Design, simulation and analysis of Miller compensation circuit for required parameters.

Submitted By

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OBJECTIVE

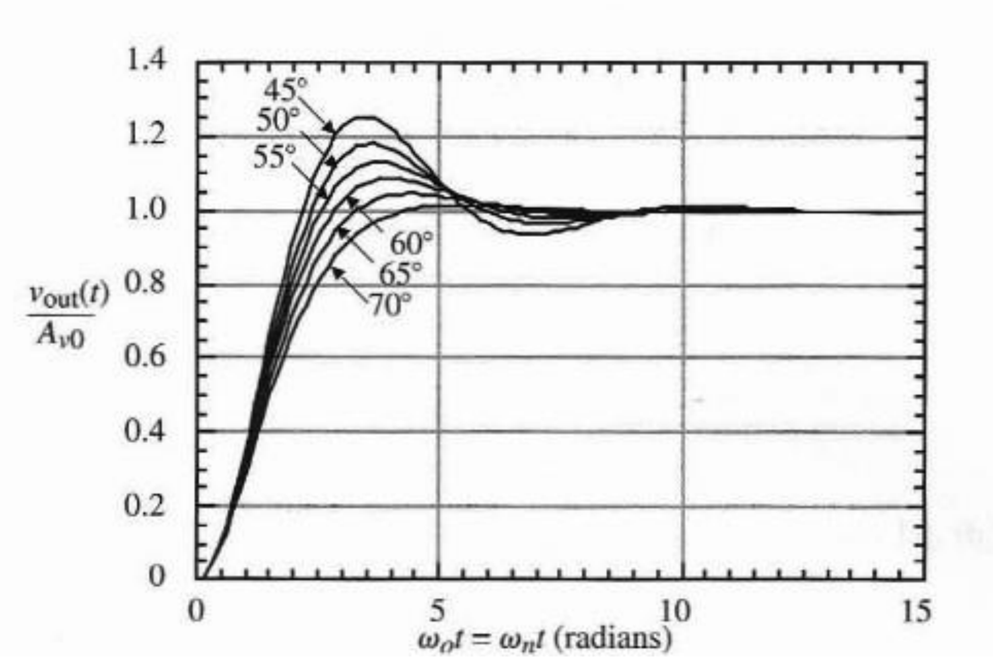
The objective of this assignment is to design the miller compensation circuit for the given parameters:

I. **Phase Margin of 60°,**
II. **Load Capacitor, C_L =10pF,**
III. **UNITY GAIN-BANDWIDTH, GB=100MHz,**
IV. **$g_m r_o$ =25,**
V. **$\frac{gm}{2\pi Cin}$ =10^{10} Hz,**
VI. **$\frac{gm}{ID}$ = 1 to 15.**

INTRODUCTION TO MILLER COMPENSATION CIRCUIT

The importance of "good stability" obtained with adequate phase margin is best understood by considering the response of the closed - loop system in the time domain, as shown in the time response of a second-order closed-loop system with various phase margins.

It can be observed that larger phase margins result in less "ringing" of the output signal. Too much ringing can be undesirable, so it is important to have adequate phase margin keeping the ringing to an acceptable level. It is desirable to have a phase margin of at least 45°, with 60°preferable in most situations.

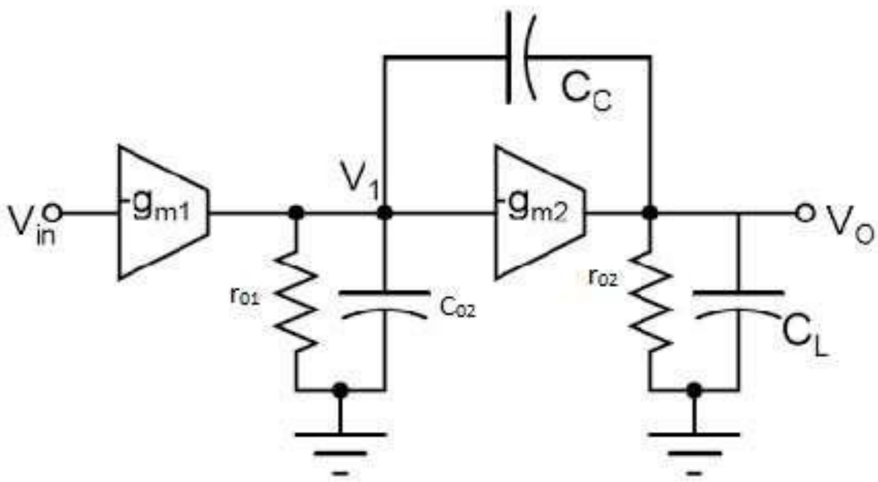


Response of a second-order system with various phase margins

"Miller compensation technique" is applied by connecting a capacitor from the output to the input of the second transconductance stage g_{m2}. The resulting small-signal model is illustrated in the figure.

Two results come from adding the compensation capacitor $C_{c.}$

1. the effective capacitance shunting r_{01} is increased by the additive amount of approximately $g_{m2}\ r_{02}\ C_c$. This moves p_1 to the new location closer to the origin of complex frequency plane by a significant amount (assuming that the second-stage gain is large).
2. p_2 is moved away from the origin of the complex frequency plane, resulting from the negative feedback reducing the output resistance of the second stage.

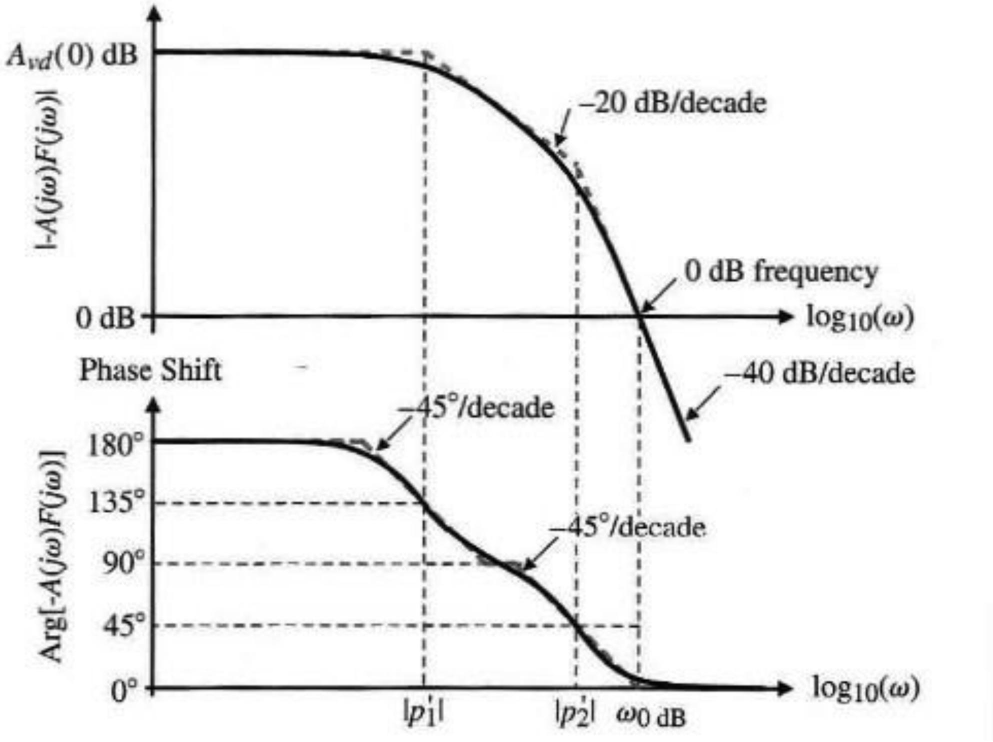


MILLER COMPENSATION CIRCUIT

$$p_1 = \frac{-1}{r01\ r02\ gm2\ Cc}$$

$$p_2 = \frac{-gm2}{Cl}$$

$$z = \frac{gm}{Cc}$$



The open-loop frequency response of a negative-feedback loop

OBSERVATIONS AND CALCULATIONS

$PM = 180° + \Phi/_{w=wgc} = 60°$

$60° - 180° = 180° - \tan^{-1} \left|\frac{Wgc}{z}\right| - \tan^{-1} \left|\frac{Wgc}{p1}\right| - \tan^{-1} \left|\frac{Wgc}{p2}\right|$

For g_{m1} = 2mS , C_L= 10pF , r_{01} = 12.5 K Ohm

$W_{gc} = 2\pi \times 10$ MHz

$-300° = -\tan^{-1} \left|\frac{Wgc}{z}\right| - \tan^{-1} \left|\frac{Wgc}{p1}\right| - \tan^{-1} \left|\frac{Wgc}{p2}\right|$

$$p_1 = \frac{-1}{r01\ \ r02\ gm\ Cc} = \frac{-1}{25 * 12.5K * Cc}$$

$$p_2 = \frac{-gm2}{10}$$

$$z = \frac{gm}{Cc}$$

i. GB = DC Gain x (location of dominant pole)

$= \text{DC Gain} \times |p_1|$

$= g_{m1} r_{01} g_{m2} r_{02} \times \left| \dfrac{-1}{r01\ r02\ gm2\ Cc} \right|$

$= \dfrac{gm1}{Cc}$

$$2\pi \times 100\text{MHz} = \frac{2\ mS}{Cc}$$

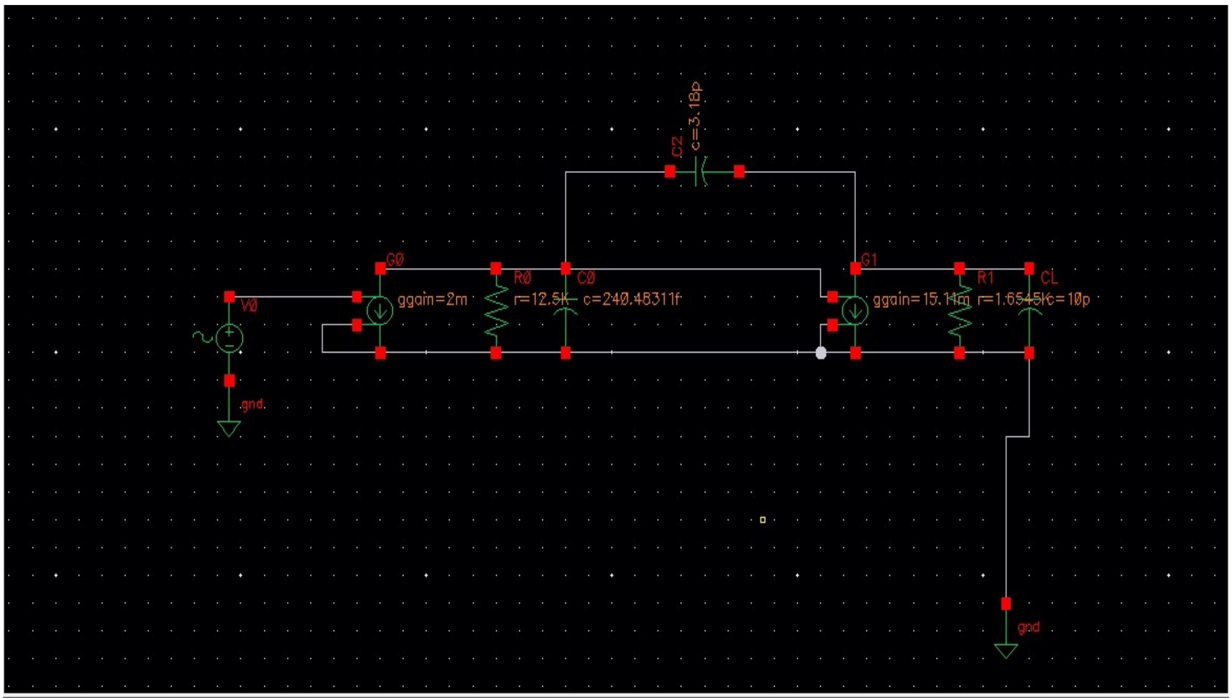
$C_c = 3.18$ pF

$$-300° = -\tan^{-1}\left|\frac{\text{W}gc}{z}\right| - \tan^{-1}\left|\frac{\text{W}gc}{p1}\right| - \tan^{-1}\left|\frac{\text{W}gc}{p2}\right|$$

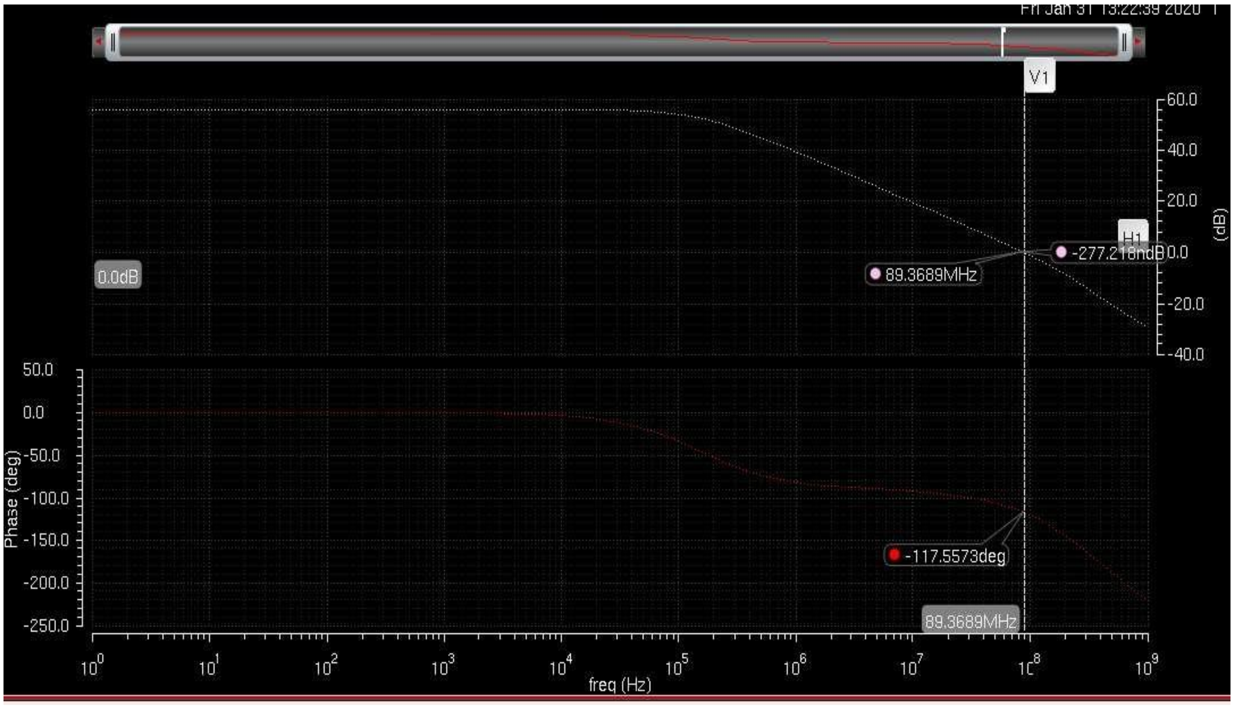
⇨ **g_{m2} = 15.11 mS**

r_{02}= 1.6545K Ohm

C_{02}= 0.24048 pF



SCHEMATIC



GAIN (dB) AND PHASE(deg.) WAVEFORM W.R.T. FREQUENCY

After Simulation,

GB = 89.3689 MHz

Phase Margin = 180° – 117.5573° = 62.4427°

ii. After the simulation of the first observation, it can be realised that the GB is lower than required, and

$$GB = \frac{gm1}{Cc}$$

So, by decreasing C_c, we can increase the GB as per the requirement.

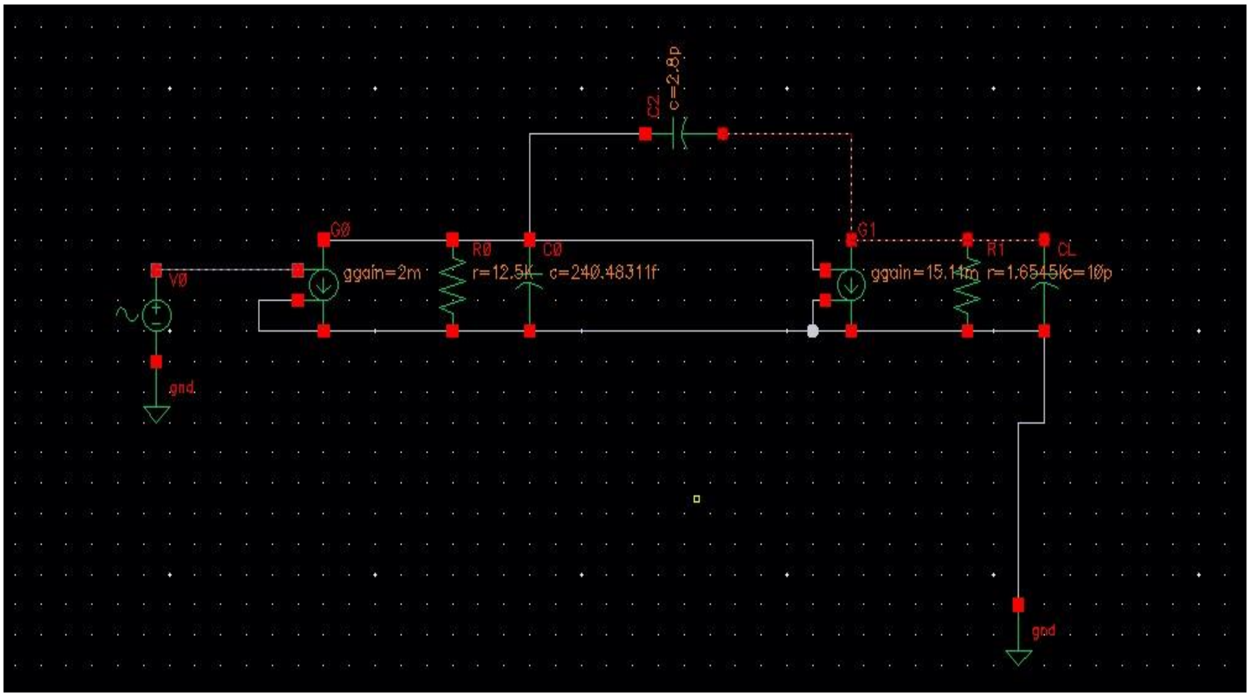
Taking,

C_c = 2.8 pF

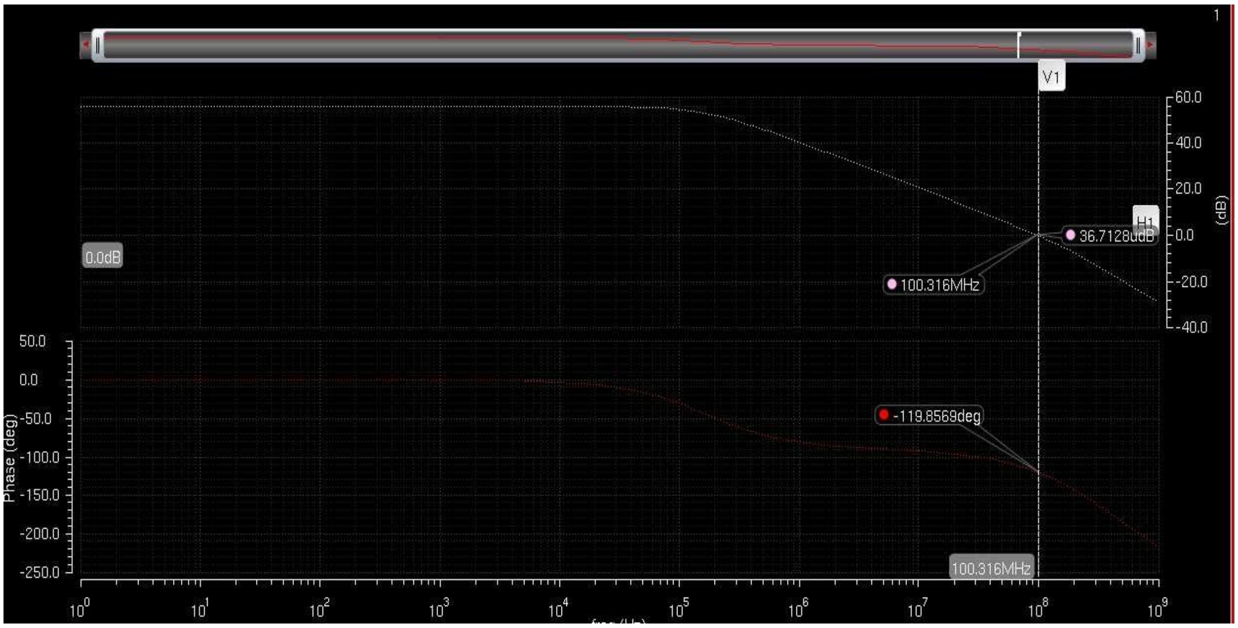
g_{m2} = 15.11 mS

r_{02}= 1.6545K Ohm

C_{02}= 0.24048 pF



SCHEMATIC



GAIN (dB) AND PHASE(deg.) WAVEFORM W.R.T. FREQUENCY

After Simulation,

GB = 100.316 MHz

Phase Margin = 180° – 119.8569° = 60.1431°

CONCLUSIONS

The two main conclusions that highlights this assignment is that

1. The change in the value of C_c is dominant in defining the Bandwidth of the system more than other parameters.
2. The change in the value of g_{m2} is more predominant in the change in phase and thus, the phase margin of the circuit.

For C_c =3.18pF , g_{m1}=2mS and g_{m2}=15.11mS:

GB = 89.3689 MHz

Phase Margin = 62.4427°

For C_c =2.8pF , g_{m1}=2mS and g_{m2}=15.11mS:

GB = 100.316 MHz

Phase Margin = 60.1431°