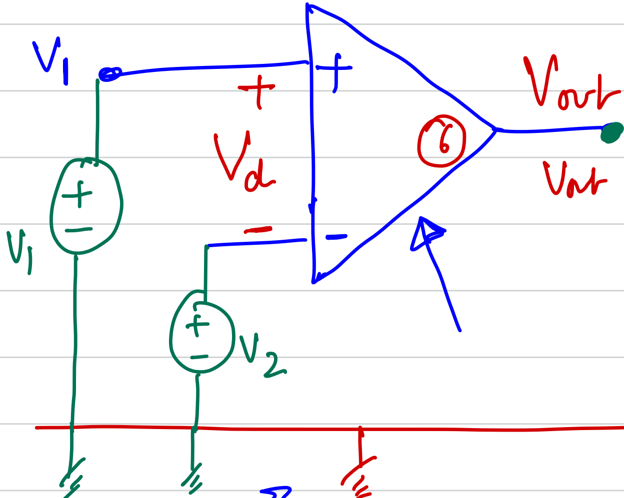


$V_{out} = A(V_1 - V_2)$

$V_{out} = A V_d$

V_{1G} V_{2G}

$V_d = V_{1G} - V_{2G}$

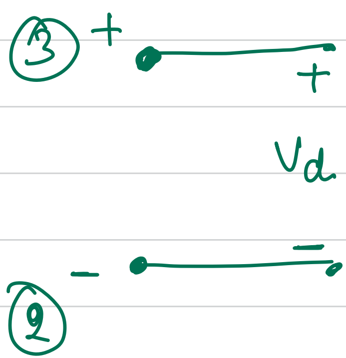
$V_d = (V_{12})$

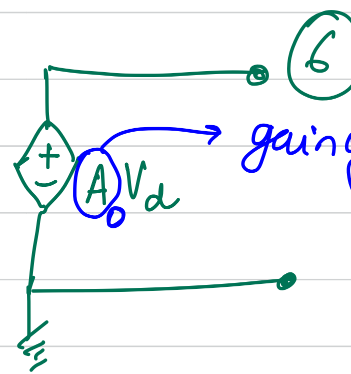
$V_d = V_1 - V_2$

$A_0 = 100, 10^6$

practical

ideal $=$ "∞" $= A_0$





gain of the operational amplifier

$V_{out} = A_0 (V_1 - V_2) = A_0 V_d$ $V_1 > V_2$

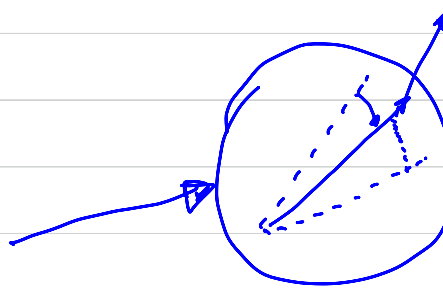
$= 10^6 \times (V_1 > V_2)$ $V_{out} \uparrow$ very high A is large

$(V_1 > V_2)$ $V_d > 0$

"V_{DD}"

$V_1 < V_2$ $V_{out} \downarrow$ very small $V_d < 0$

$\boxed{\text{Negative feedback}}$



60 km/h

Amplifier using negative feedback

$$\boxed{V_o = \underset{\sim}{K} V_i}$$

$$V_i = \left(V_o/K\right)$$

Sensing "$\left(V_o/K\right)$"

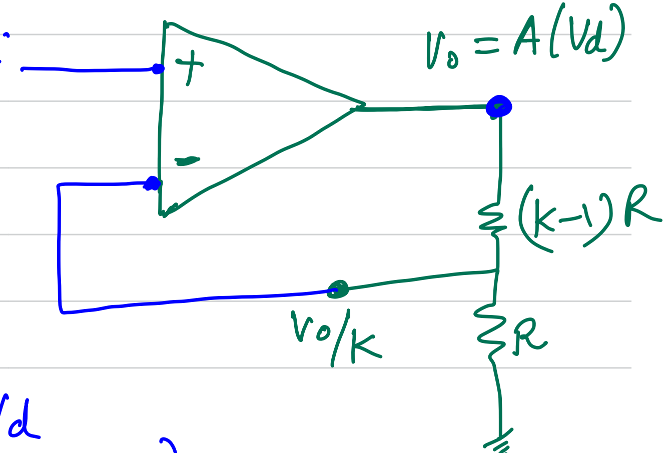
$V_i > \left(V_o/K\right)$ $\qquad V_o \uparrow$

$V_i < V_o/K$ $\qquad V_o \downarrow$

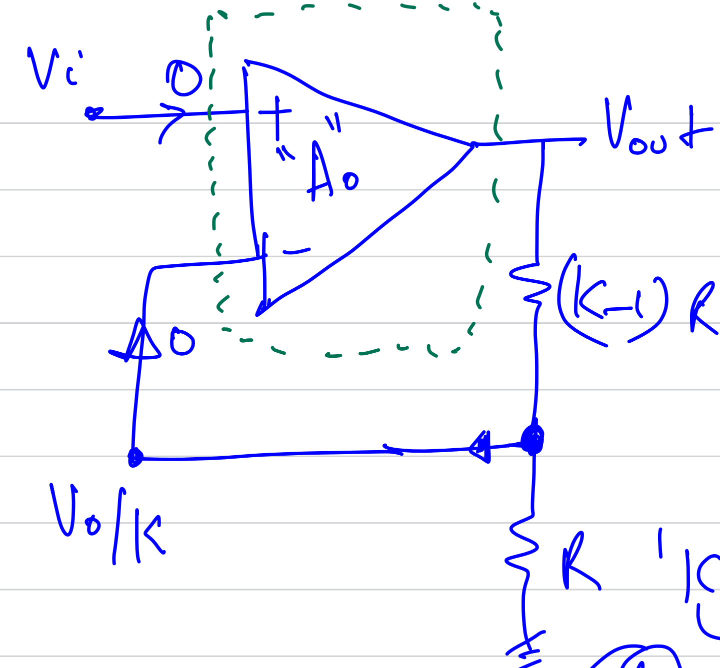
$V_o \quad \left(V_o/K\right) \quad \left(V_o/K\right)$

$= A(V_+ - V_-)$

$V_o = A(V_d)$



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

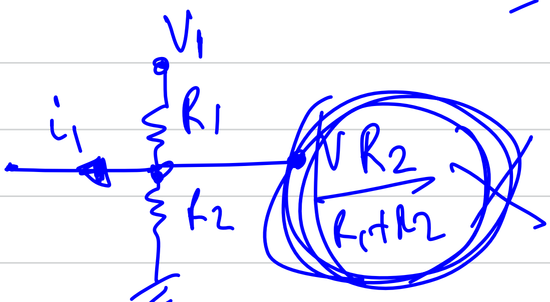


"K" → 2, 3, 10,

$$V_o = A_o\left(V_i - V_o/K\right)$$

$$V_o\left(1+\frac{A_o}{K}\right) = A_o V_i$$

$$\frac{V_o}{V_i} = \frac{A_o}{\left(1+\frac{A_o}{K}\right)} = \frac{K}{\left(1+\frac{K}{A_o}\right)}$$



10^6

$A_o >> K$

$$\frac{V_o}{V_i} = \frac{K}{\left(1+K/A_o\right)} \approx \text{"}K\text{"}$$

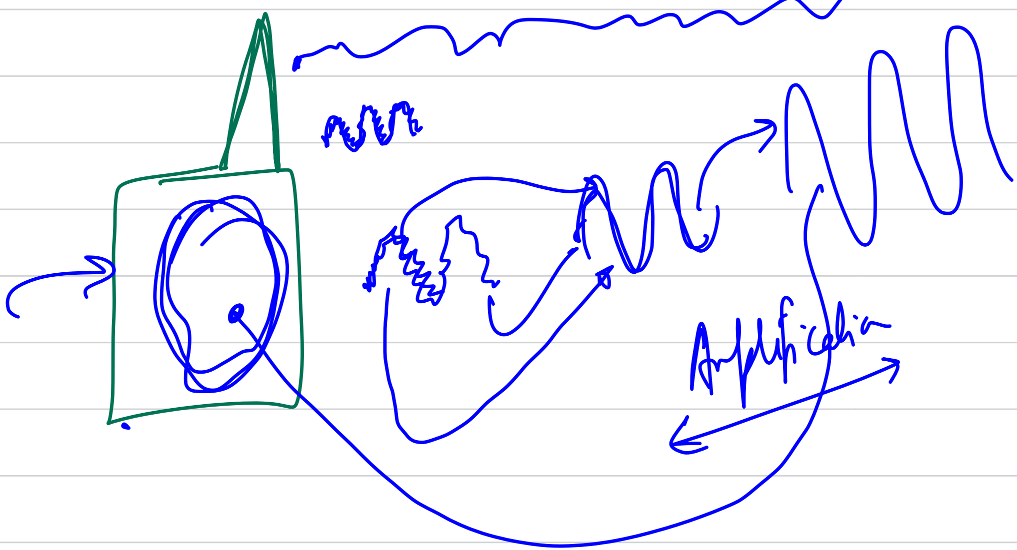
$$V_o = KV_i$$

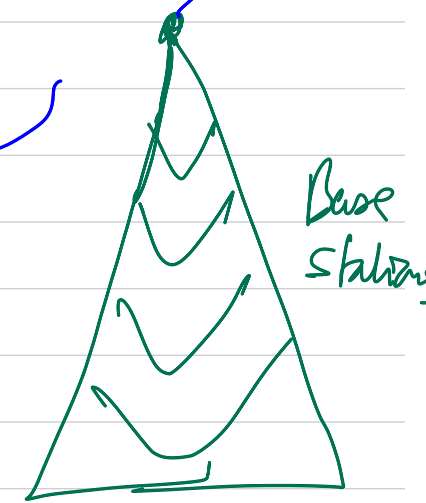
$K/A_o << 1$

$A_o = 10$, " 5, 6

$A_0 = 10^6$ $\quad$ $A_0 = \infty$ $\quad$ $\frac{V_o}{V_i} = \text{"}K\text{"} \rightarrow$ ideal

$A_0 = 1000$ $\quad$ $\frac{V_o}{V_i} \approx K$





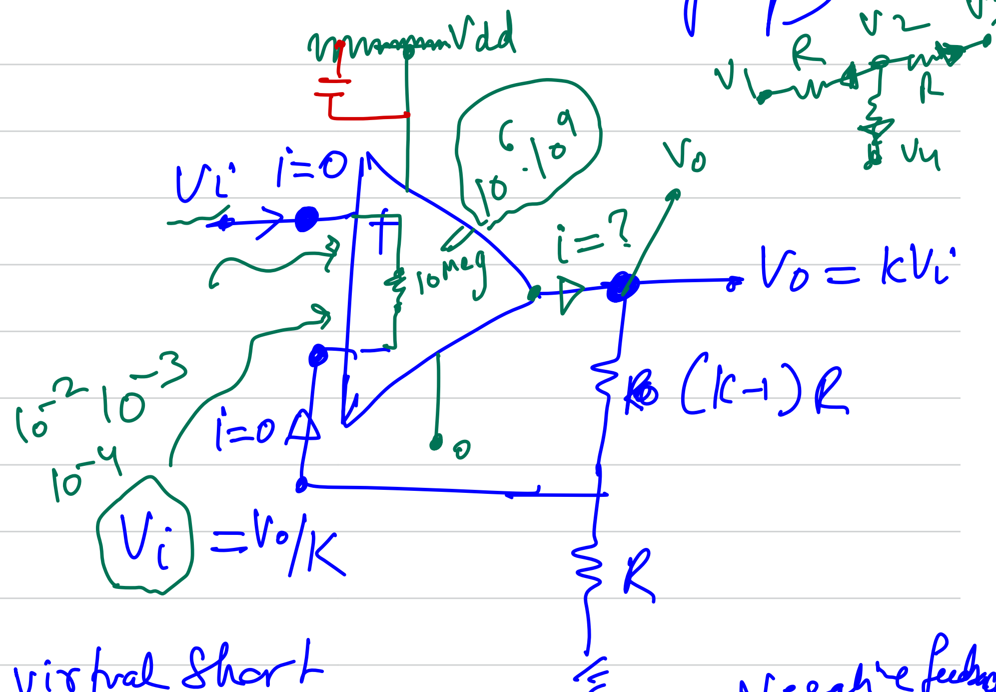
$$\frac{V_o}{V_i} = \frac{K}{\left(1 + K/A\right)}$$

$A \to$ "∞" (ideal opamp)

$$\boxed{V_o = kV_i}$$

$$V_i = V_o/K$$

Negative feedback $\rightarrow$ feeling of a short circuit $\rightarrow$ virtual short



① $(V_+ = V_-)$ { Negative feedback { Virtual short" } }

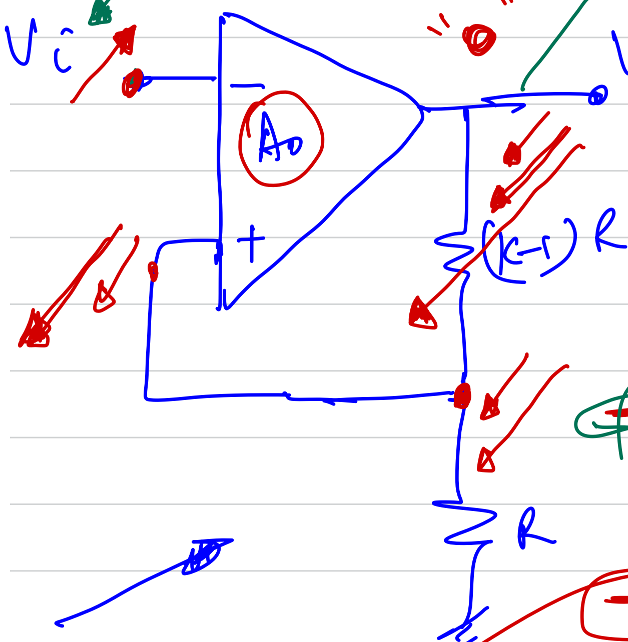
② $i_+ = 0$, $i_- = 0$

③ Do not apply KCL at o/p node

$V_o = A_o(V_+ - V_-)$

VDD

"Positive" feedback → oscillator



$$\frac{V_o}{V_i} = \frac{K}{\left(1 - \frac{K}{A_o}\right)} \simeq \text{"}K\text{"}$$

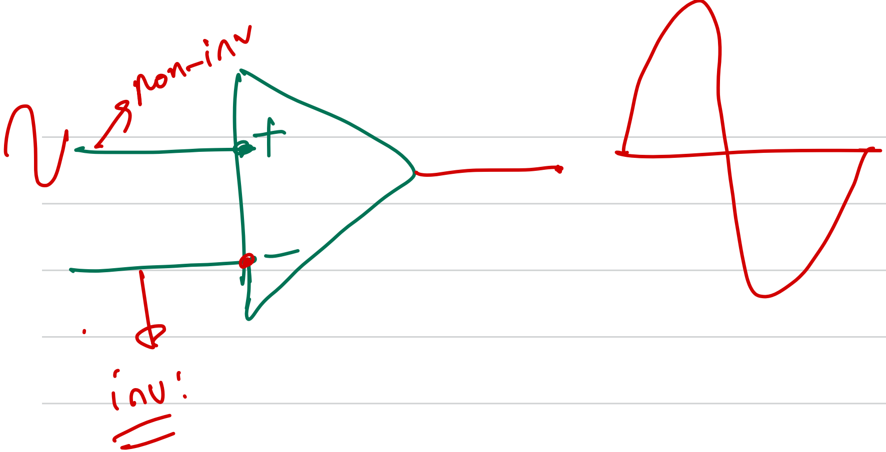
VDD

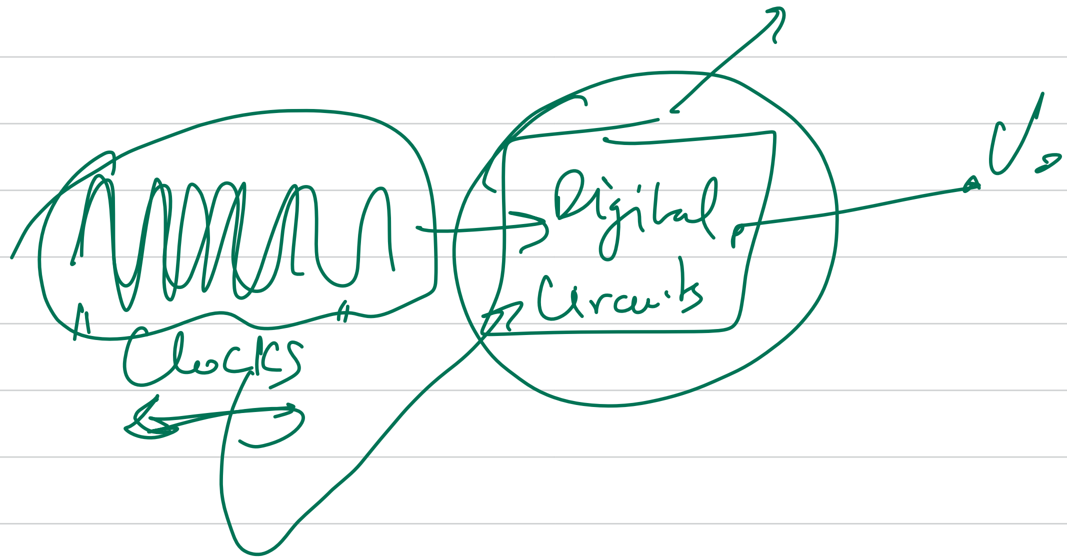
$A_o \to \infty$

$$\frac{K}{\left(1 + \frac{K}{A_o}\right)}$$

10

$-D$


non-inv
+
−
inv:


Digital
Circuits
Clocks
V_o:

"Oscillator"

$V_{dd} = V_{cc}$