Lab. 13

DESIGN AND CHARACTERIZATION OF FULL-DIFFERENTIAL OPA

1. Design of full-differential OPA

- Determine the sizes of the MOSFETs and fill in the blank of Table I.
  - The area and perimeter of MOFET are given by W*3u and W+6u, respectively.

Target specifications

Parameter	Unit	Value	Remarks
GBP	Hz	40M	CL = 1.0pF
A_d	dB	100	@ 10Hz
Phase Margin	degree	60	
Slew Rate	V/us	10	CL = 1.0pF
Bias Current	A	200u	
Reference Current	A	10u	I_{SS} = 20uA

Table I

Folded-cascode differential amplifier

MOSFET	L(m)	W(m)	M	AD, AS(m^2)	PD, PS(m)	W/L
M1, M2						
M3, M4, M7-M10	2u	10u	3	30p	16u	15
M5, M6, M11-M13	2u	10u	1	30p	16u	5

The size of M1 and M2 can be estimated from the GBP and CL.

CMFB

MOSFET	L(m)	W(m)	M	AD, AS(m^2)	PD, PS(m)	W/L
M1-M4	2u	16u	8	48p	22u	64
M5-M12						
M13-M16	2u	10u	1	30p	16u	5

Remember that the CMFB circuit is a replica of the current source load of the amplifier.

Table II

BIAS

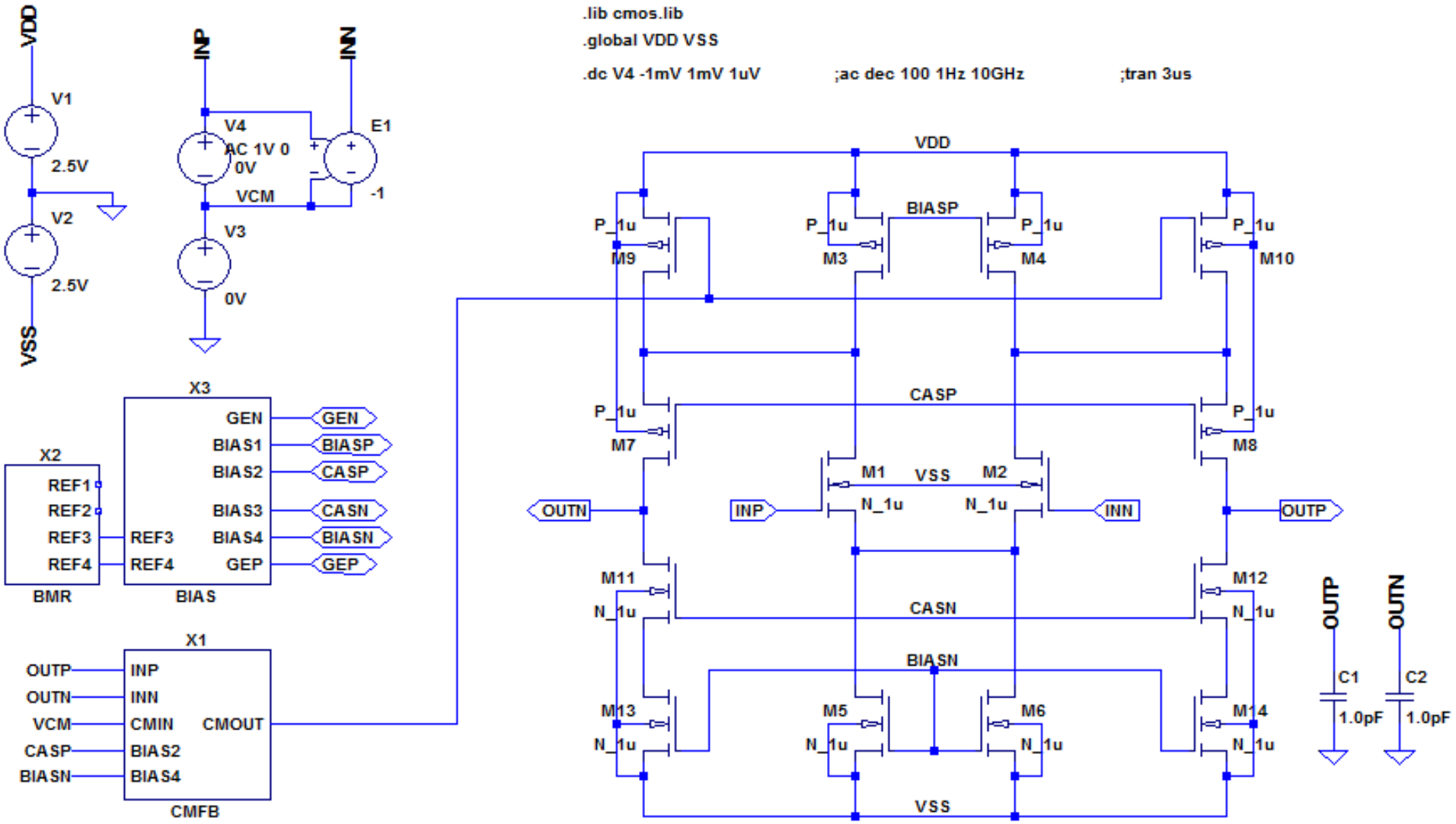
MOSFET	L(m)	W(m)	M	AD, AS(m^2)	PD, PS(m)	W/L
p-ch MOSFET	2u	10u	3	30p	16u	15
n-ch MOSFET	2u	10u	1	30p	16u	5

$$\Delta_{OV\_p-ch} = \sqrt{\frac{2I_{DS}}{\beta_p}} = \sqrt{\frac{2 \cdot 10\text{uA}}{33\text{uA/V}^2 \cdot 15}} = 0.201\text{V} \quad \Delta_{OV\_n-ch} = \sqrt{\frac{2I_{DS}}{\beta_n}} = \sqrt{\frac{2 \cdot 10\text{uA}}{98\text{uA/V}^2 \cdot 5}} = 0.202\text{V}$$

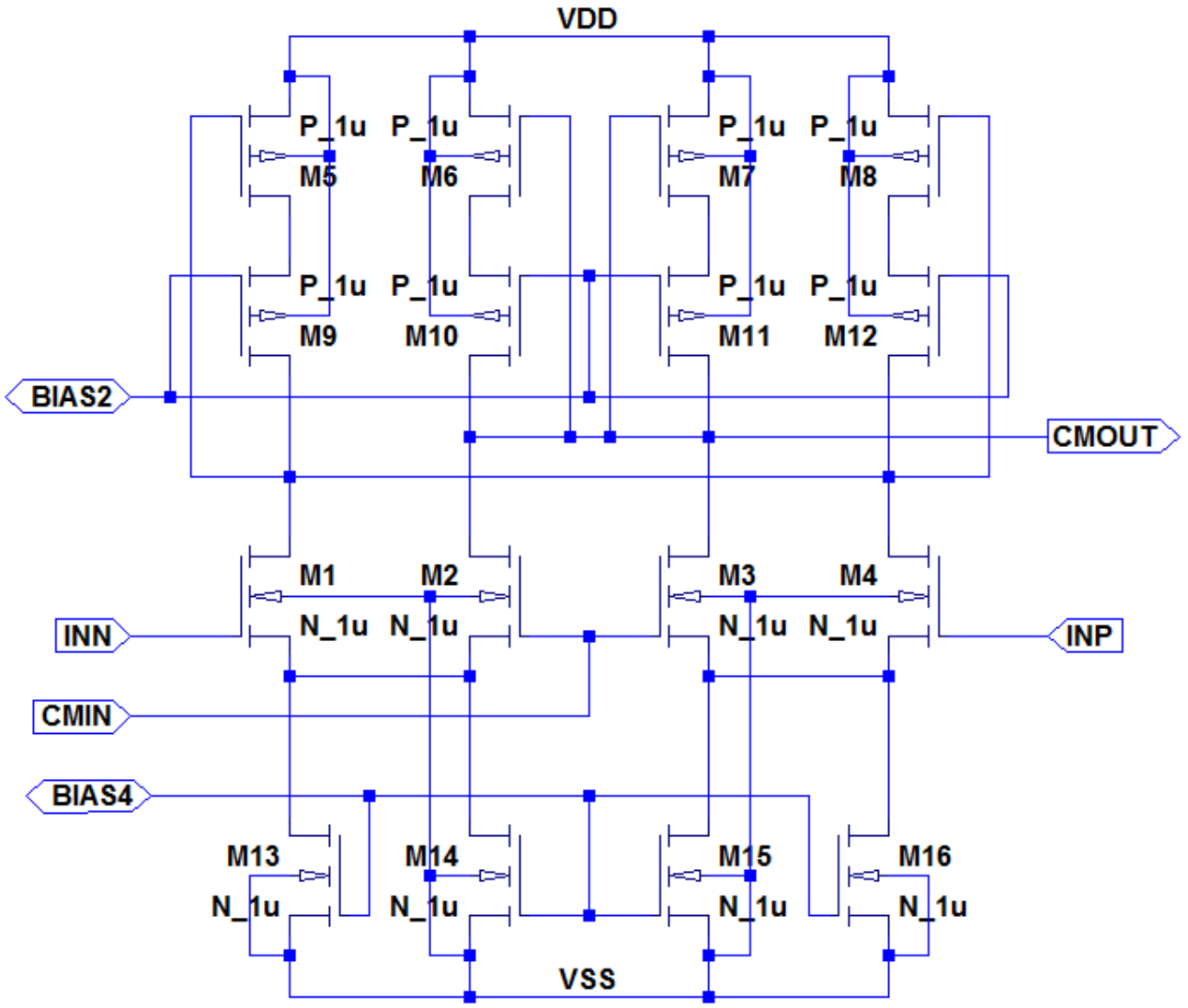
BMR

MOSFET	L(m)	W(m)	M	AD, AS(m^2)	PD, PS(m)	W/L
M1, M3, M4, M9, M10	2u	10u	1	30p	16u	5
M2	2u	10u	4	30p	16u	20
M5-M8	2u	10u	3	30p	16u	15
M11-M29	5u	5u	1	115p	11u	1

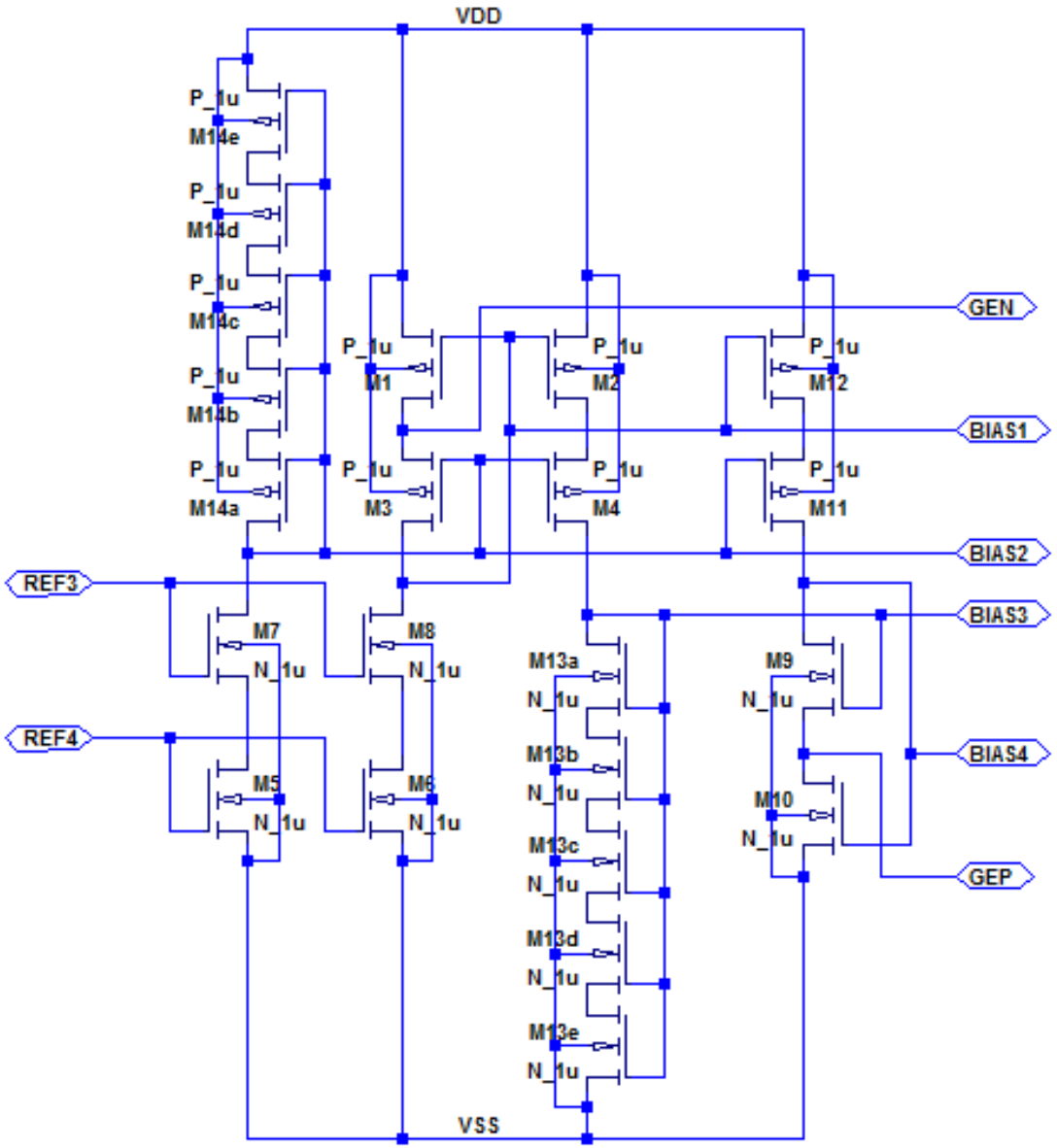
Folded cascode differential amplifier



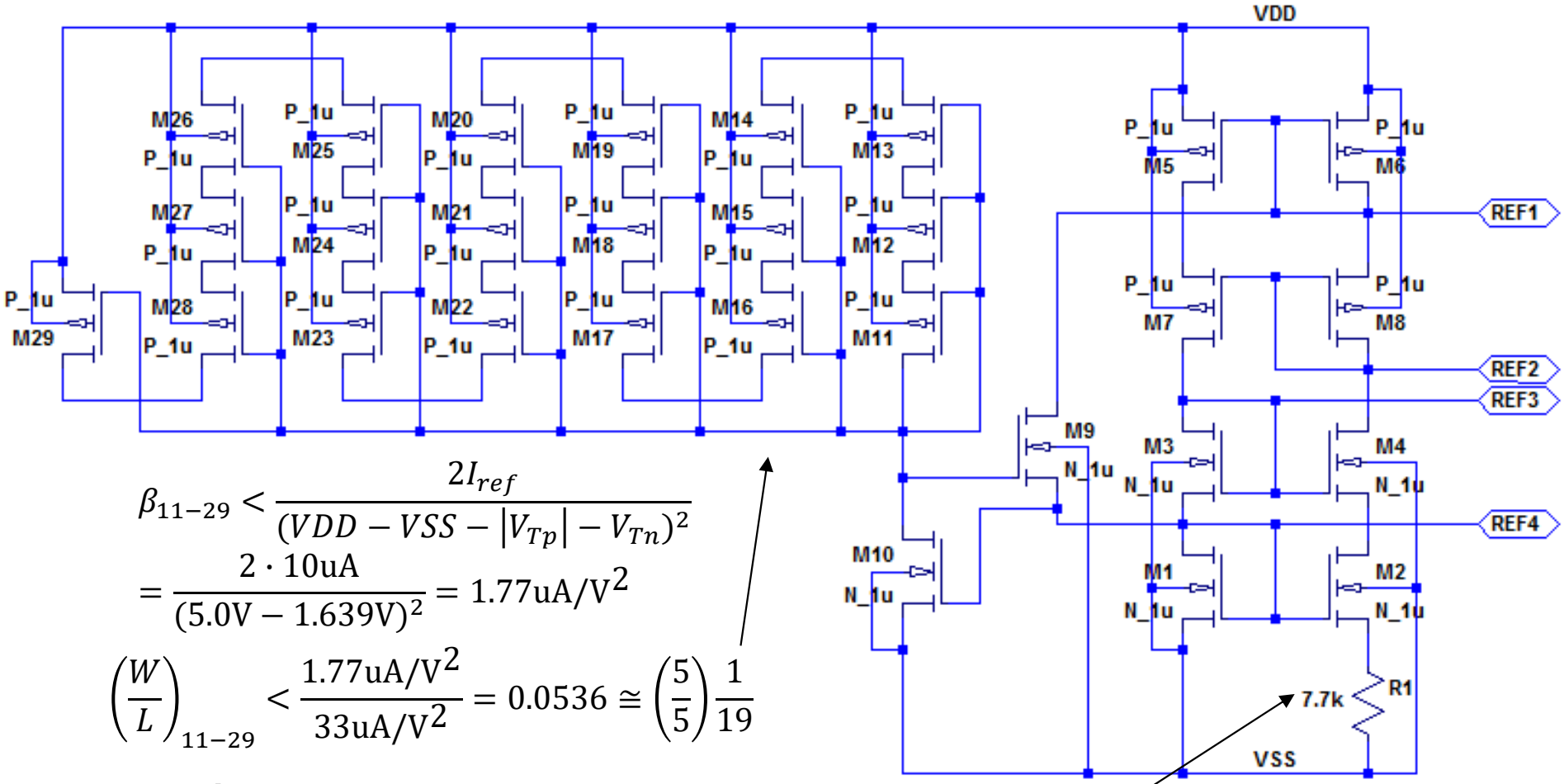
CMFB


VDD
P_1u
M5
M6
M7
M8
M9
M10
M11
M12
BIAS2
CMOUT
M1
M2
M3
M4
N_1u
INN
INP
CMIN
BIAS4
M13
M14
M15
M16
VSS

Bias


VDD
P_1u
M14e
P_1u
M14d
P_1u
M14c
P_1u
M14b
P_1u
M14a
P_1u
M1
P_1u
M2
P_1u
M12
P_1u
M3
P_1u
M4
P_1u
M11
GEN
BIAS1
BIAS2
BIAS3
BIAS4
GEP
REF3
REF4
M7
N_1u
M8
N_1u
M5
N_1u
M6
N_1u
M13a
N_1u
M13b
N_1u
M13c
N_1u
M13d
N_1u
M13e
N_1u
M9
N_1u
M10
N_1u
VSS

BMR



$$\beta_{11-29} < \frac{2I_{ref}}{(VDD - VSS - |V_{Tp}| - V_{Tn})^2}$$

$$= \frac{2 \cdot 10\text{uA}}{(5.0\text{V} - 1.639\text{V})^2} = 1.77\text{uA/V}^2$$

$$\left(\frac{W}{L}\right)_{11-29} < \frac{1.77\text{uA/V}^2}{33\text{uA/V}^2} = 0.0536 \cong \left(\frac{5}{5}\right)\frac{1}{19}$$

$$\text{R1} = \sqrt{\frac{2}{\beta_1 I_{ref}}}\left(1 - \frac{1}{\sqrt{K}}\right) = \sqrt{\frac{2}{98\text{uA/V}^2 \cdot 5 \cdot 10\text{uA}}}\left(1 - \frac{1}{\sqrt{4}}\right) = 10.1\text{k}\Omega \quad \text{(Adjusted)}$$

2. Characterization

- Carry out the DC, AC, and TRAN analysis of the full-differential OPA and attach the simulation results to your report.
  - DC characteristic of V(inp), V(inn), V(outp), V(outn), V(cmfb), Id(M1), Id(M2), and I(V1)
    - Check the offset voltage. The systematic offset should be removed by the CMFB.
  - AC characteristic of V(outp) and V(outn)
  - The step response (TRAN characteristics) of V(inp), V(inn), V(outp), and V(outn)
- Fill out the blank in Table III by using your simulation results.

Table III

- The specification estimated by the simulation.

Parameter	Unit	Value	Remarks
GBP	Hz		CL = 1.0pF
A_d	dB		@ 10Hz
Phase Margin	degree		
Slew Rate	V/us		CL = 1.0pF
Total Bias Current	A		
Reference Current	A		$I_{SS}/2$