BRAC University
Dept. of Computer Science and Engineering

Assessment: Assignment 2
Due: 11:59 AM 17 October 2023
Full Marks: 40

Semester: Fall 2023
Course Code: CSE251
Section: **15**
Course Name: Electronic Devices and Circuits

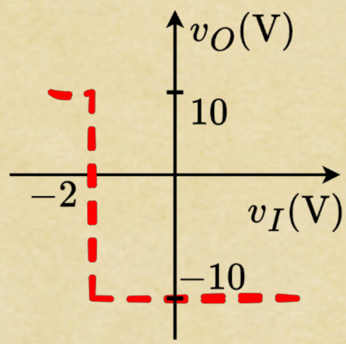
Name: ______________________________

Student ID: ______________________________

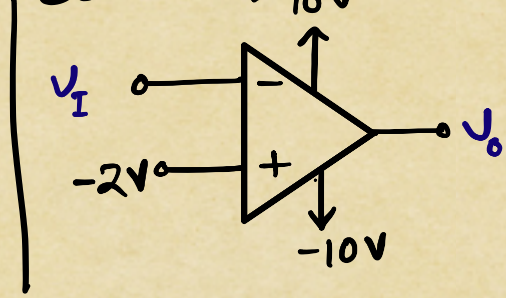
- ✓ Write down your student ID on the **top right corner of each of the pages**.
- ✓ Clearly write the solutions, along with the questions, on white paper with black ink (no need to use color pen, don't use pencils).
- ✓ Use **CamScanner**, or **Adobe Scan**, or **Microsoft Office Lens**, or any other 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: **"A1_StudentID_FullNameWithoutSpace.pdf"**. For example, if my student ID is 12345678 and my name is Shadman Shahid, the filename should be **"A1_12345678_ShadmanShahid.pdf"**.
- ✓ **Submission Link: https://forms.gle/j81vXAmKcUwarxZy8**

[CO3] Question 1: 14 Marks

a) Design a circuit using **op-amp** that has the voltage transfer characteristics as shown in the figure below. **4**
$v_O(\mathrm{V})$ is the output voltage and $v_I(\mathrm{V})$ is the input voltage.



Solution:



b) A valve is used to release (when valve is OPEN,) or maintain (when valve is CLOSED,) water pressure **10**
in a water tank. The valve operates on **ACTIVE LOW** logic. (i.e., the valve is OPENED when given a LOW voltage of **1 V**, but remains CLOSED when provided a HIGH voltage of **6 V**.)

A pressure sensor is installed in the water tank that outputs a voltage linearly proportional to pressure, as shown in the table below.

At **0.5 atm** pressure	At **1 atm** pressure	At **1.5 atm** pressure
$v_{0.5\,atm} = 0.5\ \mathrm{V}$	$v_{1\,atm} = 3\ \mathrm{V}$	$v_{low,\ \ 1.5\,atm} = 5.5\ \mathrm{V}$

The pressure in the water tank can be measured by the formula $P = h\rho g$, where $\boldsymbol{P}$, (in **Pascals (Pa)** unit) is the water pressure, $\boldsymbol{h}$ is the height of water in the tank (in $\mathbf{metres}$), $\boldsymbol{\rho}(= 1000\ \mathrm{kgm^{-3}})$ is the density of water and $\boldsymbol{g}$ is the acceleration due to gravity (in $\mathbf{ms^{-2}}$).

[1 atm = 101325 Pa]

i. **Design** a circuit using Op-Amp comparator to automatically turn OPEN the valve if water level exceeds **10 m**.
ii. **Draw** the voltage transfer characteristics (VTC) of the designed Op-Amp.

Answer 1(b)

When $h = 10\,m$; $P = h\rho g = 98000\,Pa = 0.967\,atm.$

From the table: find the exact voltage at this pressure.

$$\frac{V_{0.96atm} - V_{0.5atm}}{0.967 - 0.5} = \frac{V_{1atm} - V_{0.5atm}}{1 - 0.5}$$

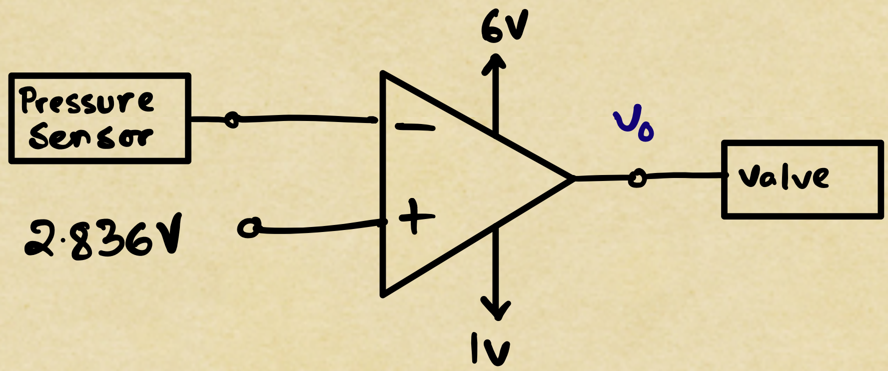
$$\Rightarrow V_{0.96atm} - V_{0.5atm} = \frac{3-0.5}{0.5} \times (0.967 - 0.5)$$

$$V_{0.96atm} = 0.5\,V + 5 \times (0.967 - 0.5)$$

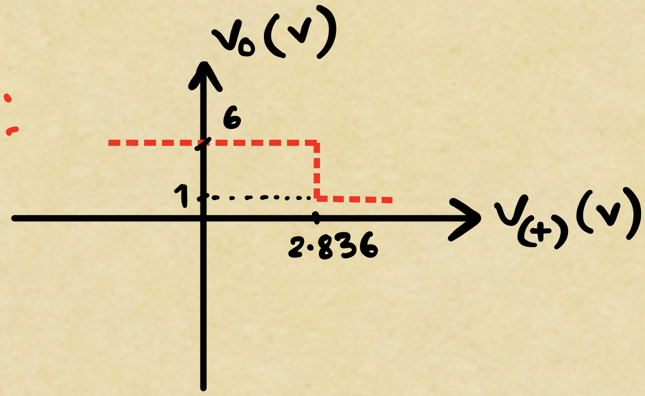
$$V_{0.96atm} = 2.836\,V$$

$\therefore$ Active low logic : High Pressure $\rightarrow$ 1V $\rightarrow$ OPEN
Low Pressure $\rightarrow$ 6V $\rightarrow$ CLOSED

So, the comparator is in inverting configuration

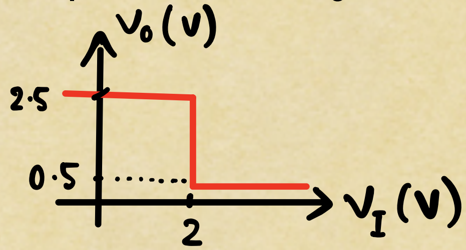


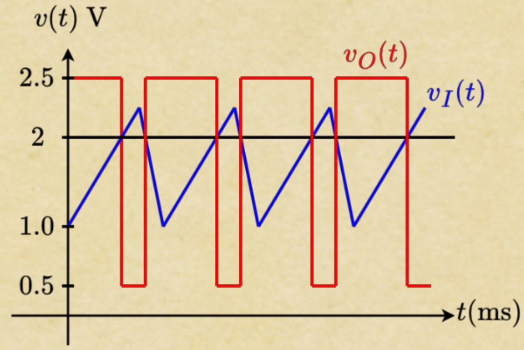
VTC :



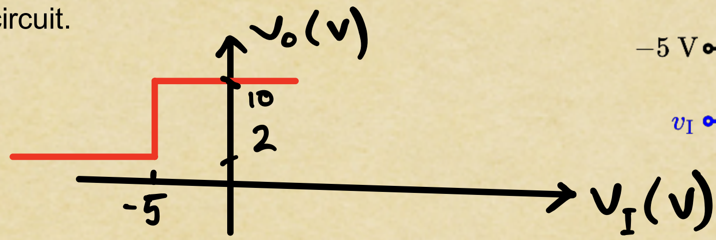
Question 2: 10 Marks

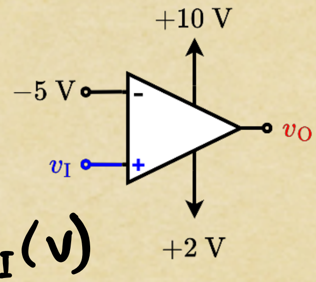
a) Draw the voltage transfer characteristic (VTC) curve (v_O vs v_I) from the adjacent waveform graph. Also draw the **Op-Amp Circuit** that would give rise to such a VTC. [CO3] 3





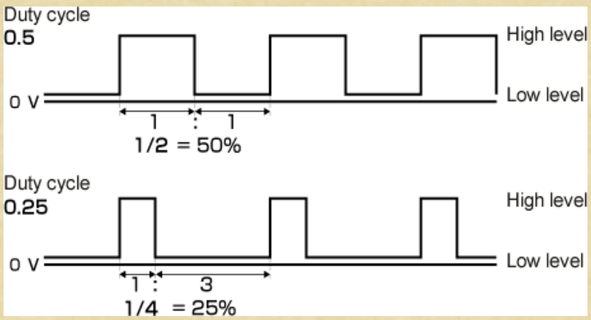
b) Draw the voltage transfer characteristic (VTC) curve (v_O vs v_I) from the adjacent Op-Amp circuit. [CO2] 2





c) **Design** an op-amp circuit to transform the sinusoidal voltage, $v_I = 5 \cdot \sin\left(\frac{2\pi}{5} \cdot t\right)$ (− t is in units of ms, and time-period T is 5 ms), to: [CO3] 5
[You must evaluate V_{REF}]

i. A square wave with a duty cycle of **50%**.
ii. A square wave with a duty cycle of **25%**.

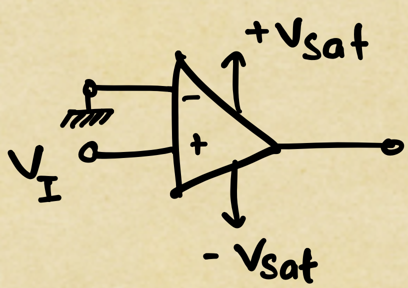


[**Duty Cycle:** Time of positive half cycle ÷ Time period]

For more information on duty cycle, click here!

[**Hint:** If $y = A \cdot \sin(\theta)$ is a sinusoidal function with period of $\mathbf{2\pi}$ then $\theta = \sin^{-1}(\frac{y}{A})$ and $\pi - \sin^{-1}(\frac{y}{A})$. So, for 25% duty cycle find the value of $\boldsymbol{y}$ for which $\Delta\theta = \left(\pi - \sin^{-1}(\frac{y}{A})\right) - \sin^{-1}\left(\frac{y}{A}\right) = \frac{\text{Time period}}{4} = \frac{\pi}{2}$]

(i)



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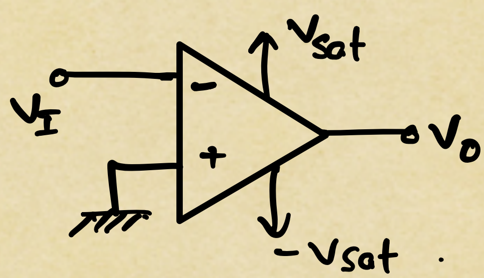
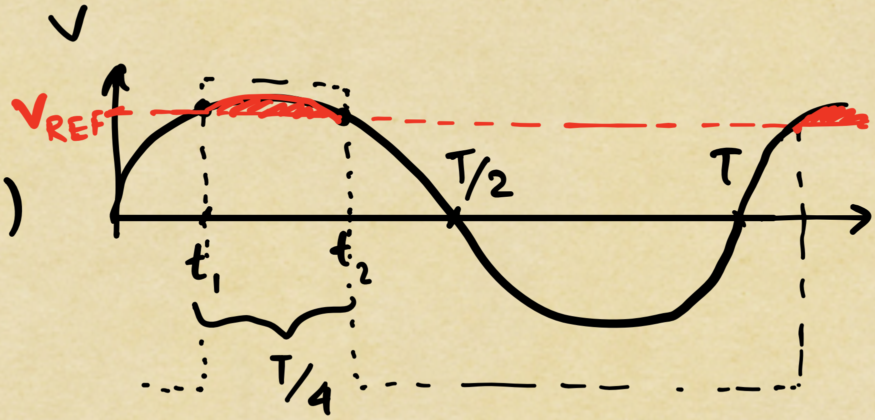


(ii)



$$t_1 = \frac{5}{2\pi} \sin^{-1}\left(\frac{V_{REF}}{5}\right)$$

$$t_2 = \frac{T}{2} - t_1 = \frac{5}{2} - \frac{5}{2\pi} \sin^{-1}\left(\frac{V_{REF}}{5}\right)$$

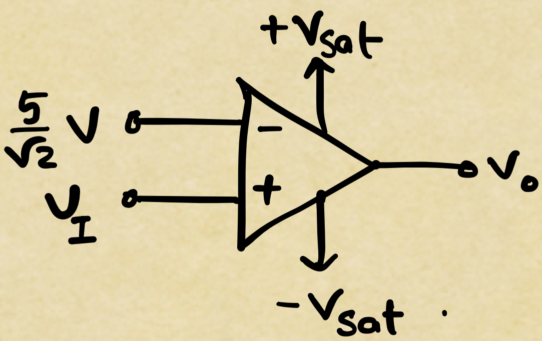
$$\therefore \quad t_2 - t_1 = \frac{T}{4} = \frac{5}{2} - 2 \cdot \frac{5}{2\pi} \sin^{-1}\left(\frac{V_{REF}}{5}\right)$$

$$\Rightarrow \frac{5}{4} = \frac{5}{2} - \frac{5 \times 2}{2\pi} \sin^{-1}\left(\frac{V_{REF}}{5}\right)$$

$$\Rightarrow V_{REF} = 5 \sin\left(\frac{2\pi}{5} \cdot \frac{5}{8}\right)$$

$$V_{REF} = \frac{5}{\sqrt{2}} V$$

$\therefore$



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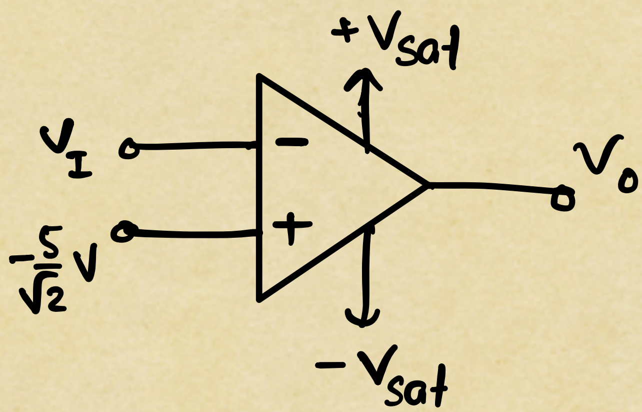
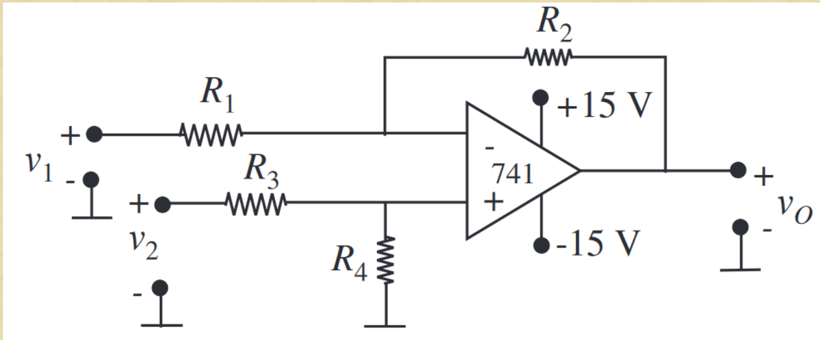


[CO2] Question 3: → Follow class lecture PDF. 10 Marks



Answer the following questions dealing with the above circuit.

a) Using the ideal Op Amp model, derive an expression for the output voltage $\boldsymbol{v_O}$ in terms of v_1, v_2, R_1, R_2, R_3, and R_4 — 4

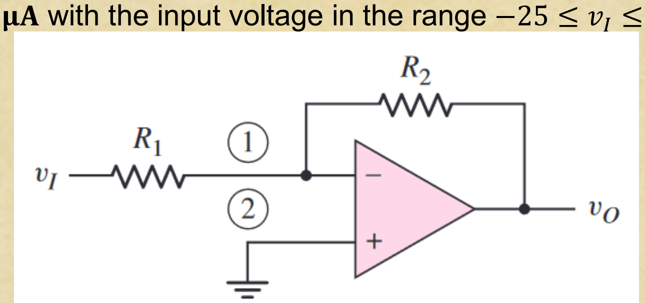
b) Does connecting a load resistor R_L between the output and ground change the previous expression for $\boldsymbol{v_O}$? Why? — 2

c) Let $\boldsymbol{v_1} = \boldsymbol{v_2}$ and $\boldsymbol{R_1} = \mathbf{1\ k\Omega}$, $\boldsymbol{R_2} = \mathbf{30\ k\Omega}$, and $\boldsymbol{R_3} = \mathbf{1.5\ k\Omega}$. Find $\boldsymbol{R_4}$ so that $\boldsymbol{v_O} = \mathbf{0}$. — 2

d) Let $\boldsymbol{v_2} = \mathbf{0}$ and $\boldsymbol{v_1} = \mathbf{1\ V}$. Using the preceding resistor values (including that computed for $\boldsymbol{R_4}$), find $\boldsymbol{v_O}$. — 2

[CO3] Question 4: 6 Marks

Design the circuit below such that the closed loop voltage gain is $\boldsymbol{A_{CL}} = \mathbf{-25}$. The maximum current in any resistor is to be limited to $\mathbf{10\ \mu A}$ with the input voltage in the range $-25 \le v_I \le 25\ \mathbf{mV}$.



a) What are the values of $\boldsymbol{R_1}$ and $\boldsymbol{R_2}$? → $R_1 = \frac{25}{10} = 2.5\ k\Omega$ — 4

$R_2 = 62.5\ k\Omega$

b) What is the range of output voltage $\boldsymbol{v_O}$? — 2

$-0.625\ V \le V_o \le 0.625\ V$

3(c)

$$\frac{R_2}{R_1} = 30 \;; \quad \frac{R_4}{R_3+R_4} = \left(1+\frac{1.5}{R_4}\right)^{-1}$$

$$v_0 = -\frac{R_2}{R_1} v_1 + \left(1+\frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right) v_2$$

$$\therefore \quad 30\cancel{v_1} = \frac{31}{\left(1+\frac{1.5}{R_4}\right)} \cancel{v_1}$$

[As $v_1 = v_2$ when $v_0 = 0$]

$$\therefore \quad 1+\frac{1.5}{R_4} = \frac{31}{30}$$

$$\boxed{\Rightarrow R_4 = 45\,k\Omega}$$

3(d) $V_0 = -15\,V$.