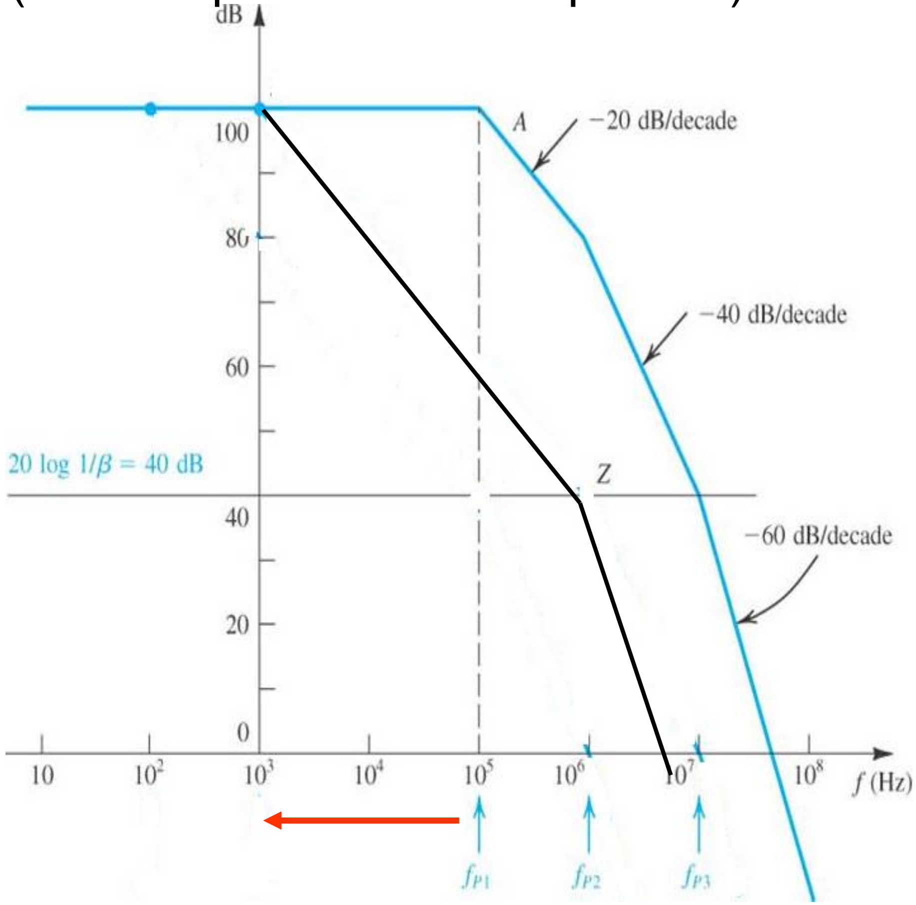
Lect. 14: Frequency Compensation

Is amplifier having below magnitude Bode plot stable for feedback having β?
(Assume poles are well separated)



Remember Phase [$\beta A(s)$] > -180 deg when $|\beta A(s)|$ = 1

-180 deg phase point occurs on -40dB/dec segment of |A|

➔ If |A| intersects 20 log(1/β) with -20dB/decade slope, then stable

How can we make it stable?

- Reduce β
- Or move the dominant pole to lower frequency

➔ Frequency Compensation

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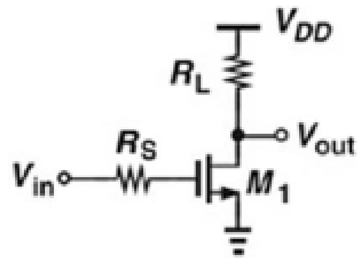
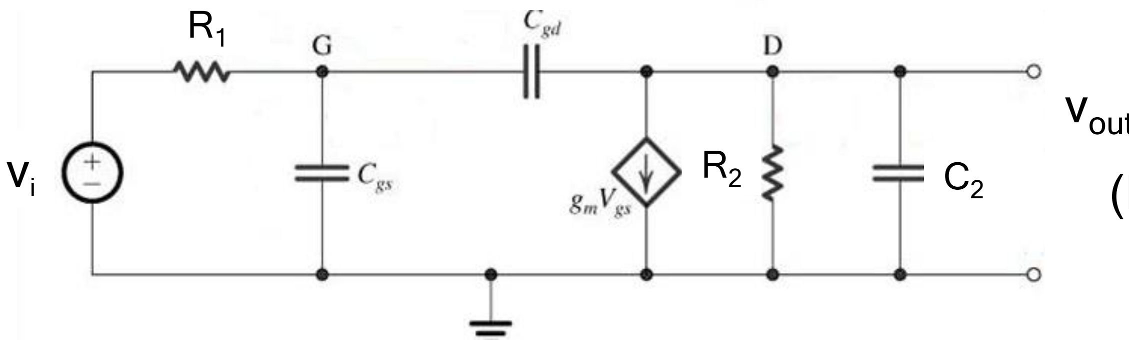
How to move a pole?

Consider CS amplifier





$(R_1 = R_S,\ R_2 = R_L,\ C_2 = C_{DB})$

(From Lect. 12)

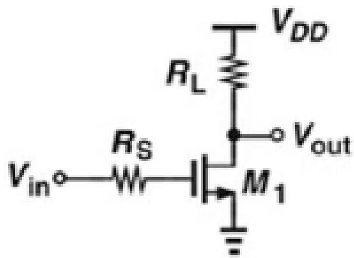
$$\frac{V_o}{V_i} = \frac{\left(g_m - sC_{gd}\right)R_2}{1 + s\left[C_{gs}R_1 + C_2R_2 + C_{gd}\left(g_mR_1R_2 + R_1 + R_2\right)\right] + s^2\left[C_{gs}C_2 + C_{gd}\left(C_{gs} + C_2\right)\right]R_1R_2}$$

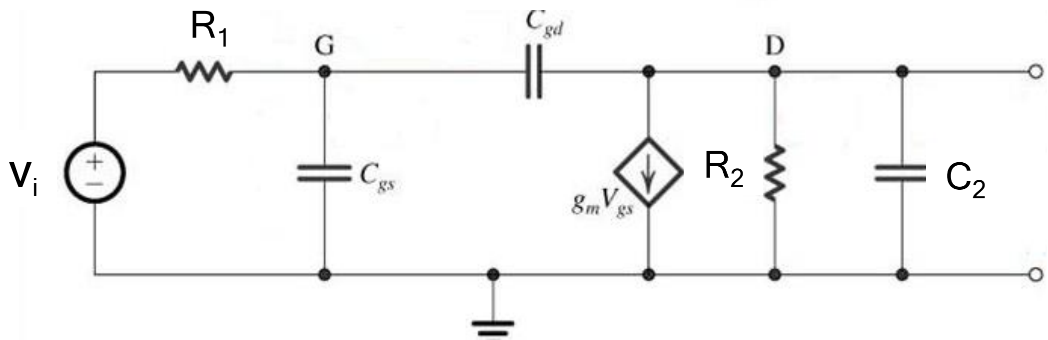
$$\omega_{P1} \sim \frac{1}{C_{gd}g_mR_2R_1} \qquad \omega_{P2} \sim \frac{g_mC_{gd}}{C_{gs}C_2 + C_{gd}\left(C_{gs} + C_2\right)}$$

Lect. 14: Frequency Compensation

How to move a pole?

Consider CS amplifier





v_{out}

(R_1=R_S, R_2= R_L, C_2 = C_{DB})

$$\omega_{P1} \sim \frac{1}{C_{gd} g_m R_2 R_1} \qquad \omega_{P2} \sim \frac{g_m C_{gd}}{C_{gs} C_2 + C_{gd}\left(C_{gs} + C_2\right)}$$

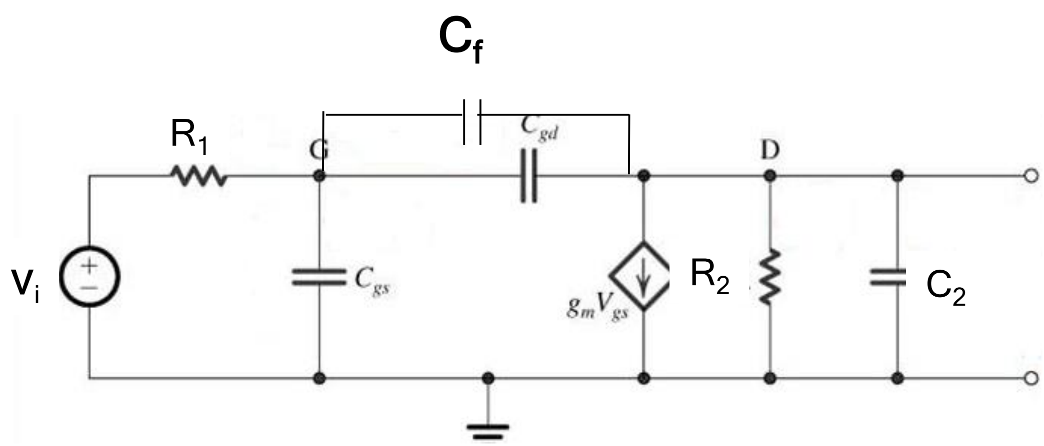
Which is the dominant pole?

Due to R_1 and Miller effect of C_{gd}

How can we move ω_{p1} to lower frequency without changing the circuit too much?

Lect. 14: Frequency Compensation

Add a feedback capacitor, C_f, (>> C_{gd}) between G and D



$C_{gd} \rightarrow C_{gd} + C_f$

$$\omega_{P1} \sim \frac{1}{C_{gd} g_m R_2 R_1} \rightarrow \frac{1}{(C_{gd} + C_f) g_m R_2 R_1} \sim \frac{1}{C_f g_m R_2 R_1}$$

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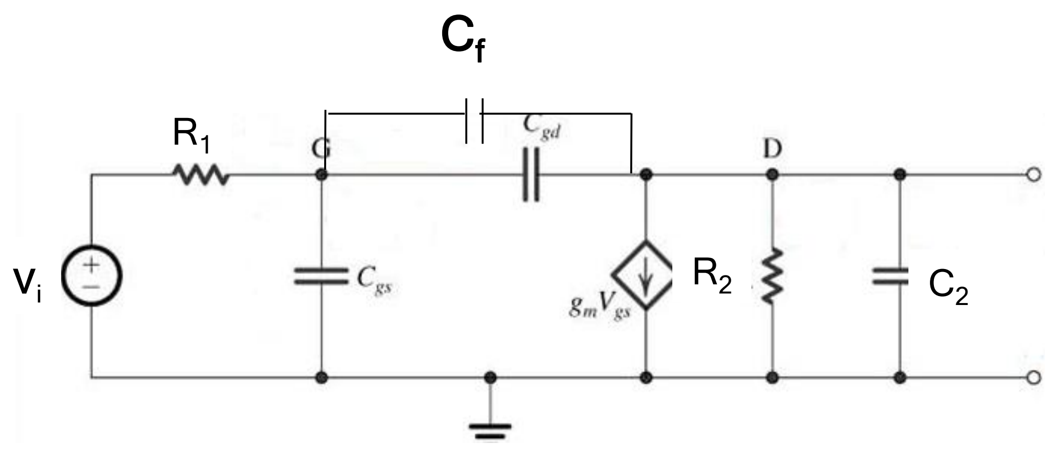
Lect. 14: Frequency Compensation



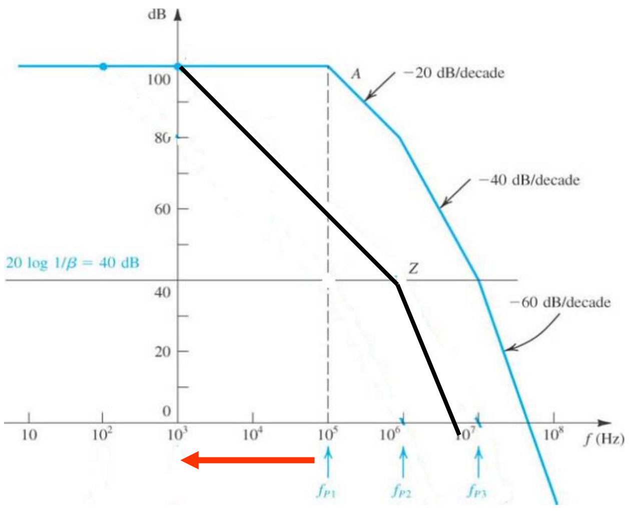
Addition of C_f between G and D

Move ω_{p1} to lower frequency

➔ More phase margin: Safer for feedback

(Lag compensation)

➔ Reduces bandwidth



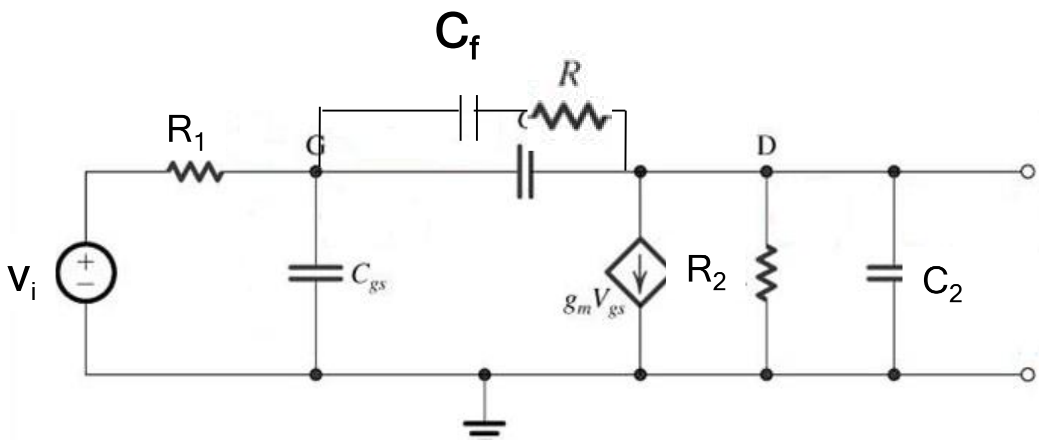
Lect. 14: Frequency Compensation

$$\frac{V_o}{V_i} = \frac{\left(g_m - sC_{gd}\right)R_2}{1 + s\left[C_{gs}R_1 + C_2R_2 + C_{gd}\left(g_mR_1R_2 + R_1 + R_2\right)\right] + s^2\left[C_{gs}C_2 + C_{gd}\left(C_{gs} + C_2\right)\right]R_1R_2}$$

Where is the zero?

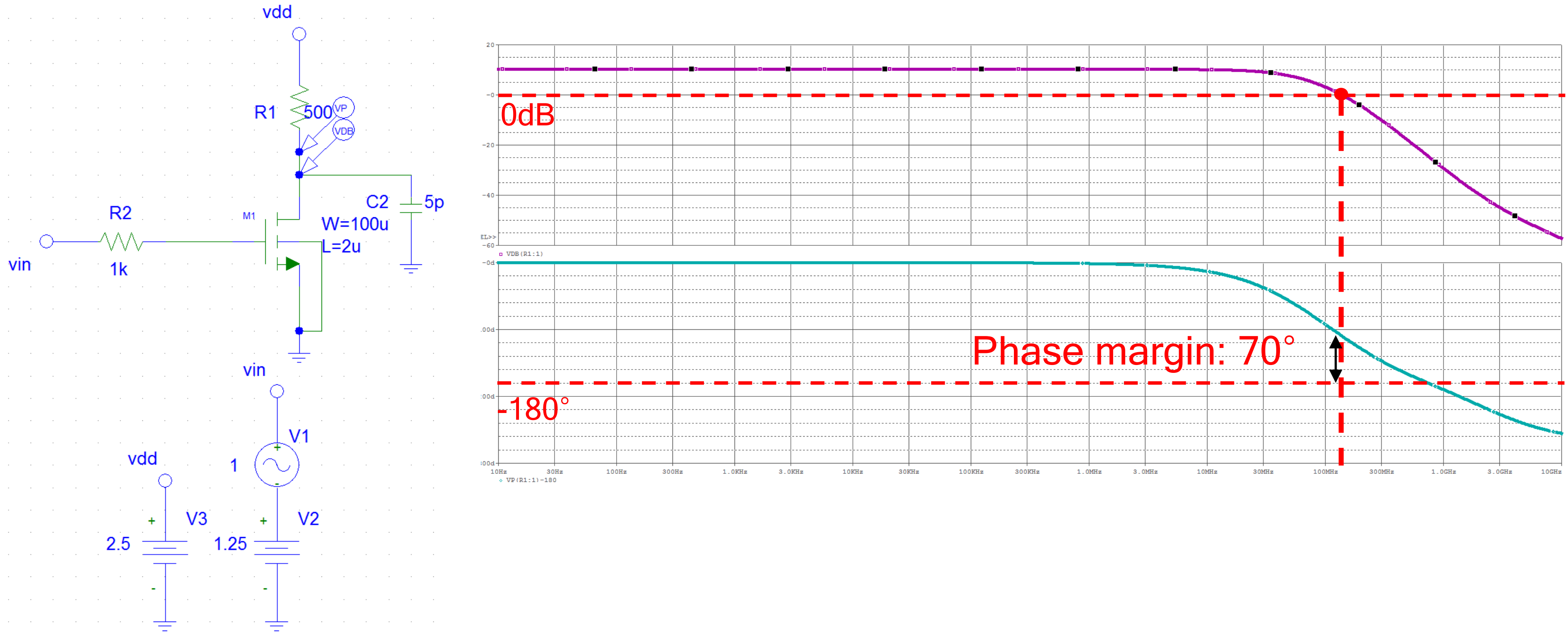
With C_F for frequency compensation? $s = \frac{g_m}{C_F}$ (right half-plane)

Phase margin? ➔ Need to move zero to the left half-plane

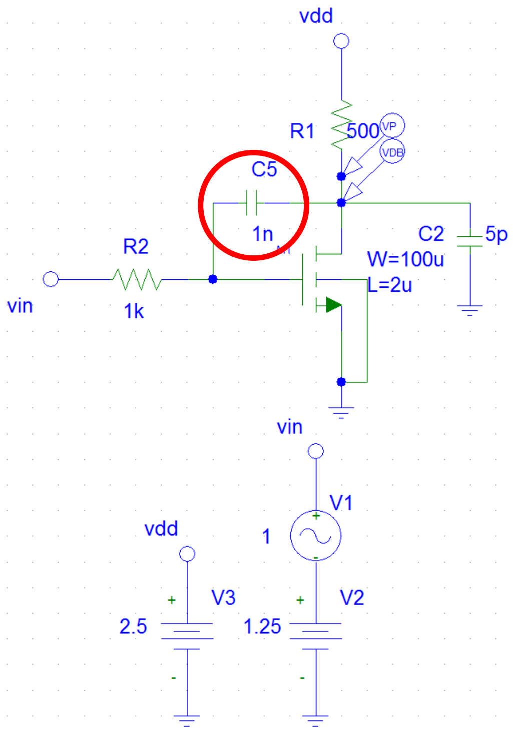


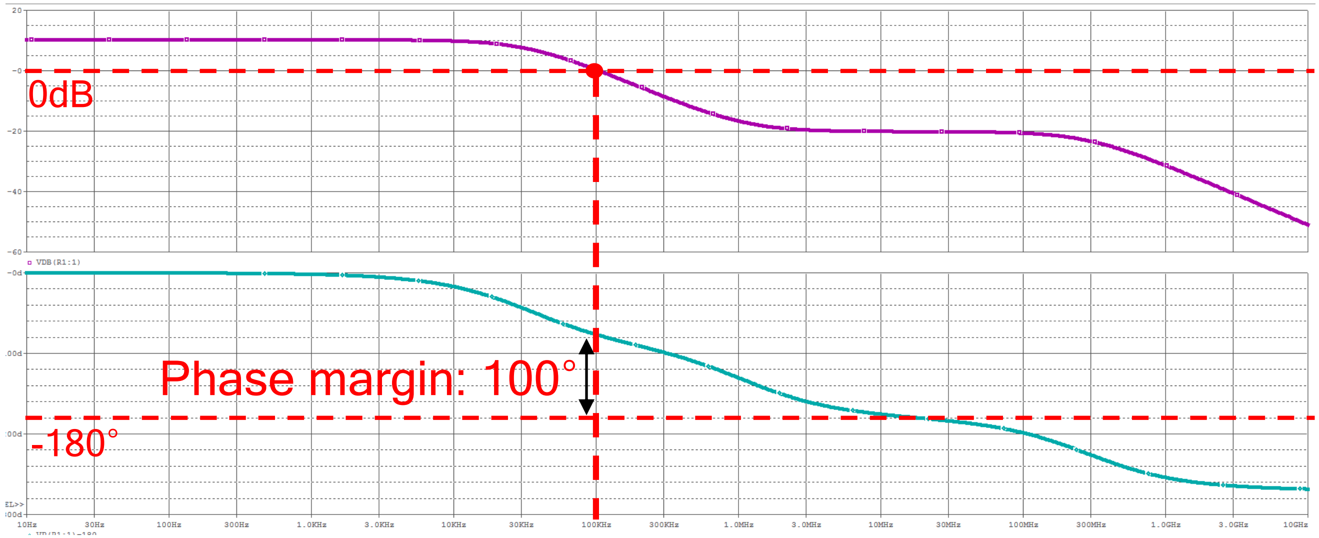
➔ Discussion with simulation results

Lect. 14: Frequency Compensation



Lect. 14: Frequency Compensation





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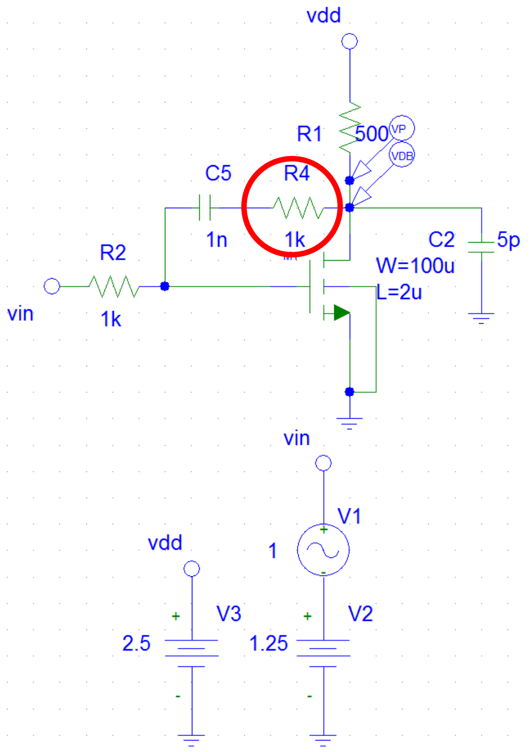
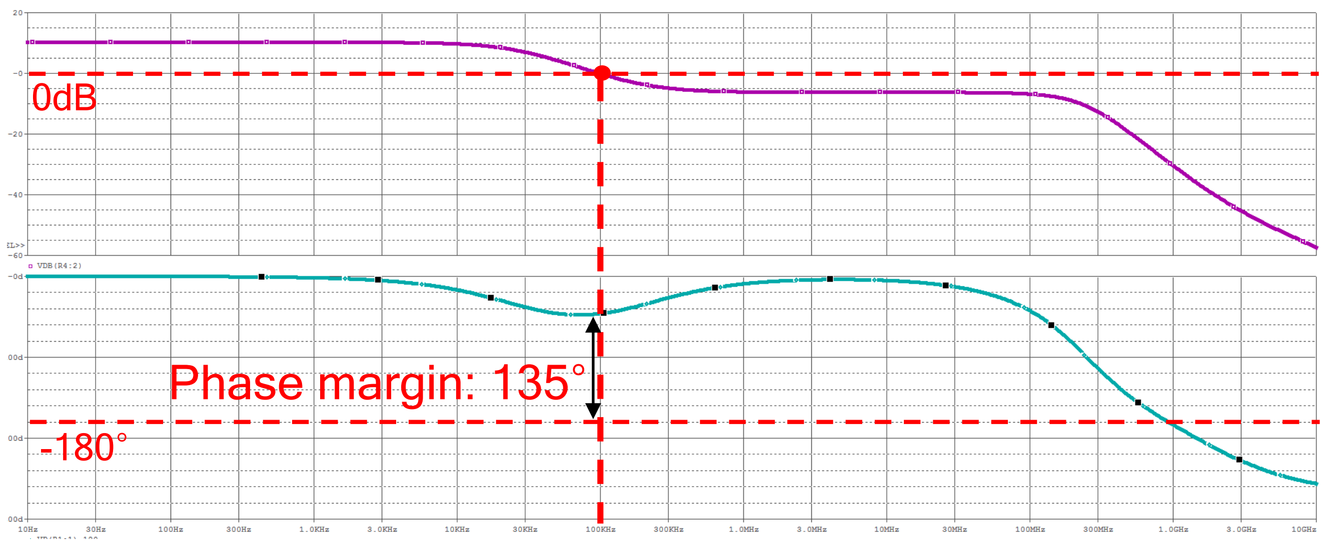
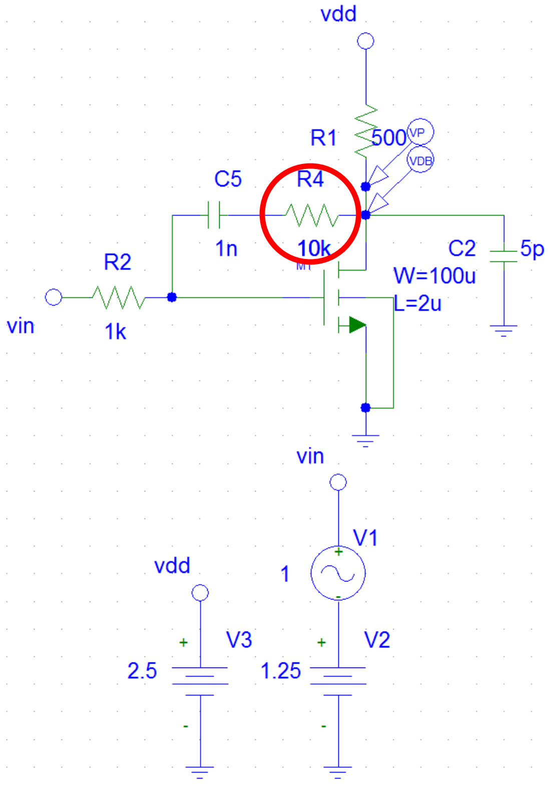
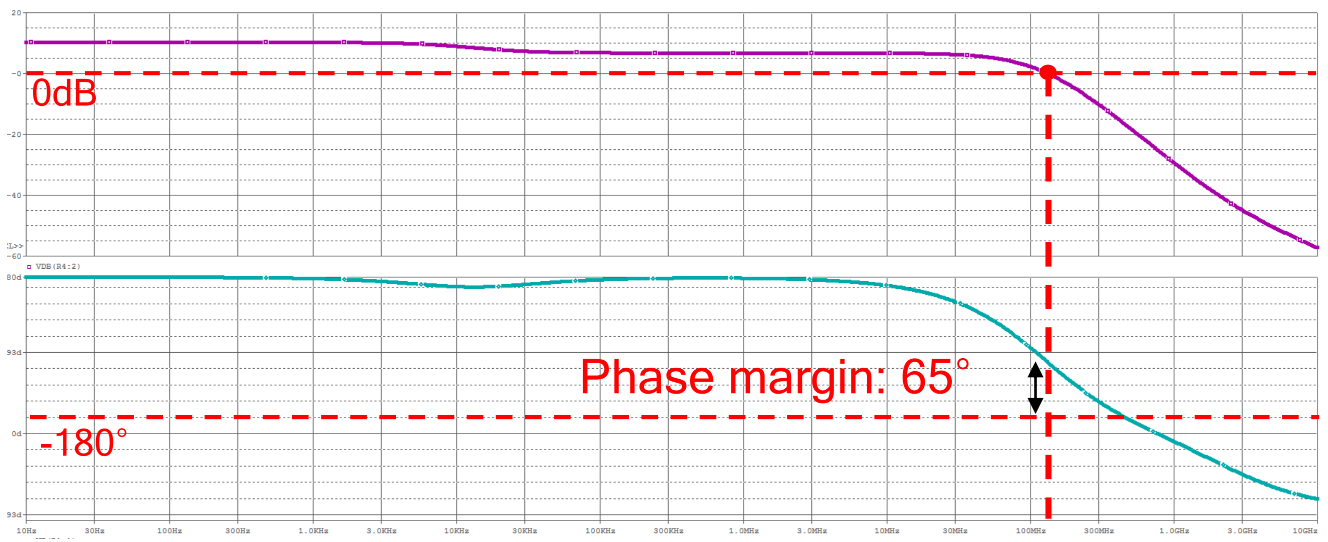
Lect. 14: Frequency Compensation



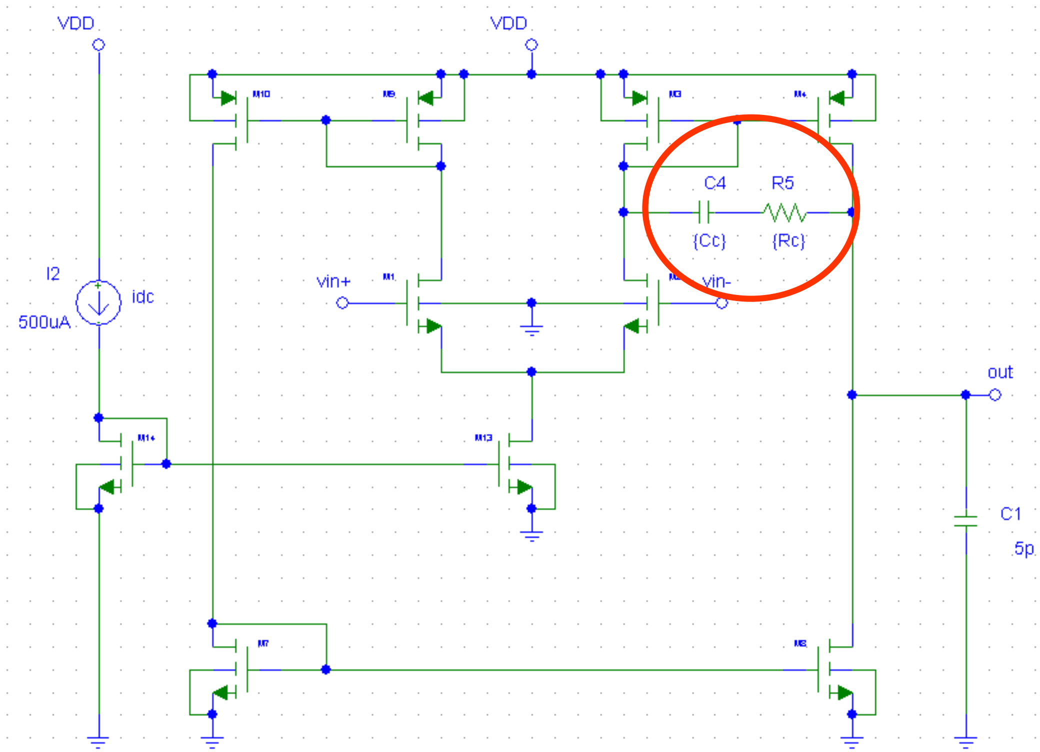


Lect. 14: Frequency Compensation





Lect. 14: Frequency Compensation



- Mirrored OTA Specifications

Parameter	Value
A_V	>56dB
Bandwidth	>60KHz
Phase Margin	>65°
V_{p-p}	>1.5V
Slew Rate	>13MV/s
CMRR	>85dB
Power Consumption	<2.5mW

Determine R and C for the optimal bandwidth and phase margin performance

Design Project help session next Monday during class: Q/A, progress check