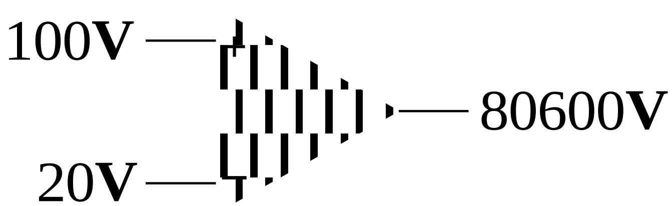
LECTURE 2 OP-AMP

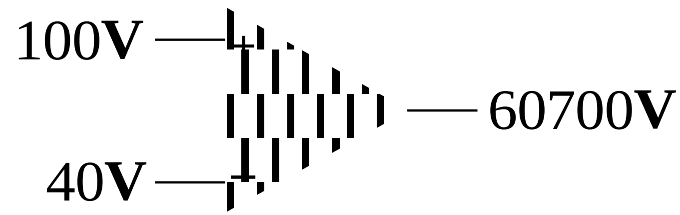
Comparison of ideal and non-ideal Op-Amp

Non-ideal Op-Amp consideration

CMRR EXAMPLE

What is the CMRR?





Solution :

$$\left.\begin{aligned} V_{d1} &= 100 - 20 = 80\,\mathbf{V} \\ V_{c1} &= \frac{100+20}{2} = 60\,\mathbf{V} \end{aligned}\right\} (1) \qquad \left.\begin{aligned} V_{d2} &= 100 - 40 = 60\,\mathbf{V} \\ V_{c2} &= \frac{100+40}{2} = 70\,\mathbf{V} \end{aligned}\right\} (2)$$

From (1) $\quad V_o = 80G_d + 60G_c = 80600\,\mathbf{V}$

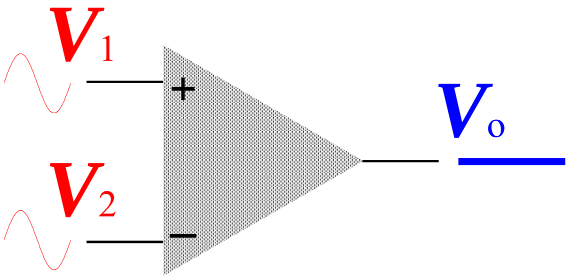
From (2) $\quad V_o = 60G_d + 70G_c = 60700\,\mathbf{V}$

$G_d = 1000$ **and** $G_c = 10 \quad \Rightarrow \mathbf{CMRR} = 20\log(1000/10) = 40\,\mathbf{dB}$

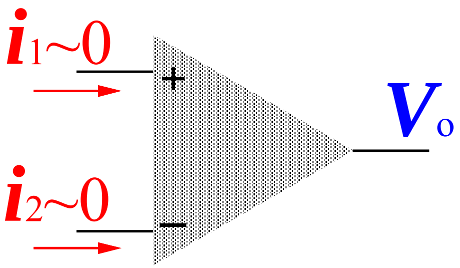
NB: This method is Not work! Why?

OP-AMP PROPERTIES

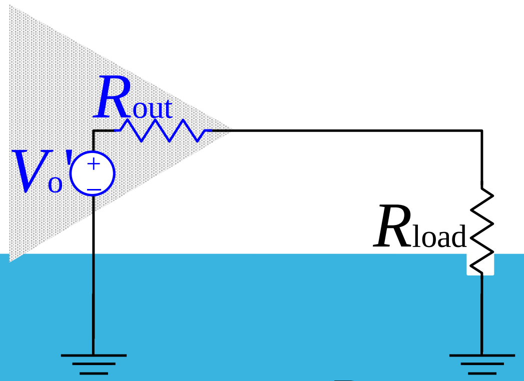
(1) Infinite Open Loop gain
- The gain without feedback
- Equal to differential gain
- Zero common-mode gain
- Pratically, G_d = 20,000 to 200,000



(2) Infinite Input impedance
- Input current i_i ~0A
- T-Ω in high-grade op-amp
- m-A input current in low-grade op-amp



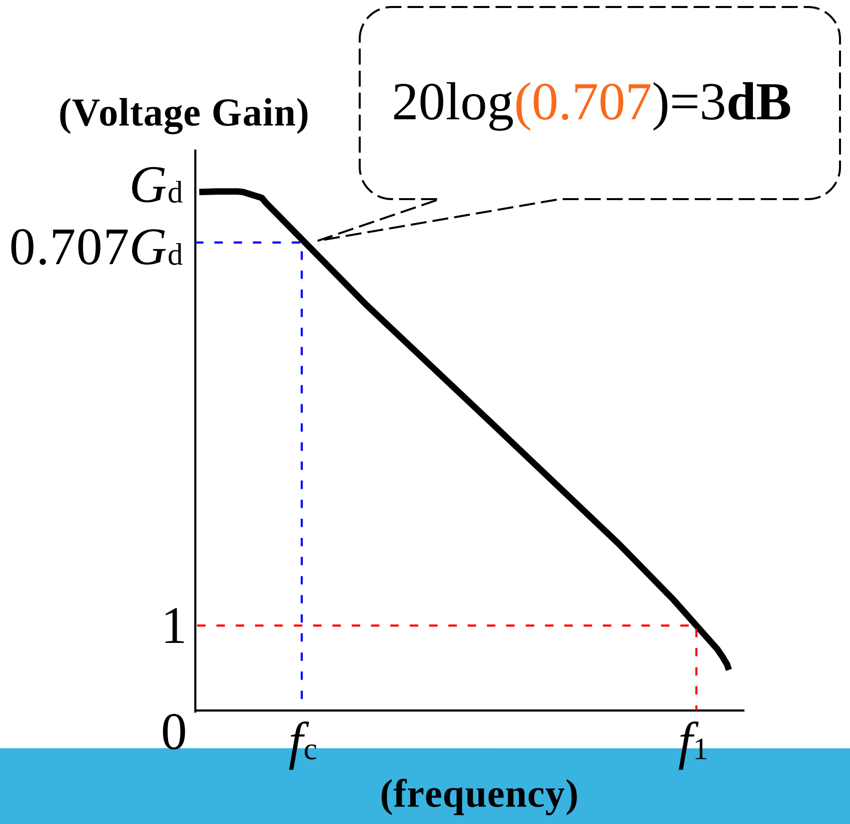
(3) Zero Output Impedance
- act as perfect internal voltage source
- No internal resistance
- Output impedance in series with load
- Reducing output voltage to the load
- Practically, R_{out} ~ 20-100 Ω



$$V_{load} = V_o' \frac{R_{load}}{R_{load} + R_{out}}$$

FREQUENCY-GAIN RELATION

- Ideally, signals are amplified from DC to the highest AC frequency
- Practically, bandwidth is limited
- 741 family op-amp have an limit bandwidth of few KHz.
- Unity Gain frequency f_1: the gain at unity
- Cutoff frequency f_c: the gain drop by 3dB from dc gain G_d



GB Product : $f_1 = G_d\, f_c$

GB PRODUCT

Example: Determine the cutoff frequency of an op-amp having a unit gain frequency f_1 = 10 MHz and voltage differential gain G_d = 20**V**/m**V**

Sol:

Since f_1 = 10 MHz

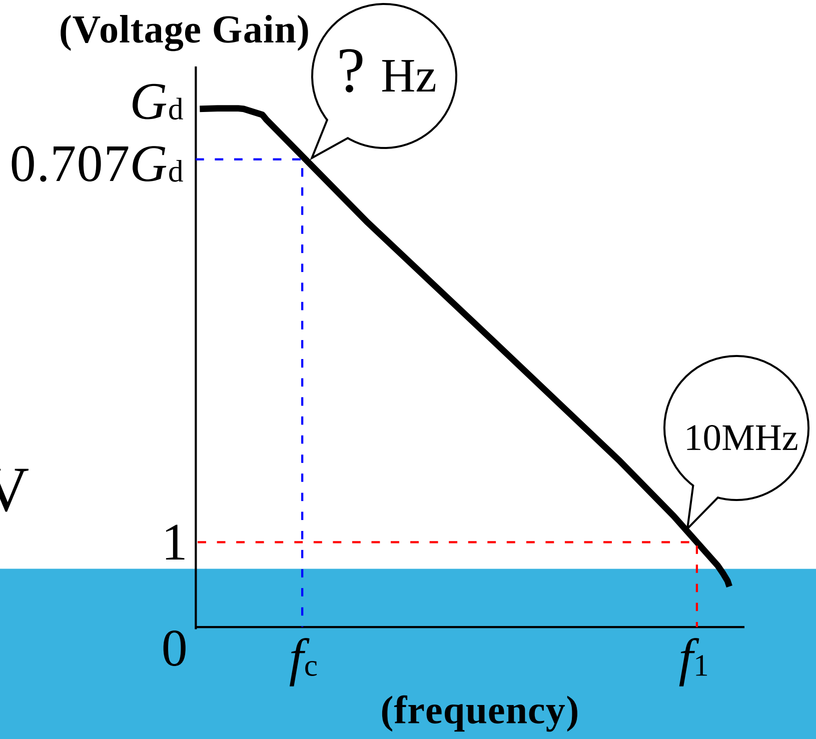
By using GB production equation

$$f_1 = G_d\, f_c$$

$$f_c = f_1 / G_d = 10 \text{ MHz} / 20 \text{ V/mV}$$

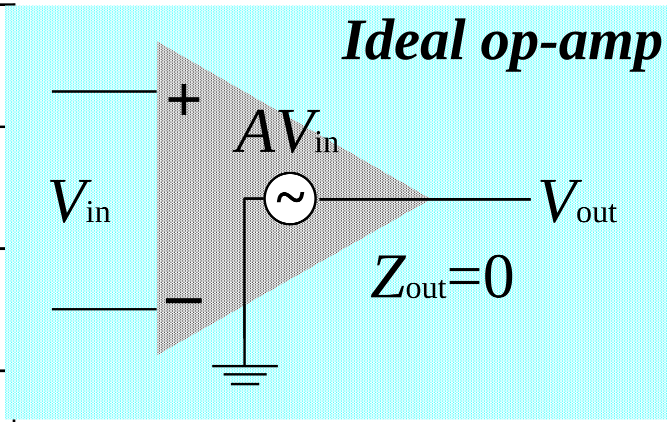
$$= 10 \times 10^6 / 20 \times 10^3$$

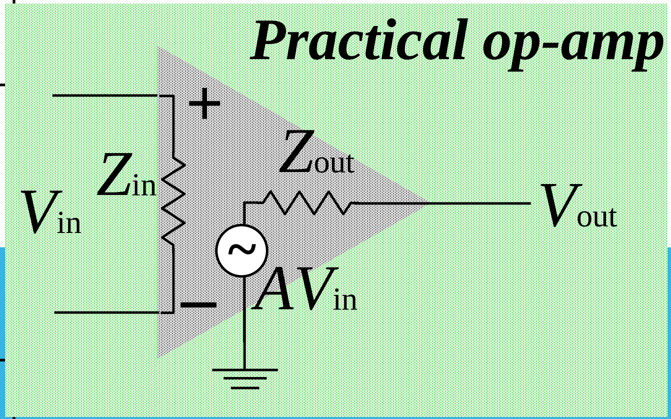
$$= 500 \text{ Hz}$$



IDEAL VS PRACTICAL OP-AMP

	Ideal	Practical
Open Loop gain *A*	∝	10^5
Bandwidth *BW*	∝	10-100Hz
Input Impedance Z_{in}	∝	>1MΩ
Output Impedance Z_{out}	0 Ω	10-100 Ω
Output Voltage V_{out}	Depends only on $V_d = (V_+ - V_-)$ Differential mode signal	Depends slightly on average input $V_c = (V_+ + V_-)/2$ Common-Mode signal
CMRR	∝	10-100dB





IDEAL OP-AMP APPLICATIONS

Analysis Method :

Two ideal Op-Amp Properties:

(1) The voltage between V_+ and V_- is zero $V_+ = V_-$

(2) The current into both V_+ and V_- termainals is zero

For ideal Op-Amp circuit:

(1) Write the kirchhoff node equation at the noninverting terminal V_+

(2) Write the kirchhoff node eqaution at the inverting terminal V_-

(3) Set $V_+ = V_-$ and solve for the desired closed-loop gain

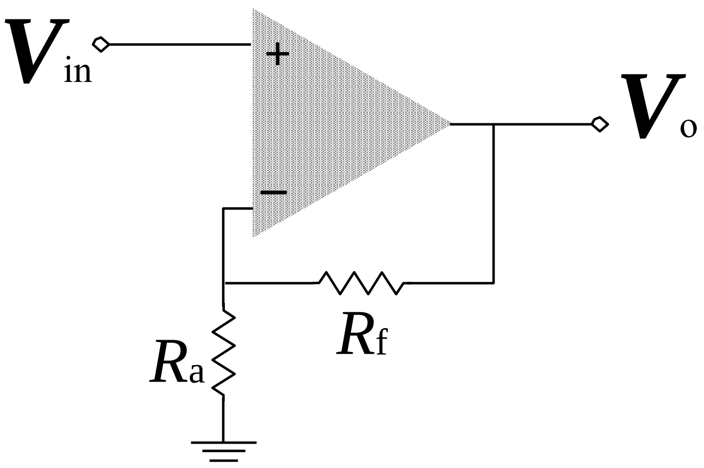
Noninverting Amplifier

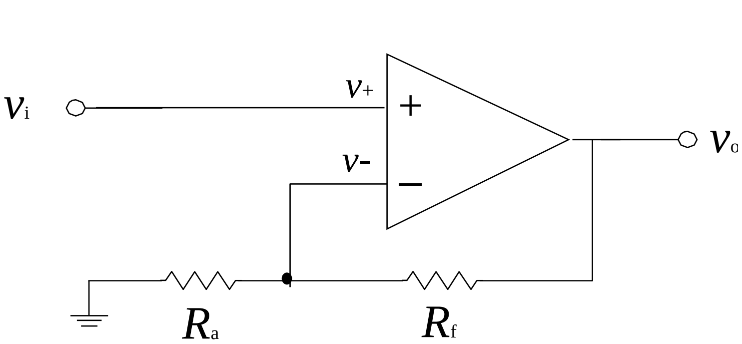
(1) Kirchhoff node equation at V_+ yields, $V_+ = V_i$

(2) Kirchhoff node equation at V_- yields, $\frac{V_- - 0}{R_a} + \frac{V_- - V_o}{R_f} = 0$

(3) Setting $V_+ = V_-$ yields

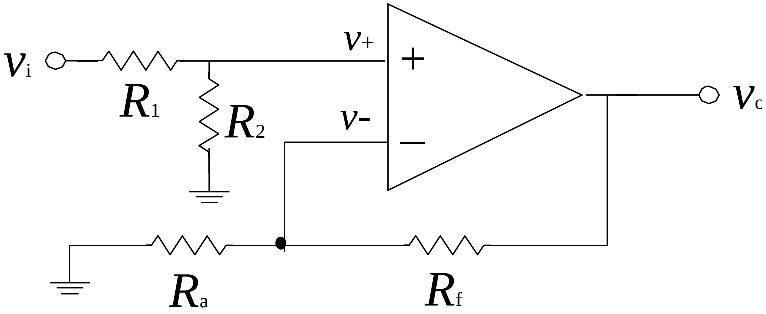
$$\frac{V_i}{R_a} + \frac{V_i - V_o}{R_f} = 0 \quad \text{or} \quad \frac{V_o}{V_i} = 1 + \frac{R_f}{R_a}$$





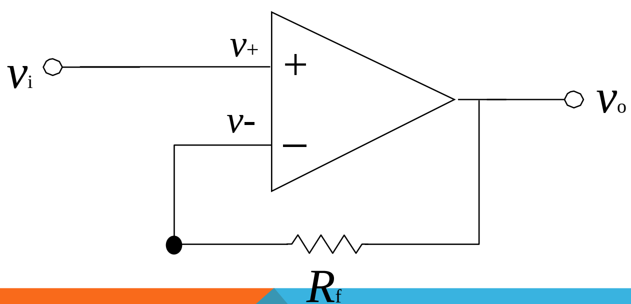
Noninverting amplifier

$$v_o = (1 + \frac{R_f}{R_a})v_i$$



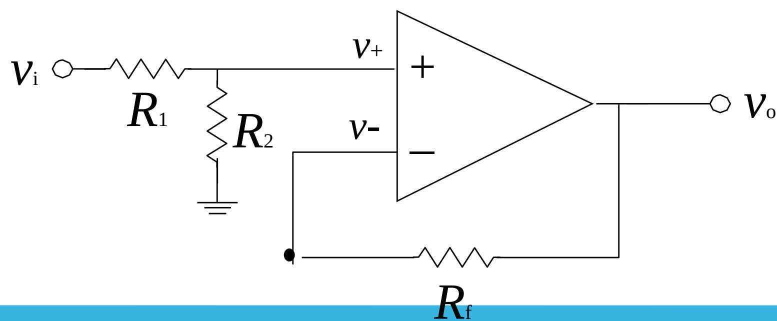
Noninverting input with voltage divider

$$v_o = (1 + \frac{R_f}{R_a})(\frac{R_2}{R_1 + R_2})v_i$$



Voltage follower

$$v_o = v_i$$



Less than unity gain

$$v_o = \frac{R_2}{R_1 + R_2}v_i$$