Module-I.

⇒ Frequency Response of an Amplifier.

★ Objective of Module 1: Determine the "speed Limitations" of circuits.

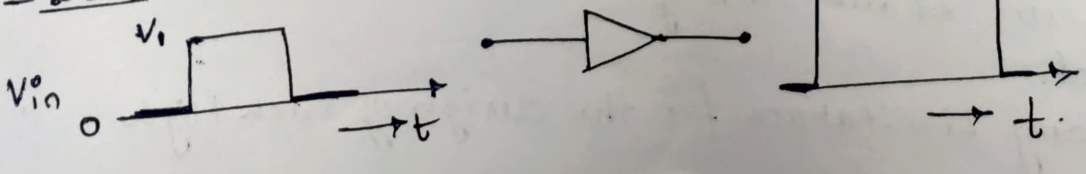
★ preview:

→ Amplifier :- It is the term used to describe a circuit which increases it's input signal, but not all amplifiers are the same as they classified according to their circuit configurations & methods of operation.

- In Electronics, Small signal amplifiers are commonly used devices as they have the ability to amplify a relatively small input signal, Eg: Sensor. Such as photo-device, into a much larger output signal to drive a relay, lamp or loud-speaker.
- The classification of an amplifier depends on the size of the signal, large or small, its physical configuration & how it processes the i/p signal that is the relationship between i/p signal & current flowing in the load.

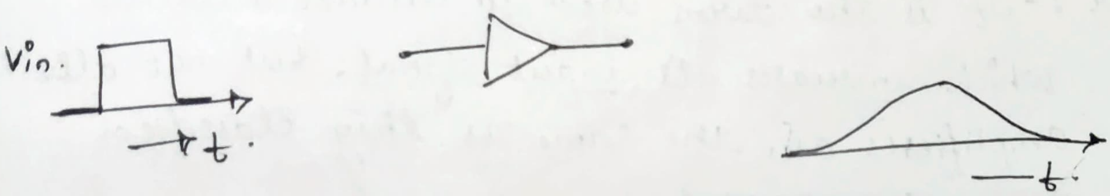
→ what do we mean by Speed Limitations of circuits:
- It means what does the circuit do If we give higher frequency to the circuit.
- Assume we bought the amplifier, & we gave a pulse s/g in time domain.

- I case :



- The above amplifier follows the i/p pretty well, jumps up the o/p i.e amplified the i/p signal pretty well, it may be amplified the original voltage of 100mV to 200mV.
- So we can say that such amplifier are good & Fast amplifier. because the o/p response quickly to the i/p changes.

- Now assume the II case,



- As the above amplifier is not capable of changing our response frequently ~~the~~ to the change happening in i/p.
- So we can say that the above amplifier is a slow amplifier.

- So that is How we need to study the limitation of the speed of the circuit.

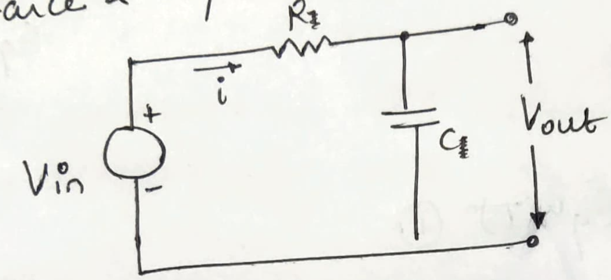
- why need to study this ?
- If you look around, there are lot of circuits you come across Everyday which are High-speed circuits.

for Eg: ① wi-fi - which operates around 2.4 GHz, 5GHz.
② Bluetooth - operates 2.4 GHz.
③ GPS - operates around 1.5GHz.
④ ~~Rada~~ RADAR - particularly automotive radars:
26GHz - 75GHz.
⑤ µprocessors: 4-GHz -5GHz.

- This is How we ~~have~~ have lots of circuits which are run on high speed.
- There are many Limitations for the design of such High Speed circuit.

I] R-C circuit Analysis :

- Lets Assume the RC, simple circuit with input voltage V_{in} & output voltage, V_{out}. where R_1 & C_1 are the active Resistance & capacitance of the circuit.



(a) Time Domain Analysis :

- Since its 'i' the current flowing in the circuit is a function of 't', Therefore current will be the function of Time. i.e $i(t)$ likewise voltage i.e $V_o(t)$.

- use KVL to the above circuit,
  V_{in} is equal to Voltage across Resistance + voltage across the capacitor.

$$V_{in} = Ri(t) + \underline{V_o(t)} \leftarrow \text{voltage across capacitor.}$$

where $V_o(t) = \frac{1}{C}\int_0^t i(t)\,dt \rightarrow$ voltage across the capacitor. $\rightarrow$ (1)

$$\therefore V_{in} = Ri(t) + \frac{1}{C}\int_0^t i(t)\,dt$$

take derivative of above Eq^n.

$$\therefore 0 = R\frac{di(t)}{dt} + \frac{1}{C}i(t) \leftarrow \text{First order differential Equation.}$$

divide above Eq^n by 'R'

$$\frac{di(t)}{dt} + \frac{1}{RC}i(t) = 0$$

Solving above Equation. i.e Differential Equation.

$$i(t) = I_0 e^{-\frac{t}{\tau}}$$

where τ is a time constant,
$\tau = RC$.

when $t=0$

$i(0) = \frac{V_{in}}{R}$ $\therefore I_0 = \frac{V_{in}}{R}$ $\Rightarrow$ Substitute I_0 in the $i(t)$ Equ.

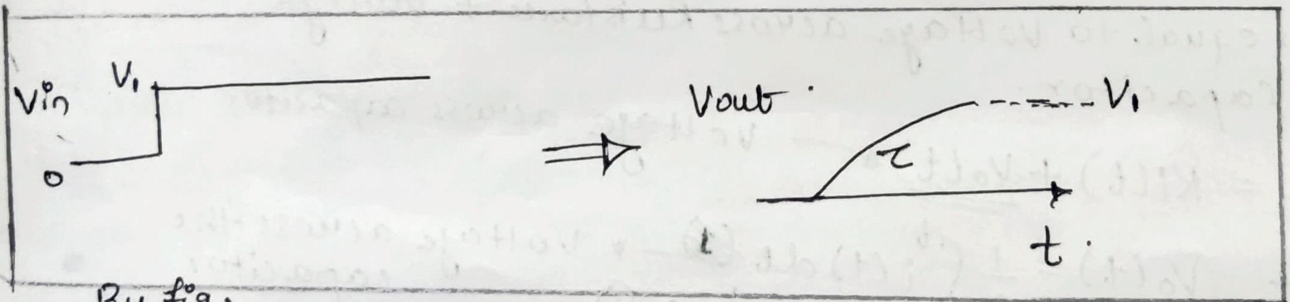
$$i(t) = \frac{V_{in}}{R} e^{-\frac{t}{\tau}}$$

Substitute $i(t)$ in Equ ①

$$V_0(t) = \frac{1}{C}\int_0^t \frac{V_{in}}{R} e^{\frac{-t}{RC}}\, dt$$

$$\boxed{V_0(t) = V_{in}\left(1 - e^{\frac{-t}{\tau}}\right)}$$

where $\boxed{\tau = RC}$.



By fig,

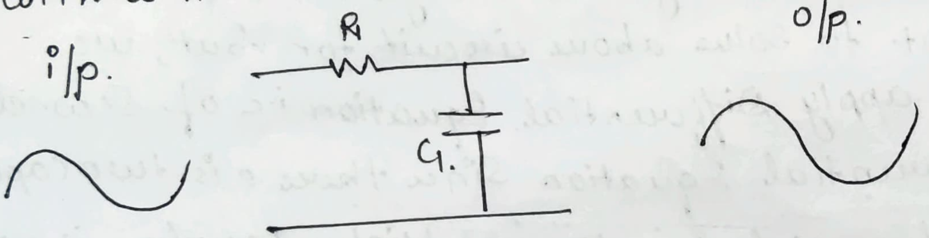
- Vin is a function of time, where Vout is a Exponential Equation which is trying to reach V_1 with the time constant 'τ'
- This Vout cannot respond quickly to i/p change if this time constant (τ) is Excessively long.
- So to improve the speed of the circuit we must minimize 'R, C'

(b) Frequency Domain Analysis: preview:

- This frequency Domain Analysis formulates the response to sinusoidal inputs
- where as sinusoidal means signals which are sin ωt or cos ωt, $\omega \to$ frequency of sig.
- Lets understand the output frequency of RC circuit by 3 cases, pictorial Representation.

1 case:

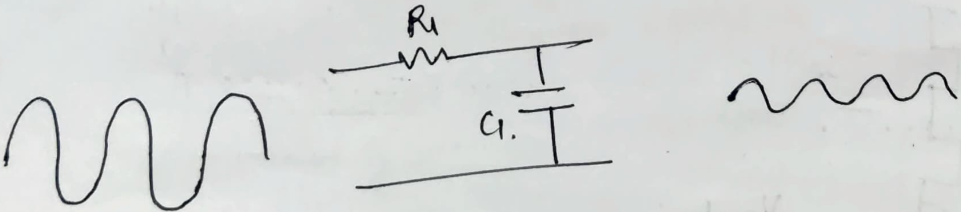
with a normal sinusoidal signal with normal frequency:



o/p has Same amplitude as i/p.

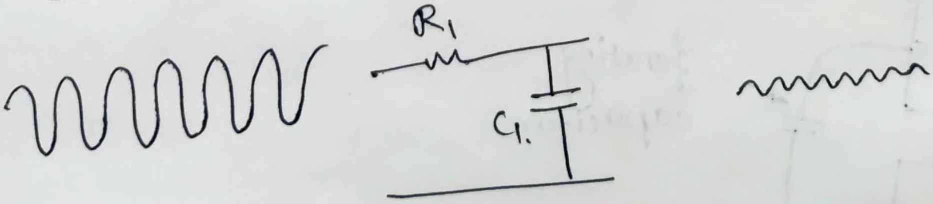
2 case:

with a Higher frequency:



For Higher freq. i/p, the o/p attenuated & Give shorter amplitude.

3 case:



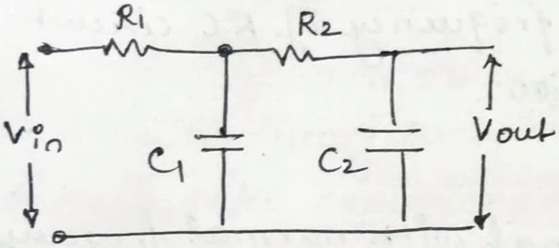
More attenuation to the o/p.

- So this is what we need to understand the complex circuit frequency analysis, How the given circuit response to the Different Higher frequency.

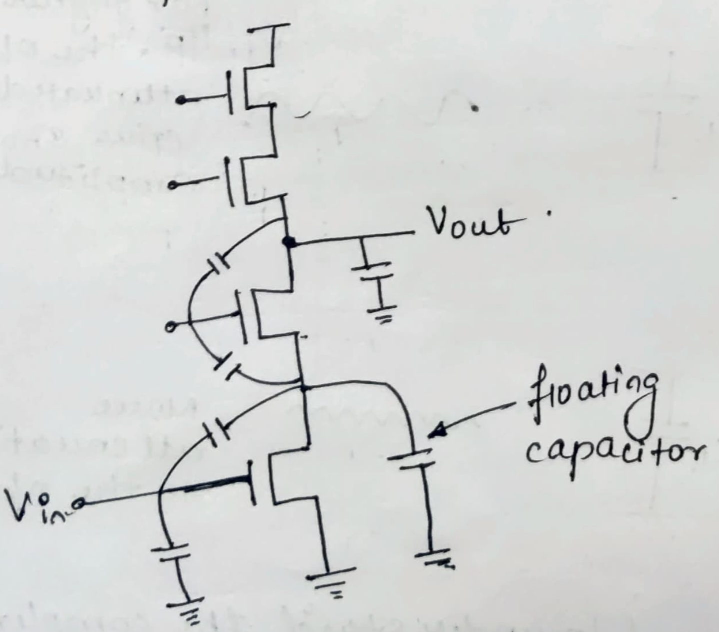
- ~~As we see~~ from the above pictorial Representation, we can assume that as the frequency increases the signal Experiences attenuation.

→ Why we go from time Domain Analysis to frequency Domain Analysis? / Need of Frequency Domain:

- Lets assume the circuit other than RC simple circuit,



- Since the capacitor charges & discharges w.r.t time
∴ If we want to solve above circuit for Vout, we need to apply Differential Equation i.e of Second Order differential Equation Since there is two capacitors
- Solving differential Equation of Higher order is not feasible.
- what if we have cascode circuit like below,



- If we are interested in frequency response above circuit, we need to assume lot of floating circuit between the MOSFET's.

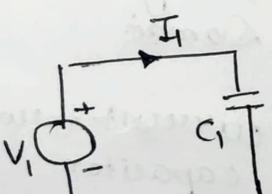
- For so many capacitor, we need to Solve Higher to Higher Order Differential Equation which is not feasible.
- To avoid the complexity, If we perform the analysis in frequency Domain, the result interpretation will be Easier than the Time Domain Analysis.

⇒ **Lets Review circuit Theory concepts:**

- To proceed with other theory we require ~~to~~ some circuit theory concepts.
- Lets take capacitor, since it is more complex component in any circuit.
- To Develop Higher & complex circuit we will proceed with basic circuit first.

①

Time Domain.



- we already know, the current flowing through the capacitor is ~~the ca~~ equal to the capacitor value times to the Derivative of voltage across the capacitor.

∴ i.e $\boxed{I_1 = C_1 \frac{dV_1}{dt}}$

Freq. Domain.

$I_1 = C_1 S V_1$

$\frac{V_1}{I_1} = \frac{1}{C_1 S}$

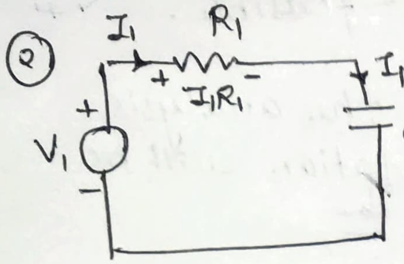
where,

$\frac{V_1}{I_1}$ called as

- Impedance of the circuit.
- Impedance is Similar to resistance Except it applies to reactive Devices such as capacitor, inductor.

Time Domain.

(2)



$V_1 =$ Voltage across Resistor + Voltage across Capacitor.

$$= R_1 I_1 + \frac{1}{C_1}\int I_1\, dt.$$

[we have, $I_1 = C_1 \frac{dv}{dt}$ Integrate to obtain 'V']

$$\therefore \boxed{V_1 = R_1 I_1 + \frac{1}{C_1}\int I_1\, dt}$$

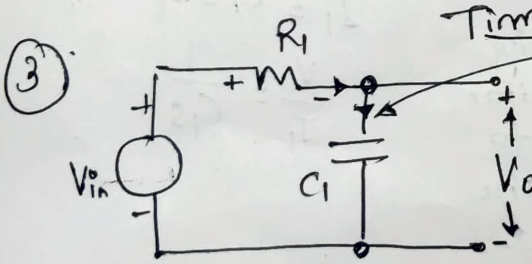
Frequency Domain.

$$\boxed{V_1 = I_1 R_1 + \frac{I_1}{C_1 s}}$$

$$\left[\frac{V_1}{I_1} = \frac{1}{C_1 s}. \quad \therefore V_1 = \frac{I_1}{C_1 s}\right]$$

$\therefore$ The Equation obtained from frequency Domain analysis is easier to solve than Time Domain.

(3)



Time domain.

$I_1 = C_1 \frac{dv_{out}}{dt}$. [current through capacitor]

Take same circuit as above, now we need to find V_{out} i.e output voltage.

- current flowing through capacitor is $I_1 = \frac{C_1 dv_{out}}{dt}$.

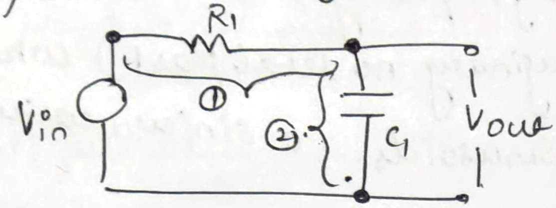
Now same current going through R_1 which gives voltage drop of $R_1 C_1 \frac{dv_{out}}{dt}$. [$\because V_R = R_1 I_1$]

$$V_{in} = V_R + V_{out}.$$

$$V_{in} = R_1 C_1 \frac{dv_{out}}{dt} + V_{out}$$

Frequency Domain.

- If you will see the ~~Rest~~ circuit there are two impedance through the terminals.



- These two impedance acting as a voltage divider of the circuit

$$\therefore V_{out} = \frac{\left(\text{Impedance through capacitor}\right)}{\left(\text{Impedance through capacitor}\right) + \left(\text{Impedance through Resistor}\right)} \times V_{in}.$$

$$\boxed{V_{out} = \frac{\frac{1}{C_1 s}}{\frac{1}{C_1 s} + R_1} V_{in}.}$$

{ Parallel circuit }

$$\therefore V_{out} = \frac{\frac{1}{\cancel{C_1 s}}}{\frac{1 + R_1 C_1 s}{\cancel{C_1 s}}} \cdot V_{in}.$$

$$\boxed{V_{out} = \frac{1}{R_1 C_1 s + 1} \cdot V_{in}.}$$

where $\frac{1}{R_1 C_1 s + 1}$ is called as Transfer function of the circuit

since it is ~~tell~~ us How ~~to~~ the i/p is transfer to the o/p.

this, $\frac{1}{R_1 C_1 s + 1}$ Represent; as $H(s)$.

$$\therefore \boxed{H(s) = \frac{1}{R_1 C_1 s + 1}}$$

~~complex number preview~~ → Transfer Function:

- 'S' is generally a complex frequency, we can assume that $\boxed{S = j\omega}$, (just an imaginary no real part) when signals of interest are sinusoids. i.e. $\sin j\omega$, $\cos j\omega$.

Eg: - Lets the H(s) we obtained through RC circuit,

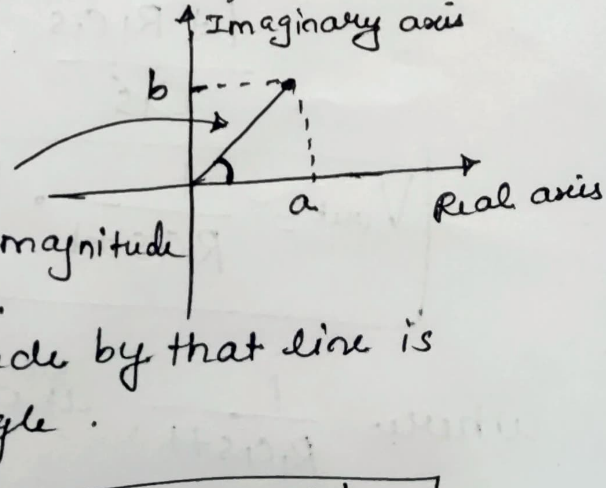
$$H(s) = \frac{1}{R_1 C_1 S + 1}$$

If we say input signal i.e V_{in} is a sinusoidal signal then $S = j\omega$.

$$\therefore \; H(j\omega) = \frac{1}{R_1 C_1 j\omega + 1}$$

= complex number preview:

A complex number a+jb can be represented in polar form:



- length of this line called as magnitude of complex No.
- The angle made by that line is called phase angle.

$\boxed{\text{magnitude} = \sqrt{a^2 + b^2}}$, $\boxed{\text{phase} = \tan^{-1}\frac{b}{a}}$

Lets take the magnitude of Transfer function of RC circuit.

$$H(s) = \frac{1}{R_1C_1s+1}$$

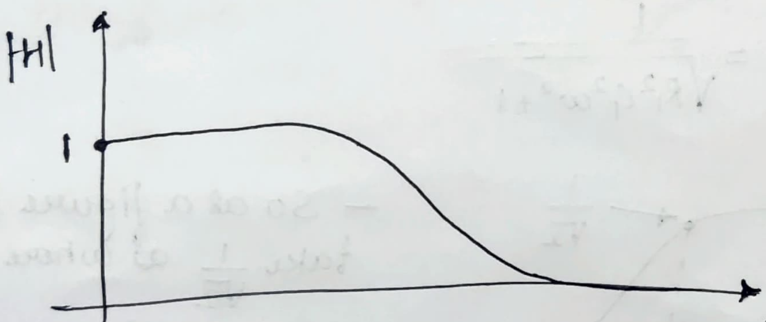
$$H(j\omega) = \frac{1}{R_1C_1j\omega+1} \Rightarrow \frac{1}{1+jR_1C_1\omega}$$

compare with $a+jb$.

where $a=1$, $b=R_1C_1\omega$.

$$\therefore \quad |H(j\omega)| = \frac{1}{\sqrt{1+R_1^2C_1^2\omega^2}} \Rightarrow \frac{1}{\sqrt{R_1^2C_1^2\omega^2+1}}$$

Lets plot the above circuit Transfer function



ω (rad/s)
$= 2\pi f$ (Hz)

If $\omega=0$, $|H|=1$

If we increase ω, the value ~~$R_1^2C_1^2\omega^2$~~ will drops.

If ~~to~~ ω reaches to infinity, the value will become 0.

- Therefore, $\omega\uparrow$ i.e. frequency increases, the circuit will drop.
- In the start we applied low frequency, the circuit gain is 1, as frequency increases the ~~gai~~ gain drops & ultimately at High frequency the ~~gia~~ gain is 0, shows nothing.

⇒ How to compute the frequency Response.

① Determine the Transfer Function, $H(s)$

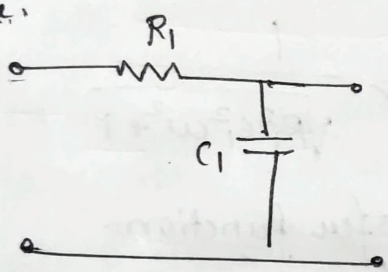
② Replace s with $(j\omega)$ ⇒ $H(j\omega)$ → (Giant complex number)

③ Compute the magnitude of $H(j\omega)$ i.e $|H(j\omega)|$

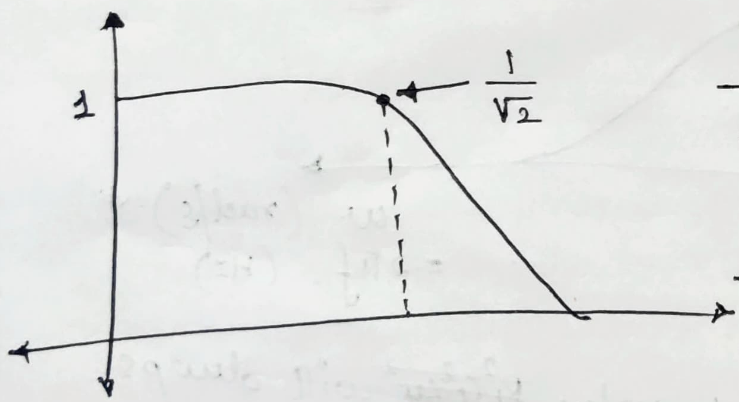
$|H(j\omega)|$ ⇒ frequency Response.

④ plot the Response to interpret circuit is fast or slow.

Example:

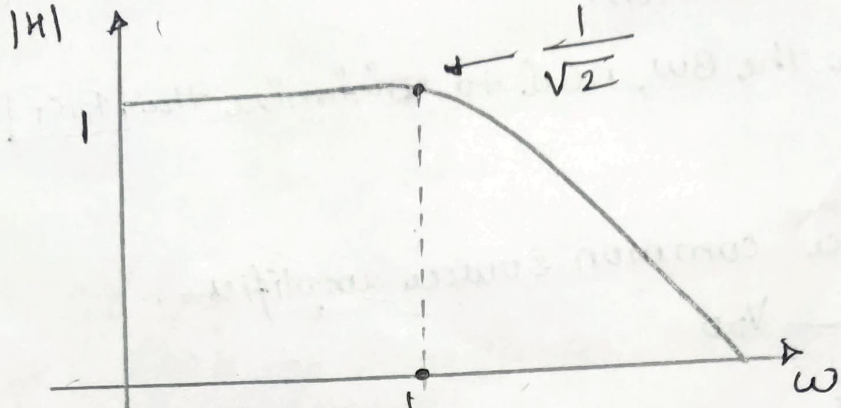


$$|H(j\omega)| = \frac{1}{\sqrt{R_1^2 C_1^2 \omega^2 + 1}}$$



- So as a figure of merit take $\frac{1}{\sqrt{2}}$ where magnitude drops.
- This is called as bandwidth of circuit.

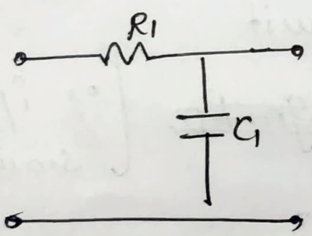
- We have one point to measure the goodness of the circuit i.e Bandwidth.
- Bandwidth means the freq. range across which the input signal will go the O/P.
- Analyse above plot.
- Equate $\frac{1}{\sqrt{R_1^2 C_1^2 \omega^2 + 1}} = \frac{1}{\sqrt{2}} = \frac{1}{R_1 C_1}$



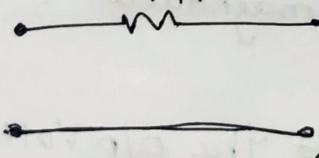
-3dB Bandwidth $= \frac{1}{R_1C_1}$

-3dB means the output is 3dB which is less than the i/p. ∵ the gain is $\frac{1}{\sqrt{2}} < 1$.

- why this circuit attenuates at this frequency?
- consider the above RC circuit.



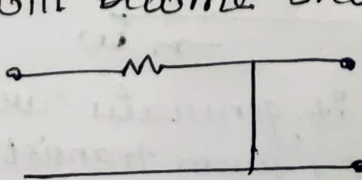
- In the start, The impedance $\left(\frac{1}{j\omega C_1}\right)$ was large, ∵ ω is small.
- So we can consider as open circuit and Reduces to this



, Such circuit cannot attenuate

It goes through this Give gain = 1

- If High frequency passes, the impedance of capacitor drops, Capacitor act as a short circuit. circuit will become short circuit.

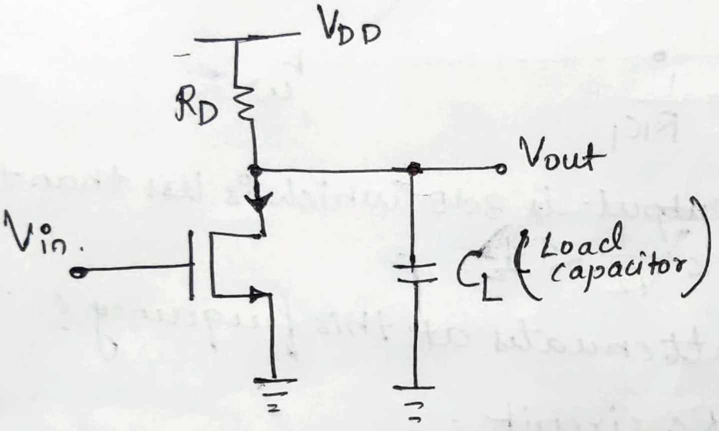


- So we get nothing on the output circuit.
- That is why circuit attenuates on High frequency.

wp.

- So from the previous interpretation, capacitors generally affects the Bandwidth.
- To maximize the BW, need to minimize the $\boxed{R_1C_1}$ i.e basically capacitor.

Example. Take common source amplifier.

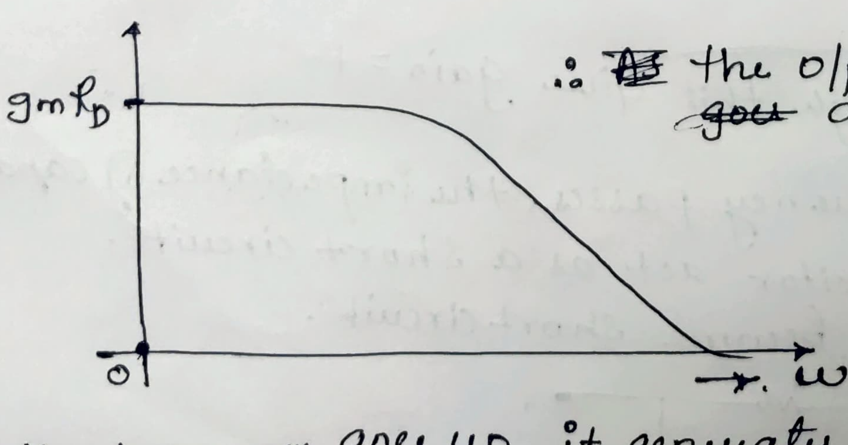


- $|A_v|$ is a voltage gain of the circuit.

where $|A_v| = \dfrac{\text{Ouput Amplitude}}{\text{i/p Amplitude}}$ ~~= gm RD~~ [∵ i/p is sinusoid]

- At low freq. the capacitor (C_L) is an open circuit, because the current through the capacitor is small, so now there is only transistor & Resistor in circuit, so the gain is '$-g_m R_D$' → $g_m R_D$, since it is magnitude.

∴



∴ ~~As~~ the o/p Voltage amplitude ~~goes~~ drop as frequency increases.

- As the frequency goes up, it generates current inside the transistor, this current coming from transistor, only less current coming from Resistor, The voltage across Resistor is small ∴ the o/p gain goes down.

⇒ Poles & zero preview.

$$H(s) = \frac{N(s)}{D(s)} = \frac{\text{Numerator}}{\text{Denominator}}.$$

Generally, Roots of Numerator called as zeros & Roots of Denominator called as poles.

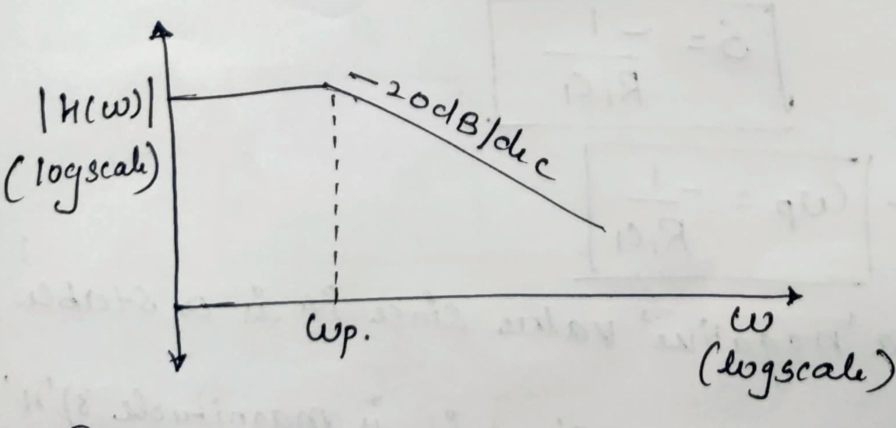
⇒ Bode's Rules :- To construct frequency Response by using poles & zeros of Transfer Function.

~~Ist Rule: As 'ω' approaches the pole~~

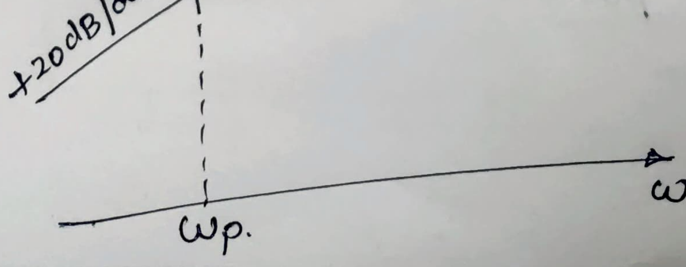
Ist Rule : As 'ω' passes the pole frequency the slope of |H| decrease by 20dB/dec.

- 20dB/dec means if frequency goes up by factor of 10 the magnitude changes the factor of 10

Example. ①

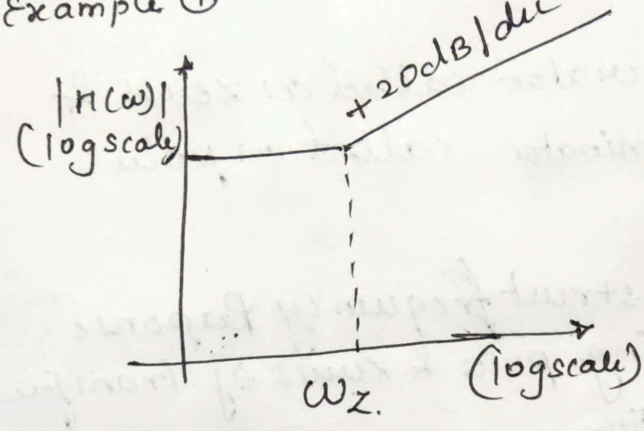


②

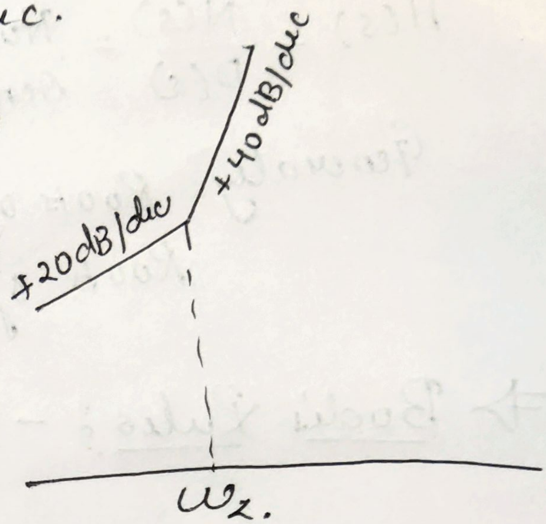


$\underline{II^{nd}}$ Rule: As 'ω' passes a zero frequency, the slope of $|H(\omega)|$ increases by 20 dB/dec.

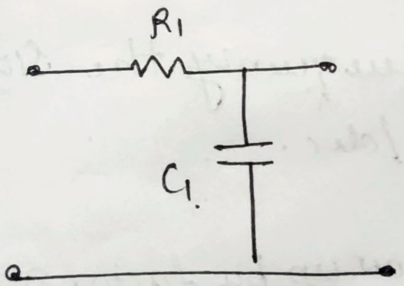
Example ①.



②



<u>Example:</u>



$$H(s) = \frac{1}{R_1C_1s + 1}$$

- There is No zero.
- Roots of Denominator to obtain pole frequency.

$$R_1C_1s + 1 = 0$$

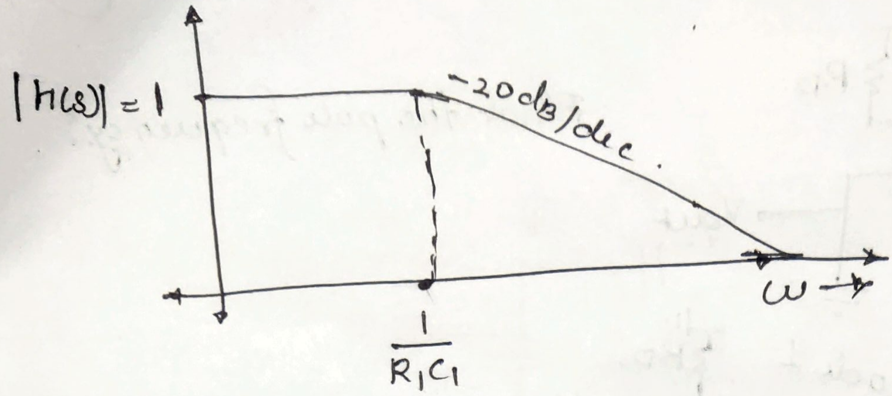
$$R_1C_1s = -1$$

$$\boxed{s = \frac{-1}{R_1C_1}}$$

$$\therefore \boxed{\omega_p = \frac{-1}{R_1C_1}}$$

- The pole has a 'negative' value since it is a stable circuit
- we take ω_p as positive since it is magnitude of 'H'

$$\therefore \omega_p = \frac{1}{R_1C_1}.$$

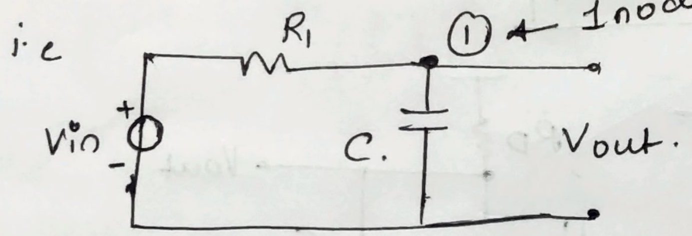


At low frequency, $\omega = 0$ $|H(\omega)| = 1$

⇒ Finding poles by inspection:

- We can Estimate or assume that each node in the signal path contributes a pole.

i.e

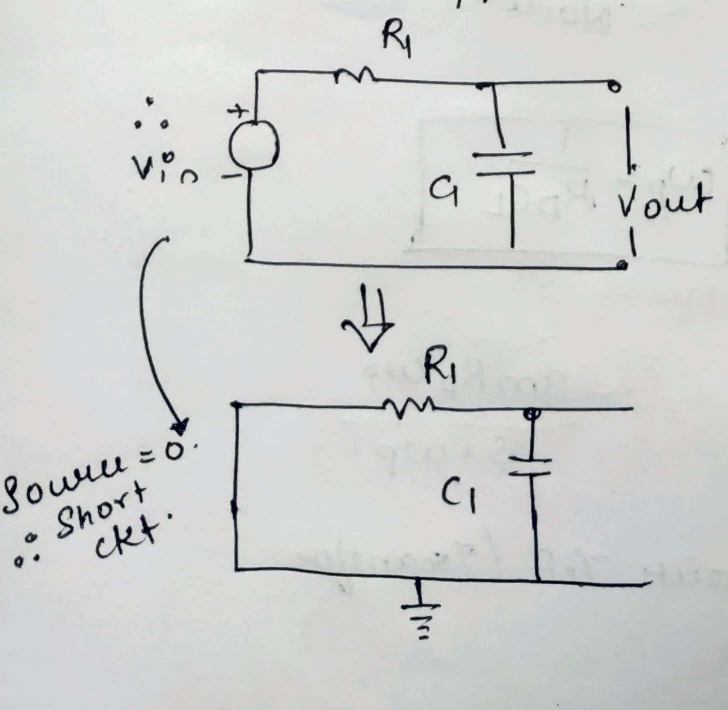


To calculate the pole:

(a) Find the Resistance from that pole to an AC ground.

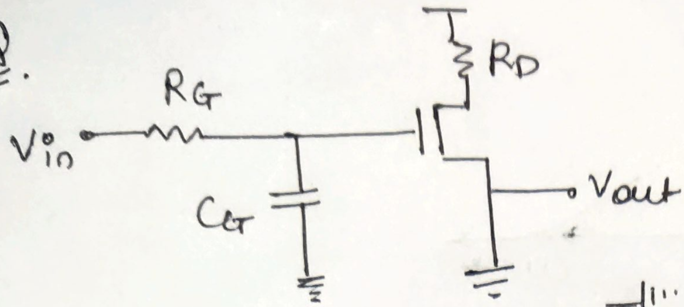
(b) Find the capacitance from that node to an AC ground.

This both case applicable when all independent Sources = 0.

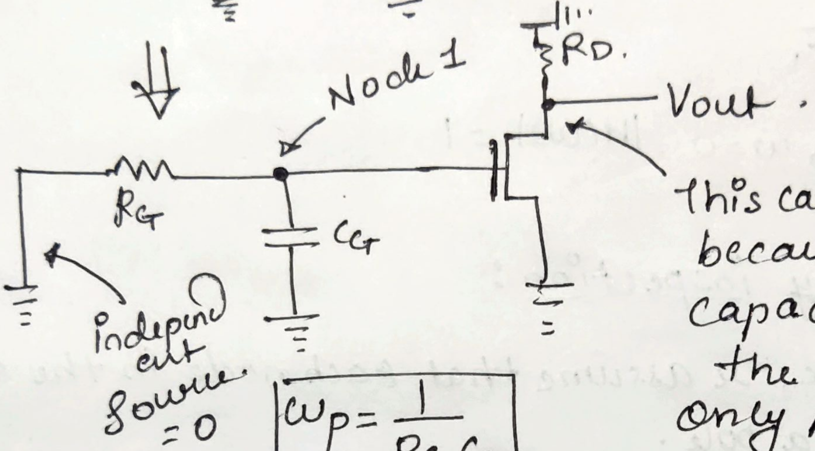


$$\omega p = \frac{1}{RC}.$$

Q. Find the pole frequency?



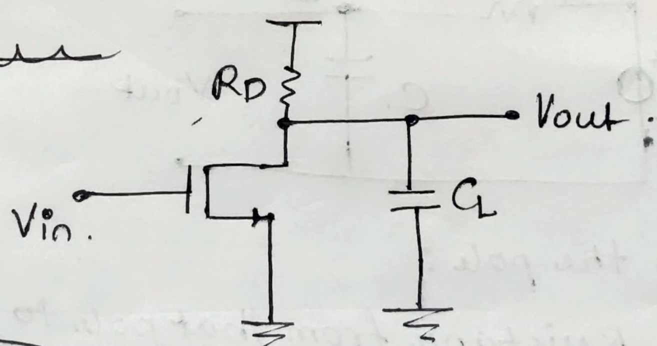
⇓



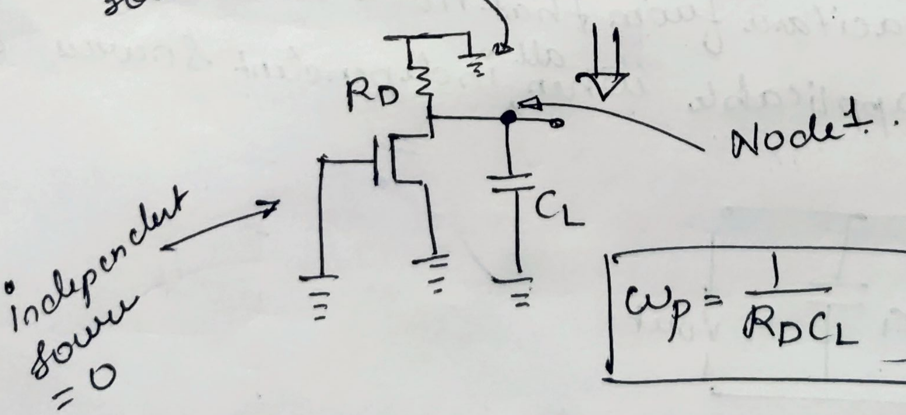
This can't be node because there is no capacitance from the node to AC Gnd. Only Resistance won't do.

$$\boxed{\omega_p = \frac{1}{R_G C_G}}$$

Q.



⇓

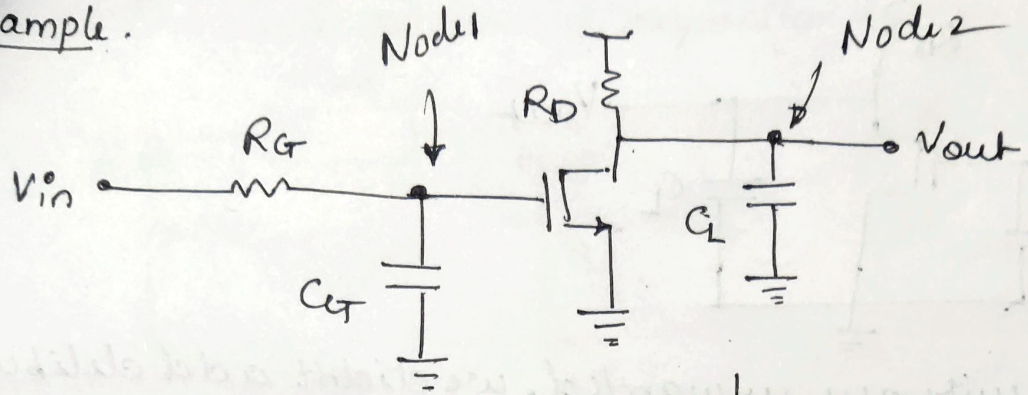


$$\boxed{\omega_p = \frac{1}{R_D C_L}}$$

$$T.F = \frac{V_{out}}{V_{in}} = \frac{-g_m R_D}{1 + \frac{s}{\omega_p}} = \frac{-g_m R_D \omega_p}{s + \omega_p}$$

- Here we try to take out T.F (Transfer function by just inspection)

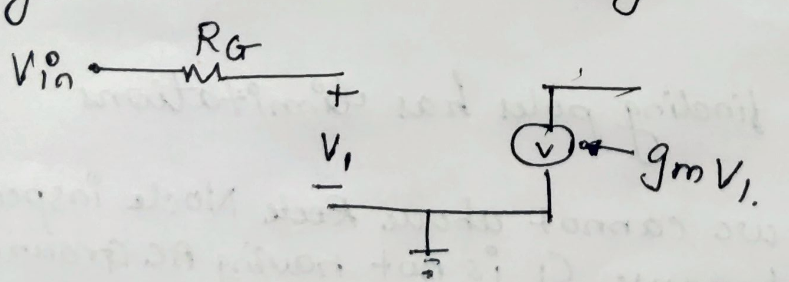
Example.



$$\omega_{p1} = \frac{1}{R_G C_{GT}} \qquad \omega_{p2} = \frac{1}{R_D C_L}.$$

$$\frac{V_{out}}{V_{in}} = \frac{-g_m R_D}{\left(1+\frac{S}{\omega_{p1}}\right)\left(1+\frac{S}{\omega_{p2}}\right)}$$

- The above Equation is derived by just inspection.
- Beside Having R_G & R_D both the resistance in the circuit Still the gain only have '$g_m R_D$', R_G doesn't affect the circuit.
- If you will consider Small signal model for the same.

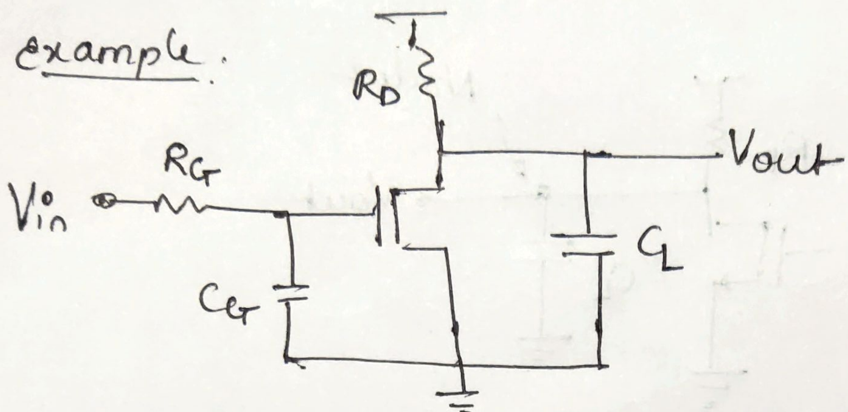


$V_1 = V_{in}$
Because there is No current through RG since it's an open circuit

∴ As low frequency R_G plays no Role in Gain.

$$\therefore \frac{V_{out}}{V_{in}} = \frac{-g_m R_D}{(1+R_G C_{GT} S)(1+R_D C_L S)}$$

example.

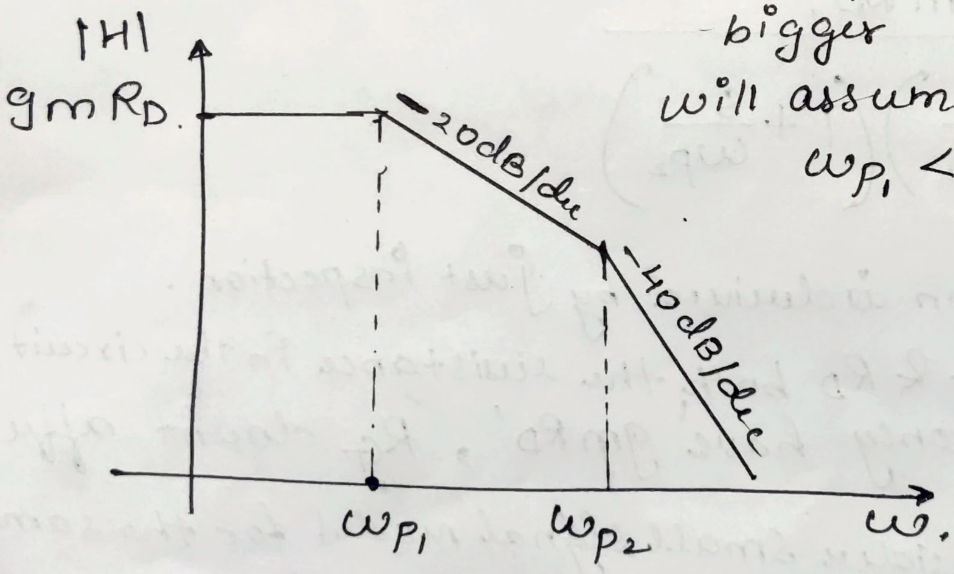


- These circuits are unwanted, we didn't add deliberately to the circuit.

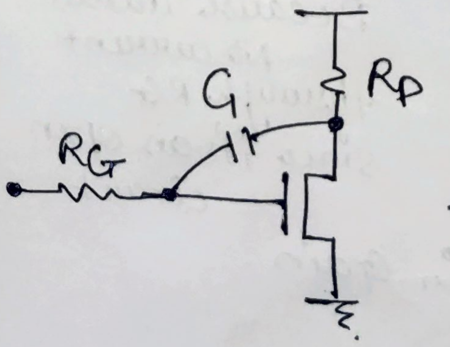
- plot freq. Response. $\omega_{p_1} = \frac{1}{R_G C_G}$ $\omega_{p_2} = \frac{1}{R_D C_L}$

we don't know which is bigger

will assume ~~ω_{p_1}~~ $\omega_{p_1} < \omega_{p_2}$.



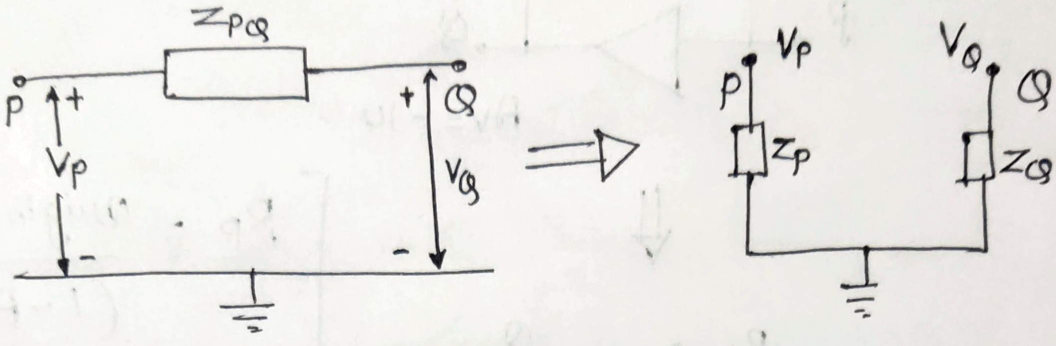
→ This method of finding poles has limitations



- we cannot above ~~Rede~~ Node inspection because C_1 is not having AC Ground.
- since we have capacitor between two Nodes.

⇒ Miller's Theorem:

- We can Decompose the floating capacitor to two grounded capacitor.



- current drawn from P from both the circuit which is Equivalent, According to Miller's Theorem.

i.e $\cancel{V_P - V_Q}$ $\cancel{I_P}$

$$\frac{V_P - V_Q}{Z_{PQ}} = \frac{V_P}{Z_P}$$

$$\frac{Z_P}{Z_{PQ}} = \frac{V_P}{V_P - V_Q}$$

$$Z_P = \frac{Z_{PQ} V_P}{V_P - V_Q}$$

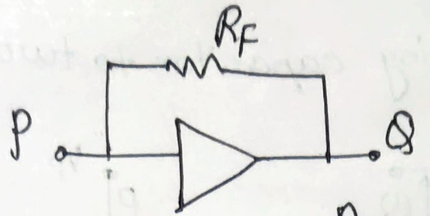
$$= \frac{Z_{PQ} \cancel{V_P}}{\cancel{V_P}\left(1 - \frac{V_Q}{V_P}\right)}$$

$$\therefore \boxed{Z_P = \frac{Z_{PQ}}{\left(1 - \frac{V_Q}{V_P}\right)}}$$

- current drawn from Q from both the circuit which is Equivalent,

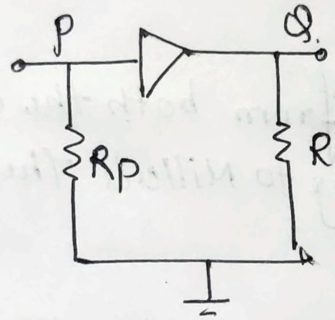
So similarly, $\boxed{Z_Q = \frac{Z_{PQ}}{\left(1 - \frac{V_P}{V_Q}\right)}}$

Example:



$A_V = -10$

$\Downarrow$



$$\left[R_P = \frac{\text{Original Impedance}}{(1 - A_V)} \qquad R_Q = \frac{\text{Original Impedance}}{\left(1 - \frac{1}{A_V}\right)} \right]$$

$$R_P = \frac{R_F}{1 - A_V} = \frac{R_F}{1-(-10)} = \frac{R_F}{11}$$

$$\left[\because \frac{V_Q}{V_P} = \frac{\text{o/p voltage}}{\text{i/p voltage}} = A_V \right]$$

$$R_Q = \frac{R_F}{\left(1 - \frac{1}{A_V}\right)} = \frac{R_F}{\left(1 - \frac{1}{(-10)}\right)} = \frac{R_F}{\left(1 + \frac{1}{10}\right)} = \frac{R_F}{\frac{11}{10}} = \frac{R_F}{1.1}$$

~~ii) The i/p Resistance~~

$\Rightarrow$ Miller's Effect :- Z_{PQ} is divided by $(1 - A_V)$ as it "appears" at the input.

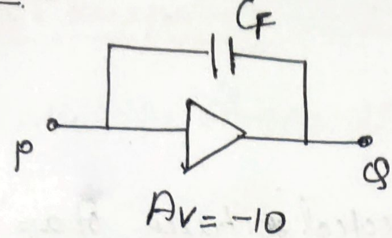
- The i/p Resistance is less than the original floating Resistance.
- this can be used where we want less impedance

Q. $A_V = +10$

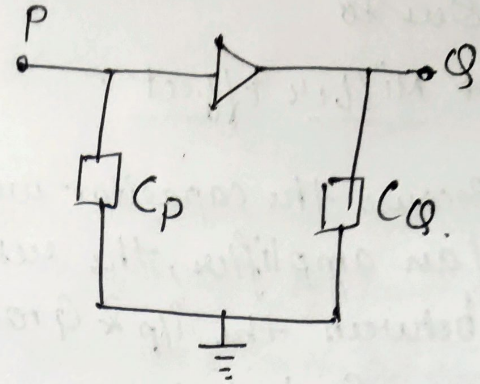
$$R_P = \frac{R_F}{1 - 10} = -\frac{R_F}{9}$$

$$R_Q = \frac{R_F}{1 - \frac{1}{10}} = \frac{R_F}{\frac{9}{10}} = \frac{R_F}{0.9}$$

Example :



$\Rightarrow$



$$\therefore C_F = \frac{1}{C_F s} \rightarrow (1)$$

$$Z_P = \frac{1}{C_F s(1-A_V)} \rightarrow (2) \qquad Z_Q = \frac{1}{C_F s\left(1-\frac{1}{A_V}\right)} \rightarrow (3)$$

If we compare (1) & (2).

Equivalent capacitor $= \cancel{C_F(1-A_V)}$

$$C_F = \frac{1}{C_F s(1-A_V)}$$

$$C_F(1-A_V) = \frac{1}{C_F s}$$

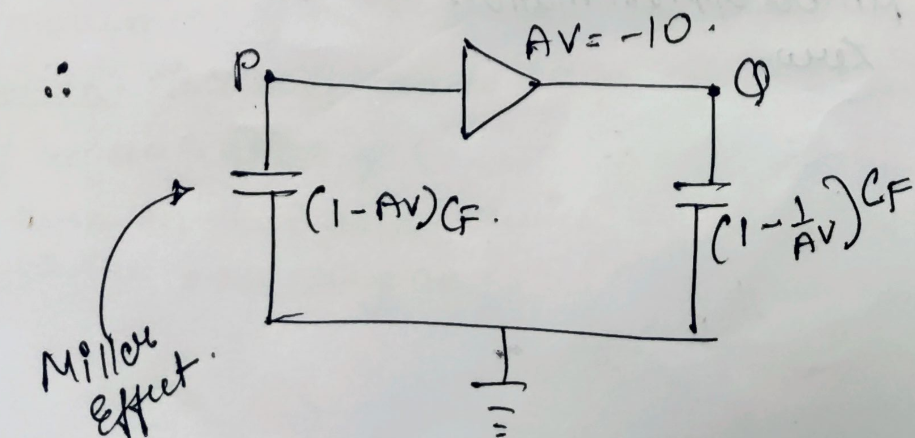
$\therefore$ Impedance at Node P. $= C_F(1-A_V)$

$= C_F(1-(-10))$

$= 11 C_F$.

Impedance at Node Q $= C_F\left(1-\frac{1}{A_V}\right) = 1.1 C_F$

$\therefore$



- ~~Due to~~

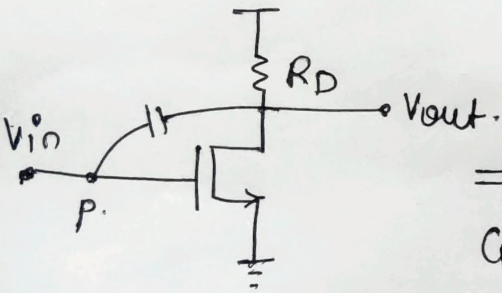
⇒ Miller Effect :

- Because the capacitor were connected ~~between~~ ~~of an~~ the i/p of an amplifier, the resultant Equivalent capacitor seen between the i/p & Ground is larger.

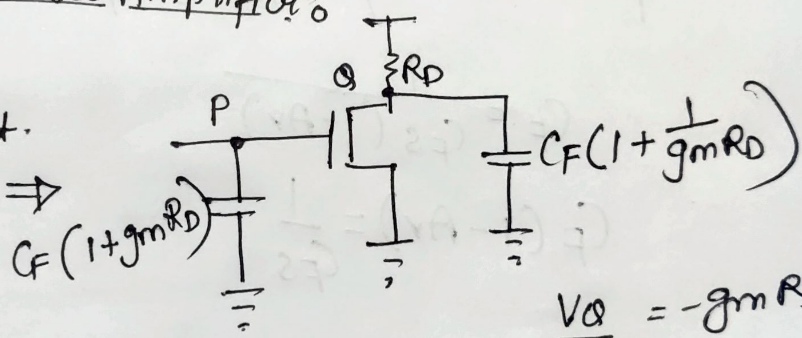
Equivalent capacitor = Original capacitance × (1) ← $(1-A_V)$ or $\left(1-\frac{1}{A_V}\right)$ [in this case]

- This is called as Miller Multiplication factor.

Example : common-source Amplifier :



⇒



$\frac{V_Q}{V_P} = -g_mR_D$

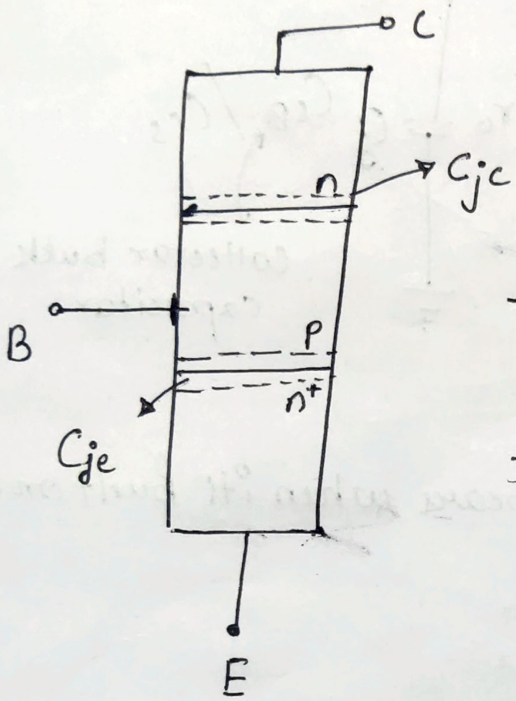
- Now there are two poles.

Caution : ① Miller's approximation has introduced a New pole.

② Miller's approximation has Eliminated the zero.

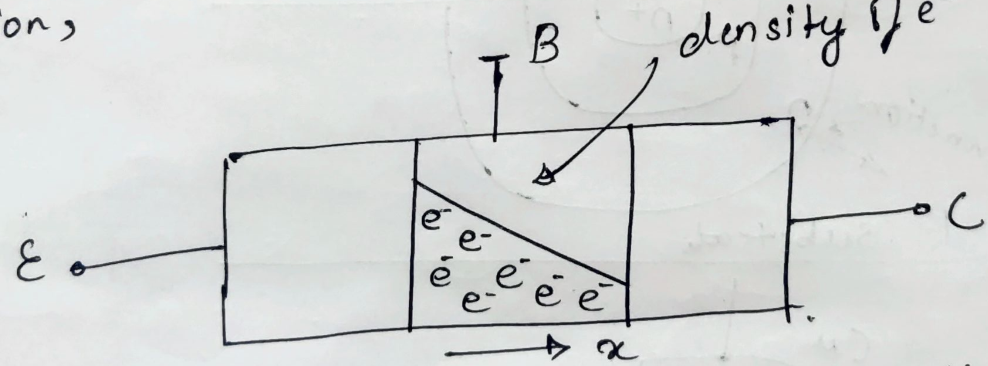
⇒ High-Frequency Model of Bipolar Transistor (BJT)

- Lets take the simple structure of (npn) Transistor.



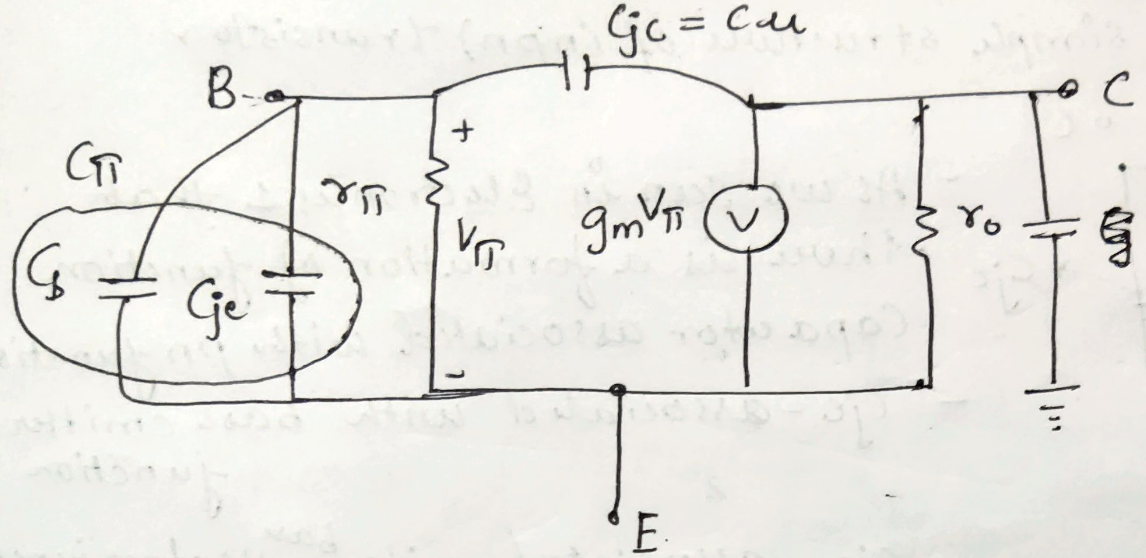
- As we seen in Electronics 1 that there is a formation of junction Capacitor associated with pn junction
- Cje - associated with base emitter junction
- Cjc - associated with base collector junction

- when bipolar T^r is ~~op~~ operating in the forward active Region,



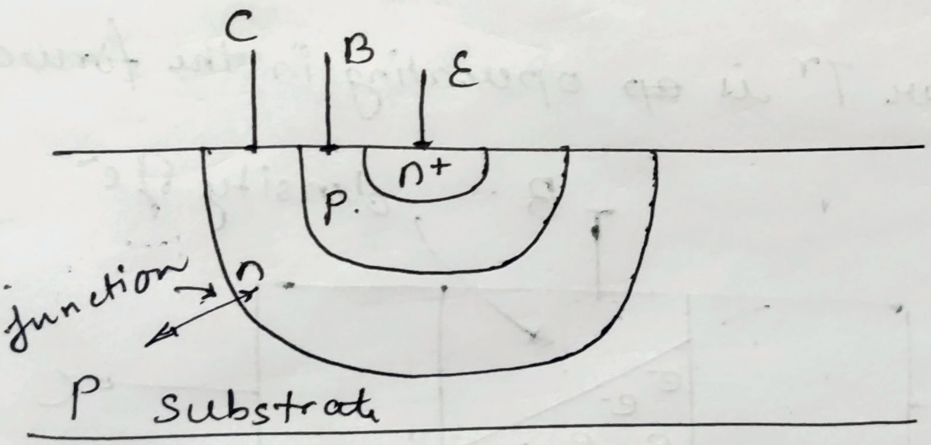
- The e^- starts from the emitter pass through the base & enter the collector.
- The movement of the e^- inside the base area is by <u>difusion</u>. This diffusion to occur we need a gradient of concentration of e^-.
- To turn on the Bipolar device we have stored the some e^- to the base region.

- Low freq. which we already developed model

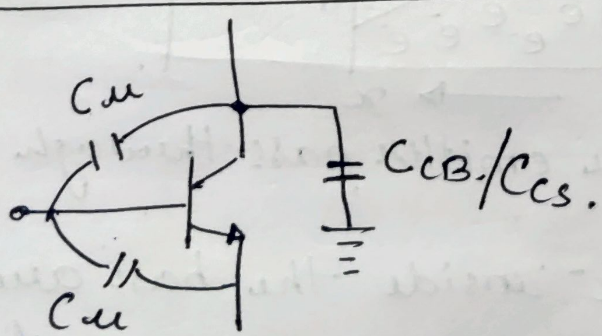


collector bulk capacitor.

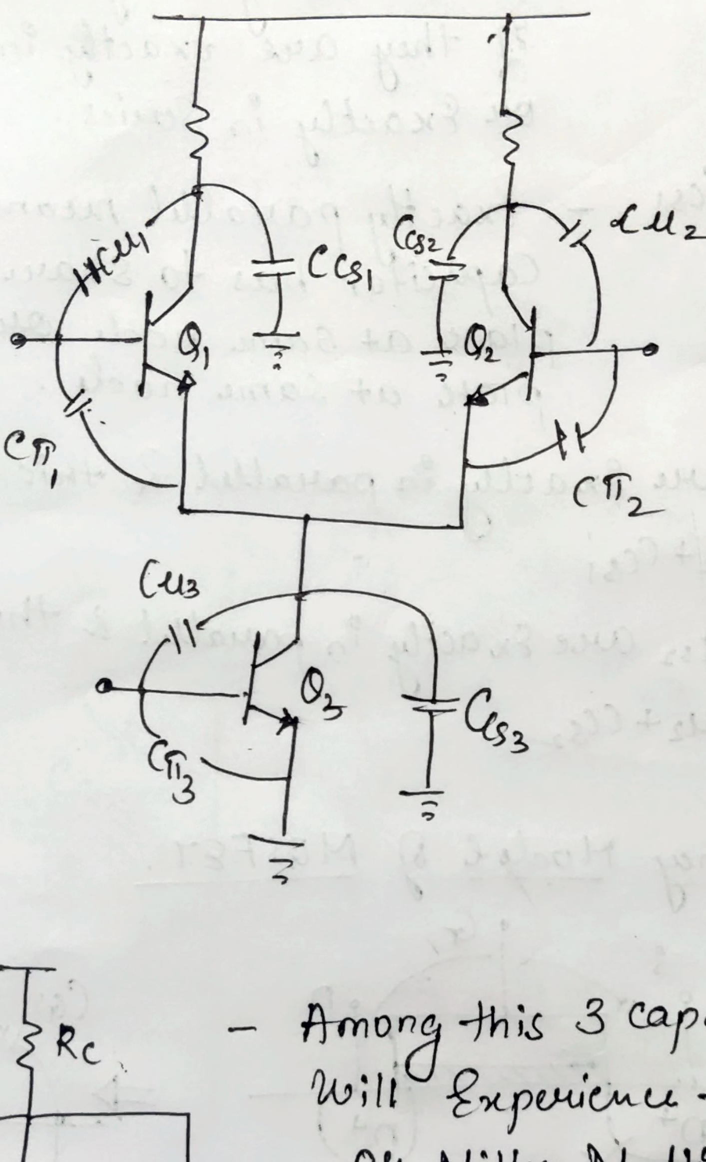
- This collector bulk capacitor appears when it's built on a wafer. Look at the below fig.



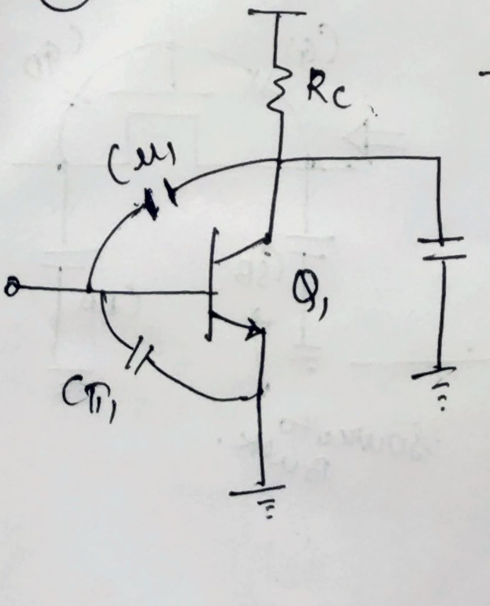
i.e.



Example ① Bipolar Differential circuit.

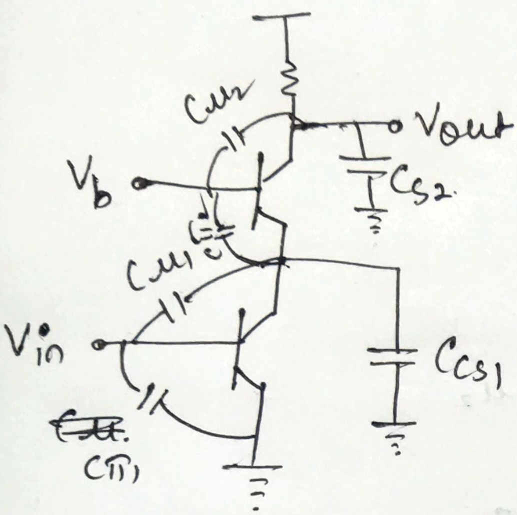


②



- Among this 3 capacitor which cap will experience the Miller Effect or Miller Multiplication -
- Cμ1 will experience the miller effect.

Example ③ Bipolar cascode amplifier:

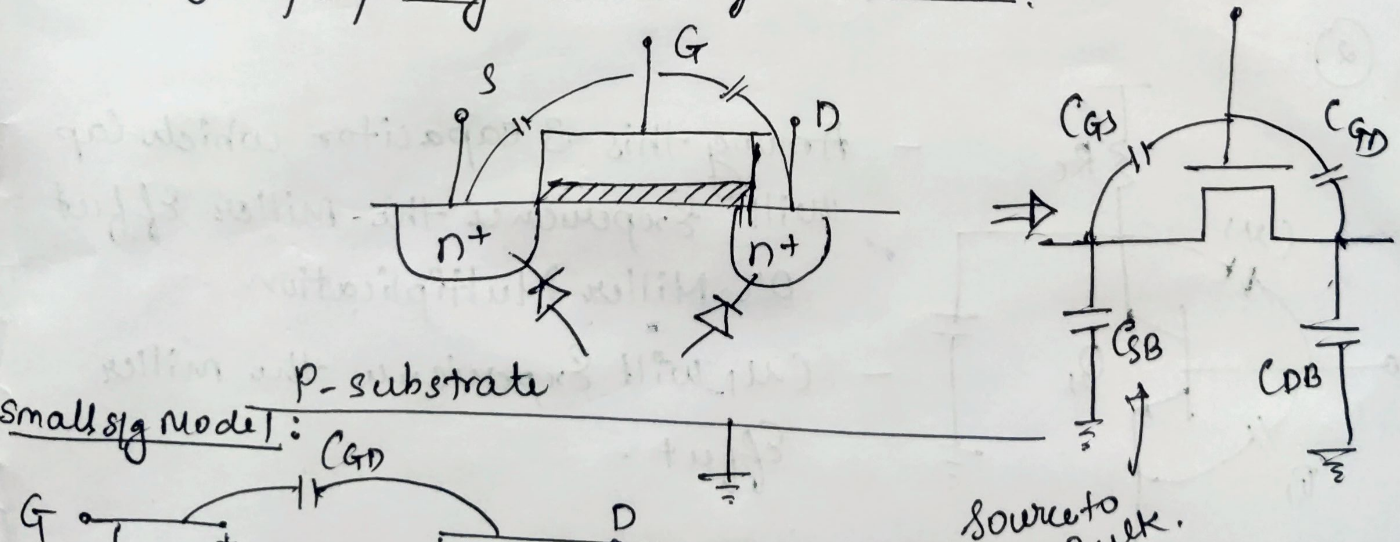


- Can some of these capacitor can be merged?
- We can easily merged two capacitances if they are exactly in parallel or exactly in series.
- Exactly parallel means two capacitor has to share the top plate at same node or bottom plate at same node.

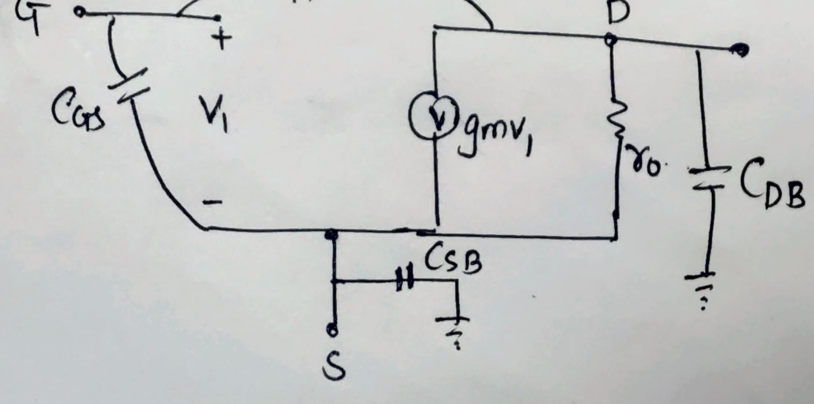
∴ $C_{\pi 2}$ & C_{CS1} are exactly in parallel & this can be merged ⇒ $C_{\pi 2} + C_{CS1}$

Also $C_{\mu 2}$ & C_{CS2} are exactly in parallel & this can be merged ⇒ $C_{\mu 2} + C_{CS2}$

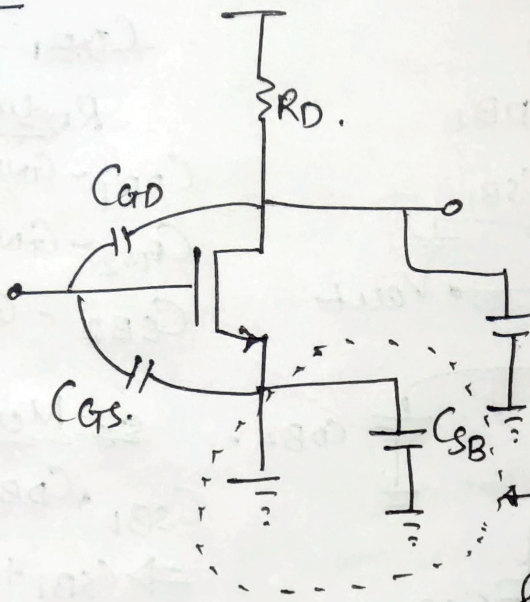
⇒ High frequency Model of MOSFET.



Small sig Model:



Example ①.

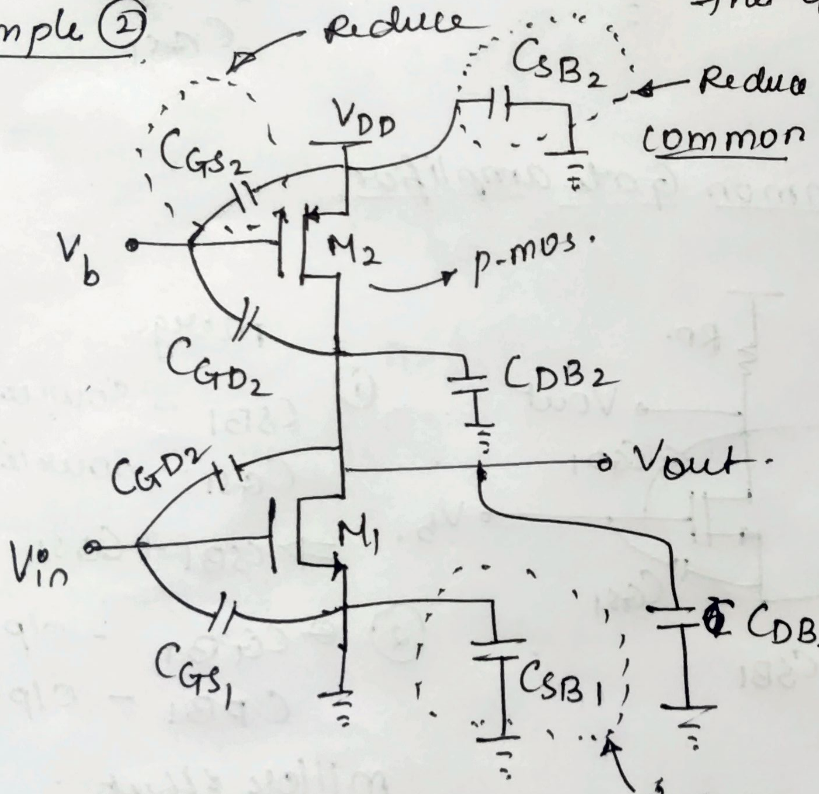


CDB. – Only CGD Experiences miller Effect.

we can Reduce this capacitor by seeing that it is between the Ground.

Example ②

common Source amplifier.

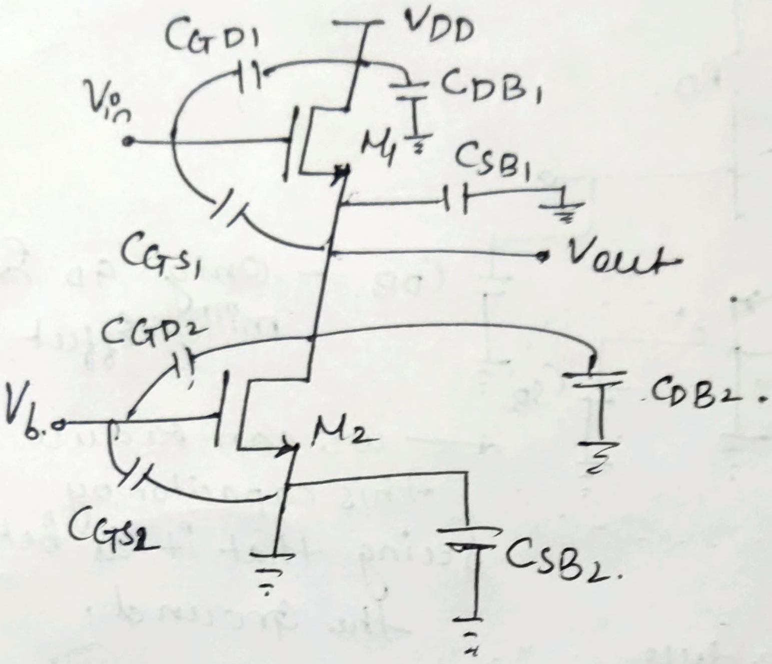


– C_{DB2}, C_{GD2}, C_{DB1} – Output node to ground.

∴ This three can be merged.

$\Rightarrow C_{DB1} + C_{GD2} + C_{DB2}$

Example 3 Source Follower.



~~CDB1 Ground~~

Reduce.

C_{DB1} – GND to GND – X

C_{GS2} – GND to GND – X

C_{SB2} – GND to GND – X

~~Ss~~ Merge.

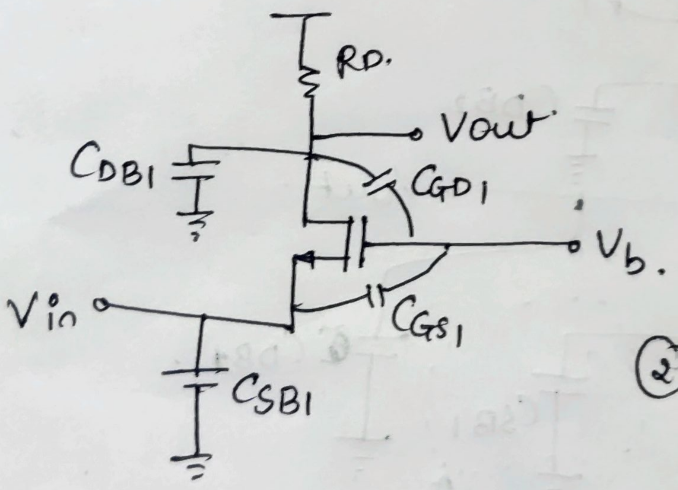
$C_{SB1}, C_{DB2}, C_{GD2}$

$\Rightarrow C_{SB1} + C_{DB2} + C_{GD2}$

Miller Effect

C_{GS1}

Example 4. Common Gate amplifier.



merge

1. C_{SB1} – Source to GND
   C_{GS1} – Source to AC Gnd
   $\Rightarrow C_{SB1} + C_{GS1}$
2. C_{GB1} – o/p to AC GND.
   C_{DB1} – O/p to AC GND.

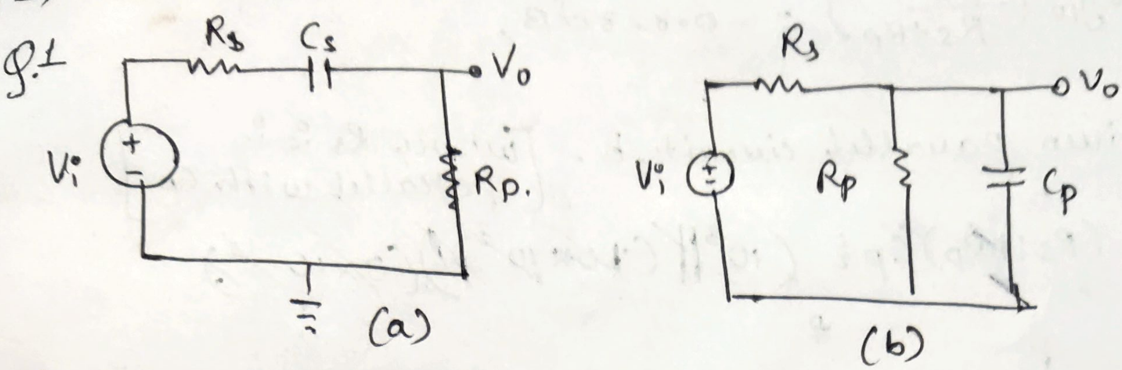
Miller Effect.

No capacitor in the circuit goes ~~for~~ from i/p to o/p.

∴ Common Gate amplifier Don't have miller effect.

→ Numericals.

Q.1



Find the corner frequiencies & maximum magnitude asymptotes of the Bode plots for a given circuit.

where $R_s = 1 k\Omega$, $R_p = 10 k\Omega$, $C_s = 1 \mu F$, $C_p = 3 pF$.

Ans. ⇒ Time constant, $\tau = RC$

τ for given series circuit (a),

$\tau_s = (R_s + R_p) C_s$ [where R_s is in series with R_p]

$= (10^3 + 10 \times 10^3)(10^{-6})$

$= 10^3 (1+10)(10^{-6})$

$= 11 \times 10^{-3}$

$= 1.1 \times 10^{-2} s$ or $11 ms$

For your understanding corner frequencies means pole frequency.

$1 k\Omega = 10^3 \Omega$

$1 \mu F = 10^{-6} F$

$1 pF = 10^{-12} F$

ω_p, pole frequency $= \frac{1}{RC} = \frac{1}{\tau}$

$\therefore f = \frac{1}{2\pi RC} = \frac{1}{2\pi \tau}$

$= \frac{1}{2\pi (11 \times 10^{-3})} = 14.5 Hz.$

magnitude, $|H(s)| = \frac{R_p}{R_s + R_p} = \frac{10}{1+10} = 0.909.$

or $20\log_{10}\left(\frac{R_P}{R_S+R_P}\right) = -0.828\,dB.$

τ for given parallel circuit, b. [where R_S is in parallel with C_P]

$$\tau_P = (R_S \| R_P)\, C_P \approx \cancel{(10^3 \| (10\times10^{3}))(3\times10^{-12})}$$

$$= \frac{1}{\frac{1}{R_S}+\frac{1}{R_P}} \cdot C_P.$$

$$= \frac{1}{\frac{R_P+R_S}{R_P R_S}} \cdot C_P$$

$$= \frac{R_P R_S}{R_P+R_S} \cdot C_P = \frac{10^3 \times 10\times10^3}{10^3 + 10\times10^3} \cdot C_P = \frac{\cancel{10^3}\times10\times10^3}{\cancel{10^3}(1+10)} \cdot C_P$$

$$= \frac{\cancel{10}\times10^3}{\cancel{10}(1+0.1)} \cdot C_P = \frac{10^3}{1.1} \cdot C_P$$

$$= \frac{10^3}{1.1} \times 3\times10^{-12}$$

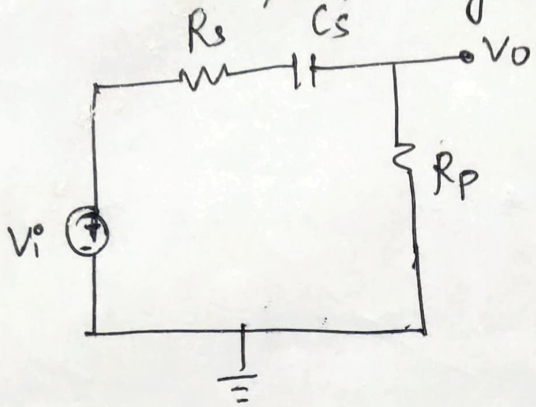
$$= \frac{3}{1.1}\times10^{-9} = 2.73\times10^{-9}\,s$$

$$f = \frac{1}{2\pi \tau_P} = \frac{1}{2\pi\times(2.73\times10^{-9})} = 58.3\,MHz.$$

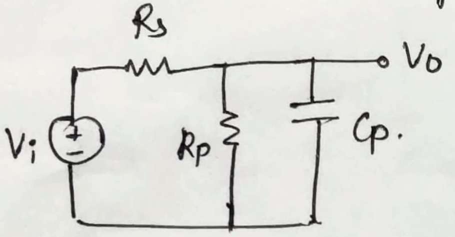
maximum magnitude is the same as calculated,

0.909 or −0.828 dB.

Q.2 For the given circuit below where $R_S = R_P = 4k\Omega$ ~~Find~~ if the corner frequency is $f = 20Hz$, determine the value of C_S.



Q3. For the given circuit below, with the parameters $R_S = R_P = 10k\Omega$, If the corner frequency is $f = 500kHz$, determine the value of C_P.



Q4. Determine the corner frequencies & Bandwidth of a passive circuit containing two capacitors, consider the below circuit where $R_S = 10k\Omega$, $R_P = 20k\Omega$, $C_S = 1\mu F$, C_P $4pF$.

P