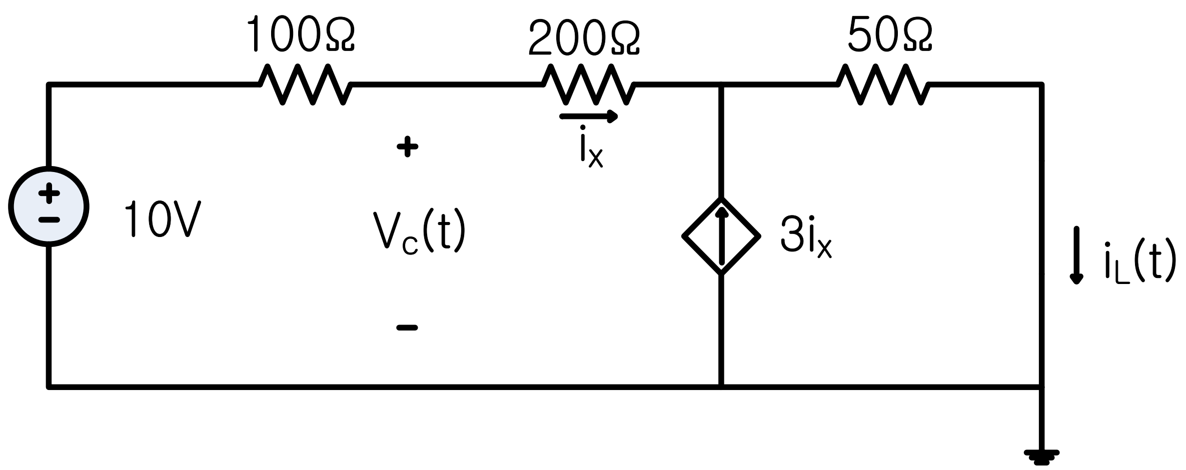
#1

(a)



KCL을 이용하면

$$10 = 100i_x(0^-) + 200i_x(0^-) + 50(i_x(0^-) + 3i_x(0^-))$$

$$\therefore i_x(0^-) = 0.02A$$

$$i_L(0^-) = i_x(0^-) + 3i_x(0^-) = 0.08A$$

$$V_c(0^-) = 10 - 100i_x(0^-) = 8V$$

(+2점)

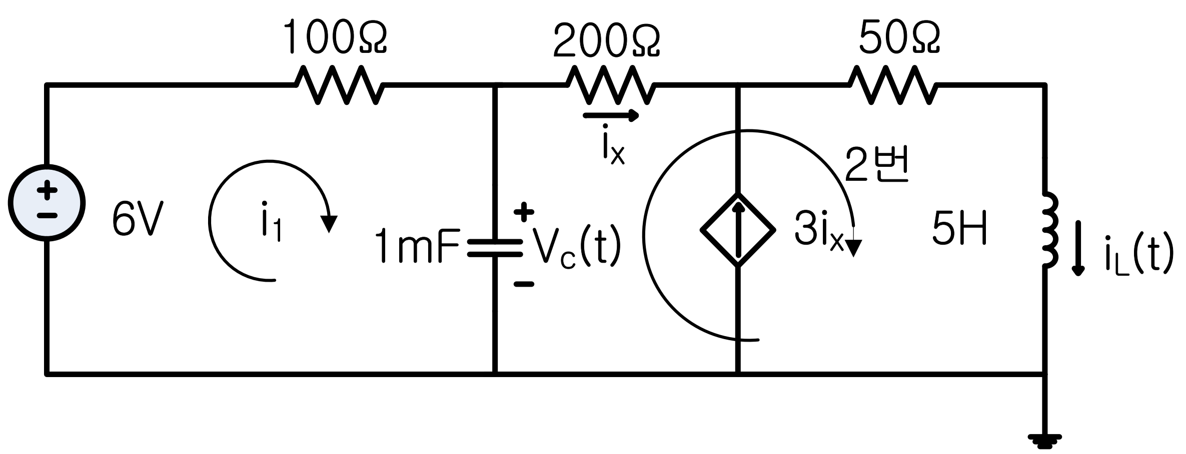
inductor에서는 전류가 연속이고 capacitor에서 전압이 연속이어야 하므로

$$i_L(0^+) = i_L(0^-) = 0.08A$$

$$V_c(0^+) = V_C(0^-) = 8\mathrm{V}$$

(각각 +1점)

(b)



$$i_1 = i_x + 0.001\frac{dV_c}{dt}$$

i_1으로 KCL적용

$$6 = 100\left(i_x + 0.001\frac{dV_c}{dt}\right) + V_c$$

$$i_x = \frac{1}{4}i_L$$

$$6 = 25i_L + 0.1\tfrac{dV_c}{dt} + V_c \qquad \text{(식 1)}$$

$$\therefore 6 = 100\left(\frac{1}{4}i_L(0^+) + 0.001\frac{dV_c(0^+)}{dt}\right) + V_c(0^+)$$

$$\frac{dV_c(0^+)}{dt} = -40V$$

(+2점)

Super mesh를 2번 loop로 적용

$$V_c = 200i_x + 50(i_x + 3i_x) + 5\frac{di_L}{dt}$$

$$V_c = 100i_L + 5\tfrac{di_L}{dt} \qquad \text{(식 2)}$$

$$\therefore \frac{di_L(0^+)}{dt} = 0\mathrm{A}$$

(+2점)

(식 2)를 이용하여 V_c를 (식 2)통해 대입하면

$$6 = 25i_L + 0.1\frac{d}{dt}(100i_L + 5\frac{di_L}{dt}) + 100i_L + 5\frac{di_L}{dt}$$

$$6 = 0.5\frac{d^2i_L}{dt^2} + 15\frac{di_L}{dt} + 125i_L$$

$$\therefore \frac{d^2i_L}{dt^2} + 30\frac{di_L}{dt} + 250i_L = 12$$

(+4점)

(c)b에서 구한 식을 통해 먼저 Natural Response를 구한다.

$$\frac{d^2 i_L}{dt^2} + 30\frac{di_L}{dt} + 250 i_L = 0$$

$$s^2 + 30s + 250 = 0$$

$$\therefore \mathrm{s} = -15 \pm 5\mathrm{i}$$

$$i_{L,n} = e^{-15t}(Asin5t + Bcos5t)$$

(+1점)

Forced response는 dc이므로 assumed solution도 dc가 된다.

$$i_{L,f} = C$$

$$i_L(t) = e^{-15t}(Asin5t + Bcos5t) + C$$

(+1점)

$$\frac{d^2 i_L}{dt^2} + 30\frac{di_L}{dt} + 250 i_L = \frac{d^2 i_{L,n}}{dt^2} + 30\frac{di_{L,n}}{dt} + 250 i_{L,n} + \frac{d^2 i_{L,f}}{dt^2} + 30\frac{di_{L,f}}{dt} + 250 i_{L,f} = 0 + 250C = 12$$

$$\mathrm{C} = 0.048$$

(+1점)

$$i_L(0^+) = 0.08 = B + C$$

$$\mathrm{B} = 0.032$$

(+1점)

$$\frac{di_L(0^+)}{dt} = 0 = 5\mathrm{A} - 0.48$$

$$\mathrm{A} = 0.096$$

$$i_L(t) = e^{-15t}(0.096sin5t + 0.032cos5t) + 0.048$$

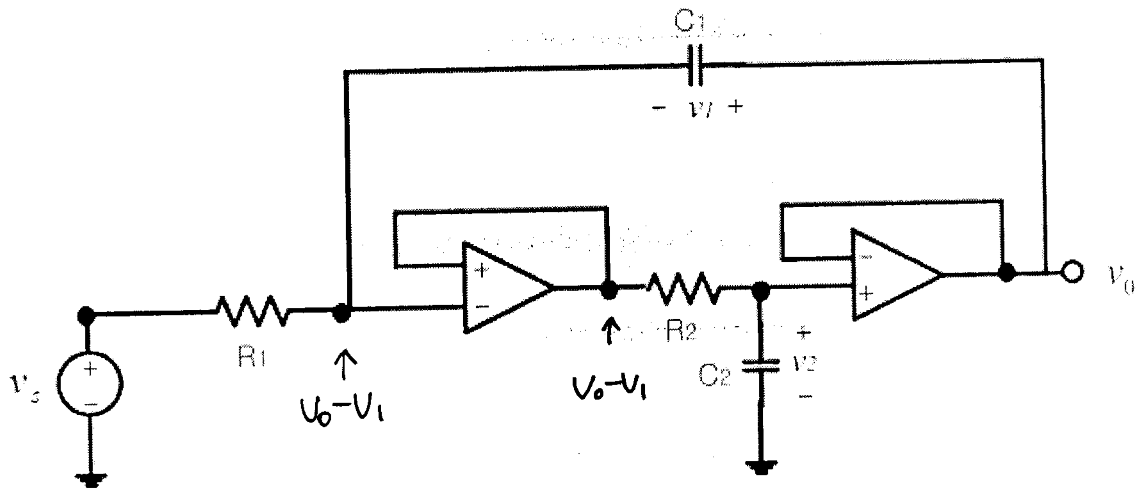
(+1점)

b에 (식 2)를 이용하여 $V_c(t)$를 구한다.

$$V_c(t) = 100 i_L(t) + 5\frac{di_L(t)}{dt} = e^{-15t}(1.6sin5t + 3.2cos5t) + 4.8$$

(+3점)

#2



(a) $v_o(t)$ 회로방정식, damping coefficient, resonant frequency 구하기

$$\frac{V_o - V_1 - V_s}{R_1} = C_1 \frac{dV_1}{dt} \quad \cdots ㉠ \quad \rightarrow 1점$$

$V_o = V_2$

$$C_2 \frac{dV_o}{dt} + \frac{V_o - (V_o - V_1)}{R_2} = 0 \quad \cdots ㉡ \quad \rightarrow 1점$$

㉠ 변형 $\quad C_1 s V_1 = \dfrac{V_o - V_1 - V_s}{R_1} \quad \cdots ㉢$

㉡ 변형 $\quad C_2 s V_o + \dfrac{V_1}{R_2} = 0 \quad \cdots ㉣ \quad V_1 = -R_2 C_2 s V_o \quad \cdots ㉤$

㉤을 ㉢에 대입

$$R_1 C_1 s(-R_2 C_2 s V_o) = V_o + R_2 C_2 s V_o - V_s$$

$$R_1 R_2 C_1 C_2 s^2 V_o + R_2 C_2 s V_o + V_o = V_s$$

$$s^2 V_o + \frac{s V_o}{R_1 C_1} + \frac{V_o}{R_1 R_2 C_1 C_2} = \frac{V_s}{R_1 R_2 C_1 C_2}$$

$$\frac{d^2 V_o}{dt^2} + \frac{1}{R_1 C_1} \frac{dV_o}{dt} + \frac{1}{R_1 R_2 C_1 C_2} V_o = \frac{1}{R_1 R_2 C_1 C_2} V_s \quad \rightarrow 2점$$

$$2\alpha = \frac{1}{R_1 C_1} \qquad \omega_0^2 = \frac{1}{R_1 R_2 C_1 C_2} \qquad \alpha = \frac{1}{2 R_1 C_1} \qquad \omega_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

→ 각각 1점

(b) $R_1 = 10k\Omega \quad R_2 = 20k\Omega \quad C_1 = 1\mu F$ 일때 회로가 overdamped 될 조건

$\alpha^2 > \omega_0^2$

$\alpha = \dfrac{1}{2R_1C_1}$ $\qquad \dfrac{1}{4R_1^2C_1^2} > \dfrac{1}{R_1R_2C_1C_2}$ → 2점

$C_2 > \dfrac{4R_1C_1}{R_2}$ $\qquad C_2 > 2\mu F$ → 2점

(c) $R_1 = 1k\Omega \quad C_1 = 2\mu F \quad R_2 = 1k\Omega \quad C_2 = 0.5\mu F$

$$\frac{d^2V_o}{dt^2} + \frac{1}{R_1C_1}\frac{dV_o}{dt} + \frac{1}{R_1R_2C_1C_2}V_o = \frac{1}{R_1R_2C_1C_2}V_s$$

$$\Rightarrow \frac{d^2V_o}{dt^2} + 500\frac{dV_o}{dt} + 10^6 V_o = 10^6 V_s$$

$s^2 + 500s + 10^6 = 0 \qquad s = -250 \pm 250\sqrt{15}\, i$

$V_n = e^{-250t}(B_1 \cos 250\sqrt{15}t + B_2 \sin 250\sqrt{15}t)$ ... 2점

$V_f = K \qquad 10^6 K = 10^6 V_s \qquad t \geq 0 \quad V_s = 10u(t)$

$K = 10 \qquad \hookrightarrow V_s = 10$

$V_f = 10$ ... 1점

$V_o(t) = V_n + V_f = e^{-250t}(B_1\cos 250\sqrt{15}t + B_2 \sin 250\sqrt{15}t) + 10$ 2점

$t=0$ 일때 $V_2(0) = 0 = V_o(0)$

$t=0$ 일때 $C_2\dfrac{dV_o}{dt} + \dfrac{V_1}{R_2} = 0 \qquad \dfrac{dV_o(0)}{dt} = 0$

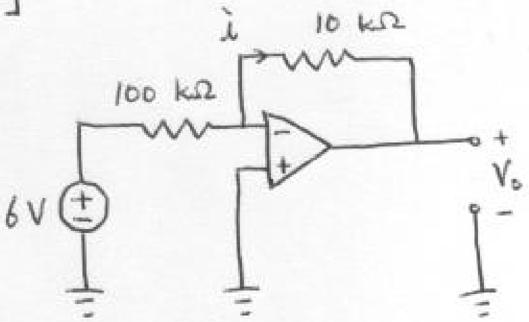
$V_1(0) = 0$

$V_o(0) = 0 = B_1 + 10 = 0 \qquad B_1 = -10$

$\dfrac{dV_o(0)}{dt} = 0 = -250B_1 + 250\sqrt{15}B_2 \qquad B_2 = \dfrac{-10}{\sqrt{15}}$

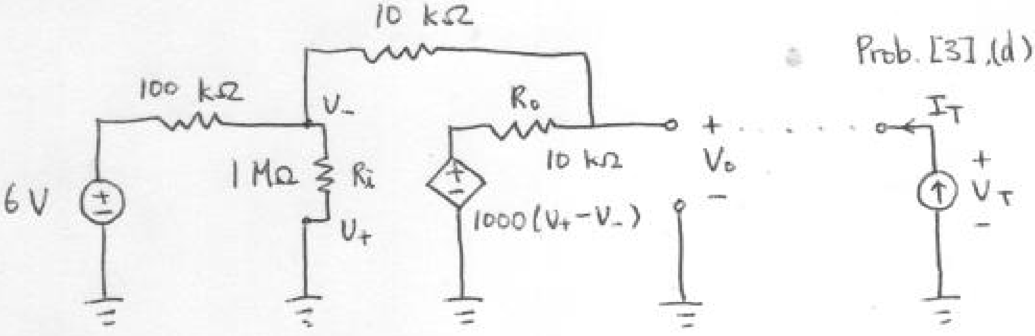
$V_o(t) = e^{-250t}\left(-10\cos 250\sqrt{15}t - \dfrac{10}{\sqrt{15}}\sin 250\sqrt{15}t\right) + 10$ ... 3점

[3]



(a) $i = \dfrac{6-0}{100 \times 10^3}$, $V_o = -\dfrac{6}{100 \times 10^3} \cdot 10^4 = \underline{-0.6 \text{ V}}$ //

(b)



KCL at node (V_-), node (V_o)

(c) $\dfrac{V_- - 6}{100 \times 10^3} + \dfrac{V_-}{10^6} + \dfrac{V_- - V_o}{10 \times 10^3} = 0$

$\dfrac{V_o - 1000(V_+ - V_-)}{10 \times 10^3} + \dfrac{V_o - V_-}{10 \times 10^3} = 0$, $V_+ = 0$

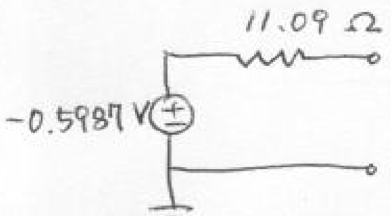
Eliminating V_-, $V_o = -\dfrac{9}{902} \cdot 60 = \underline{-0.5987 \text{ V}}$ //

(d)

$\dfrac{V_- - 6}{100 \times 10^3} + \dfrac{V_-}{10^6} + \dfrac{V_- - V_T}{10 \times 10^3} = 0$

$\dfrac{V_T - V_-}{10 \times 10^3} + \dfrac{V_T - (1000(V_+ - V_-))}{10 \times 10^3} - I_T = 0$

Eliminating V_-, $V_T = \dfrac{10^4}{902} \cdot I_T - \dfrac{540}{902}$

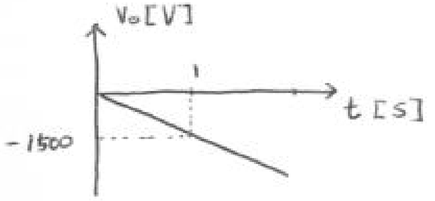


[4]

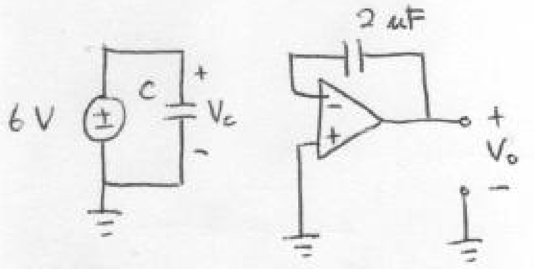
(a)

$$\frac{6}{2\times10^3} = -2\times10^{-6}\frac{dV_o(t)}{dt}, \quad V_o(0) = 0\ V$$

$$V_o(t) = -1500t\ V$$



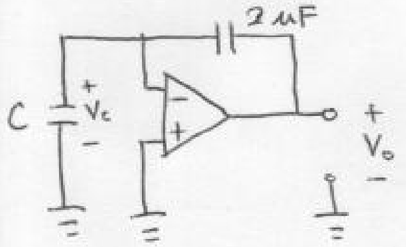
(b) sw = a,



$V_c = 6\ V$

$C\dfrac{dV_o(t)}{dt} = 0 \quad \therefore V_o$ is constant

sw = b,



KCL: $C\dfrac{dV_c}{dt} + 2\times10^{-6}\cdot\dfrac{d(-V_o)}{dt} = 0$

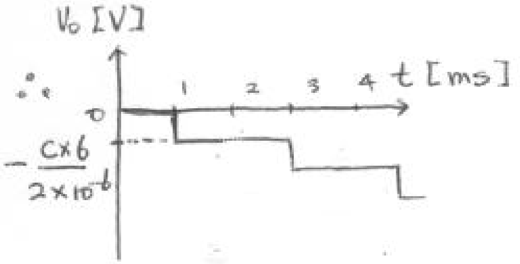
$$\rightarrow \frac{dV_o}{dt} = \frac{C}{2\times10^{-6}}\cdot\frac{dV_c}{dt}$$

Since, i) the accumulated charge in capacitor C is added to the capacitor of 2 uF.

ii) $Q = CV$, $\Delta V = \dfrac{\Delta Q}{C}$ when C is constant.

$$\Delta V_o = \frac{C}{2\times10^{-6}}\cdot\Delta V_c = -\frac{C}{2\times10^{-6}}\cdot6$$

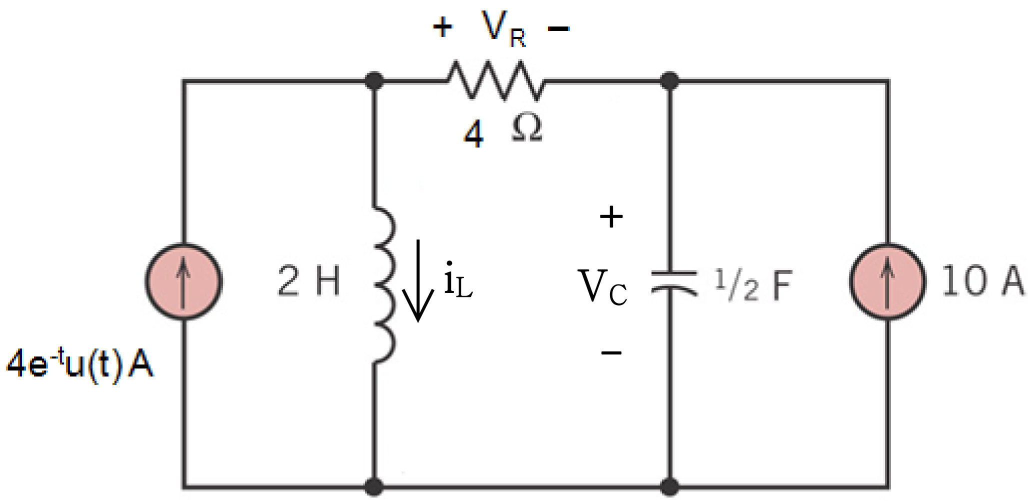
$\therefore$



(c) $$\frac{-\frac{6\cdot C}{2\times10^{-6}}}{2\times10^{-3}} = -1500, \quad \underline{C = 1\ \mu F}$$

(d) Since the result of (a) and (c) are identical, switching capacitor can be viewed as <u>'resistor'</u>

Problem # 5



$For\ \ t < 0\ (initial\, condition)$
$i_L(0^-) = 10A = i_L(0^+)$
$V_C(0^-) = 40\,V = V_C(0^+)$

$t > 0$

$$V_C = V_L - V_R = 2\frac{di_L}{dt} - V_R$$

$$i_L = 4e^{-t} - \frac{V_R}{4}$$

$$V_C = -8e^{-t} - \frac{2}{4}\frac{dV_R}{dt} - V_R$$

$by\, KCL\ @\ upper\, node\, of\ 10A\ \ current\, source,$

$$10 = i_C - \frac{V_R}{4} = \frac{1}{2}\frac{dV_C}{dt} - \frac{V_R}{4}$$

$$= 4e^{-t} - \frac{1}{4}\frac{d^2V_R}{dt^2} - \frac{1}{2}\frac{dV_R}{dt} - \frac{V_R}{4}$$

$$\frac{d^2V_R}{dt^2} + 2\frac{dV_R}{dt} + V_R = 16e^{-t} - 40$$

$characteristic \ \ equation$

$s^2+2s+1=0$

$s=-1,-1$

$V_{R,n}=(A_1+A_2t)e^{-t}$

$V_{R,f}=K+Bt^2e^{-t}$

$$\begin{aligned}16e^{-t}-40 &= K+Bt^2e^{-t}\\ &\quad + 2(2Bt-Bt^2)e^{-t}\\ &\quad +(2B-4Bt+Bt^2)e^{-t}\\ &= K+2Be^{-t}\end{aligned}$$

$\therefore K=-40,\ B=8$

$V_R(t)=(A_1+A_2t+8t^2)e^{-t}-40$

$$\begin{aligned}V_C(0^+) &= -8-\frac{2}{4}\frac{dV_R}{dt}|_{0+}-\ V_R(0^+)\\ &= -8-\frac{1}{2}(-A_1+A_2)-(A_1-40)\\ &= 32-\frac{1}{2}A_1-\frac{1}{2}A_2=40\end{aligned}$$

$\therefore A_1+A_2=-16$

$$\begin{aligned}i_L(0^+) &= 4-\frac{1}{4}V_R(0^+)\\ &= 4-\frac{1}{4}(A_1-40)\\ &= 14-\frac{1}{4}A_1=10\end{aligned}$$

$\therefore A_1=16,\ A_2=-32$

$V_R(t)=(16-32t+8t^2)e^{-t}-40\,[V]$

Problem #6

(a)

Ideal OP-Amp has infinity gain $(A_V = \infty)$

Since OP-Amp has saturation voltage $(\pm V_{sat})$,

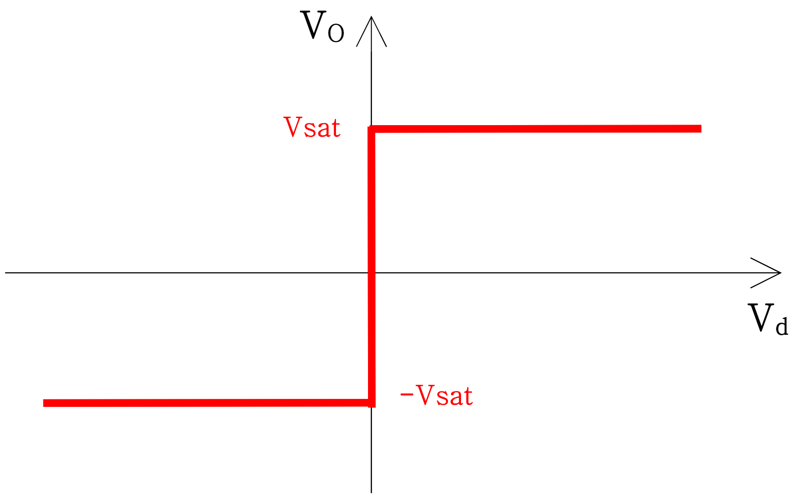
$$V_o = \begin{cases} V_{sat} & (V_0 > V_{sat}) \\ V_o & (-V_{sat} < V_o < V_{sat}) \\ -V_{sat} & (V_0 < -V_{sat}) \end{cases}$$

$$V_o = A_V(V_+ - V_-) = A_V V_d$$

since $A_V = \infty$,

$$V_o = \begin{cases} V_{sat} & (V_d > 0) \\ -V_{sat} \sim V_{sat} & (V_d = 0) \\ -V_{sat} & (V_d < 0) \end{cases}$$

Therefore, the relationship between Vd and Vo is



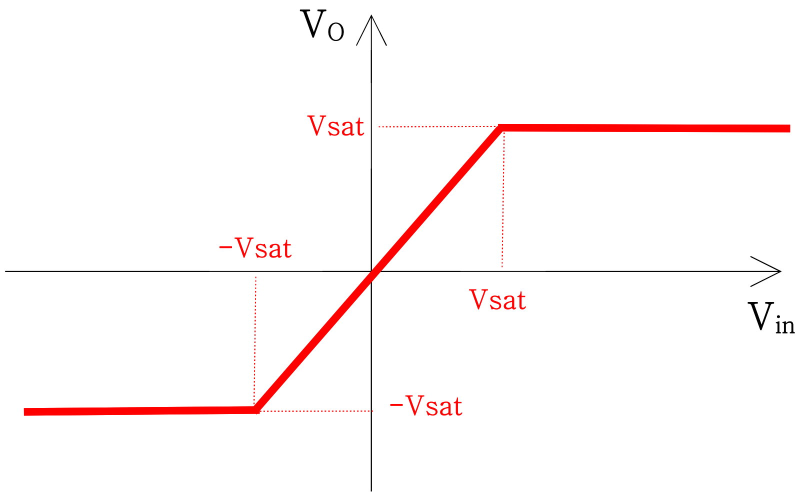
(b)

$$V_o = A_V(V_+ - V_-) = A_V(V_{in} - V_o)$$

$$V_o = \frac{A_V}{1 + A_V} V_{in} = V_{in} (\because A_V = \infty) \ (-V_{sat} < V_o < V_{sat})$$

$$\therefore V_o = \begin{cases} V_{sat} & (V_{in} > V_o) \\ V_{in} & (V_{in} = V_o) \\ -V_{sat} & (V_{in} < V_o) \end{cases}$$

Therefore, the relationship between V_{in} and Vo is



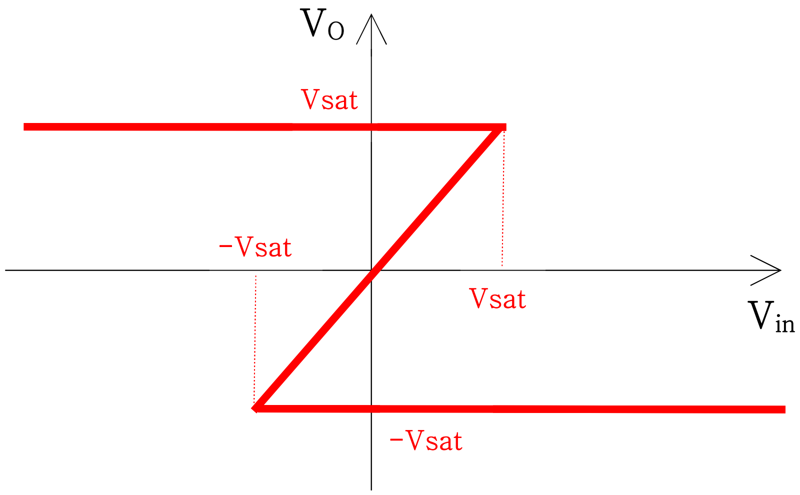
(c)

$$V_o = A_V(V_+ - V_-) = A_V(V_o - V_{in})$$

$$V_o = \frac{A_V}{-1 + A_V} V_{in} = V_{in} (\because A_V = \infty)\ (-V_{sat} < V_o < V_{sat})$$

$$\therefore V_o = \begin{cases} -V_{sat} & (V_{in} > V_o) \\ V_{in} & (V_{in} = V_o) \\ V_{sat} & (V_{in} < V_o) \end{cases}$$

Therefore, the relationship between V_{in} and Vo is



(d)

(b): negative feedback: feeding back part of the output (connected to V−) in such a way as to partially oppose the input => stable

(one input -> one output => stable)

(c): positive feedback: feeding back part of the output (connected to V+) so as to increase the input => unstable

(one input -> 3 outputs for $(-V_{sat} < V_{in} < V_{sat})$ => unstable)