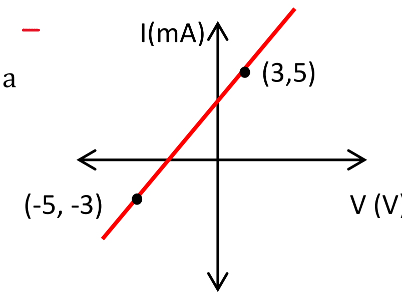
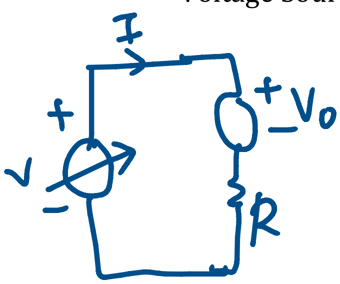
Q1. Design the device from the given I-V characteristics assuming you have two 1V sources and three 3 kΩ resistors.



Sol: As the graph doesn't go through origin, we can assume the device is a Voltage Source in series with a Resistor.



$$V = IR + V_0$$

$$I = \frac{V}{R} - \frac{V_o}{R} ------(1)$$

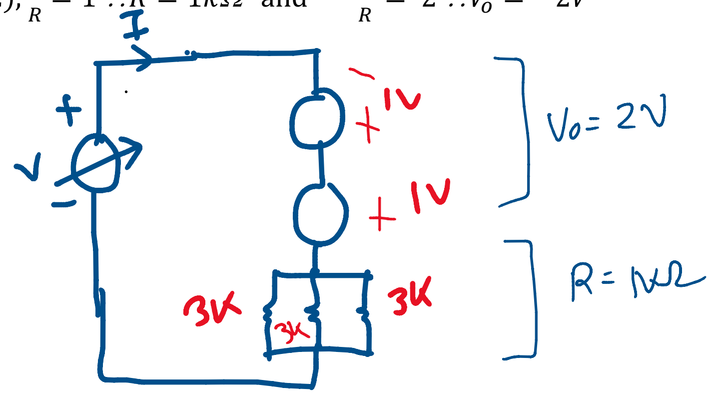
The straight-line equation of the given I-V curve-

$$\frac{I-5}{V-3} = \frac{5-(-3)}{3-(-5)} = 1$$

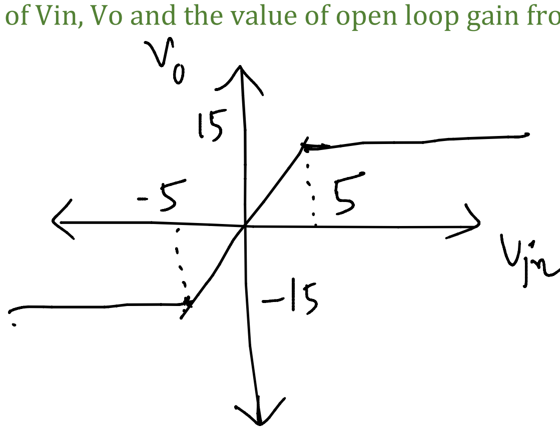
$$or, I = V + 2 ------(2)$$

From equation (1) and (2), $\frac{1}{R} = 1 \therefore R = 1k\Omega$ and $-\frac{V_o}{R} = 2 \therefore V_o = -2V$

So, the device is:



Q2. Find out the valid range of Vin, Vo and the value of open loop gain from the following VTC-



Soln:

The valid region of an amplifier is the linear region not the saturation regions. So, valid input range is:

$$-5 \leq V_{in} \leq 5$$

Valid output range is:

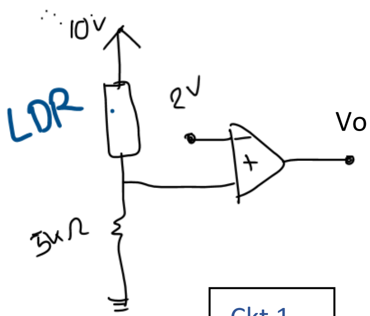
$$-15 \leq V_o \leq 15$$

gain =A= slope of linear region

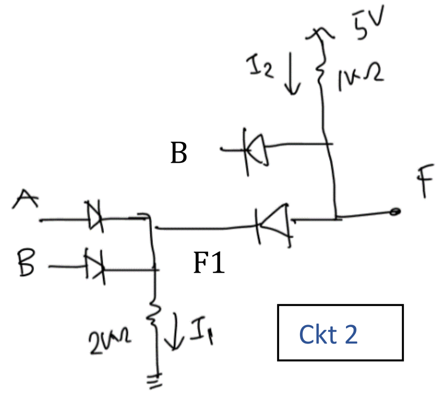
Slope= $\frac{15-(-15)}{5-(-5)} = \frac{30}{10}$

$\therefore$ A= 3

Q3. **For ckt 1, Assume, light is on→ LDR resistance= 1kΩ→ Op-amp output, Vo= A**
light is off→ LDR resistance= 50 kΩ→ Op-amp output, Vo= B
V_{S+}= 10V, V_{S-}= -5V, Find the value of F, I_1 and I_2

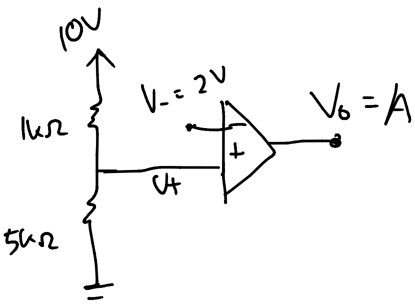


Ckt 1



Ckt 2

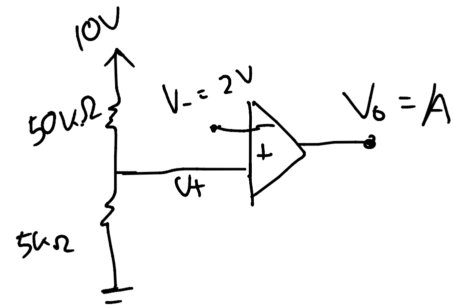
Sol:



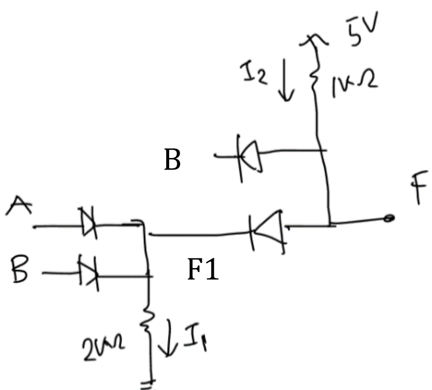
Light On

When light is on, $V_+ = \frac{5k\Omega}{5k\Omega+1k\Omega} * 10V = 8.33V$
V_-= 2V, So $V_+ > V_-$ ∴Vo= **A= V_{S+}= 10V**

When light is off, $V_+ = \frac{5k\Omega}{5k\Omega+50k\Omega} * 10V = 0.909V$
V_-= 2V, So $V_+ < V_-$ ∴Vo= **B= V_{S-}= -5V**



Light Off

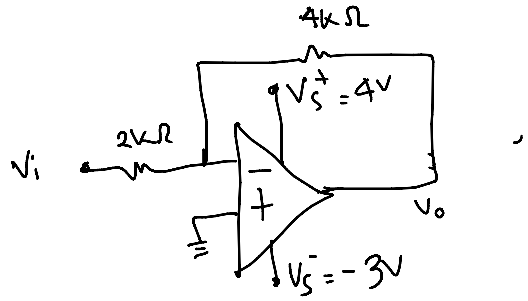


Now,
F1= A **or** B
= max (A, B)
= max (10V, -5V) = 10V
F= B **and** F1
= min (B, F1)
= min (-5V, 10V)
∴F = -5V

Current, $\boldsymbol{I_1} = \frac{F1}{2k\Omega} = \frac{10V}{2k\Omega} = 5\ mA$

Current, $\boldsymbol{I_2} = \frac{5V-F}{1k\Omega} = \frac{5V-(-5V)}{1k\Omega} = 10\ mA$

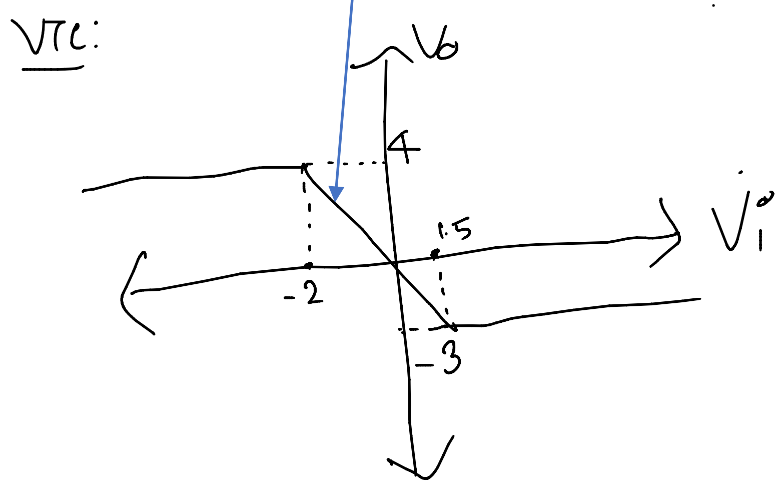
Q4. Draw VTC of the following circuit.



Sol: This is an inverting op-amp.

$$Vo = -\frac{R2}{R1}Vi$$

So. gain = $-\frac{R2}{R1} = -\frac{4k\Omega}{2k\Omega} = -2$= slope of linear region in VTC



Valid output range:

$$V_{S-} \le V_o \le V_{S+}\ or, -3 \le V_o \le 4$$

Now,

$$Vo = gain * Vi = -2 * Vi$$

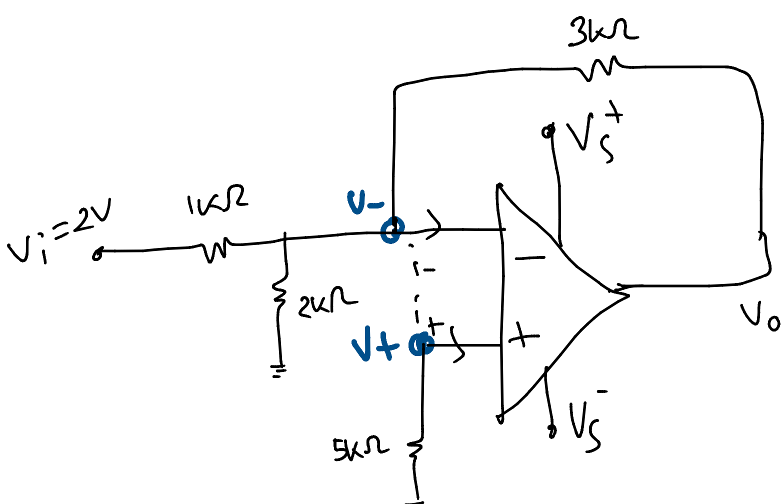
when, Vo= 4V, $Vi = \frac{Vo}{-2} = \frac{4V}{-2} = -2V$

when, Vo= -3V, $Vi = \frac{Vo}{-2} = \frac{-3V}{-2} = 1.5V$

Q5. Implement $f = (A + \overline{B})C + \overline{D}$ with diode logic gates.

Sol: There are **not gates** $(\overline{B}, \overline{D})$ in this expression. But inverter (not gate) cannot be implemented by diodes. So, the given function cannot be implemented by diode logic gates.

Q6. Find Vo from the given op-amp circuit.



Sol:

In ideal op-amp $i_+ = i_- = 0$ mA

As $i_+ = 0$ mA, so $V_+ = 0$V [no voltage drops across 5 kΩ due to 0 current]

So, $V_- = V_+ = 0$V [virtual short circuit]

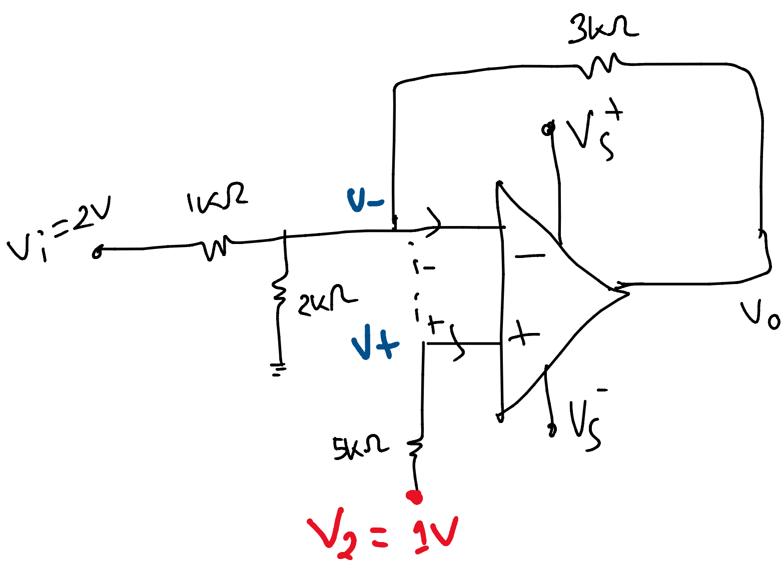
2kΩ is shorted (both node voltage= 0V)

So, this is basically an inverting op-amp

$$Vo = -\frac{R2}{R1}Vi = -\frac{3\ k\Omega}{1\ k\Omega} * 2V = -6V$$

2 kΩ and 5 kΩ are just dummy resistors here. They have no effect on the output of the circuit.

Q7. Find Vo from the given op-amp circuit.



Sol:

In this case, 5 kΩ is not connected to ground anymore.

In ideal op-amp $i_+ = i_- = 0$ mA

As $i_+ = 0$ mA, so $V_+ = V2 = 1V$ **[no voltage drops across 5 kΩ due to 0 current]**

So, $V_- = V_+ = 1V$ [virtual short circuit]

Here, 2kΩ is not shorted like Q6

Nodal equation (node V_-):

$$\frac{V_-}{2\,k\Omega} + \frac{V_- - Vi}{1\,k\Omega} + \frac{V_- - Vo}{3\,k\Omega} = 0$$

$$=> \frac{1V}{2\,k\Omega} + \frac{1V - 2V}{1\,k\Omega} + \frac{1V - Vo}{3\,k\Omega} = 0$$

$$\therefore \boldsymbol{Vo = -\frac{1}{2}V = -0.5V}$$

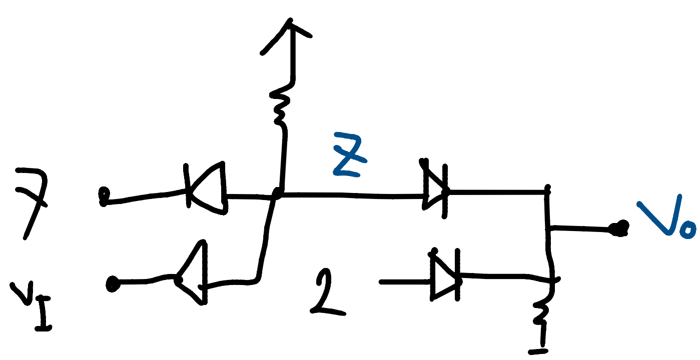
Q8: Design separate circuits, using only diodes, to implement the following functions,

a) $\mathbf{z = min\ (v_I, 7)}$ and $\mathbf{v_O = max(z, 2)}$

b) Draw the VTC curve. [Hint: v_O vs v_I]

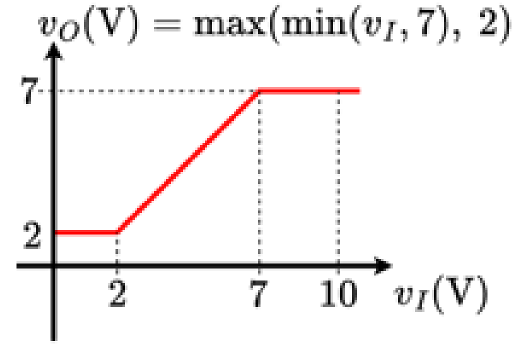
Sol: a) z= $7v_I$ [as minimum operation means AND gate]

$v_O = 2+z$ [as maximum operation means OR gate]

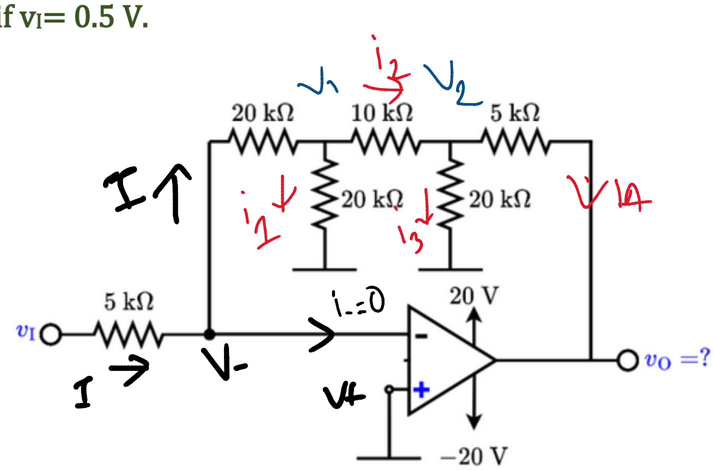


b) $v_0 = 2+z = 2 + 7v_I$

If $v_I \leq 2V$, $v_0 = 2 + 7v_I = \max(2V, \min(7, v_I))$
$= \max(2V, v_I) = 2V$ (constant)
If $2V < v_I < 7V$, $v_0 = \max(2V, \min(7, v_I)) = \max(2V, v_I) = v_I$ (straight line)
If $v_I \geq 7V$, $v_0 = \max(2V, \min(7, v_I)) = \max(2V, 7V) = 7V$ (constant)



Q9. Find v_O if $v_I = 0.5$ V.



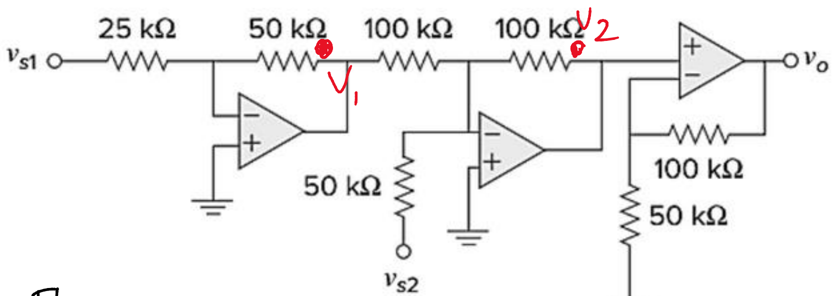
$V_+ = 0V$, So, $V_- = V_+ = 0V$ [virtual short circuit]
Current, $\boldsymbol{I} = \frac{v_I - V_-}{5\,k\Omega} = \frac{0.5\,V}{5\,k\Omega} = 0.1\,mA$
Current, $\boldsymbol{I} = \frac{(V_-) - V1}{20\,k\Omega} = \frac{-V1}{20\,k\Omega} = 0.1\,mA \Rightarrow V1 = -2\,V$
$\boldsymbol{i1} = \frac{V1}{20\,k\Omega} = \frac{-2\,V}{20\,k\Omega} = -0.1\,mA$

$\boldsymbol{i2} = I - i1 = 0.2\,mA = \frac{V1 - V2}{10\,k\Omega} = \frac{-2\,V - V2}{20\,k\Omega} \Rightarrow V2 = -4\,V$

$\boldsymbol{i3} = \frac{V2}{20\,k\Omega} = \frac{-4\,V}{20\,k\Omega} = -0.2\,mA$

$\boldsymbol{i4} = i2 - i3 = 0.4\,mA = \frac{V2 - vo}{5\,k\Omega} = \frac{-4\,V - vo}{5\,k\Omega} \Rightarrow \boldsymbol{vo = -6\,V}$

Q10. Determine v0, when vs1 = 1V and vs2 = 2V are given as inputs.



$$V_1 = -\frac{50}{25} \times V_{S1} = -2V \quad \text{(inverting opamp)}$$

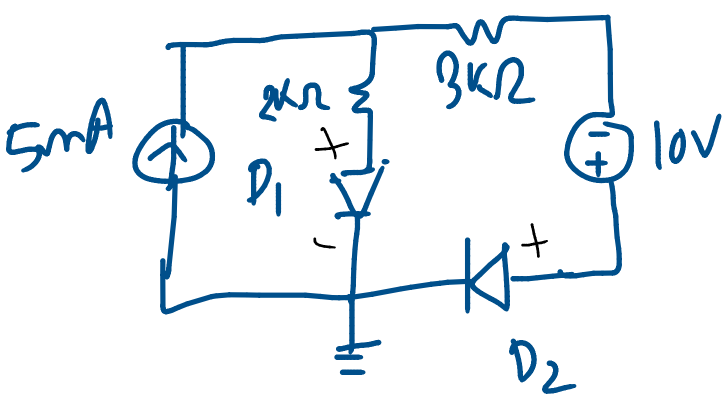
$$V_2 = -\left(\frac{100}{100} V_1 + \frac{100}{50} V_{S2}\right) \quad \text{(inverting adder)}$$

$$= -(-2V + 4V) = -2V$$

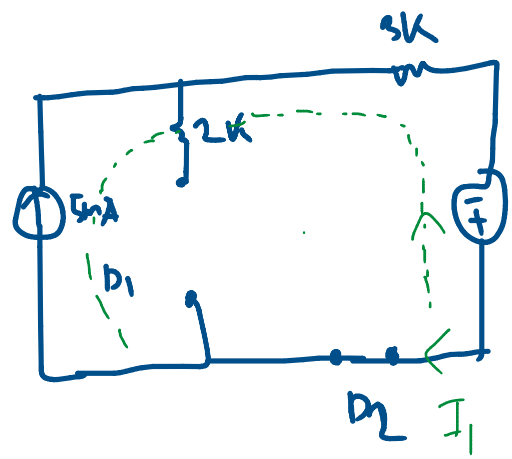
$$V_0 = \left(1 + \frac{100}{50}\right) V_2 \quad \text{(non-inverting opamp)}$$

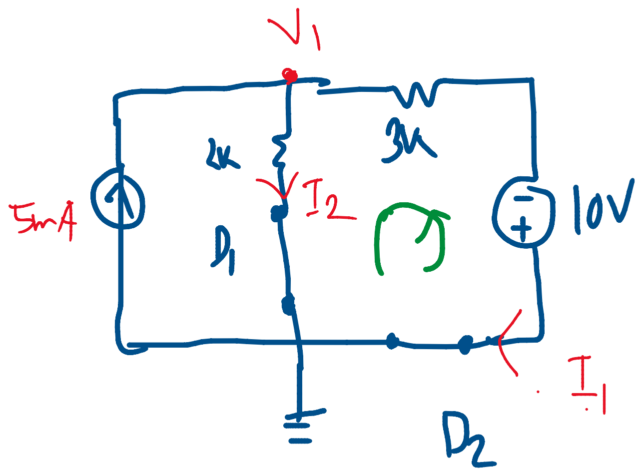
$$\boxed{V_0 = -6V}$$

Q11. Find diode states for the circuit shown below. Assume ideal diodes.



Assuming D1 off (open ckt), D2 on (short ckt)
I1= 5 mA (>0) assumption ok for D2
KVL: 10 V- 3k * 5 mA + V1=0
⇨ V1= 15 V - 10 V= 5 V
Va= V1= 15 V (as open ckt) & Vc= 0 V
Voltage difference across D1, V_D= Va- Vc= 15 V (>0 V) assumption wrong for D2
So, **assumption wrong!**



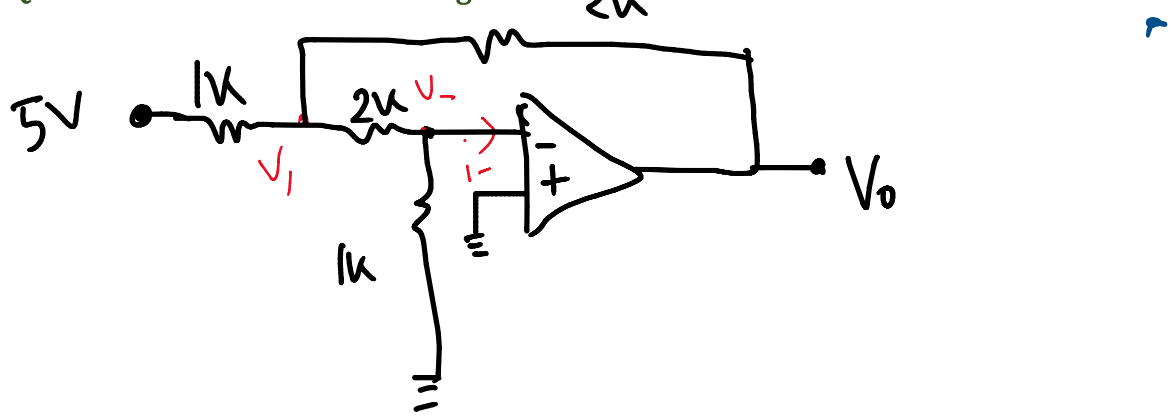


Now, Assuming D1, D2 both on (short ckt)

KVL: 10 V- 3k * I1 + 2k * I2=0 ---(1)
KCL: I1 + I2 = 5 mA--- (2)

Solving (1) & (2), I1= 4 mA and I2= 1 mA
As both diode current is positive that means both D1 & D2 are ON.
Assumption Correct!

Q12. Find out Vo for the following circuit.



Soln: $V_+ = 0 = V_-$ [virtual short]

nodal analysis: $\frac{(V_-) - V_1}{2k} + \frac{V_-}{1k} = 0$

$\Rightarrow \frac{0 - V_1}{2k} + \frac{0}{1k} = 0$ $\boxed{\therefore V_1 = 0V}$

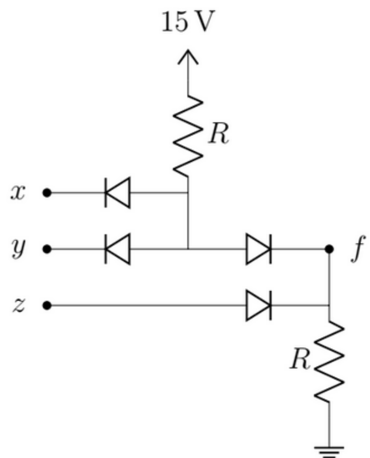
nodal analysis: $\frac{V_1 - 0V}{2k} + \frac{V_1 - 5V}{1k} + \frac{V_1 - V_o}{2k} = 0$

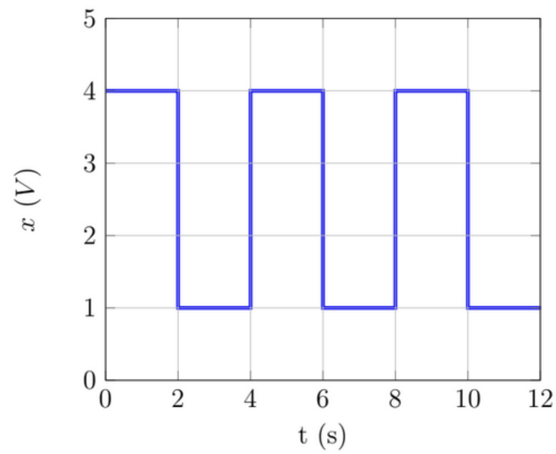
$\Rightarrow \frac{0-0}{2k} + \frac{0-5V}{1k} + \frac{0-V_o}{2k} = 0$

$\Rightarrow \boxed{V_o = -\frac{2k}{1k} \times 5V = -10V}$

same as inverting op-amp

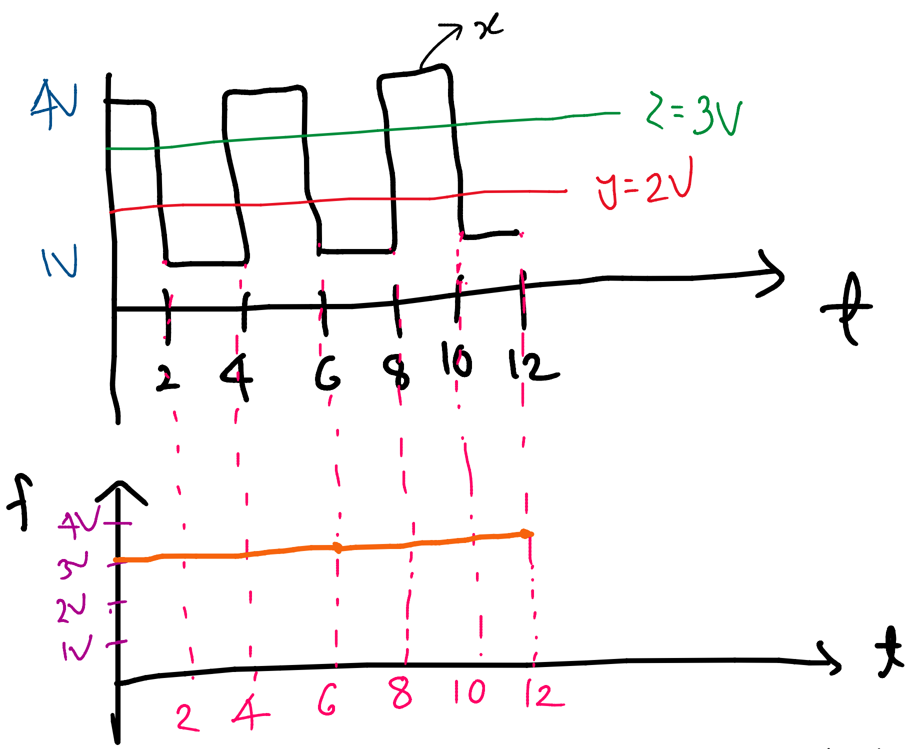
Q13: Draw the waveform (voltage vs time graph) of f, where y = 2 V, z = 3 V, and x has a waveform as shown in the figure on the right.





Soln:

$f = x \cdot y + z = \max(\min(x, y), z)$



$0 \le t \le 2s$:

$f = \max(\min(4V, 2V), 3V)$

$= \max(2V, 3V)$

$= 3V$

$2s \le t \le 4s$;

$f = \max(\min(1V, 2V), 3V)$

$= \max(1V, 3V) = 3V$

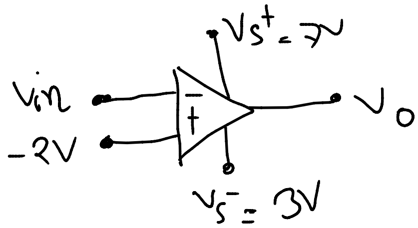
$4s \le t \le 6s$:

$f = \max(\min(4V, 2V), 3V)$

$= \max(2V, 3V)$

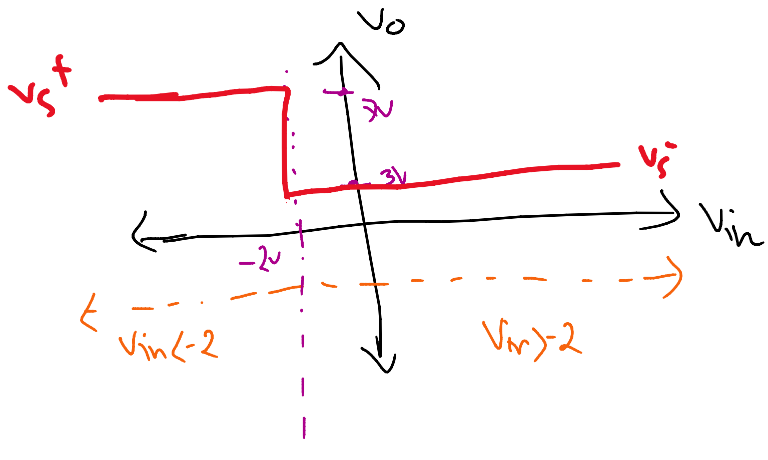
$= 3V$

Q14: Draw the VTC of the following circuit-



→ Open loop op amp

Soln:

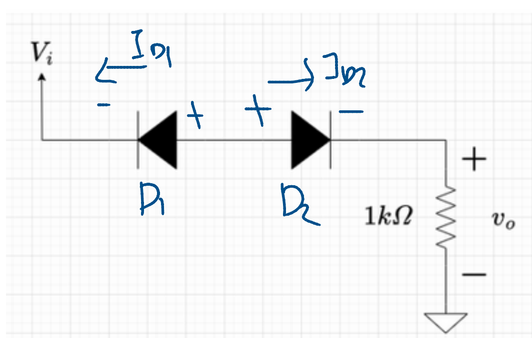


$V_d = (V_+) - (V_-)$
$= -2 - V_{in}$

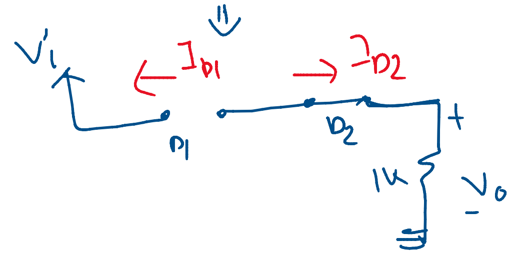
$V_d > 0 \rightarrow V_o = V_s^+$
$\Rightarrow -2 - V_{in} > 0$
$\Rightarrow \boxed{V_{in} < -2} \rightarrow V_o = V_s^+ = 7V$

So, $V_{in} > -2 \rightarrow V_o = V_s^- = 3V$

Q15: Find Vo and the states of the diodes if Vi= 10 V [consider ideal diodes].



If we assume, D_1 off, D_2 on
open short



but in that case, $I_{D2} = 0$ [open ckt]
∴ wrong assumption!
∴ Both diodes are off.

$\boxed{V_o = 0V}$

If two diodes are connected back-to-back (both cathodes are short (a) or both anodes are short (b)), then both of the diodes must be off.