EECS 240
Analog Integrated Circuits

Topic 10: Folded Cascode OTA

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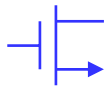
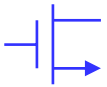
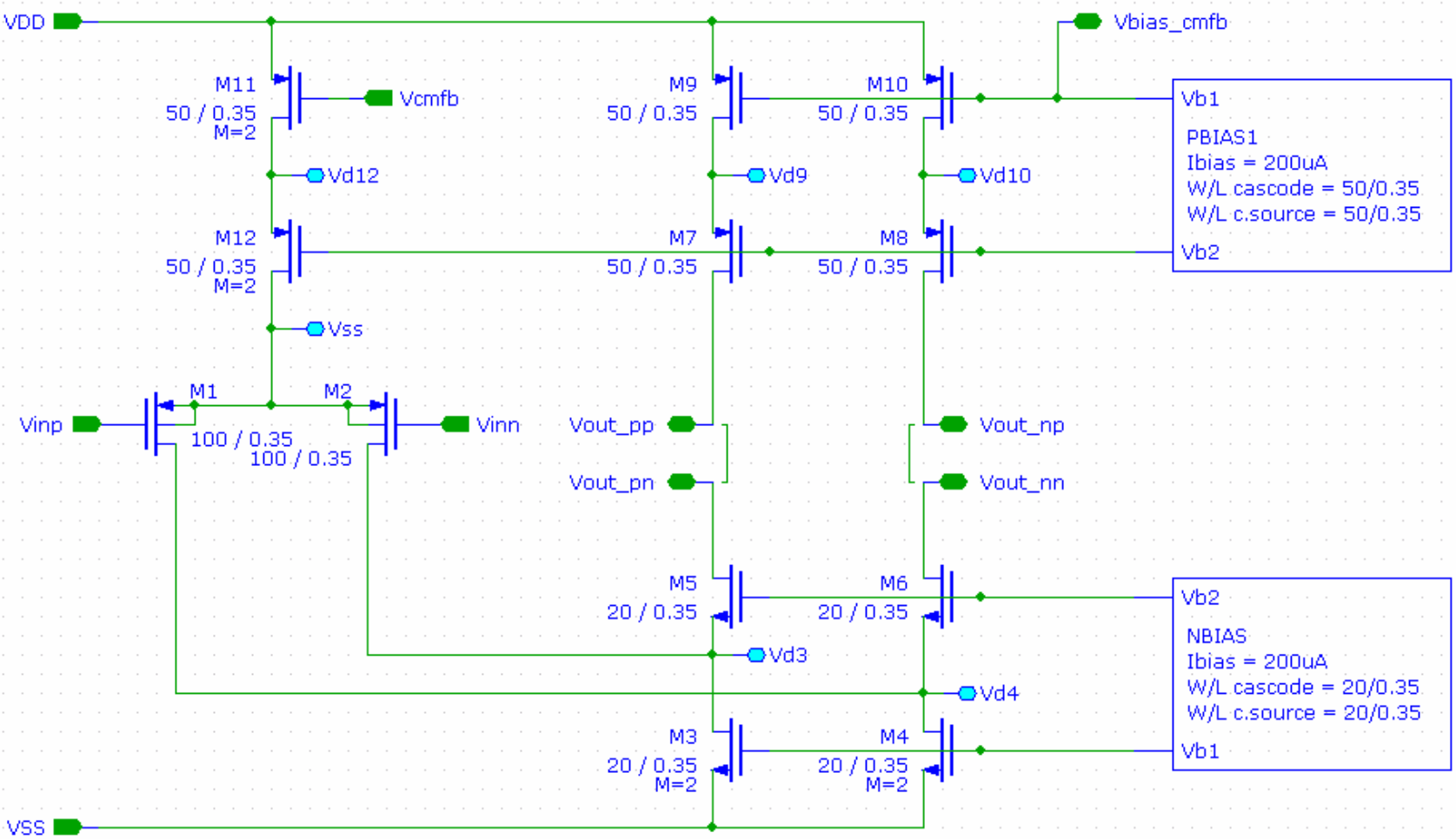


Folded Cascode

- Good general purpose single-stage OTA
- Analysis
  - Bias
  - Gain
  - Input capacitance
  - Frequency response
  - Feedback, stability
  - Settling time
  - Noise
  - Common-Mode Feedback
- Design
  - Specifications
  - Circuit parameters

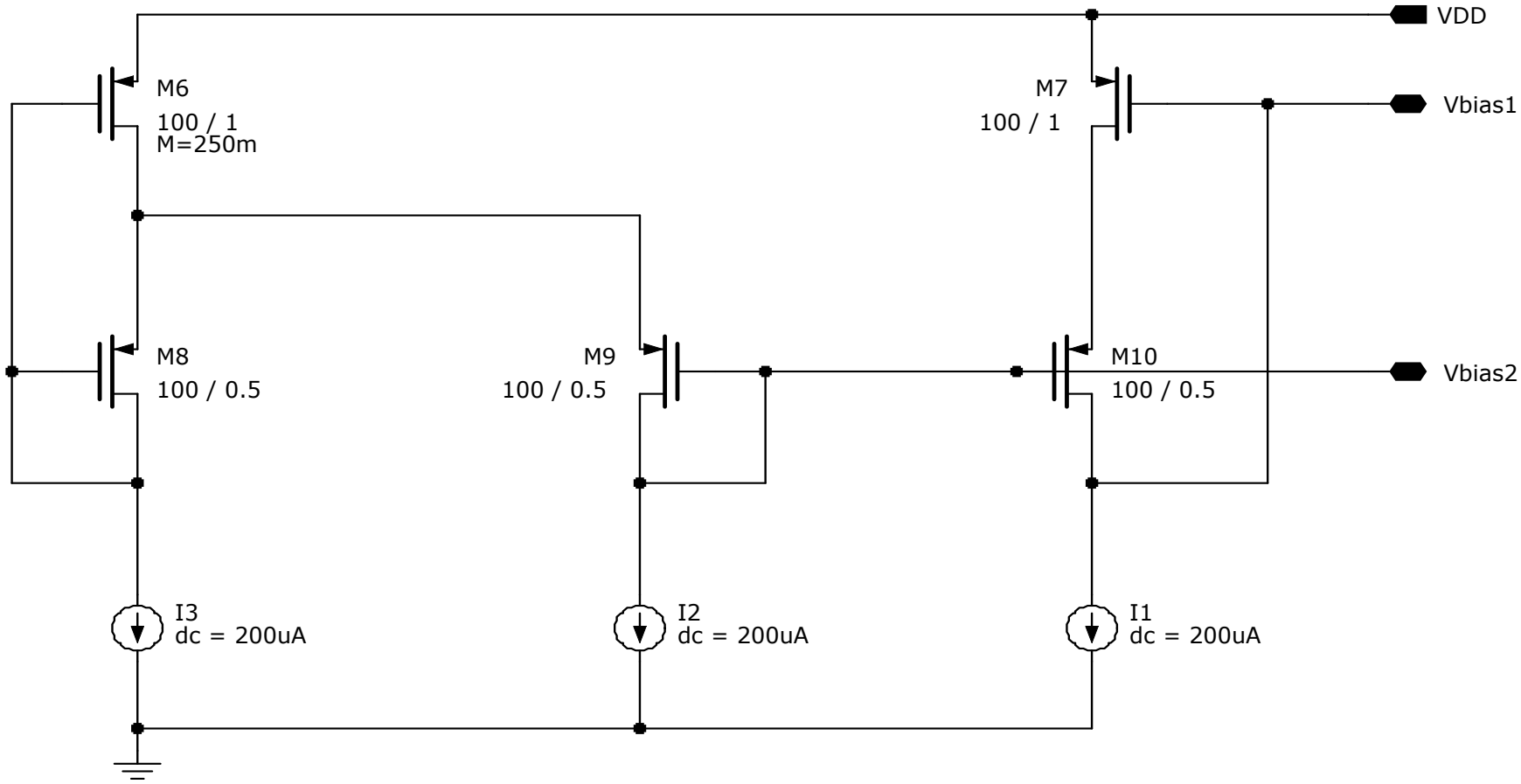


Schematic



Many more transistors, but overall characteristics very similar to common-source stage.

Bias Subcircuit



For device sizes on page 7.

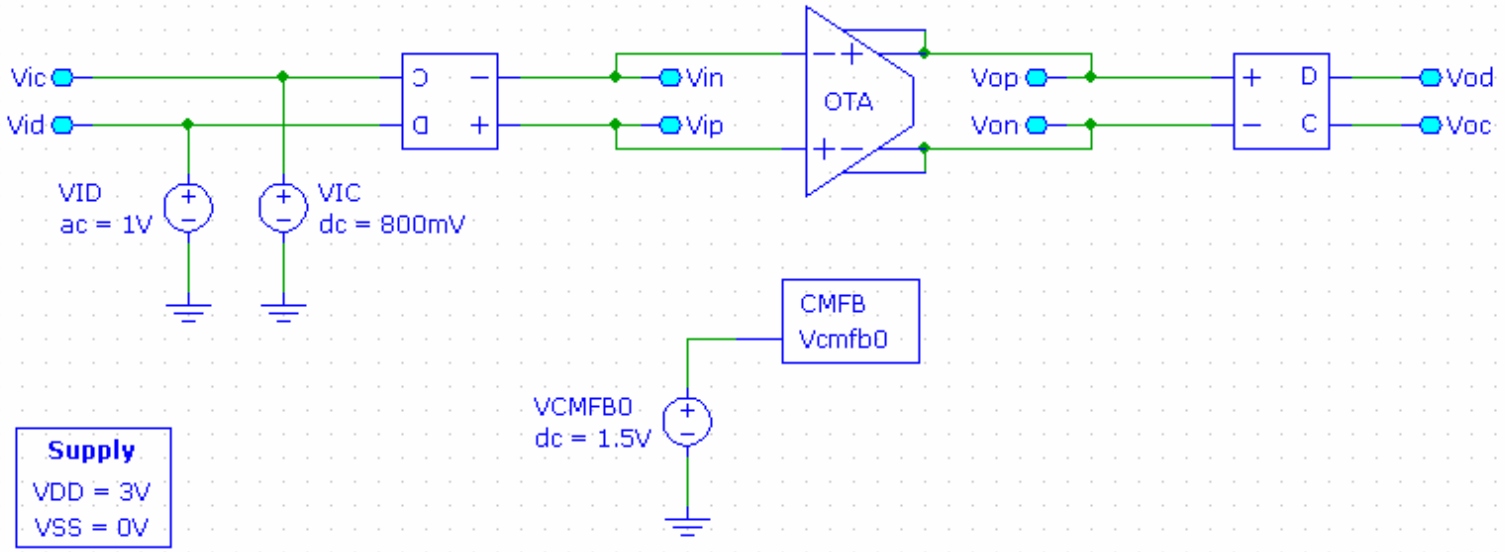
DC Gain, Bias

Folded Cascode: Open-Loop Gain

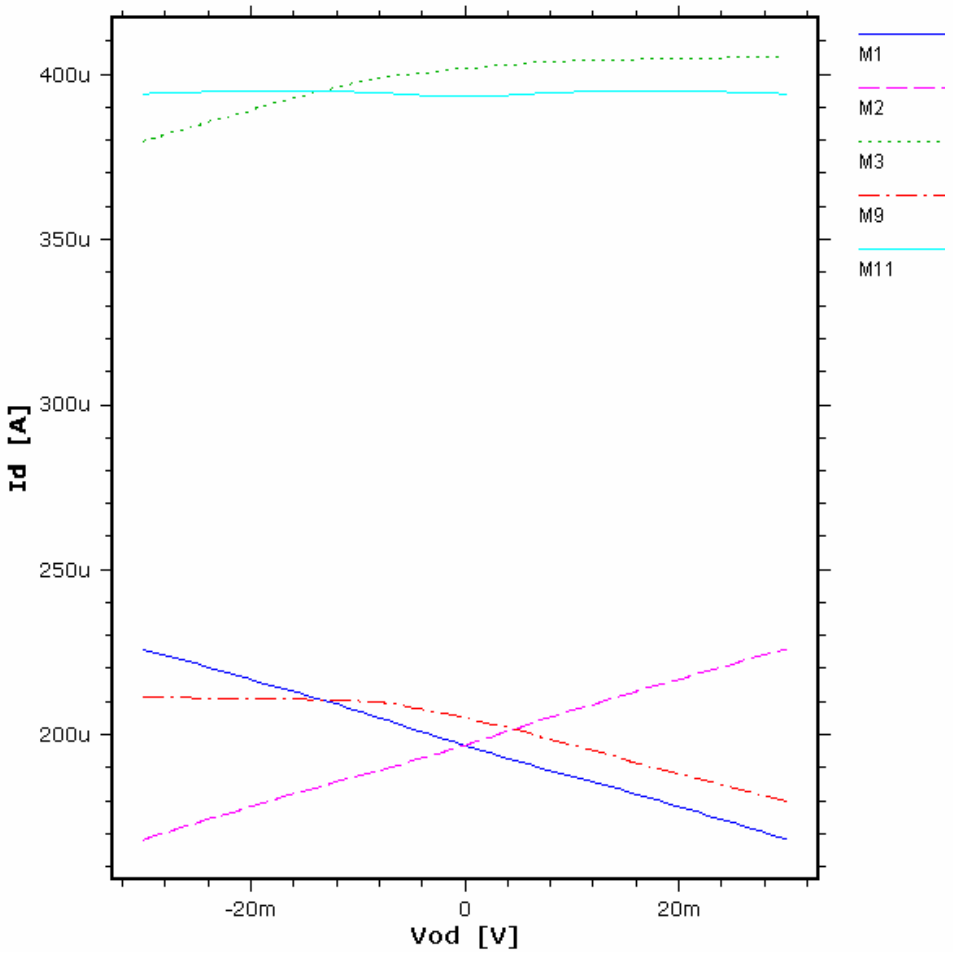
ISS = 400uA
(W/L)_1 = 100/0.35
(W/L)_3 = 20/0.35
(W/L)_5 = 20/0.35
(W/L)_7 = 50/0.35
(W/L)_9 = 50/0.35

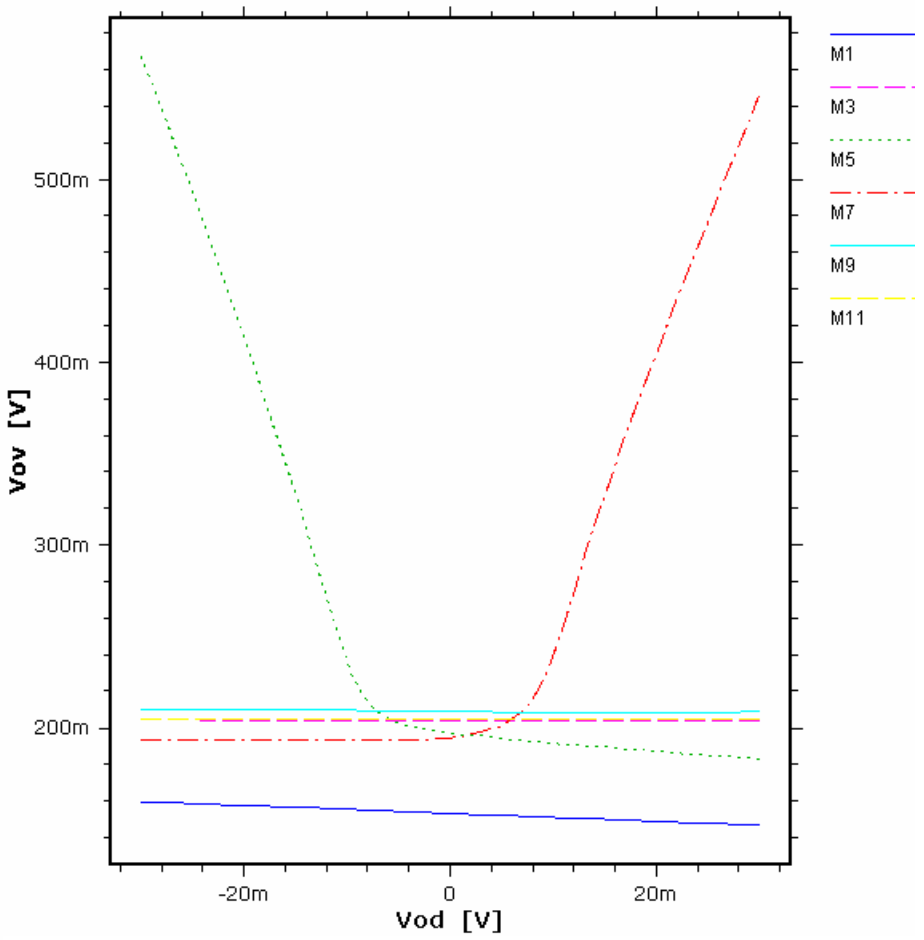
DC Analysis DC_Adm
Device VID
sweep from -50m to 50m (100 steps)

DC Analysis DC_Acm
Device VIC
sweep from 0 to 3 (30 steps)

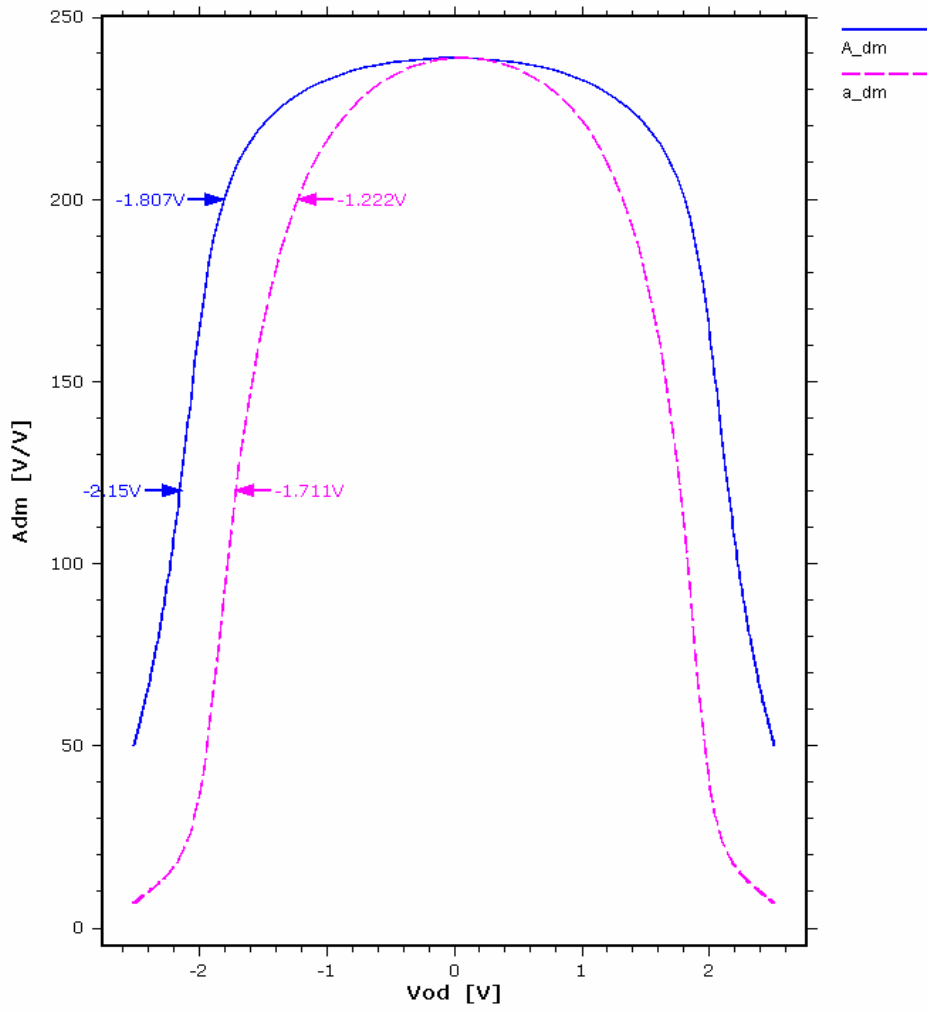


Bias … Differential Inputs

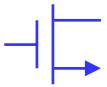




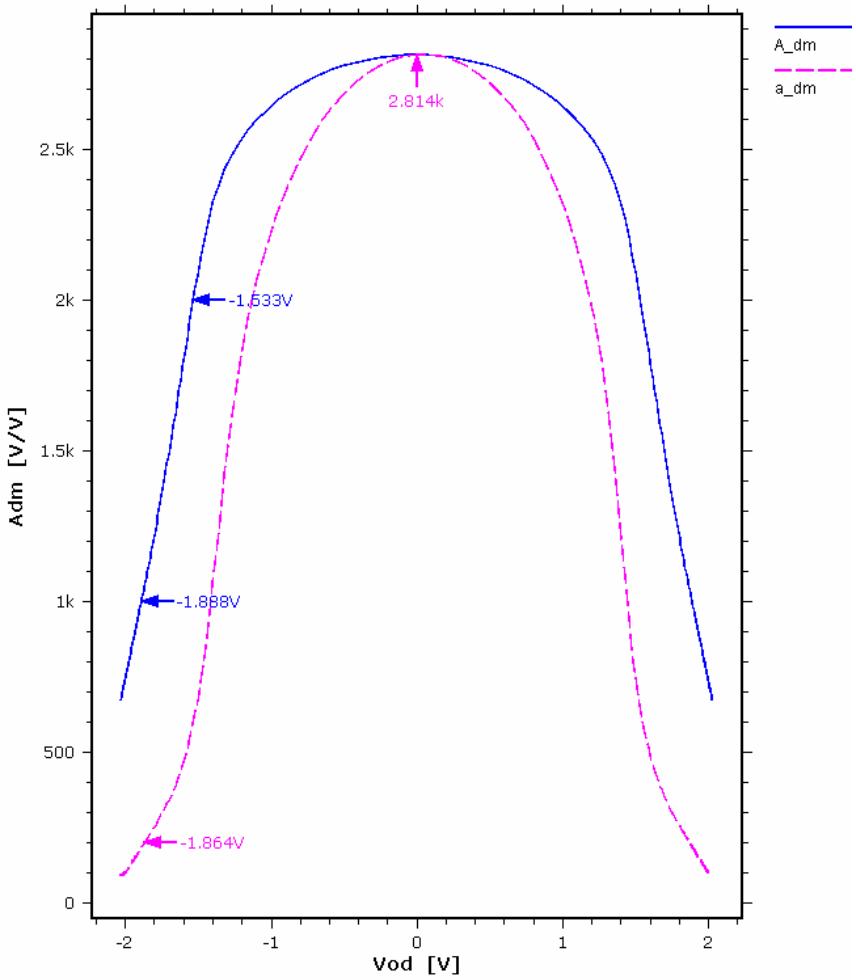
Low Frequency Gain, A_{dm}

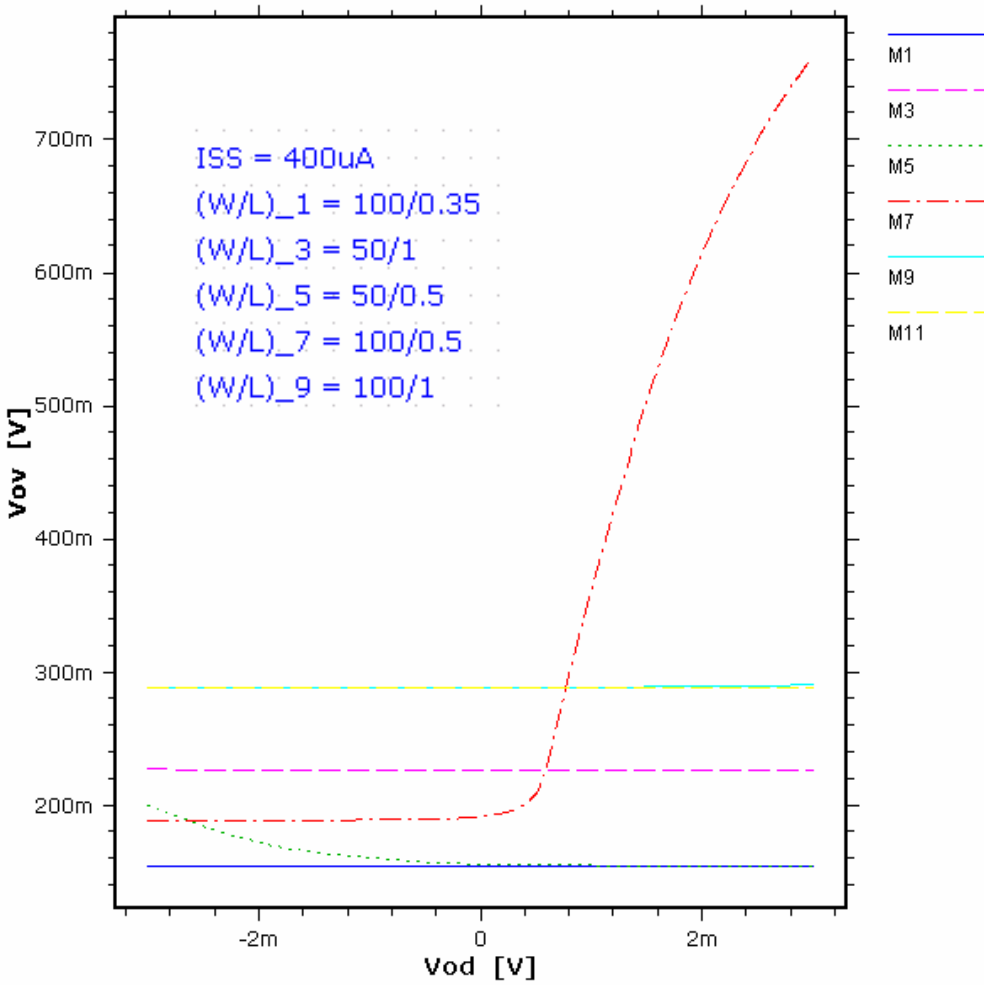


- Gain / Output Range tradeoff
  - A_{dm}=120 → ΔV_{od} = 4.3V
  - A_{dm}=200 → ΔV_{od} = 3.6V (nominal parameter)
- Increasing A_{dm}:
  - Moderate:
    - Increase L
    - Affects V*, phase margin
  - Substantial:
    - Double Cascode
    - Gain boosting
    - Multi-stage amplifier

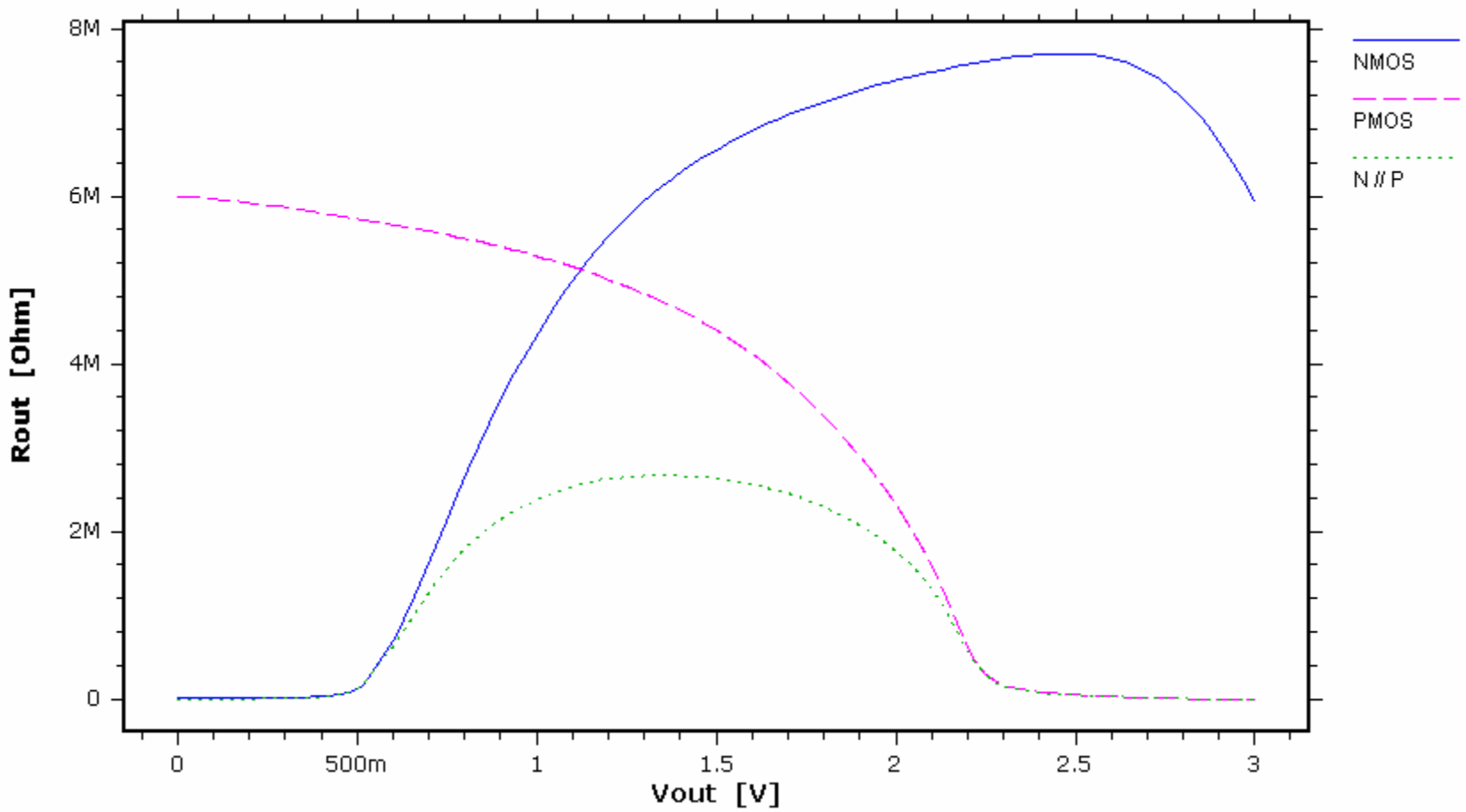


Increased A_{dm}





Output Resistance



Beware of imbalance between NMOS and PMOS current source

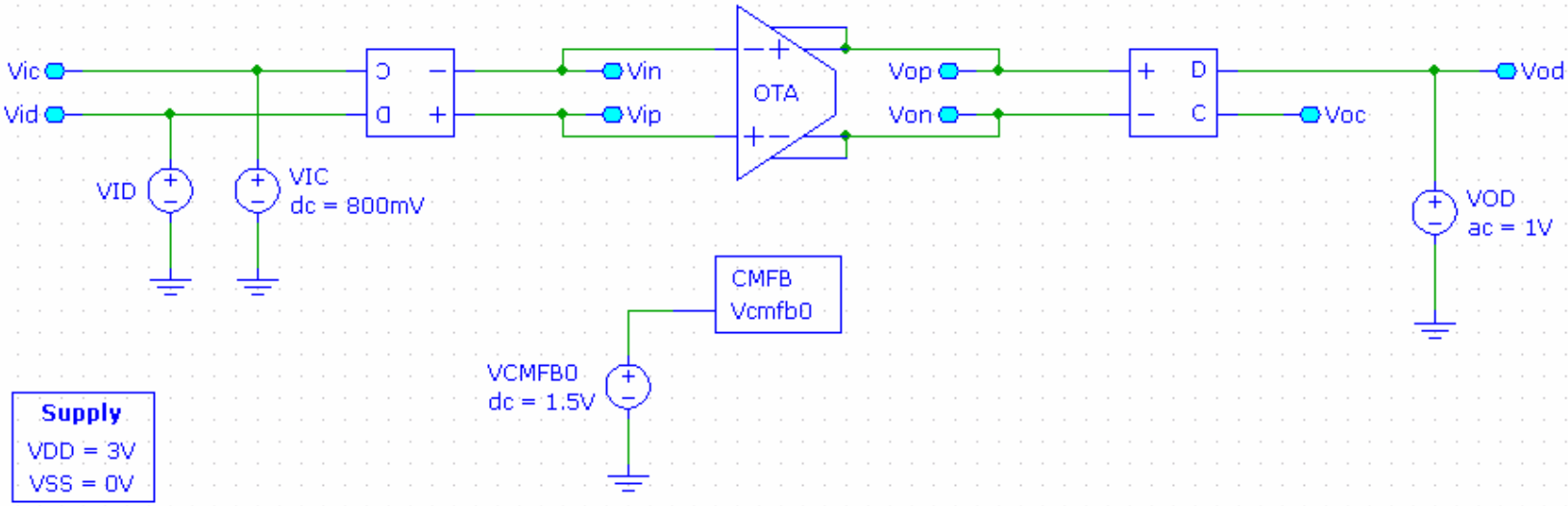
G_m, C_{od} Test Circuit

Folded Cascode: Gm

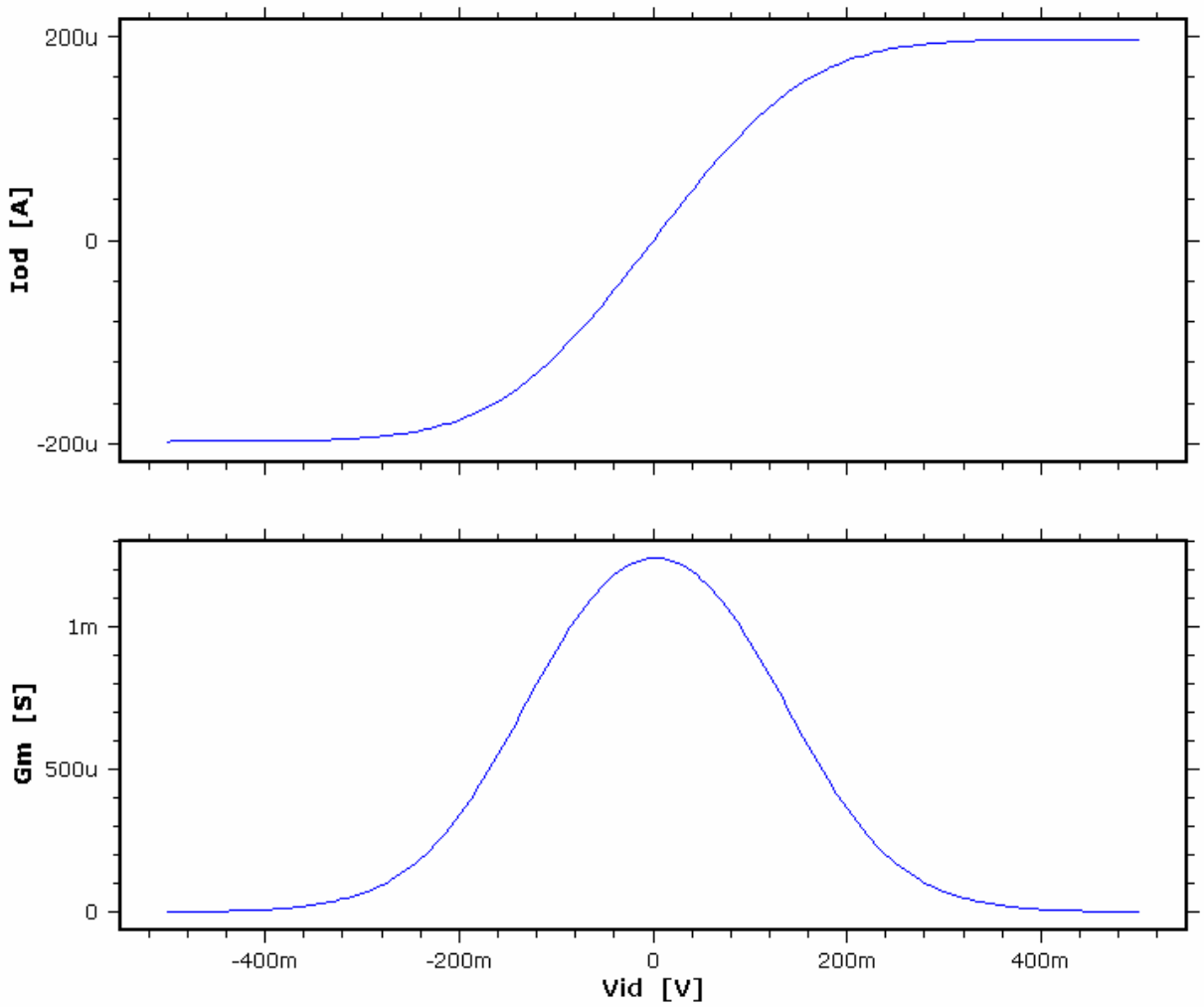
ISS = 400uA
(W/L)_1 = 100/0.35
(W/L)_3 = 50/1
(W/L)_5 = 50/0.5
(W/L)_7 = 100/0.5
(W/L)_9 = 100/1

DC Analysis DC
Device VID
sweep from -500m to 500m (200 steps)

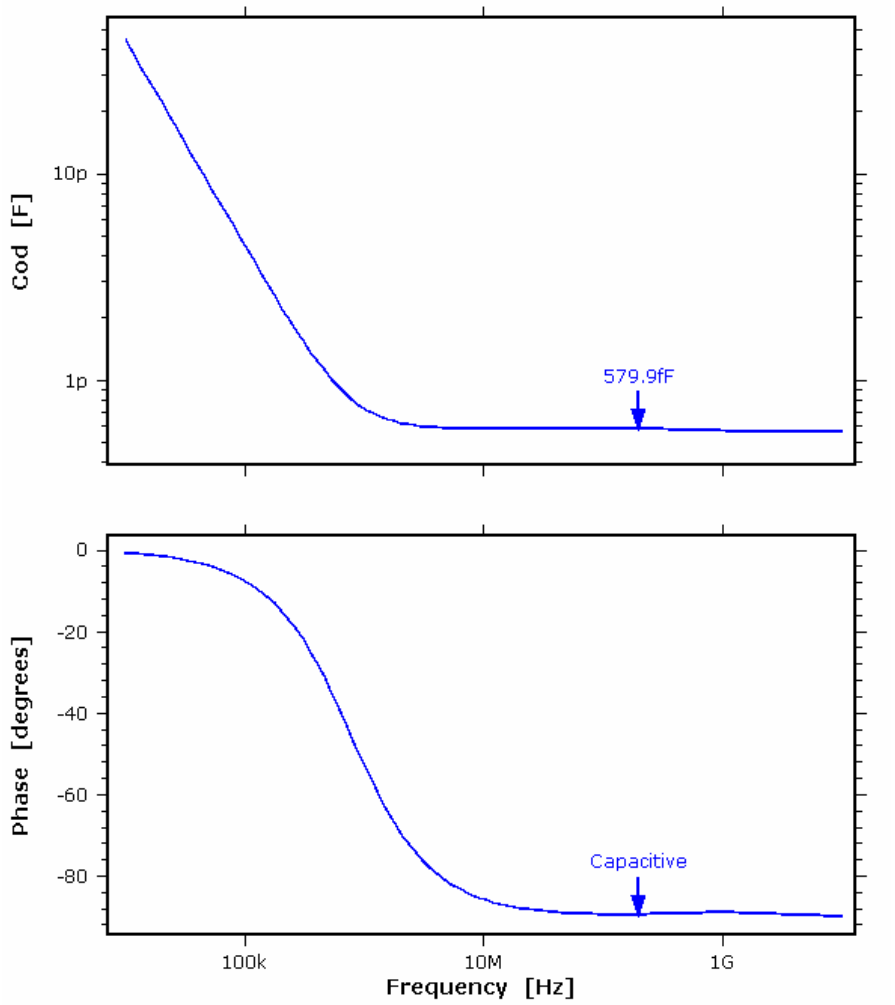
AC Analysis AC1
log sweep from 10k to 10G (101 steps)



Transconductance



Differential Output Capacitance



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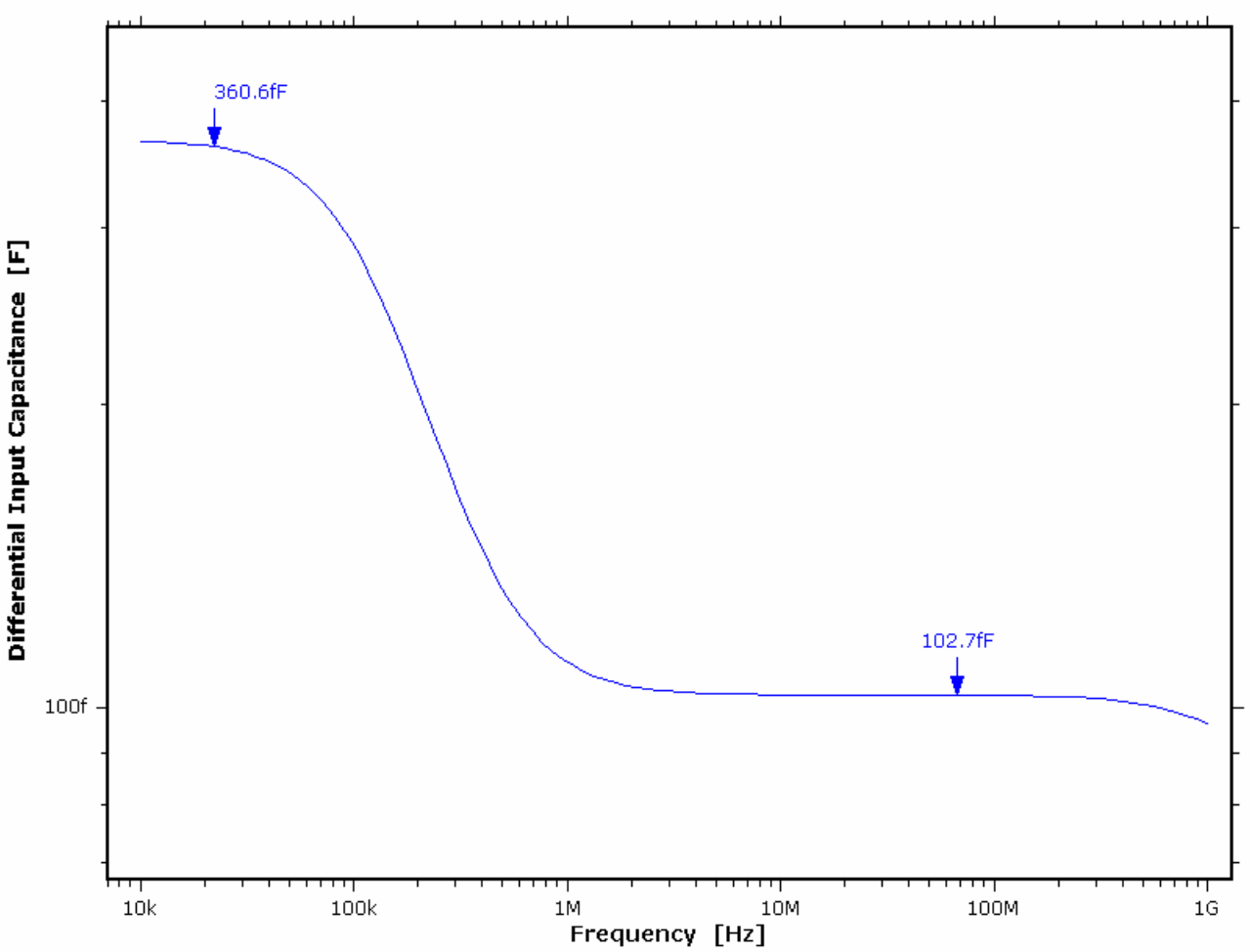
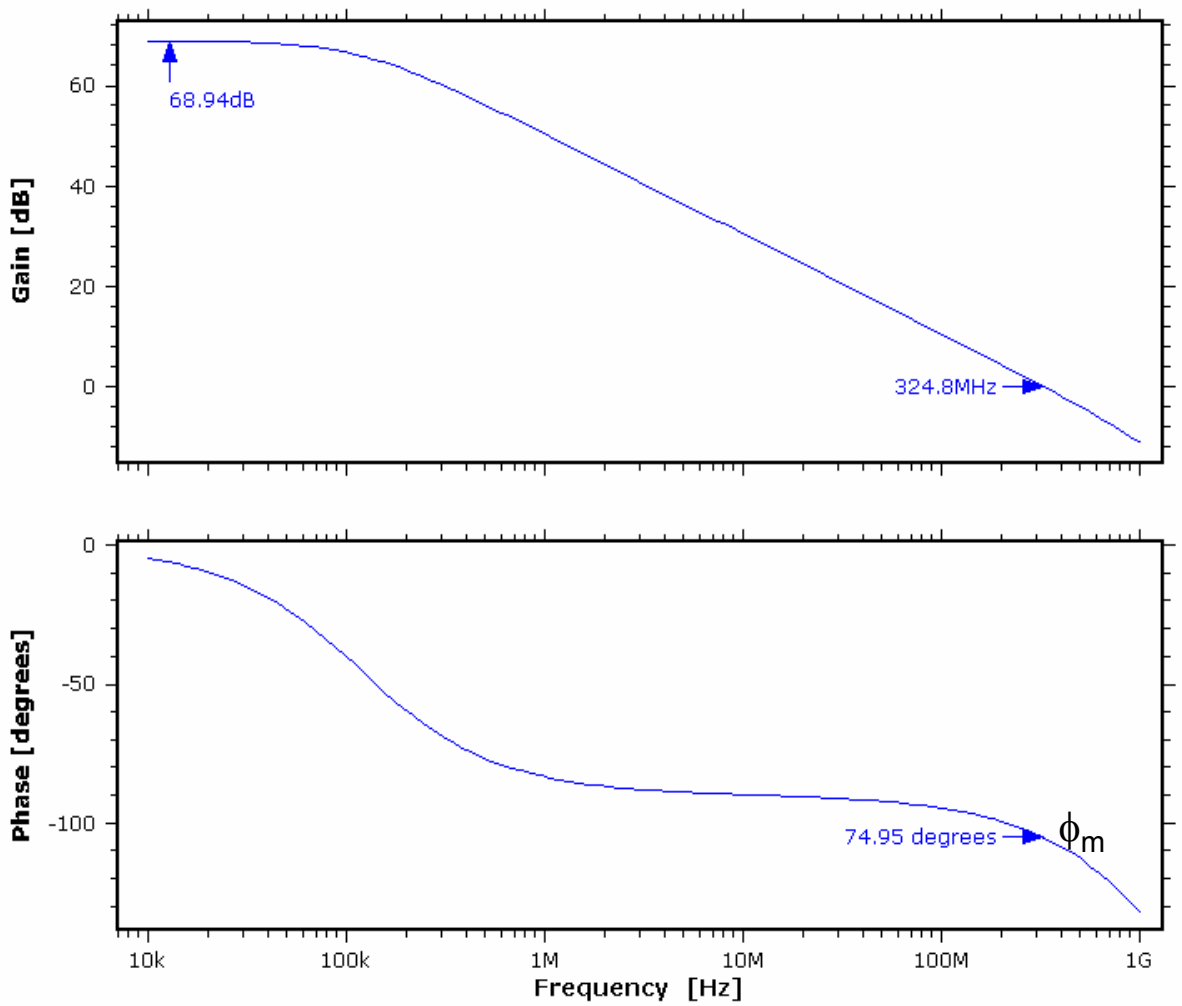


C_{GS1}
$= 2/3\ C_{ox}\ W\ L$
$= 117$ fF

Miller effect significantly increases C_{id} at low frequency

Cascoding M1, M2 helps (at the expense of reduced input common-mode range)

Frequency Response (A_{dm})



- Bandwidth
  - Strong function of C_L
  - Increasing f_u?
- Feedback
  - Stability
  - Phase margin
  - Increasing ϕ_m
  - Increasing C_L increases ϕ_m in single-stage amplifier (costly)