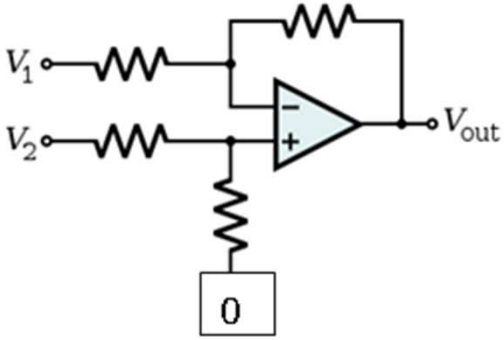
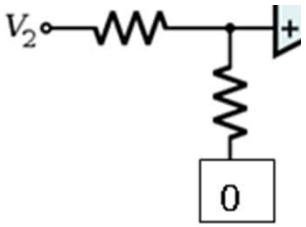
Lecture 6
Review of Instrumentation Amp
Impedance matching – power transfer

Reference:
"bible" of RF circuit design:
Thomas H. Lee "The design of CMOS Radio-Frequency Integrated Circuits"

Review of Lab 5 – Instrumentation Amplifier





Impedance looking into V_1

Set V_2 to zero

→ $v_+ = 0$

→ $v_- = v_+ = 0$

*→ V_1 sees resistance **R** to ground*

Impedance looking into V_2

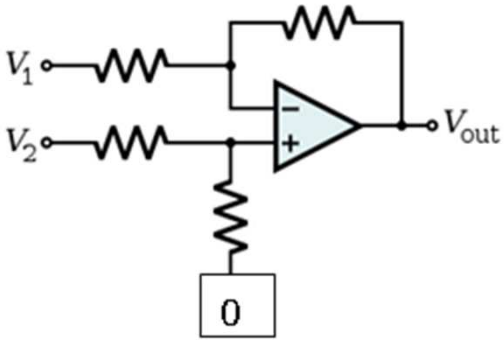
Set V_1 to zero

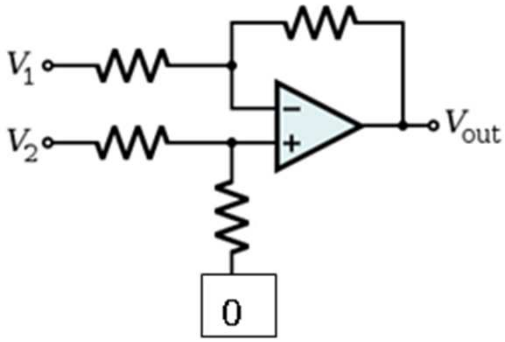
→ No current into v_+

→ Can 'ignore' the bulk of the circuit

*→ V_1 sees resistance **2R** to ground*

Response of difference amplifier





Difference Response:

$\boldsymbol{V_1 \neq 0}$, $V_2 = 0$

$v_- = (V_{out} - V_1)/2 \quad v_+ = 0 \rightarrow v_- = 0 \rightarrow V_{out} = V_1$

$\boldsymbol{V_2 \neq 0}$, $V_1 = 0$

$v_+ = V_2/2; \quad i_+ = V_2/R; \quad i_- = V_{out}/R$

$i_+ + i_- = 0 \rightarrow (V_{out} + V_2)/R = 0 \rightarrow V_{out} = -V_2$

Superposition: $V_{out} = V_1 - V_2$

Common mode response

$\boldsymbol{V_1 = V_2 = V_{cm}}$

$v_+ = V_{cm}/2 \qquad v_- = V_{cm}/2$ *(by golden rule)*

$v_- = (V_{out} + V_{cm})/2$ *(current sum at v_- terminal)*

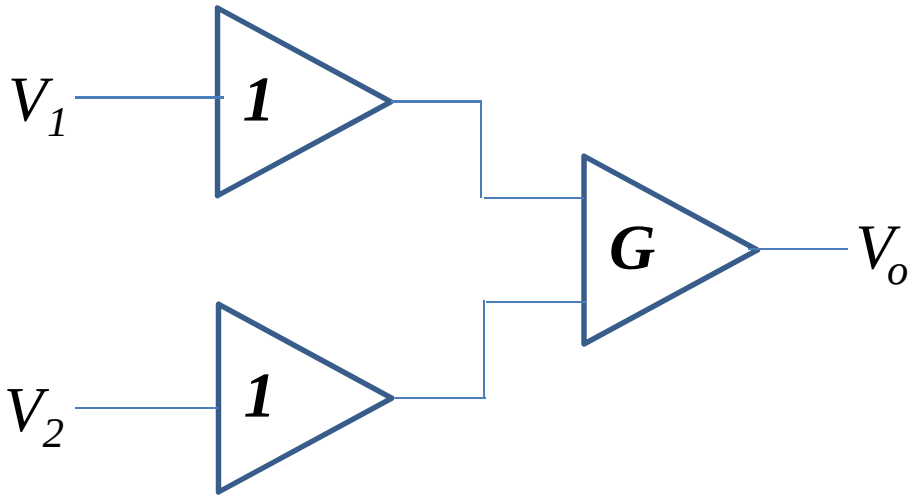
$V_{out} = 0$

Assuming ideal case 4 R's equal

In practice:

$$V_o = V_{cm}\left(\frac{R_4}{R_3 + R_4}\right)\left(1 - \frac{R_2 R_3}{R_1 R_4}\right)$$

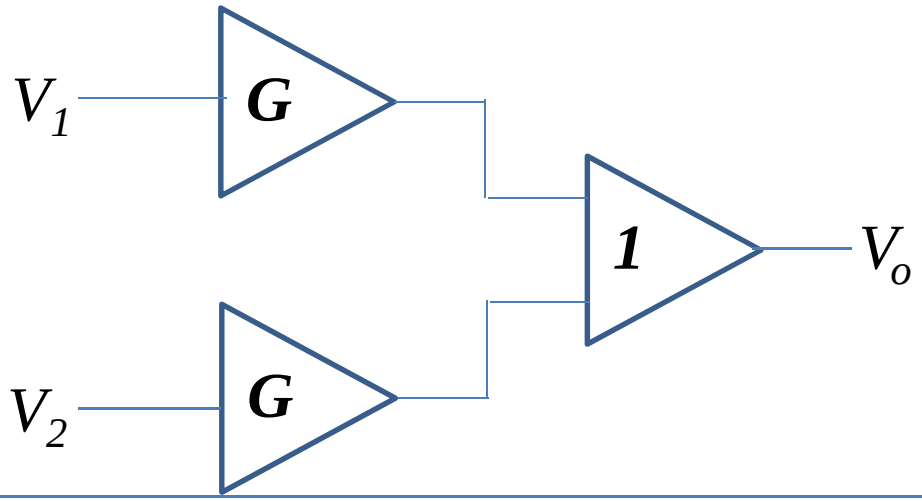
It is best to put the gain stage as close to the input signal as possible



☺ Inputs see high impedance

☹ Difference amplifier gain G no longer has $A_{cm} = 0$

☹ S/N is worsened by noise of unity gain buffer

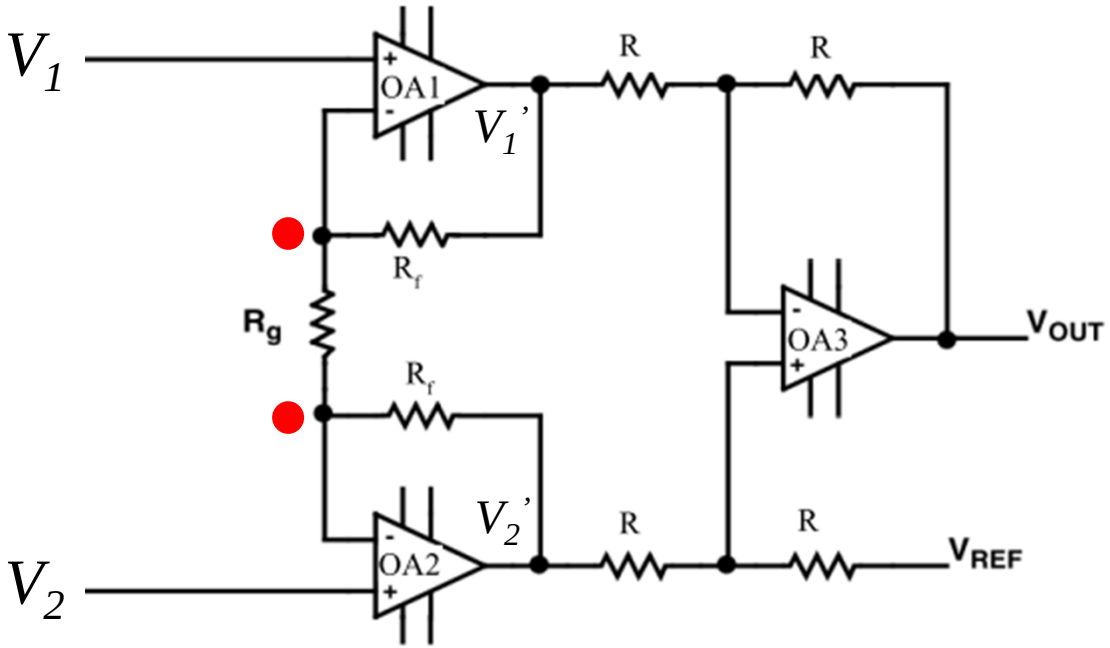


☺ Inputs see high impedance

☺ Difference amplifier has $A_{cm} = 0$

☹ Need precise component matching to get equal G for V_1 and V_2

Kill two stones with one bird
Reduce component count, Increase CMRR



***Differential Gain** is set by R/R_g*
(Easy to calculate by superposition)

***Common mode**: $V_1 = V_2$*

v_- of OA1 and OA2 are equal (two red dots)

$\rightarrow$ No current flows through R_g

$V_1 \rightarrow V_1'$ and $V_2 \rightarrow V_2'$

- ☺ Inputs see high impedance
- ☺ All resistors equal except R_g
- ☺ V_o referred to V_{ref}
- ☺ *A_{cm}~0 within tolerance of 6 R, R_g*