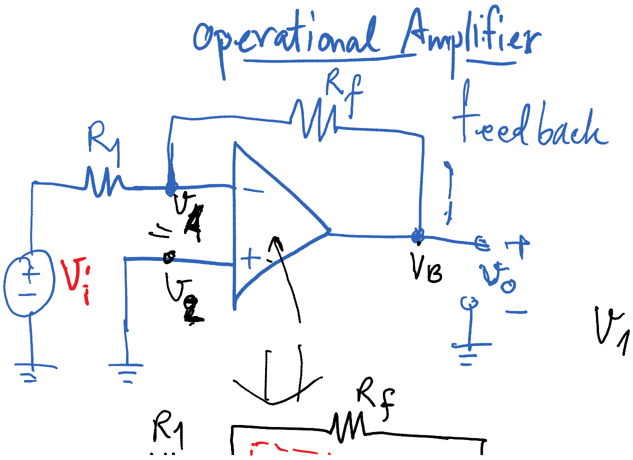
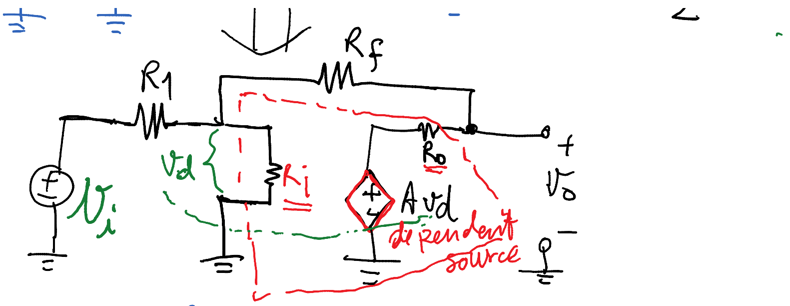
Op-Amp

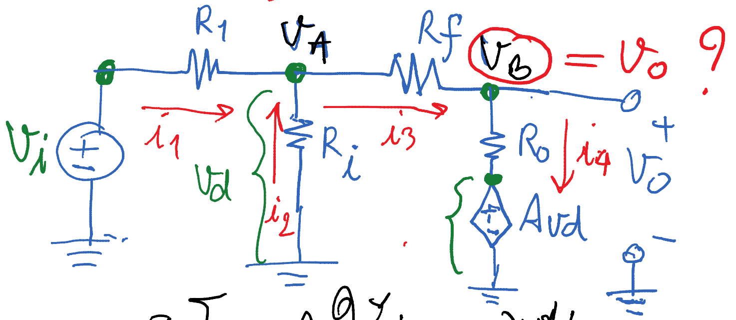
9 มีนาคม 2560

13:20



$$V_1 = V_2$$





จากโหนด A ใช้ KCL จะได้ว่า

$$i_1 + i_2 = i_3 \quad \text{——— (1)}$$

$$\frac{v_i - \cancel{v_A}^{\,0}}{R_1} + \frac{\cancel{v_A}^{\,0}}{R_i} = \frac{\cancel{v_A}^{\,0} - V_B}{R_f} \quad \text{——— (2)}$$

สรุป $V_A = 0$ ——— (3)

นำ (3) แทนใน (2) จะได้

$$\frac{v_i}{R_1} = -\frac{V_B}{R_f} \quad \text{——— (4)}$$

จาก $v_B = v_o$ ——— (5)

แทน (5) ลงใน (4) จะได้

$$\frac{v_i}{R_1} = -\frac{v_o}{R_f}$$

อัตราการขยาย

$$\boxed{\frac{v_o}{v_i} = -\frac{R_f}{R_1}}$$

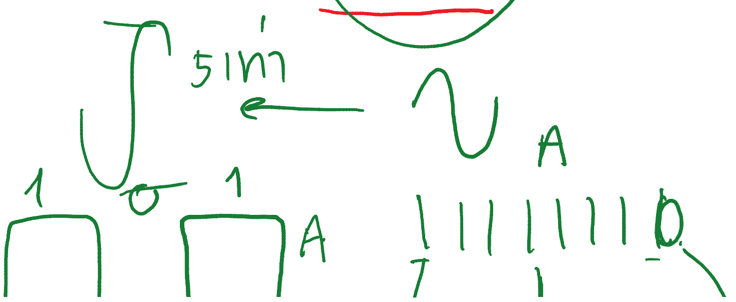
Inverting Amplifier ★★★

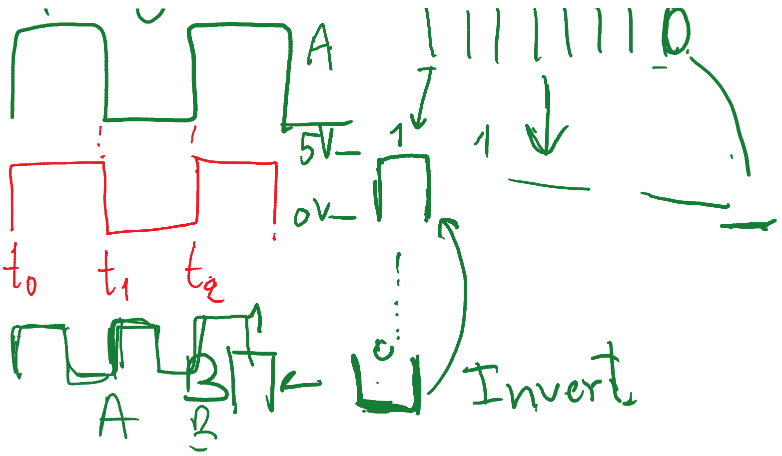
$$v_o = -\boxed{\frac{R_f}{R_1}}\, v_i$$

1V(DC)

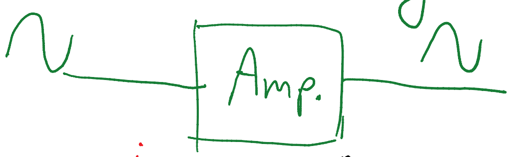
$$-5V = v_o = -A\,v_i$$

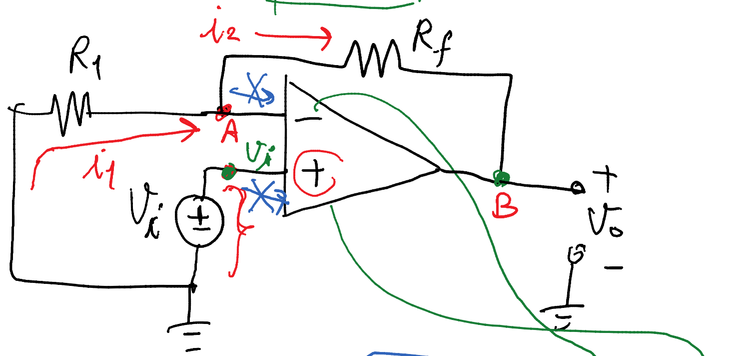
Invert (180)





Non-Inverting Amplifier





① จากหลักการของดมเศร็ $\boxed{V_A = V_i}$ หรือ $V_- = V_+$

② กระแสที่จุด A ใช้ KCL

$$i_1 = i_2 \quad \text{———} \quad (1)$$

$$\frac{0 - V_A}{R_1} = \frac{V_A - V_o}{R_f} \quad \text{———} \quad (2)$$

ต่อ จาก $V_A = V_i$ ——— (3)

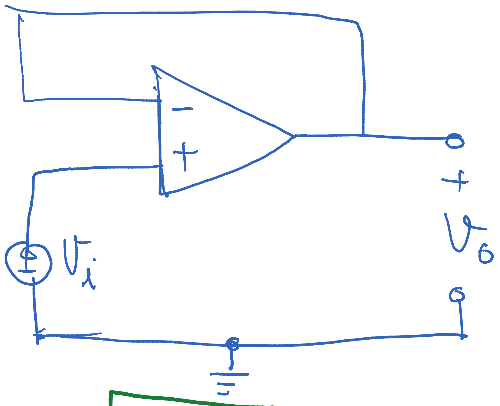
นำ (3) แทนใน (2)

$$\frac{-V_i}{R_1} = \frac{V_i - V_o}{R_f} \quad \text{———} \quad (4)$$

$$-V_i\left(\frac{1}{R_1} + \frac{1}{R_f}\right) = -V_o \quad \text{———} \quad (5)$$

$$\boxed{\frac{V_o}{V_i} = 1 + \frac{R_f}{R_1}} \ ☆☆☆$$

Voltage follower (Buffer)



โจทย์ $V_o = -5V_1 + 3V_2$

Inv.

−1

$-5V_1$

Inv.

$\frac{R_f}{R_i} = 5$

$+3V_2$

$3V_2$

Inv.

$V_o = \underset{5}{-Av_1} + \boxed{\frac{1+A}{1+B}} v_2$

step of Analysis

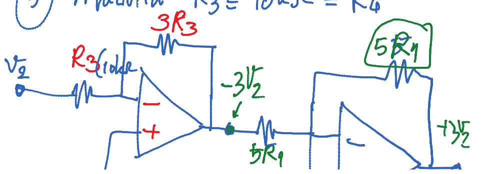
1. We set $A = 5 \Rightarrow \frac{R_f}{R_1} = 5$
2. กำหนดให้ $\frac{R_2}{R_1} = 5 \Rightarrow R_2 = 5R_1$
3. ถ้ากำหนดให้ $R_1 = 10k\Omega \rightarrow R_2 = 50k\Omega$
4. กำหนดให้ $3 = \frac{1+A}{1+B}$ ดังนั้น $3 = \frac{1+5}{1+B}$

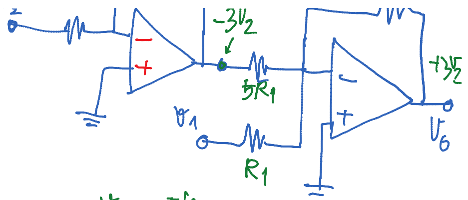
$$3(1+B) = 1+5$$
$$1+B = 2$$
$$B = 1 \quad ※$$

จาก difference Amp จะได้ว่า $B = \frac{R_3}{R_4}$

$\therefore \frac{R_3}{R_4} = 1$ หรือ $R_3 = R_4$

5. กำหนดให้ $R_3 = 10k\Omega = R_4$





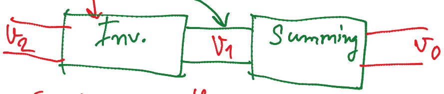
$$V_o = -5V_1 + 3V_2$$

Method 2

ครั้งเดียว $-5V_1$ $+3V_2$ 2 ครั้ง

Inv Inv

Summing Inv.

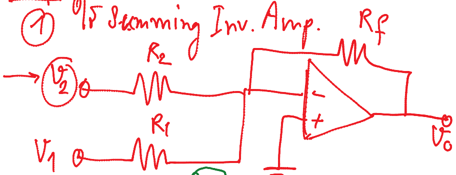


จากโจทย์ $V_o = -5V_1 + 3V_2$

$$= \underbrace{-5V_1}\ -\ \underbrace{(-3V_2)}$$

Step

① ใช้ Summing Inv. Amp.



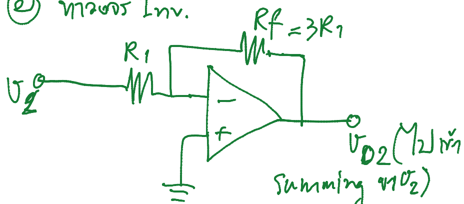
$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2\right)$$

$$\therefore \frac{R_f}{R_1} = 5, \quad \frac{R_f}{R_2} = 1$$

ดังนั้น $R_f = 5R_1$, $R_f = R_2 = 10\,k\Omega$

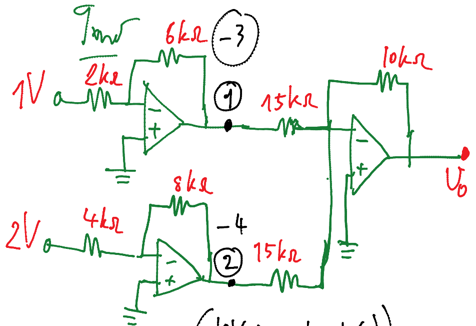
$$R_f = 5R_1$$

② ทำวงจร Inv.



$$V_{o2} = -\frac{R_f}{R_1}V_2 \quad \therefore R_f = 3R_1$$

โจทย์



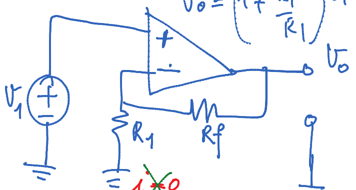
$$V_o = \left(\frac{10k}{15k}(3) + \frac{10k}{15k}(4)\right)$$

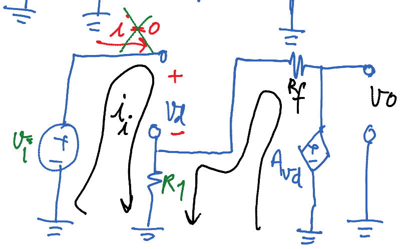
$$= 4.667\ V$$

- ~~Ideal~~ case
- non-Ideal case

non-inverting

$v_o = \left(1 + \frac{R_f}{R_1}\right) v_i$





Mesh(i_i)

$$-v_i + v_d + \cancel{i_i R_1} + i_f R_1 = 0 \quad \text{—①}$$

เนื่องจาก $i_i = 0$ ∴

$$-v_i + v_d + i_f R_1 = 0 \quad \text{—②}$$

Mesh (i_f)

จากรูป $A v_d = v_o$

ทำ KVL จะได้ว่า

$$-v_o + i_f R_f + i_f R_1 + \cancel{i_i R_1} = 0 \quad \text{—③}$$

$$v_o = i_f (R_1 + R_f) \quad \text{—④}$$

จาก ② จะหา i_f จะได้ว่า

$$i_f R_1 = v_i - v_d$$

$$\therefore i_f = \frac{v_i - v_d}{R_1} \quad \text{—⑤}$$

นำสมการที่ ⑤ แทนใน ④

$$v_o = \left(\frac{v_i - v_d}{R_1}\right)(R_1 + R_f) \quad \text{—⑥}$$

$$v_o = \frac{v_i (R_1 + R_f)}{R_1} - \frac{v_d (R_1 + R_f)}{R_1} \quad \text{—⑦}$$

จาก $A v_d = v_o$

$$\therefore v_d = \frac{v_o}{A} \quad \text{—⑧}$$

นำ ⑧ แทนใน ⑦

$$v_o = \frac{v_i (R_1 + R_f)}{R_1} - \frac{v_o}{A}\left(\frac{R_f + R_1}{R_1}\right) \quad \text{—⑨}$$

$$v_o\left(1 + \frac{R_1 + R_f}{A R_1}\right) = v_i \left(\frac{R_1 + R_f}{R_1}\right) \quad \text{—⑩}$$

$$\text{⑪} \quad \frac{v_o}{v_i} = \frac{R_1 + R_f}{R_1} \Big/ \left(1 + \cancel{\frac{R_1 + R_f}{A R_1}}\right)$$

ซึ่ง A = อัตราการขยาย สูงมากๆ

จะได้ว่า

$$\boxed{\frac{v_o}{v_i} = \frac{R_1 + R_f}{R_1} \approx 1 + \frac{R_f}{R_1}}$$

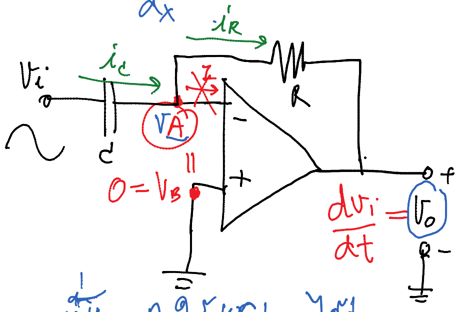
-invert, non-inv, sub / sum / buffer

$\overline{A}$

$\frac{dy}{dt}$ / $\int y\,dt$

Differentiator Amplifier

$\frac{dy}{dx} = 0$



ที่โหนด A ใช้ KCL จะได้ว่า

$i_c = i_R$ —— ①

จาก $i_c = C\frac{dv}{dt}$ ตัวเก็บประจุ

กระแส

$(V_i - V_A)\, C\frac{dV}{dt} = \frac{V_A - V_o}{R}$ —— ②

$(V_i - \cancel{V_A})\, CS = \frac{\cancel{V_A} - V_o}{R}$ —— ③

จากรูป $V_A = 0$ ดังนั้น

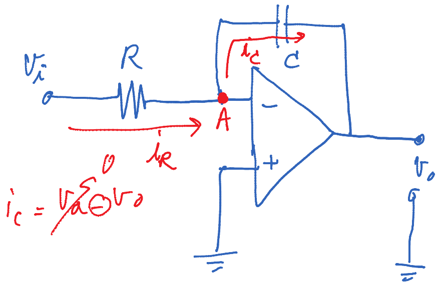
$V_i CS = -\frac{V_o}{R}$

$C\frac{dV_i}{dt} = -\frac{V_o}{R}$

$\boxed{\frac{dv_i}{dt} = -\frac{V_o}{CR}}$ ☆☆☆

$dV_i = -\int \frac{V_o}{CR}\,dt$

Integrating Amplifier



$i_c = \cancel{V_A} - V_o$

$i_R = i_c$

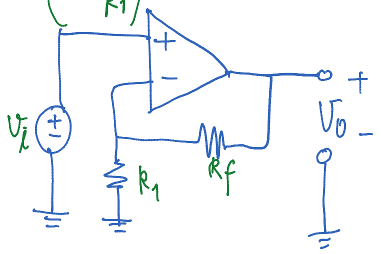
$\frac{V_i - V_A}{R} = -C\frac{dV_o}{dt}$

$\therefore \boxed{V_o = \frac{-1}{RC}\int V_i\,dt}$ ☆☆

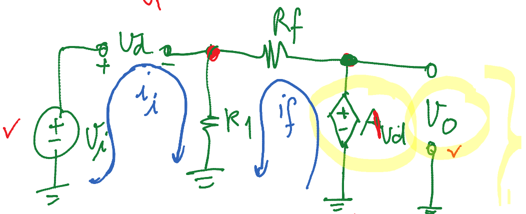
$$\therefore \boxed{V_o = \frac{-1}{RC}\int V_i\,dt} \quad ★★$$

Sec 2 (non-Ideal non-Inverting Amp.)

$$V_o = \left(1+\frac{R_f}{R_1}\right)V_i$$



หาค่า $\frac{V_o}{V_i} = ?$



Mesh (i_i)

$$-V_i + V_d + R_1(\cancel{i_i}+i_f) = 0 \quad —— ①$$

$$-V_i + V_d + R_1 \cdot i_f = 0 \quad —— ②$$

Mesh (i_f)

$$-AV_d + i_f R_f + R_1(i_f + \cancel{i_i}) = 0 \quad —— ③$$

$$-AV_d + i_f(R_1+R_f) = 0 \quad —— 4$$

จากรูป $AV_d = V_o$

$$-V_o + i_f(R_1+R_f) = 0 \quad —— ⑤$$

$$\therefore i_f = \frac{V_o}{R_1+R_f} \quad —— ⑥$$

จาก ② ได้ $V_d = \frac{V_o}{A}$

จาก $AV_d = V_o$

$$-V_i + \frac{V_o}{A} + R_1 i_f = 0 \quad —— ⑦$$

$$i_f = \frac{\left(V_i - \frac{V_o}{A}\right)}{R_1} \quad —— ⑧$$

$$\frac{V_o}{R_1+R_f} = \frac{V_i - \frac{V_o}{A}}{R_1} \quad —— ⑨$$

$$\frac{V_0}{R_1+R_f} = \frac{V_i - \frac{V_0}{A}}{R_1} \quad \text{——— (9)}$$

$$V_0 = V_i\left(\frac{R_f+R_1}{R_1}\right) - \frac{V_0}{A}\left(\frac{R_f+R_1}{R_1}\right) \quad \text{— (10)}$$

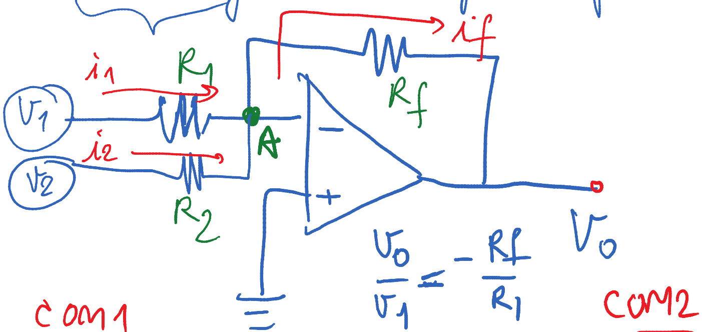
$$V_0\left(1+\frac{R_f+R_1}{AR_1}\right) = V_i\left(\frac{R_f+R_1}{R_1}\right) \quad \text{— (11)}$$

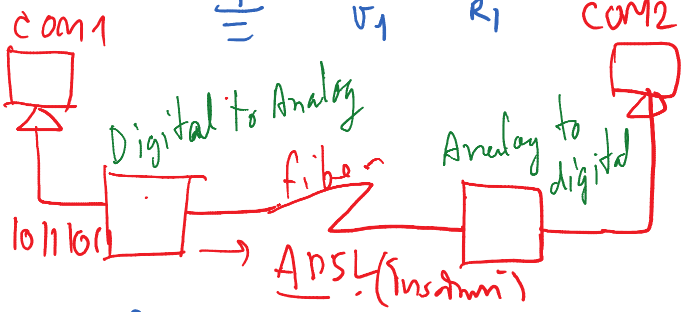
$$\frac{V_0}{V_i} = \frac{R_f+R_1}{R_1} \Big/ \left(1+\cancel{\frac{R_f+R_1}{AR_1}}\right)$$

ถ้า A>>> (A=อัตราขยาย)

$$\boxed{\therefore \frac{V_0}{V_i} = 1+\frac{R_f}{R_1}}$$

Summing Inverting Amplifier





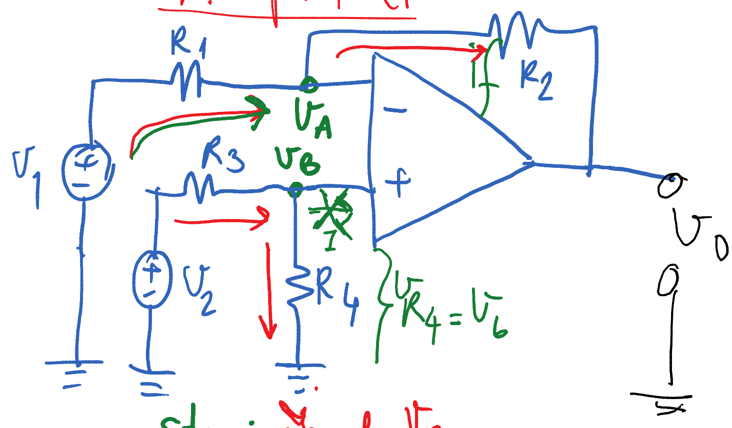
ที่ node A ใช้ KCL จะได้ว่า $i_1+i_2=i_f$ ——— (1)

$$\frac{V_1-0}{R_1}+\frac{V_2-0}{R_2} = \frac{0-V_0}{R_f} \quad \text{——— (2)}$$

$$V_0 = -\left(\frac{V_1 \cdot R_f}{R_1}+\frac{V_2 \cdot R_f}{R_1}\right)$$

Subtracting (diff...)

Subtracting (difference) Amplifier



Step: ที่ node V_B

จาก Voltage Vidider.

$$V_b = \frac{R_4}{R_3+R_4} \cdot V_2 \quad —— ①$$

วิเคราะห์ที่ node V_B

$$\frac{V_2 - V_B}{R_3} = \frac{V_B - 0}{R_4} \quad —— ②$$

นำ ① แทนใน ②

$$\frac{V_2 - \left(\frac{R_4}{R_3+R_4} \cdot V_2\right)}{R_3} = \frac{\left(\frac{R_4}{R_3+R_4} \cdot V_2\right)}{R_4} \quad — ③$$

จาก $V_B = \frac{R_4}{R_3+R_4} \cdot V_2 \longrightarrow$ หาร R_4 แล้ว

$$V_B = \frac{1}{\frac{R_3}{R_4}+1} V_2$$

ถ้ากำหนดให้ $R_3/R_4 = B$

$$\therefore \boxed{V_B = \frac{1}{B+1} V_2} \quad —— ④$$

นำ ④ แทนใน ③

$$\frac{V_2 - \left(\frac{V_2}{1+B}\right)}{\cancel{R_3}} = \frac{R_3\left(\frac{V_2}{1+B}\right)}{\cancel{R_4}}$$

$$V_2 - \frac{V_2}{1+B} = \underbrace{\frac{R_3}{R_4}}_{=B}\left(\frac{V_2}{1+B}\right)$$

$$\frac{\quad}{1+B} \qquad -\left(\frac{\quad}{R_4}\right)\left(\frac{\quad}{1+B}\right)$$

$$v_2\left(1-\frac{1}{1+B}\right)=\frac{B}{1+B}v_2$$

ที่ node v_A ใช้ KCL จะได้

จากรูป $i_f = \frac{v_1 - v_A}{R_1}$ หรือ $i_f = \frac{v_A - v_o}{R_2}$

$$v_o = v_A - i_f R_2$$

$$v_o = v_A - \frac{v_1 - v_A}{R_1} R_2 \qquad \frac{R_2}{R_1} = A$$

$$v_o = v_A - (v_1 - v_A)A$$

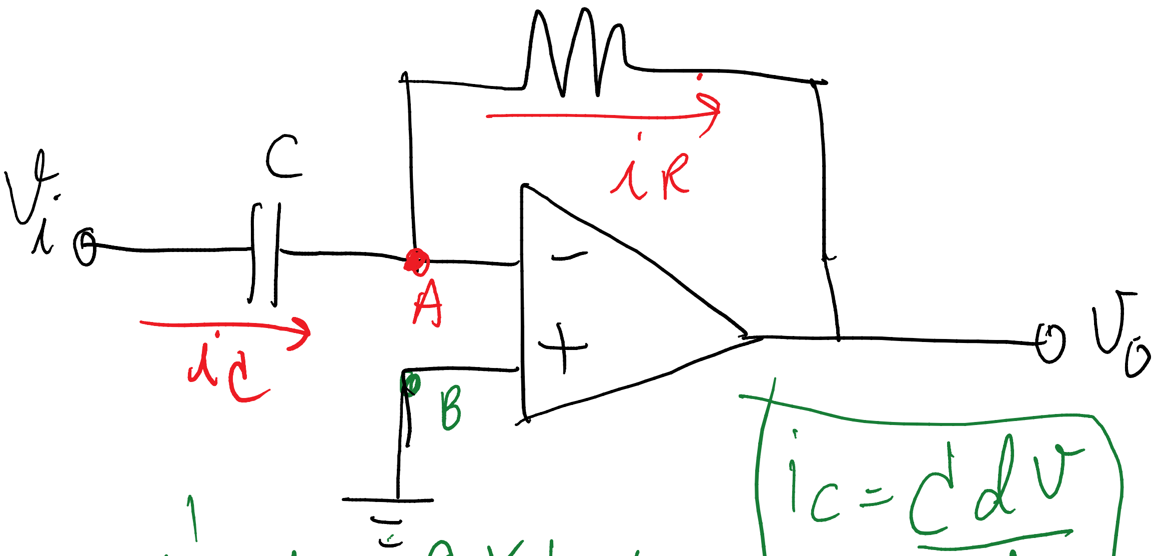
$$v_o = -Av_1 + (1+A)v_A$$

$$\boxed{v_o = -Av_1 + \frac{1+A}{1+B}v_2}$$

Differentiator Amplifier

$\frac{dy}{dx}$ / x''

R



$$\boxed{i_C = C\frac{dv}{dt}}$$

ที่ node A ใช้ KCL

$$i_C = i_R$$

$$(v_i - \cancel{v_A})sC = \frac{\cancel{v_A} - v_o}{R}$$

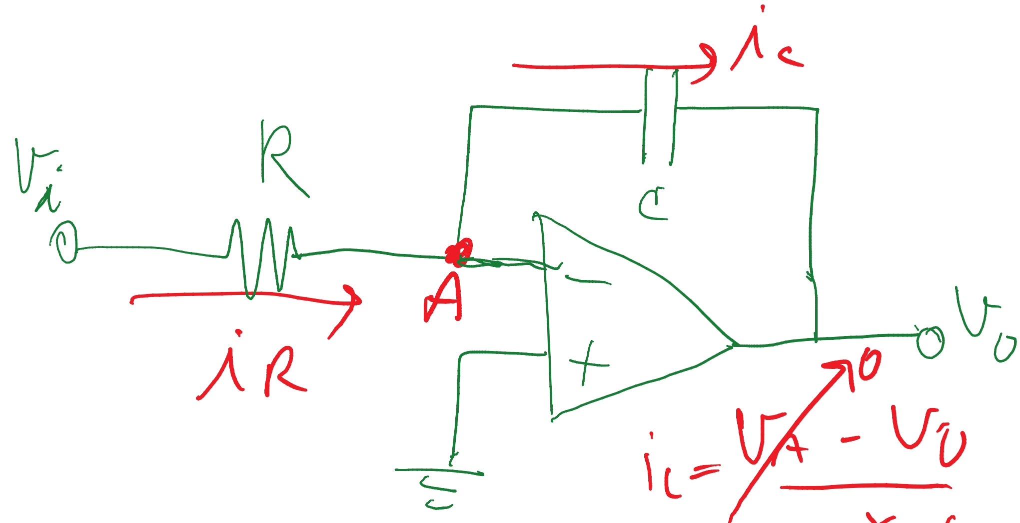
$$v_A = 0$$

$$v_i sC = -\frac{v_o}{R}$$

$$C\frac{dv_i}{dt} = -\frac{v_o}{R}$$

$$\boxed{\frac{dv_i}{dt} = \frac{-1}{RC} \cdot v_o}$$

Integrating Amplifier



$i_c = \frac{\cancel{v_A} - v_o}{-X_C}$

$\therefore \quad i_R = i_C$

$$\frac{v_i}{R} = -C\frac{dv_o}{dt}$$

$$\boxed{v_o = -\frac{1}{RC}\int v_i\,dt}$$