BRAC University
Dept. of Computer Science and Engineering

Assessment: Assignment 1
Due: 11:59 PM 8 February 2024
Full Marks: **60**

BRAC UNIVERSITY
Inspiring Excellence

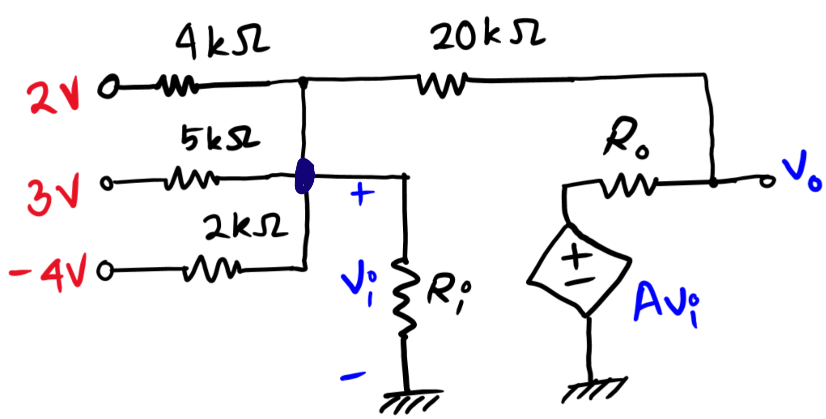
Semester: Spring 2024
Course Code: CSE251
Section: **10 / 11**
Course Name: Electronic Devices and Circuits

Name: ______________________________

Student ID: ______________________________

- ✓ Write down your student ID on the **top right corner of each of the pages**.
- ✓ Clearly write the solutions, along with the questions, on white paper with black ink (no need to use color pen, don't use pencils).
- ✓ Use **CamScanner**, or **Adobe Scan**, or **Microsoft Office Lens**, or any other software to scan the pages and make a **single PDF file**.
- ✓ After creating the PDF, make sure that **(a)** there are no pages missing, **(b)** all of the pages are legible, **(c)** your student ID on each page are visible.
- ✓ Please note, **collaboration ≠ copying**. You are allowed to discuss the questions and clear confusion you might have, but you have to write your solutions independently and be able to explain your answers during a random viva.
- ✓ **[Very Important]** Rename the PDF in the following format: **"<Section>_A1_StudentID_FullNameWithoutSpace.pdf"**. For example, if I am in section **10** and my student ID is 12345678 and my name is Shadman Shahid, the filename should be **"10_A1_12345678_ShadmanShahid.pdf"**.
- ✓ **Submission Link: https://forms.gle/DCqCu22oxdxKRod96**

Question 1: 10 Marks



In the above circuit $A = 200$, $R_i = 200\ k\Omega$ and $R_o = 1\ k\Omega$. Answer the following questions

a) Write the node equations for the nodes indicated by v_i and v_o. [CO1] 4

b) Solve the node equations to find the values of v_i and v_o. [CO2] 3

c) Can circuit theorems based on linearity principle (such as superposition principle) be applied to the above circuit? Explain in short why or why not. [CO1] 3

Solution:

a) At node v_i:

$$\frac{2-v_i}{4} + \frac{3-v_i}{5} + \frac{-4-v_i}{2} = \frac{v_i - v_o}{20} + \frac{v_i}{200} \quad \text{.......(i)}$$

At node v_o:

$$\frac{v_i - v_o}{20} + \frac{Av_i - v_o}{1} = 0 \quad \text{--------(ii)}$$

b) Simplifying:

(i) becomes:

$$v_i\left(\frac{1}{4}+\frac{1}{5}+\frac{1}{2}+\frac{1}{20}+\frac{1}{200}\right)-v_o\left(\frac{1}{20}\right)=\frac{2}{4}+\frac{3}{5}-\frac{4}{2}$$

$$\therefore\ 1.005v_i-0.05v_o=-0.9 \quad \text{------ (iii)}$$

(ii) becomes:

$$v_i\left(-\frac{1}{20}-\frac{200}{1}\right)+v_o\left(1+\frac{1}{20}\right)=0$$

$$-200.05v_i+1.05v_o=0 \quad \text{------ (iv)}$$

Solving (iii) & (iv) we get:

$$\boxed{\begin{aligned} v_i &= 0.1056\ \text{V} \\ v_o &= 20.123\ \text{V} \end{aligned}}$$

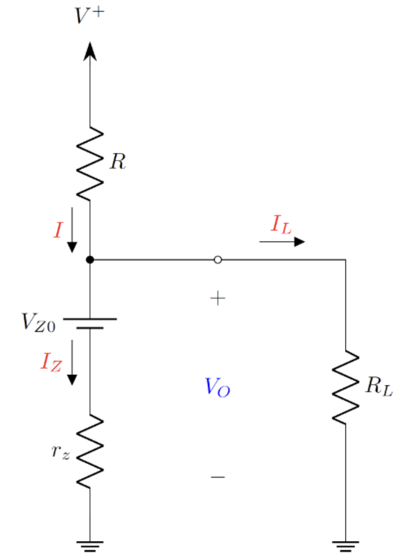
c) Yes! Because all the circuit elements are linear. (Even the voltage dependent voltage source, because the voltage dependence (Av_i) is linear.)

$$V_o=I_LR_L=0.5\times20=10\text{V}$$

$$I_z=\frac{V_o-V_{z0}}{r_z}=\frac{10-2.5}{0.04}=$$

Question 2: 8 Marks

For $R = 200\,\Omega$, $R_L = 20\,k\Omega$, $r_z = 40\,\Omega$, $V_{ZO} = 2.5\,V$, and $I_L = 0.5\,mA$.



a) Find V_O, I_Z [CO2] 4

b) Find I, V^+. [CO2] 4

a) $V_o = I_L R_L = 0.5 \times 20 = \boxed{10\ V}$

$I_L = \dfrac{V_o - V_{z0}}{r_z} = \dfrac{10-2.5}{0.04} = \boxed{187.5\ mA}$.

b) $I = I_L + I_z = (0.5 + 187.5)\ mA = \boxed{188\ mA}$

$V^+ = V_o + IR = (10 + 187.5 \times 0.2)\ V = \boxed{47.6\ V}$

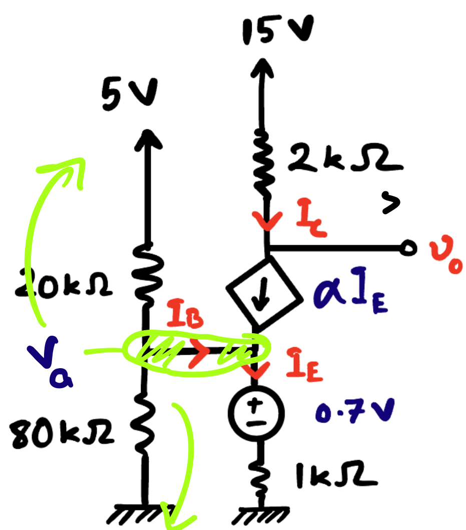
Question 3: 10 Marks

In the adjacent circuit $\alpha = 0.95$.

a) Derive an expression of I_E in terms of I_B and α. [CO1] 3

b) Find the value of the currents I_E, I_B and I_C. [CO2] 4

c) Find the value of the voltage at the output node v_o. [CO2] 3



a) $I_E = I_B + \alpha I_E$ (From node V_a)

$I_E(1-\alpha) = I_B$

$I_E = \dfrac{I_B}{1-\alpha}$

b) Node analysis at (V_a): $\left(\dfrac{V_a - 5}{20} + \dfrac{V_a}{80} + \dfrac{V_a - 0.7}{1} = \alpha I_E\right)$

$$V_a\left(\frac{1}{20}+\frac{1}{80}\right)+(V_a-0.7)\left(\frac{1}{1}\right)-5\left(\frac{1}{20}\right)-\alpha I_E=0$$

$$\therefore V_a\left(\frac{1}{16}\right)+V_a-0.7-0.25-\alpha(V_a-0.7)=0$$

$$V_a\left(\frac{1}{16}+1-0.95\right)=0.7+0.25-0.95\times0.7$$

$$\Rightarrow V_a=\frac{0.285}{0.1125}\ V=2.533\ V.$$

b (Ans)

$$I_B=\frac{5-V_a}{20}-\frac{V_a}{80}=\frac{11}{120}\ mA=\boxed{0.09166\ mA}$$

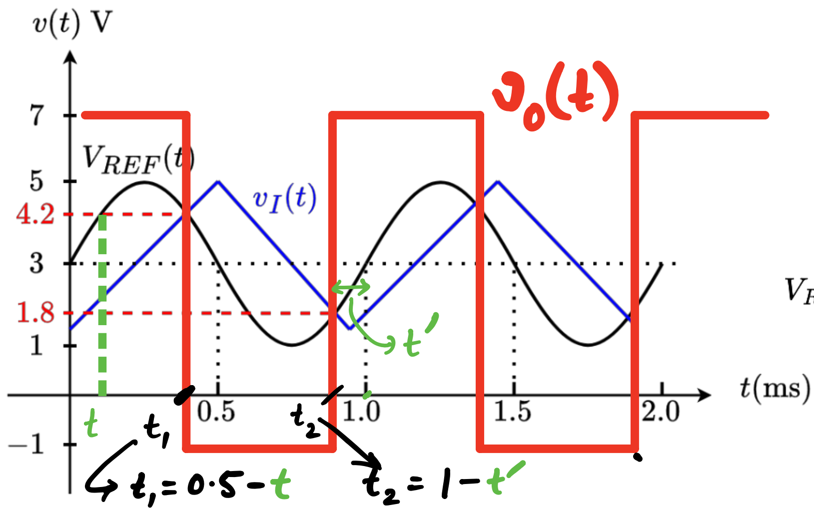
$$I_E=\frac{V_a-0.7}{1}=\frac{11}{6}\ mA=\boxed{1.833\ mA}$$

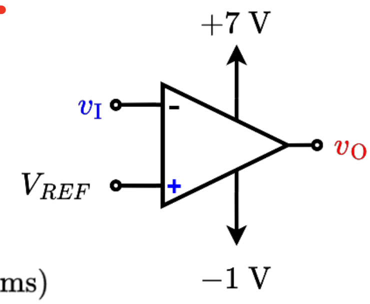
$$I_c=\alpha I_E=\boxed{1.7467\ mA}$$

(c) $\Rightarrow V_o=15-I_c\times2=\boxed{11.5066\ V}$

Question 4: [CO2] 12 Marks

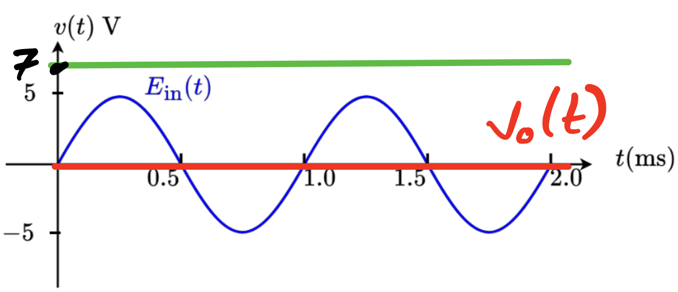
a) Assume that the Op-amp on the right is ideal. The wave shapes of v_I and V_{REF} are shown on the adjacent graph. 6

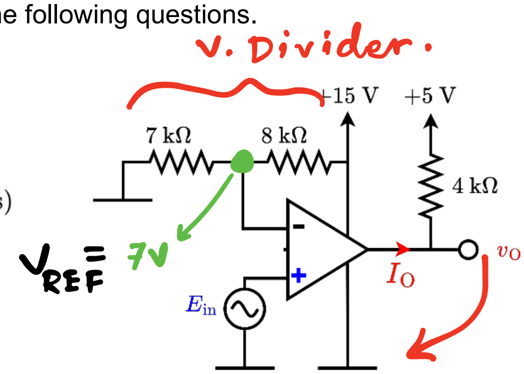




- **Draw** the waveshape of the output voltage of the op-amp $v_O(t)$ on the graph provided above. Indicate the time (t) in which switching would occur in $v_O(t)$. **(Print this page and draw the graph on the same graph paper)**

b) Assume that the Op-Amp on the right is ideal. Answer the following questions. 6





i. Sketch accurately the graph of V_O vs E_{in} **(VTC).**

ii. Sketch accurately the graphs of V_O vs t. Find out the time (t) in which switching would occur in $V_O(t)$.

↳ Never.

↓

V_o is 0 V (The negative saturation) as E_{in} is always less than $V_{REF} = 7V$.

So, v_o never switches.

4 (a)

$$2\sin\left(\frac{2\pi}{1}t\right)+3=4.2$$

$$t=0.102\,ms.$$

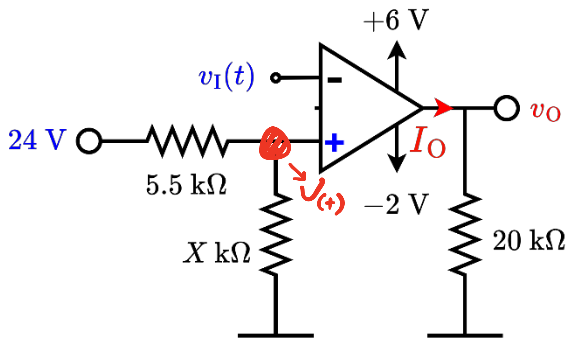
$$\therefore t_1=\frac{1}{2}\,ms-0.102\,ms=0.398\,ms$$

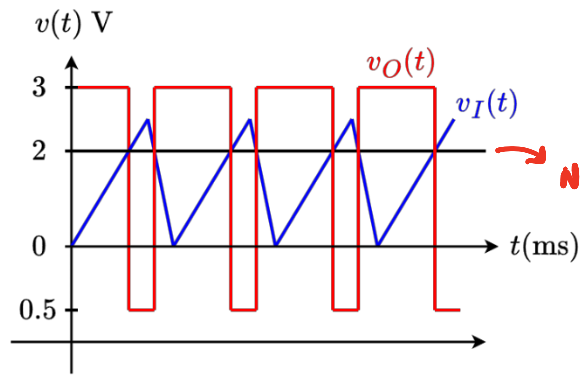
$$2\sin\left(\frac{2\pi}{1}t\right)+3=1.8$$

$$t'=-0.102\,ms$$

$$t_2=1-0.102\,ms=0.898\,ms.$$

Question 5: 10 Marks





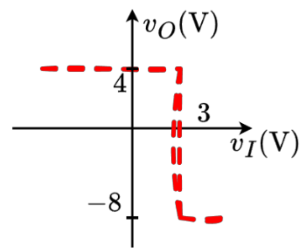
New reference

2V

a) For $X = 2.5$, and $v_I = 9$ V, find v_O and I_O. [CO3] 3

b) Find the value of X and the new saturation voltages (positive and negative) to implement the waveshape in the right figure. [CO3] 4

c) Design a circuit using op-amp that has the voltage transfer characteristics as shown in the figure below. v_O (V) is the output voltage and v_I (V) is the input voltage. [CO3] 3



a) $X = 2.5$

$$\therefore V_{(+)} = \underbrace{\frac{2.5}{2.5+5.5}}_{\text{V. Divider at } V_{(+)} \text{ node}} \times 24\text{ V} = 7.5\text{V (Reference)}$$

If $V_I = 9\text{V} = V_{(-)}$ (input voltage)

$V_I > V_{(+)}$ (Reference). [Inverting configuration]

So; $V_o = -2\text{V}$ as $[V_{(+)} - V_{(-)} = (7.5-9)\text{V} = -1.5\text{V}$

$\therefore V_{(+)} - V_{(-)} < 0\text{V}]$

$$\boxed{I_o = \frac{V_o}{20} = -0.1\text{ mA}}$$

b) $V_{REF} = V_{(+)} = 2\,V$

$$V_{(+)} = \frac{X}{X+5.5} \times 24 = 2$$

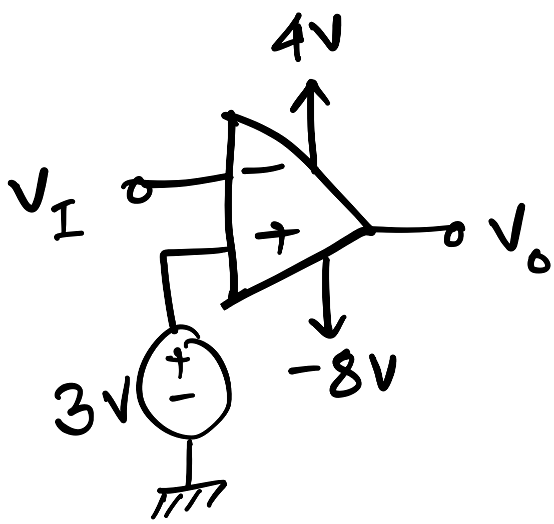
$$\frac{X}{X+5.5} = \frac{2}{24}$$

$$24X = 2X + 11$$

$$22X = 11$$

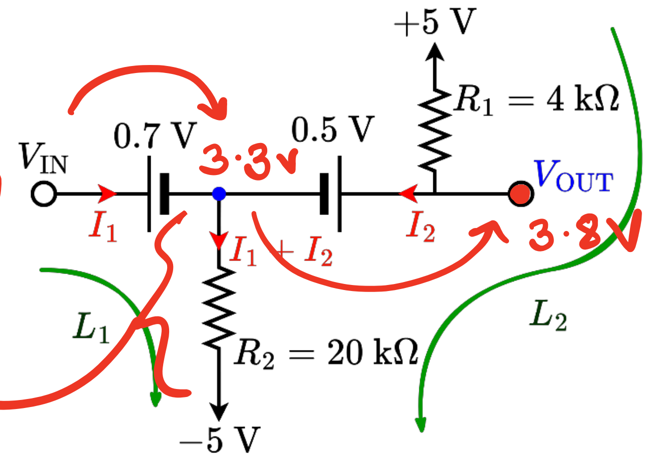
$$\boxed{X = 0.5}$$

c)



Question 6: 10 Marks

$$\frac{5-3.8}{R_1}=I_2$$

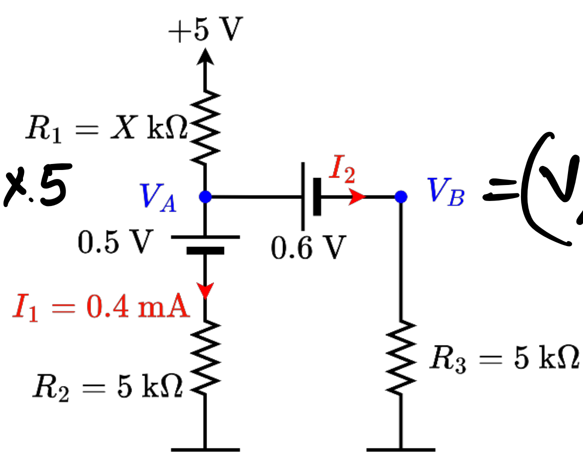


$$I_1+I_2=\frac{3.3-(-5)}{R_2}$$

a) [$V_{IN} = 4.0$ V] Write down the two KVL equations for the lines (loops) indicated by the ~~red~~ lines L_1 and L_2. green. [CO1] 3

b) [$V_{IN} = 4.0$ V] Solve the circuit to find V_{OUT}, I_1 and I_2. You may use either mesh analysis or nodal analysis. [CO2] 4

$V_A = 0.5 + 0.4 \times 5$
$= 2.5\text{V}$



$V_B = (V_A - 0.6)\text{V} = 1.9\text{ V}$

$I_2 = \dfrac{1.9-0}{5} = 0.38$ mA

c) Design the circuit; i.e., find X to get $\boldsymbol{I_1 = 0.4\ \text{mA}}$. [Use any technique of your choice.] Find V_A, I_2 and V_B. [CO2] 3

c

$\therefore I = I_1 + I_2 = 0.4 + 0.38 = 0.78$ mA

$\therefore R_1 = \dfrac{5-2.5}{0.78} = X$

$\therefore \boxed{X = \dfrac{2.5}{0.78}\text{ V} = 3.205\text{ V}}$

6a. **L_1:** $V_{IN} - 0.7 - R_2(I_1+I_2) = -5$ —— (i)

$\underset{(4.0V)}{\downarrow}$

L_2: $5 - R_1 I_2 - 0.5 - R_2(I_1+I_2) = -5$ —— (ii).

b. $\frac{3.3+5}{20} = I_1 + I_2 = 0.415\,mA$.

$5 - 4.3 + 0.5$

$V_{OUT} = V_{IN} - 0.7 + 0.5 = 4 - 0.2\,V$

$$\boxed{V_{OUT} = 3.8\,V}$$

$I_2 = \frac{5-3.8}{4} = 0.3\ mA$

$I_1 = 0.465 - 0.3\,mA = 0.115\,mA$

Or;

Solving (i) & (ii)

$I_1 = 0.115\ mA$

$I_2 = 0.3\ mA$.

& $V_0 = 5 - R_1 I_2 = (5 - 1.2)\,V$