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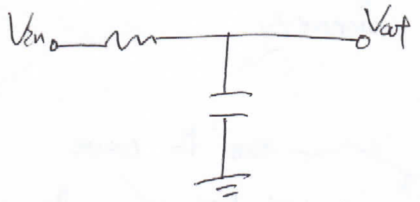
## Integrator




$$\frac{V_{out}}{V_{in}} = \frac{1}{1+j\omega RC}$$

if $j\omega RC \gg 1$, $\hookrightarrow \frac{1}{j\omega RC}$.

$\therefore V_{out} = \frac{1}{RC}\int V_{in}dt.$

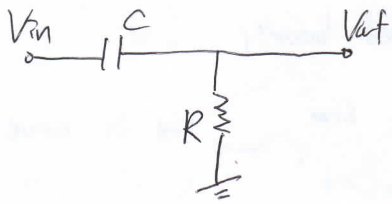
if $\omega RC = \frac{\omega}{\omega_{3dB}} \gg 1$

LPF becomes integrator.

Not in the case of op-Amp.

better design.

## Differentiater.




$$\frac{V_{out}}{V_{in}} = \frac{R}{\frac{1}{j\omega C}+R.}$$

$$= \frac{j\omega RC.}{1+j\omega RC.}$$

if $\omega RC = \frac{\omega}{\omega_{3dB}} \ll 1.$

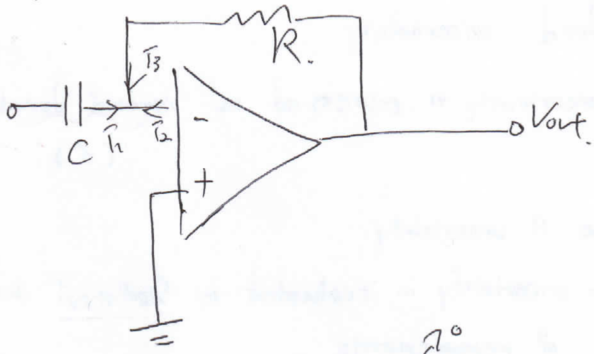
$\rightarrow \frac{V_{out}}{V_{in}} = j\omega RC$

$\therefore V_{out} = j\omega RC\, V_{in}$

$= RC\frac{dV_{in}}{dt}.$

HPF with $\frac{\omega}{\omega_{3dB}} \ll 1.$

## 9. Op-Amp Differentiator.




$$I_1 = C\frac{d[V_{in} - \cancel{V^-}^{\,0}]}{dt} = C\frac{dV_{in}}{dt}.$$

$$I_2 = 0.$$

$$I_3 = \frac{V_{out} - \cancel{V^-}^{\,0}}{R} = \frac{V_{out}}{R}.$$

$$\therefore C\frac{dV_{in}}{dt} + \frac{V_{out}}{R} = 0.$$

$$\therefore V_{out} = -RC\frac{dV_{in}}{dt}.$$

$\therefore$ differentiator.

better design.

In practice

$|V_{out}| \ll V_{cc}.$

but if ~~$|V_{out}| \ll V_{cc}.$~~ "

$V_{in}$ has big noise, ?

$\Rightarrow$ "Roll off circuit"

$\rightarrow$ suppress.. by $C_2, R_2$

HW 6.

derive the $C_2, R_2$ addition, gives "Roll off" function to differentiator

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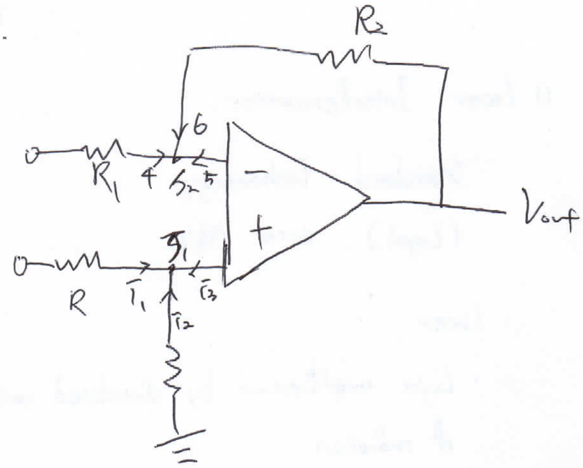
10.




$J_1$

$$i_1 = \frac{V_2 - V^+}{R_1}$$

$$i_2 = \frac{0 - V^+}{R_2}$$

$$i_3 = 0.$$

$$\therefore \frac{V_2 - V^+}{R_1} + \frac{-V^+}{R_2} = 0.$$

$$\therefore V^+ = \frac{R_2 V_2}{R_1 + R_2}$$

$J_2$

$$i_4 = \frac{V_1 - (V^-)}{R_1} \quad = V^+.$$

$$i_5 = 0$$

$$i_6 = \frac{V_{out} - V^-}{R_2}$$

$$\therefore i_4 + i_5 + i_6 = 0.$$

$$V_{out} = +\frac{R_2}{R_1}(V_2 - V_1)$$

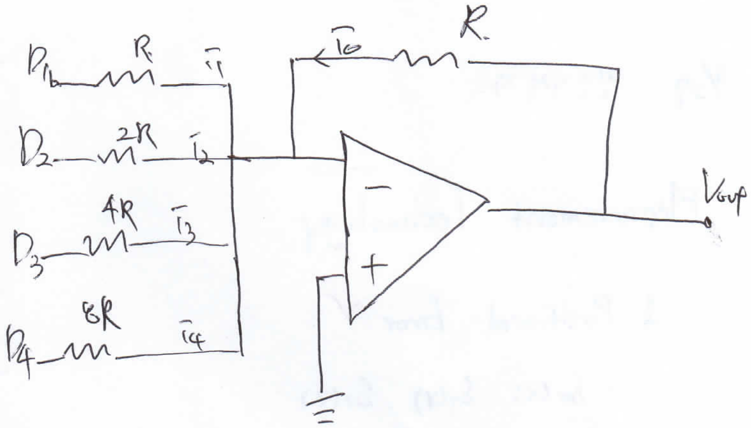
amplication differen-

differential Amplifier.

$$+\frac{R_2}{R_1} = Gain \gtreqless 1.$$

11. D/A Converter.

$$[D_1, D_2, D_3, D_4] \xrightarrow{D/A} V$$




$$i_1 = \frac{D_1 - V^-}{R} = \frac{D_1}{R}$$

$$i_2 = \frac{D_2}{2R}$$

$$i_3 = \frac{D_3}{4R}$$

$$i_4 = \frac{D_4}{8R}$$

$$i_0 = \frac{V_{out} - \cancel{V^-}}{R} \quad \frac{V_{out}}{R}.$$

$$\therefore \frac{D_1}{R} + \frac{D_2}{2R} + \frac{D_3}{4R} + \frac{D_4}{8R} + \frac{V_{out}}{R} = 0.$$

$$\therefore V_{out} = -R\left[\frac{D_1}{R} + \frac{D_2}{2R} + \frac{D_3}{4R} + \frac{D_4}{8R}\right]$$

$$= -\left[D_1 + \frac{D_2}{2} + \frac{D_3}{4} + \frac{D_4}{8}\right]$$

$$D_i = [0, 1]$$

if $[1,1,1,1] \Rightarrow [1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}]$.

Digital $\Rightarrow$ Analog

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if 5 bit D/A.

$$V_{out} = -R\left[\frac{D_1}{R} + \frac{D_2}{2R} + \frac{D_3}{4R} + \frac{D_4}{8R} + \frac{D_5}{16R}\right].$$

R' tolerance = 10%.

due to manufacturing

if R of $D_1$ is 0.9 R instead of R.

$$V_{out} = -\left[\frac{D_1}{0.9} + \frac{D_2}{2} + \frac{D_3}{4} + \frac{D_4}{8} + \frac{D_5}{16}\right].$$

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if [1,0,0,0,0] ⇒ $V_{out} = -\left[\frac{1}{0.9} + 0\right] = -1.01$.

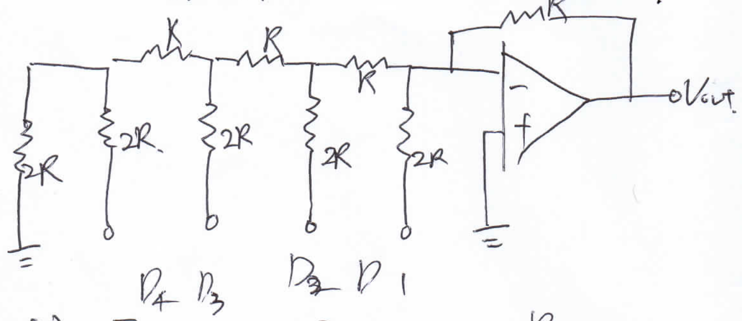
if [1,0,0,0,1] ⇒ $V_{out} = -\left[1 + \cdots \frac{1}{16}\right] =$

⇒ 4bit maximum //.

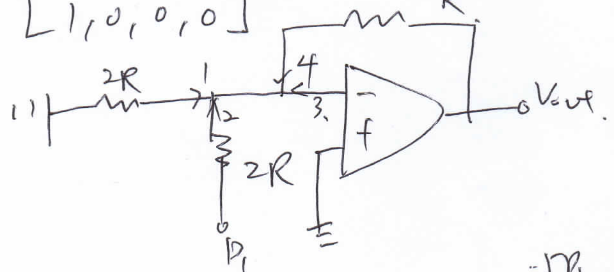
(∵ > 10% tolerance)

12. D/A converter ②

"Ladder method".




if) [1,0,0,0]




$i_1 = 0$

$i_2 = \frac{D_1}{2R}$

$i_3 = 0$

$i_4 = \frac{V_{out}}{R}$

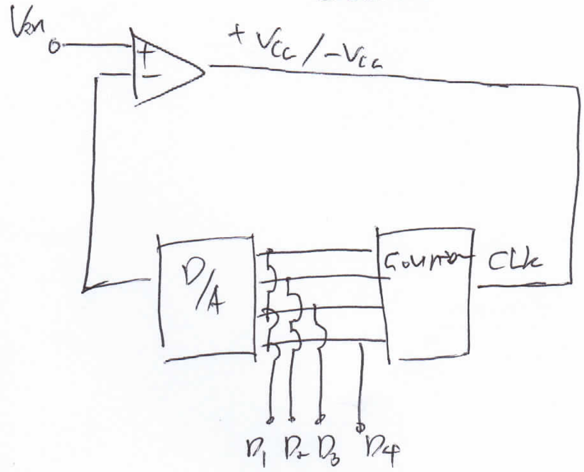
$$\therefore V_{out} = -\left[\frac{D_1}{2} + \frac{D_2}{4} + \frac{D_3}{8} + \frac{D_4}{16}\right]$$

↳ only use R, 2R.

tolerance 문제 X

13. A/D converter.

: D/A converter + Analoge comparator + ~~converter~~ Counter




"Succesive Approximation Method"

- Slow responce than D/A
- counter/CLK required.
- Resolution ≪ LSB.