)$$

$$V_o = -\frac{50 \times 100k}{100k} \times V_{o1} = 1\ \sin(2\pi \times 2000t)$$

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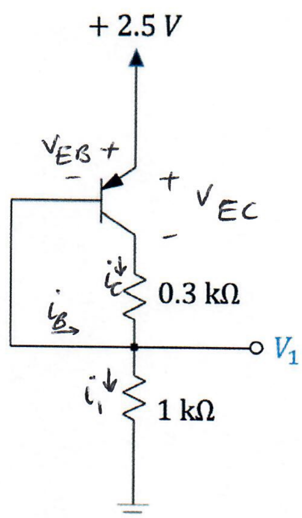
Problem 2. (10 points)

In the following circuit, <u>find</u> the values of the collector and base currents and the node voltage V1. Assume $\beta = 100,\ V_{D0} = 0.7\ V, V_{sat} = 0.2\ V.$



Assume BJT is off: $V_{EB} < V_{D0}$ and $i_B = 0$, $i_C = 0$

EB-KVL: $2.5\,V = V_{EB} + 1k \times i_1$

KCL: $i_1 = i_B + i_C$

$i_B = i_C = 0 \longrightarrow i_1 = 0 \longrightarrow$ $2.5V = V_{EB} + 0$ $\longrightarrow V_{EB} = 2.5\,V > V_{D0}$

Assumption was wrong

BJT is ON, Assume Active mode of operation: $i_C = \beta i_B$, $V_{EC} \geq V_{D0}$

$V_{EB} = 0.7V$

$i_1 = i_B + i_C = (1+\beta)\, i_B$

EB-KVL: $2.5\,V = 0.7V + 1k \times i_1 \longrightarrow i_1 = 1.8\,mA$

$\longrightarrow i_B = \dfrac{1.8\,mA}{101} = 17.8\,\mu A$, $i_C = 1.78\,mA$

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problem 2. cont.

EC-KVL: $2.5 = V_{EC} + 0.3k \times i_c + 1k \times i_1$

$2.5 = V_{EC} + 0.3k \times 1.78mA + 1k \times 1.8mA$

$\rightarrow V_{EC} = 0.166\ V < V_{D_0}$ $\rightarrow$ Assumption was wrong

Assume saturation: $V_{EC} = 0.2V$, $i_c < \beta i_B$

EC-KVL: $2.5V = 0.2 + 0.3k \times i_c + 1k \times i_1$

EB-KVL: $2.5V = 0.7V + 1k \times i_1 \rightarrow \boxed{i_1 = 1.8\ mA}$ not changed

$2.3V = 0.3k \times i_c + 1.8V \rightarrow \boxed{i_c = 1.67\ mA}$

$i_B = i_1 - i_c = 0.13mA$, $\beta i_B = 13mA > i_c$ ✓

$\boxed{i_B = 0.13\ mA}$

Assumption is correct.
BJT is in saturation

$\boxed{V_1 = i_1 \times 1k = 1.8V}$

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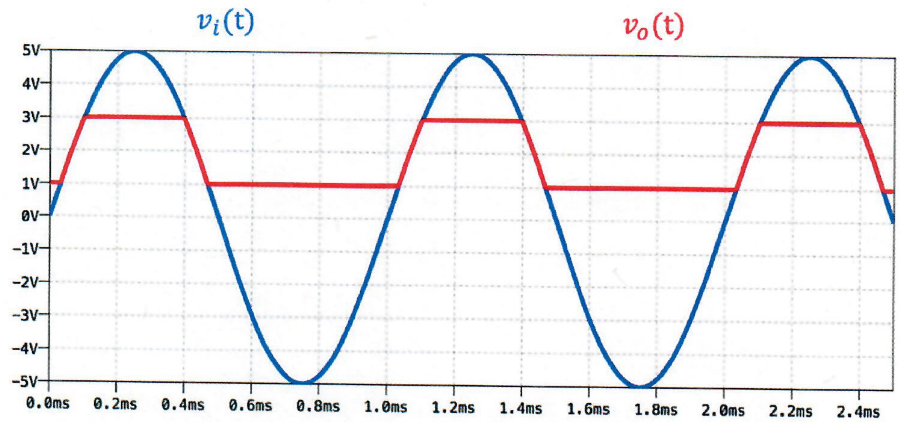
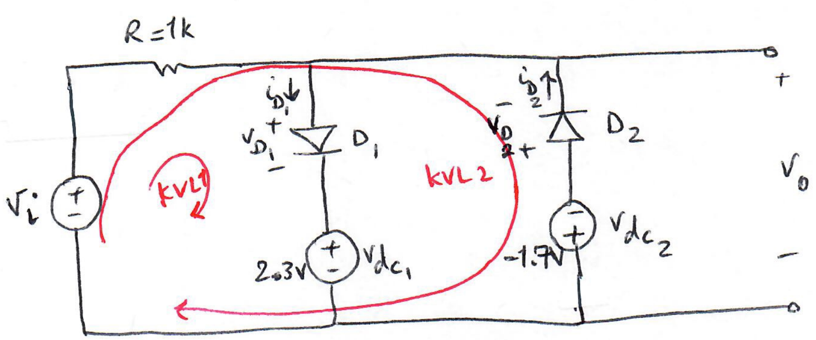
Problem 3. (10 points)

Part a. (8 points)

I. Design a two-port network using diodes (a diode waveform shaping circuit) that would generate the output waveform shown in the below graph when the input signal $v_i = 5\sin(\omega t)$ is applied to the network. On the graph, $v_i(t)$ is drawn in blue color and $v_o(t)$ is drawn in red color.
You can use regular PN junction diodes, Zener diodes, voltage sources and any other circuit elements in your design.

II. Draw the transfer function for this circuit.





when D_1 is ON and D_2 is off , $V_{D_1} = 0.7$, $i_{D_1} \geq 0$, $V_{D_2} < 0.7$, $i_{D_2} = 0$

$$V_o = V_{D_1} + V_{dc_1} = V_{D_0} + 2.3V = 3V \rightarrow \boxed{V_o = 3V}$$

KVL1: $$i_{D_1} = \frac{V_i - (V_{D_1} + V_{dc_1})}{R} , \quad i_{D_1} \geq 0 \rightarrow \boxed{V_i \geq 3V}$$

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When D_2 is ON and D_1 is off, $i_{D_2} \geq 0$, $V_{D_2} = 0.7$, $V_{D_1} < 0.7$, $i_{D_1} = 0$

$$V_o = -V_{D_2} - V_{dc_2} = -0.7 - (-1.7V) = 1V \longrightarrow \boxed{V_o = 1V}$$

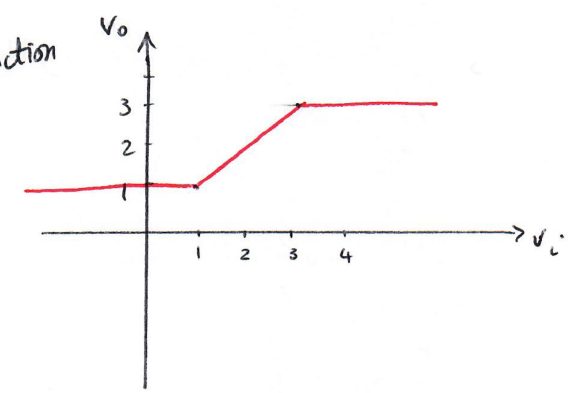
KVL2 : $V_i = -R\, i_{D_2} - V_{D_2} - V_{dc_2}$

$$i_{D_2} \geq 0 \longrightarrow \frac{-V_i - V_{D_2} - V_{dc_2}}{R} \geq 0 \longrightarrow \frac{-V_i - 0.7 - (-1.7)}{1k} \geq 0$$

$$\longrightarrow \boxed{V_i \leq 1V}$$

For $\boxed{1V < V_i < 3V}$, D_1 & D_2 are off & $\boxed{V_o = V_i}$

The transfer function



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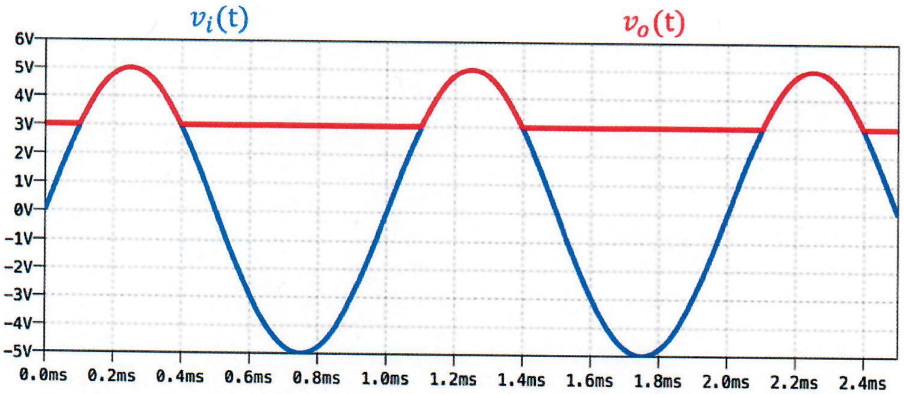
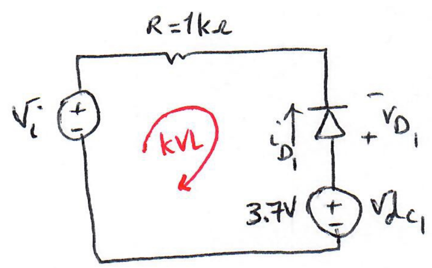
Part b. (2 points)

Design a two-port network using diodes (a diode waveform shaping circuit) that would generate the output waveform shown in the below graph when the input signal $v_i = 5\sin(\omega t)$ is applied to the network. On the graph, $v_i(t)$ is drawn in blue color and $v_o(t)$ is drawn in red color.

You can use regular PN junction diodes, Zener diodes, voltage sources and any other circuit elements in your design.



From the graph, when $V_i \geq 3V \rightarrow V_o = V_i$ and when $V_i \leq 3V \rightarrow V_o = 3V$



when D_1 is ON: $V_{D_1} = 0.7V$, $i_{D_1} \geq 0$

KVL: $V_i = -i_{D_1} \times 1k\Omega - V_{D_1} + V_{dc_1}$

$$i_{D_1} = \frac{-V_i - V_{D_0} + V_{dc_1}}{1k\Omega} \geq 0$$

$\rightarrow V_i \leq -V_{D_0} + V_{dc_1}$

$V_i \leq -0.7 + 3.7 = 3V$

$V_o = -V_{D_0} + V_{dc_1} = 3V$

$\rightarrow \boxed{V_i \leq 3V}$ and $\boxed{V_o = 3V}$

for $V_i > 3V$, D_1 is off and $i_{D_1} = 0 \rightarrow V_o = 0 + V_i = V_i$, $\boxed{V_o = V_i}$