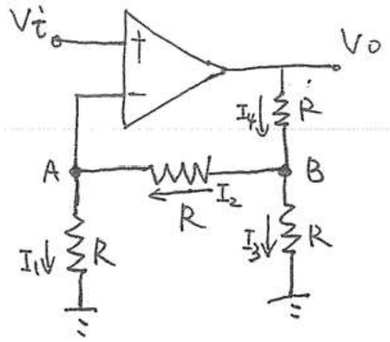
Tutorial 9 Operational Amplifier Abstraction

Question 1: We have the following Op-amp circuit. Determine the circuit gain Av=Vo/Vi.



∵ this is a negative feedback Op-Amp Circuit.

∴ $I_+ = I_- = 0 \quad V_+ = V_-$

Note $V_+ = v_i$, so $v_- = v_i \Rightarrow v_A = v_i$

At node A:

∵ $I_- = 0$ ∴ $I_1 = I_2 \Rightarrow \frac{v_A - 0}{R} = \frac{v_B - v_A}{R}$

$$\Rightarrow v_B = 2v_A = 2v_i$$

At node B:

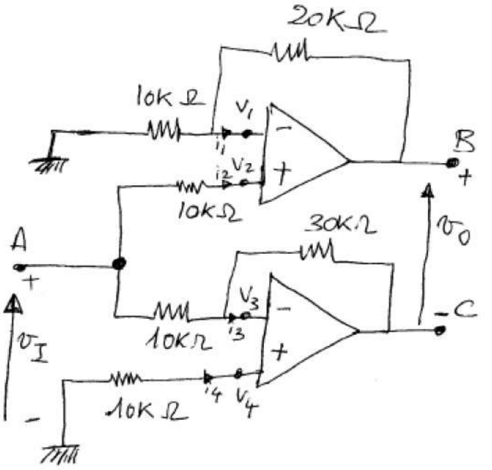
∵ $I_4 = I_2 + I_3$ ∴ $\frac{v_o - v_B}{R} = \frac{v_B - v_A}{R} + \frac{v_B - 0}{R}$

$$v_o - 2v_i = 2v_i - v_i + 2v_i$$

$$v_o = 5v_i$$

$$\Rightarrow A_v = \frac{v_o}{v_i} = \frac{5v_i}{v_i} = 5$$

Question 2:



a) Negative feedback in both cases $\Rightarrow$ Golden Rules

$$\boxed{\begin{array}{l} V_1 = V_2 \quad \rightarrow (1) \\ V_3 = V_4 \quad \rightarrow (2) \end{array}}$$

General Rules $\rightarrow$
No current Flowing into the op. amps.

$$\boxed{i_1 = i_2 = i_3 = i_4 = 0} \rightarrow (3).$$

Using (3) you can derive that:

$\rightarrow V_2 = V_A \quad (4)$

$\rightarrow V_1 = \dfrac{V_B}{3} \quad (5)$

$\rightarrow V_4 = 0 \quad (6)$

combine (1) (4) & (5) $\Rightarrow \boxed{V_B = 3V_A}$ (7)

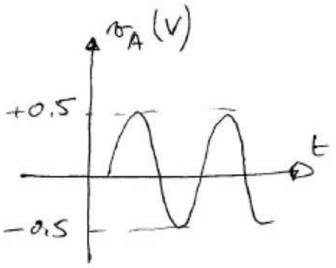
combine (6) & (2) $\Rightarrow \dfrac{V_A - V_3}{10K} = \dfrac{V_3 - V_C}{30K}$

$$\Rightarrow \frac{V_A - 0}{10K} = \frac{0 - V_C}{30K}$$

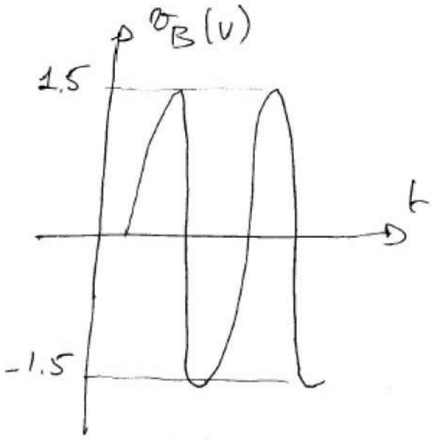
$$\Rightarrow \boxed{V_C = -3V_A} \quad (8)$$

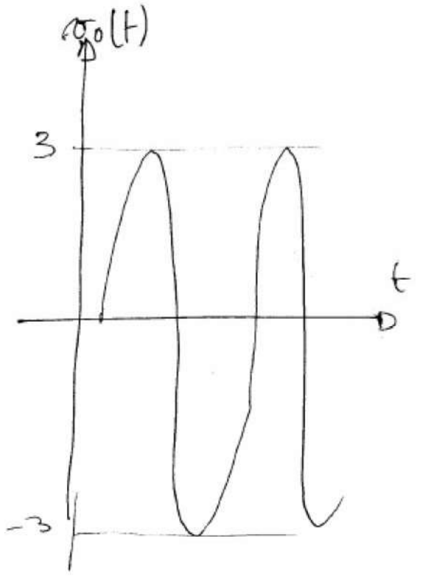
$$v_0 = v_B - v_C = 3V_A - (-3V_A) = 6\,V_A$$

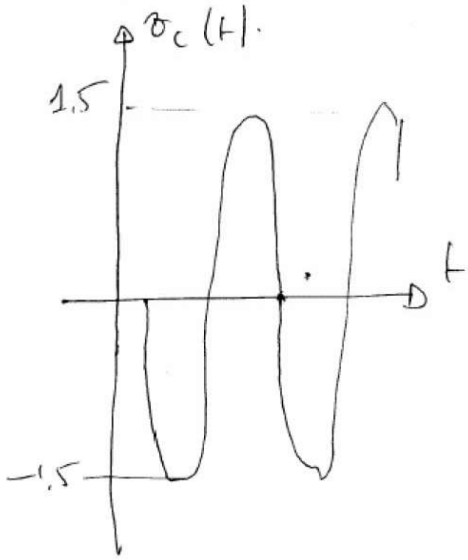
$$\boxed{v_0 = 6 v_A} \quad (9)$$



1V peak-to-peak
sine wave







b) $\dfrac{v_O}{v_I} = \dfrac{v_O}{v_A} = 6$ From Equation (9).

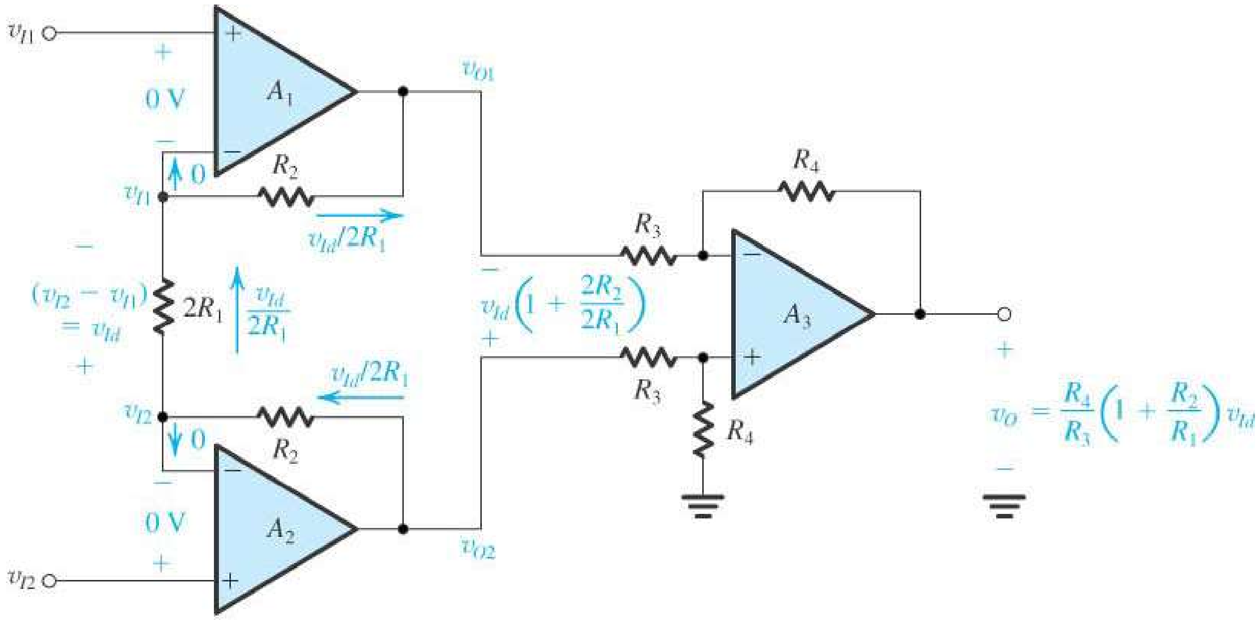
c) $-14 \leq v_B \leq +14$ to avoid saturation

since $v_O = v_B - v_C = v_B - (-v_B) = 2v_B$

$\Rightarrow$ maximum wave output $\Rightarrow$

$-28 \leq v_O = 2v_B \leq +28 \Rightarrow$ 56V peak-to-peak value.

Question 3:



v_{I1}
+
0 V
−
A_1
R_2
0
v_{I1}
$v_{Id}/2R_1$
v_{O1}
−
$(v_{I2} - v_{I1})$
$= v_{Id}$
+
$2R_1$
$\frac{v_{Id}}{2R_1}$
$v_{Id}/2R_1$
v_{I2}
0
R_2
−
0 V
+
A_2
v_{I2}
v_{O2}
R_4
R_3
−
$v_{Id}\left(1 + \frac{2R_2}{2R_1}\right)$
+
R_3
A_3
R_4
+
$v_O = \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right)v_{Id}$
−

(c)

Question 4:

Note that you have here both negative and positive feedback.

we will here again use superposition.

Calculate v_{o1}?

$$\boxed{v_+ = \beta \frac{v_{o1}}{2}} \quad (10)$$

$$\frac{v_1 - v_-}{R} = \frac{v_- - v_{o1}}{R}$$

$$\boxed{v_- = \frac{v_1 + v_{o1}}{2}} \quad (11)$$

General Rule:

$$v_{o1} = A\left(v_+ - v_-\right)$$

$$v_{o1} = A\left(\frac{\beta v_{o1}}{2} - \frac{v_1 + v_{o1}}{2}\right)$$

$$v_{o1} = \frac{1}{\beta - 1 - \frac{2}{A}} v_1$$

since $A > 10^6 \Rightarrow \frac{2}{A} \to 0$

$$v_{o1} \simeq \frac{1}{\beta - 1} v_1$$

Calculate v_{o2}?

$$\boxed{v_- = \frac{v_{o2}}{2}} \quad (12)$$

$$\frac{v_2 - v_+}{R} = \frac{v_+ - \beta v_{o2}}{R}$$

$$\boxed{v_+ = \frac{v_2 + \beta v_{o2}}{2}} \quad (13)$$

General Rule:

$$v_{o2} = A\left(v_+ - v_-\right)$$

$$v_{o2} = A\left(\frac{v_2 + \beta v_{o2}}{2} - \frac{v_{o2}}{2}\right)$$

$$v_{o2} = -\frac{1}{\beta - 1 - \frac{2}{A}} v_2$$

since $A > 10^6 \Rightarrow \frac{2}{A} \to 0$

$$v_{o2} \simeq -\frac{1}{\beta - 1} v_2$$

$$\boxed{v_o = v_{o1} + v_{o2} = \frac{1}{1 - \beta}\left(v_2 - v_1\right)}$$