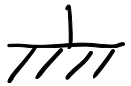
L11 – Differential Measurement

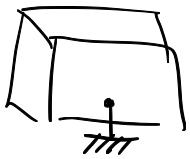
Grounds : A "conductor"

- Symbols

Earth
Mains



Chassis.



PCB ground.
IC ground.

- "Two Groups"

① Safety ground.

-: Not conducting i during normal ops.

- Role: protect people.

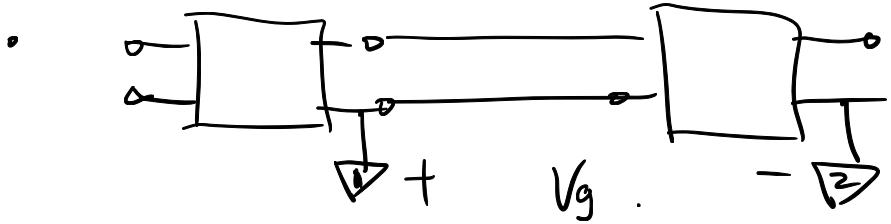
② Signal / power ground

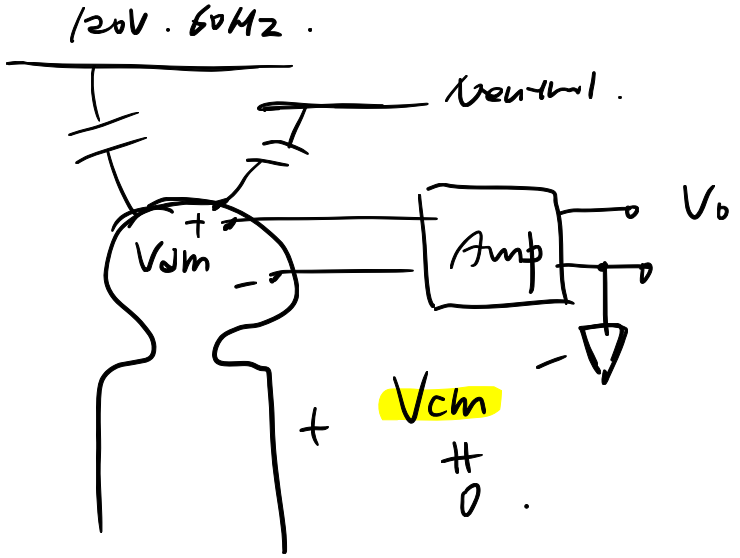
- Conducting 2 during normal ops.

  e.g.) PCB ground plane / trace.

- Role { ① voltage : common ref pot. for node voltages.
  ② current : common low-Z path for return currents

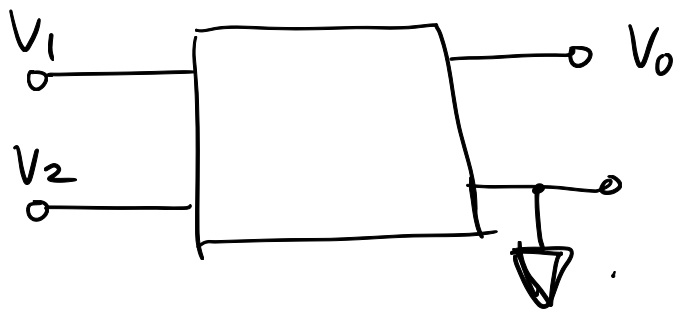
< Common-mode Voltage >





- Need an amp : Diff-input. single-ended output

  "Differential Amp"

- 

Common-mode Voltage : $V_{cm} \triangleq \frac{V_1 + V_2}{2}$

Differential Voltage : $V_{dm} \triangleq V_1 - V_2$

- In many cases, V_{cm} is unwanted & unknown.

  $\Rightarrow$ we want to reject it

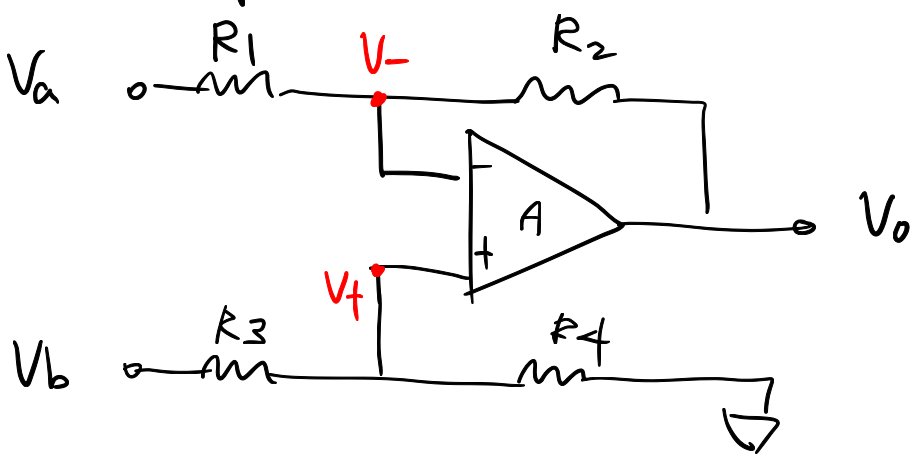
- V_{dm} contains info. but is small. $\rightarrow$ we want amplifier

$$V_o = \uparrow A_{dm}(V_1 - V_2) + \downarrow A_{cm}\left(\frac{V_1+V_2}{2}\right)$$

Common-mode Rejection Ratio (CRMM)

$$CMRR \triangleq \frac{A_{dm}}{A_{cm}} \quad \text{if } A_{cm} \to 0 \Rightarrow \boxed{CMMR \to \infty}$$

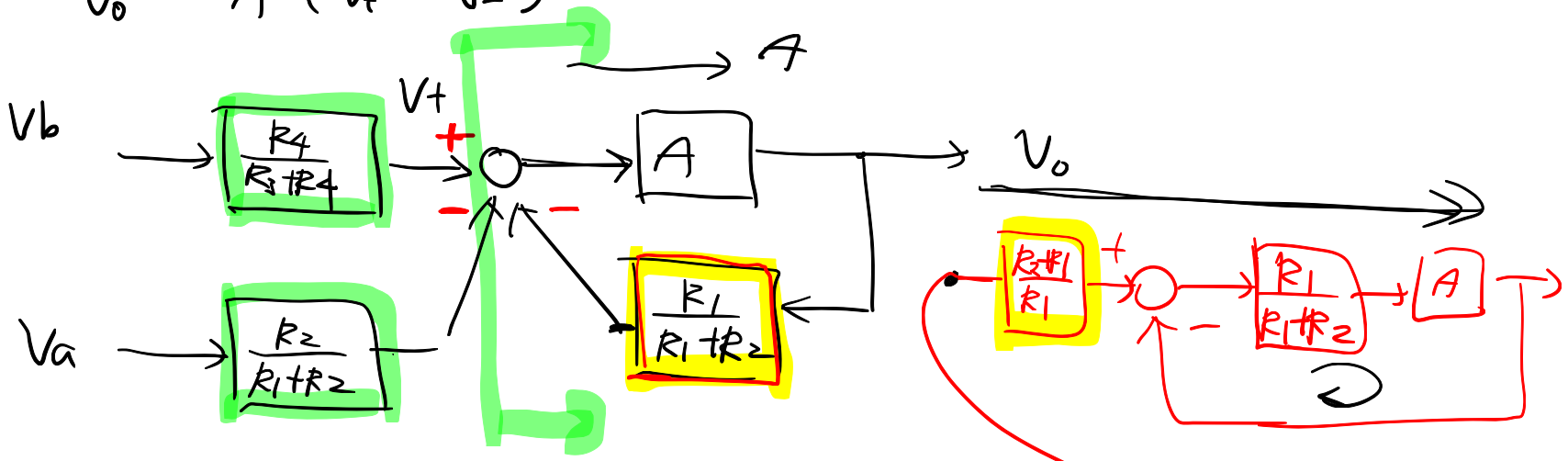
- Diff Amp.



$$V_+ = \frac{R_4}{R_3+R_4} V_b$$

$$V_- = \frac{R_2}{R_1+R_2} V_a + \frac{R_1}{R_1+R_2} V_o$$

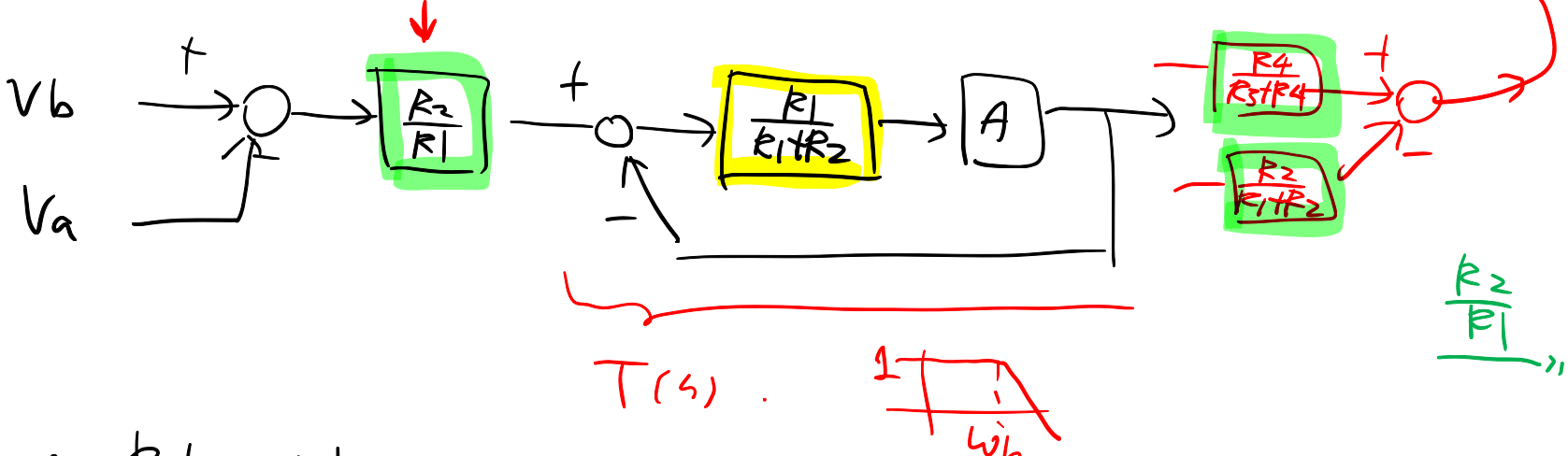
- $V_o = A(V_+ - V_-)$



◎ If $\frac{R_4}{R_3} = \frac{R_2}{R_1} \Rightarrow \frac{R_4}{R_3+R_4} = \frac{R_2}{R_1+R_2}$

① $L(s)$

②



- Below ω_h : $V_o = \frac{R_2}{R_1}(V_b - V_a)$

- $V_{cm} = \frac{1}{2}(V_b + V_a)$ $\Rightarrow$ $V_o = \underbrace{\frac{R_2}{R_1}}_{A_{dm}} \cdot V_{dm} + \underbrace{0}_{A_{cm}} \cdot V_{cm}$

  $V_{dm} = (V_b - V_a)$

$$CMRR = \frac{A_{dm}}{A_{cm}} \rightarrow \text{“}\infty\text{”}.$$

- $A_{cm} \neq 0$. $\Rightarrow$ CMRR is finite.

- CMRR is limited by R. tolerance. (ε)

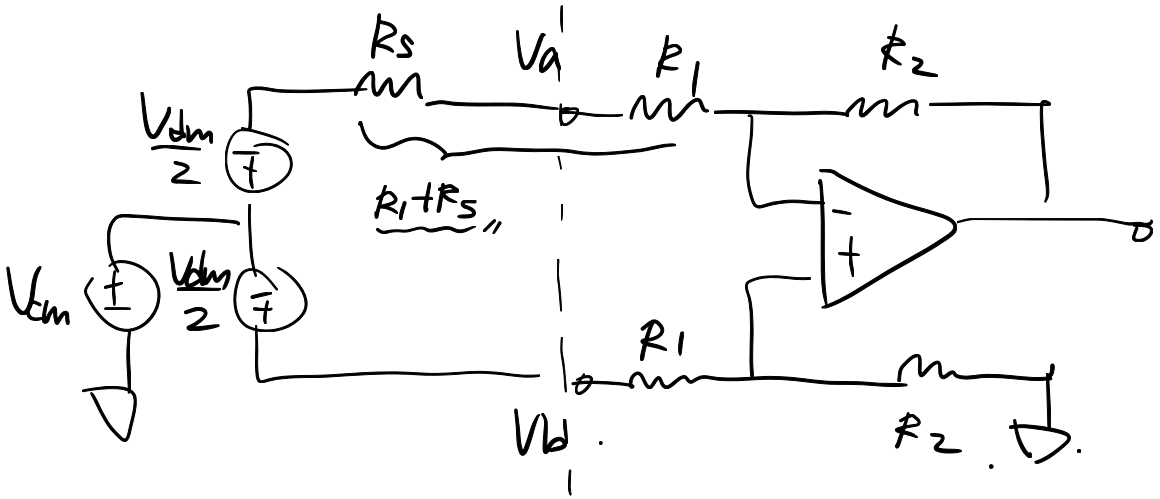
  $\left(CMRR \geq \frac{R_2/R_1 + 1}{4\varepsilon} \right)$

- <u>Diff-Amp</u>. when ① the source Z is small.

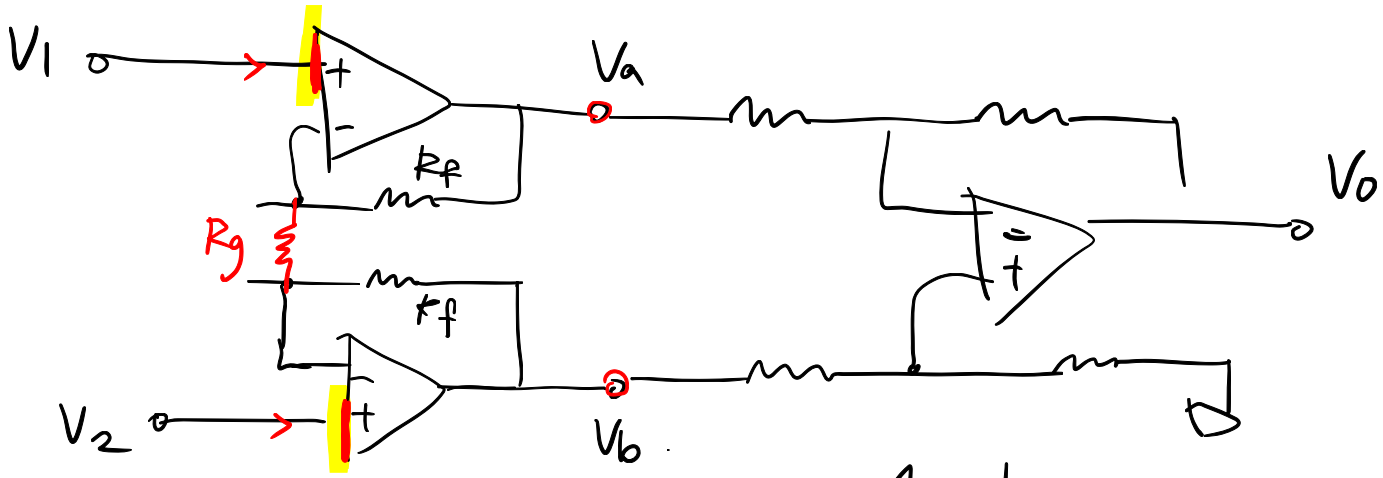
  ② V_{cm} is large.

  <u>$V_{cm} > V_s$</u>

- Limitations



< Buffered Diff-Amp >



$A_{cm} \neq 0$

$$V_a = \frac{R_f + R_g/2}{R_g/2} V_1$$

$$V_b = \frac{R_f + R_g/2}{R_g/2} V_2 .$$

$$V_o = \underbrace{A_{dm}\left(\frac{R_f + R_g/2}{R_g/2}\right)}_{A_{dm}'}(V_2 - V_1) + \underbrace{A_{cm}\left(\text{''}\right)}_{A_{cm}'}\left(\frac{V_2 + V_1}{V_2}\right)$$

$$\text{CMRF}' = \frac{A_{dm}'}{A_{cm}'} = \frac{A_{dm}}{A_{cm}}$$