21.03.2022

Op-Amp. : Negative Feedback

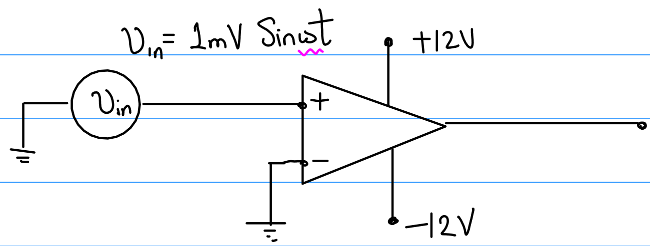
Recap: (i) Ideal & Practical Op-Amp. Parameters

(ii) Differential & Common mode Operation

(iii) Inverting Op-Amp. $\left(\underbrace{A_{CL(IN)} = -\frac{R_2}{R_1}}\right)$

Tune the gain as per the choice of the external resistors R_1 & R_2

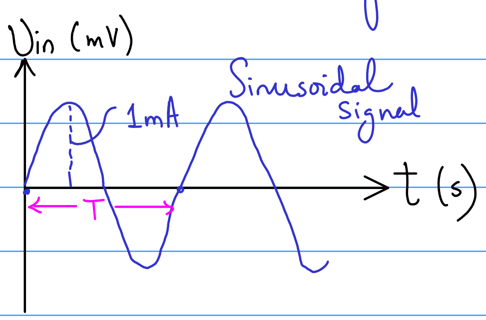
Q: Lets us understand what will happen when we connect the ckt. as per the following:

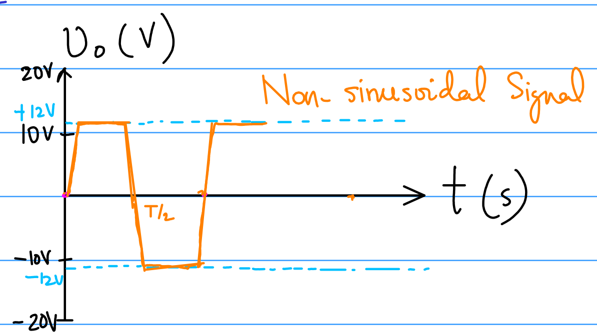


$v_o = 10^5 \cdot 1mV\ Sin\omega t$

$v_o = 100V\ Sin\omega t$

Assuming practical value of $A_{OL} = 10^5$



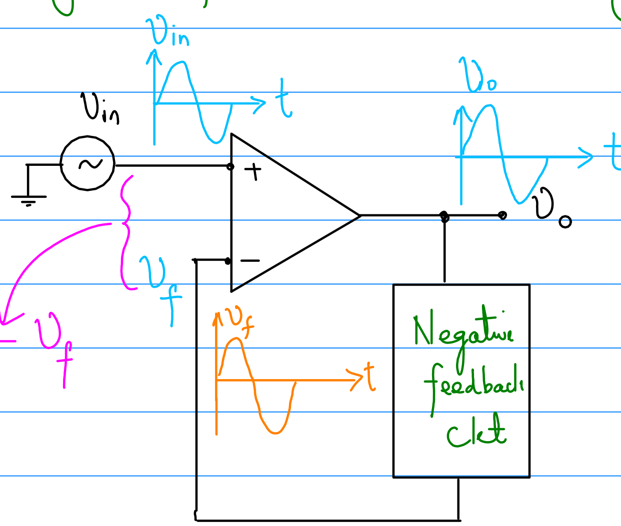


Negative Feedback:

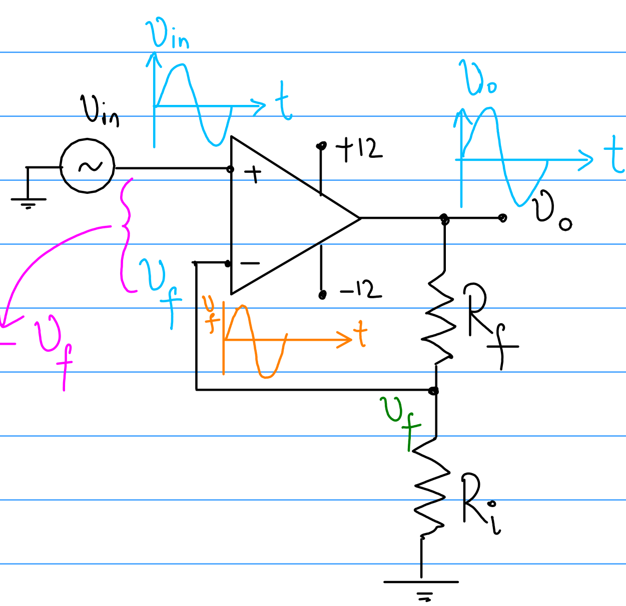
1. Tune the gain of the op-amp with help of external ckt. element (Resistor.)

2. By tuning the gain, we can restrict the op-amp to operate in linear regime. (Not to go into saturation regime).

Non-inverting Amp. ckt. with negative feedback:



$v_{diff} = v_{in} - v_f$



$v_{diff} = v_{in} - v_f$

$$v_f = \frac{R_i}{R_i + R_f} v_o$$

$$v_f = B v_o$$

where $B = \frac{R_i}{R_i + R_f}$

Now, with the negative feedback ckt; the op-amp have effective differential input voltage;

$$V_{diff}(\text{input}) = \underbrace{V_{in}}_{\text{applied to NI input}} - \underbrace{V_f}_{\text{applied to inverting input}}$$

$$V_{diff}(\text{input}) = V_{in} - B V_o$$ where $B = \frac{R_i}{R_i + R_f}$

If we have open-loop gain A_{OL}

$$V_o = A_{OL} \cdot V_{diff}(\text{input})$$ where A_{OL} = Open-loop gain.

$$\Rightarrow V_o = A_{OL} \cdot (V_{in} - B V_o)$$

$$\Rightarrow V_o + A_{OL} \cdot B \cdot V_o = A_{OL} \cdot V_{in}$$

$$\Rightarrow V_o (1 + A_{OL} \cdot B) = A_{OL} \cdot V_{in}$$

$$\Rightarrow \frac{V_o}{V_{in}} = \frac{A_{OL}}{1 + A_{OL} \cdot B}$$

$$\Rightarrow A_{CL(NI)} = \frac{V_o}{V_{in}} = \frac{A_{OL}}{1 + A_{OL} \cdot B}$$

$$\Rightarrow \boxed{A_{CL(NF)} = \frac{A_{OL}}{1 + A_{OL} \cdot B}}$$

As we know, $A_{OL} \sim 10^4 - 10^6$ & $B = \frac{R_i}{R_i + R_f}$

the product $A_{OL} \cdot B \gg 1$

Under this condⁿ:

$$A_{CL(NI)} = \frac{\cancel{A_{OL}}}{\cancel{A_{OL}} \cdot B}$$

$$\Rightarrow A_{CL(NI)} \simeq \frac{1}{B} = \frac{R_i + R_f}{R_i}$$

$$\Rightarrow \boxed{A_{CL(NI)} = 1 + \frac{R_f}{R_i}}$$

under the condⁿ $A_{OL} \cdot B \gg 1$

Conclusion: • Closed loop gain is independent of the value of the open-loop gain.

OR

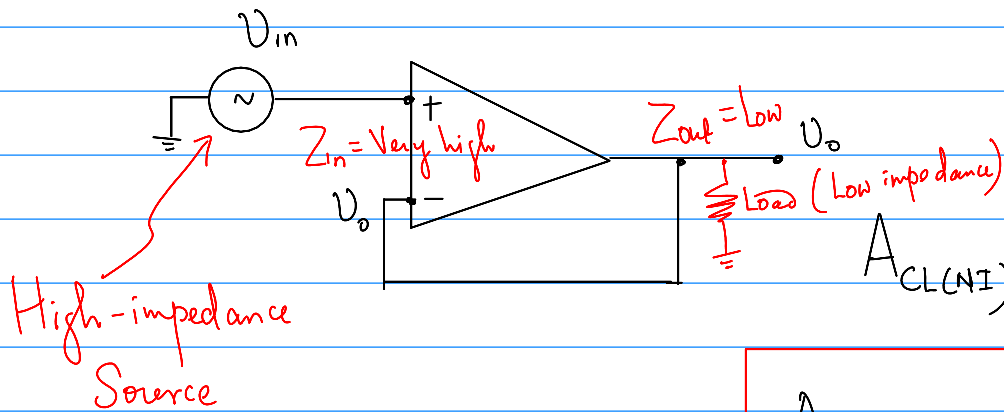
Closed loop gain is dependent on the external ckt element. (R_i & R_f)

	VOLTAGE GAIN	INPUT Z	OUTPUT Z	BANDWIDTH
1.) Without negative feedback	A_{ol} is too high for linear amplifier applications $10^4 - 10^6$	Relatively high (see Table 12–1) ~ MΩ	Relatively low ~ few Ω	Relatively narrow (because the gain is so high) 1 Hz
2.) With negative feedback	A_{cl} is set to desired value by the feedback circuit (R_i & R_f) dependent	Can be increased or reduced to a desired value depending on type of circuit (R_i & R_f) dependent	Can be reduced to a desired value (R_i & R_f) dependent	Significantly wider dependent

Voltage-Follower ckt :

High-impedance Source ⟶ Low-impedance load!

⇒ in voltage-follower ckt : $A_v = 1$ (unity)



$$A_{CL(NI)} = 1 + \frac{R_f}{R_i}$$

Not connected

$$\boxed{A_{CL(NI)} \simeq 1}$$