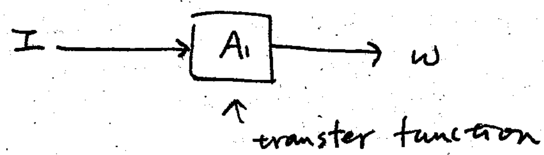
- open-loop control

ex: Fan

if $\omega = A_1 \cdot I$

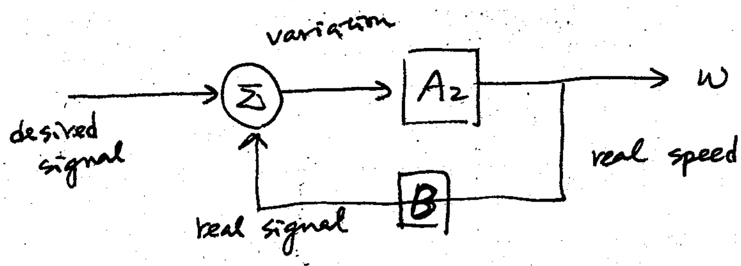
(ω ← angular velocity; I ← current)



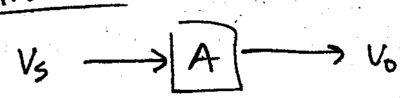
※ ω may change with time because motor may heat up and alter the performance (A_1 may change)

→ common problem for open-loop control

- Feedback Control



example: circuit



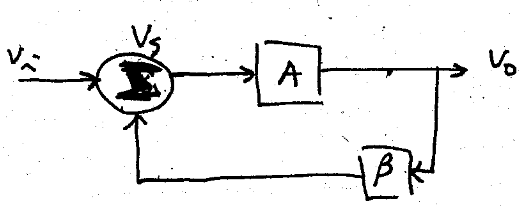
$V_o = A V_s$

$dV_o = A\,dV_s + V_s\,dA$ ($A\,dV_s = 0$)

$= V_s\,dA$

∴ $\frac{dV_o}{V_o} = \frac{dA}{A}$

→ if A changes 1%, V_o changes 1%



$V_o = A V_s = A(V_i + \beta V_o)$

$V_o(1 - A\beta) = A V_i$

$A_f = \frac{V_o}{V_i} = \frac{A}{1 - A\beta}$ ← close-loop gain

e.g. 741 amplifier $A \approx 2\times10^5$

if $\beta = -0.1$

→ $A_f = \frac{2\times10^5}{1 - 2\times10^5(-0.1)} \doteq 10$

→ if A change +1% ⇒ $A_f = 9.9995$

if A is huge

$$A_f \approx \frac{A}{-A\beta} = -\frac{1}{\beta} \qquad V_o = A_f V_i = \frac{A}{1-A\beta} V_i$$

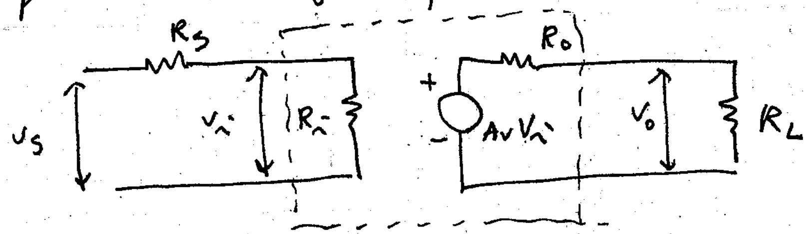
derive yourself

$$\rightarrow \quad \frac{dV_o}{V_o} = \frac{dA}{A} \cdot \frac{1}{(1-A\beta)}$$

A changes 1% $\Rightarrow$ V_o changes 0.005%

However, the gain changes from 2×10^5
$\longrightarrow$ only 10

- Amplifier (ex/ voltage amplifier)



voltage amplifier

$$V_i = V_S \frac{R_i}{R_i + R_S}$$ better $R_i \gg R_S \rightarrow V_i \approx V_S$

* no reduction at the input

$$V_o = A_v V_i \cdot \frac{R_L}{R_L + R_o}$$ better $R_o \ll R_L \rightarrow V_o \approx A_v V_i \approx A_v V_S$

ex/ HP equipment $R_i = 1\,M\Omega$
$R_o = 50\,\Omega$

same on current amplifier $\longrightarrow$ small R_i, big R_o

- Ideal Amplifiers

741

$R_{in} > 2\,M\Omega$ ($I_{in} \approx 80\,nA$)
Gain $\approx 2\times10^5$ (low frequency)

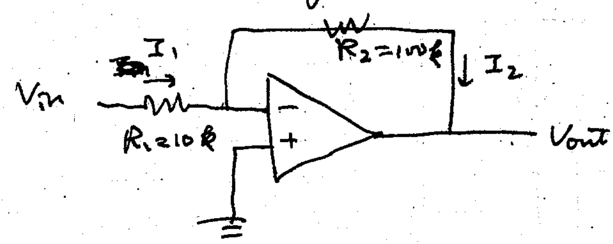
circuit analysis can assume

$R_{in} = \infty$
Gain $= \infty$

& check

$$\Rightarrow \begin{cases} I_{in} = 0 & \because R_{in} = \infty \\ V_+ - V_- = 0 & \because V_{out} = G \cdot (V_+ - V_-) \end{cases}$$

example: inverting amplifier



① $I_{in} = 0$

$\Rightarrow I_1 \approx I_2$

② $V_+ - V_- = 0 \Rightarrow V_+ \approx V_- = 0$

$I_2 = I_1 = \frac{V_{in}}{R_1}$

$V_{out} = 0 - I_2 R_2 = -\frac{R_2}{R_1} V_{in}$

$$Gain = -\frac{R_2}{R_1} = -10$$

check assumption

if $V_{in} = 0.5\ V$

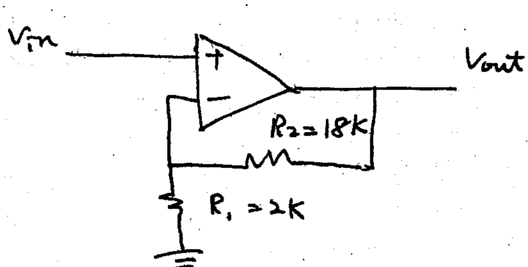
$I_1 = \frac{0.5}{10k} = 50\ \mu A \gg 80\ nA$ ok

$V_{out} = -5\ V \Rightarrow V_+ - V_- = \frac{-5}{2 \times 10^5}$

$= 2.5 \times 10^{-5}\ V \approx 0$ ok

real examples

- non-inverting amplifier



$V_{in} = V_+ = V_- = V_{out} \cdot \frac{R_1}{R_1 + R_2}$

$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$

$= 10$

if $R_2 = 0 \Rightarrow \frac{V_{out}}{V_{in}} = 1$

voltage follower