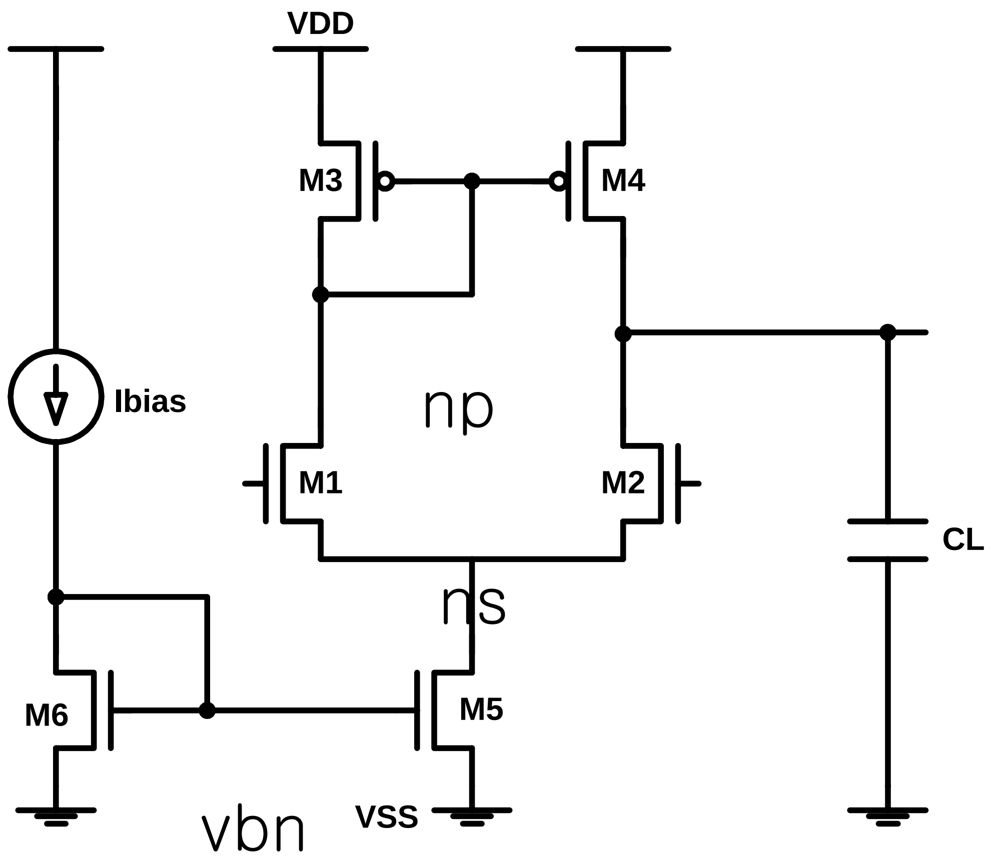
HW 1: Differential amplifier

due Oct. 05 (Wed.) class



Attach a 0.2pF capacitor between np and Vss.

Attach a 0.2pF capacitor between ns and Vss.

HW1: Spec for diff amp

- supply voltage, process : 3.3V, 0.35um process
- input common mode range(ICMR) : 1.1 V < ICMR < 2.7 V
- differential voltage gain : > 100 (40dB)
- phase margin : > 90 °
- -3dB bandwidth : 100kHz (load cap = 5pF)
- slew rate : >= 10V/us (load cap = 5pF)
- power : <= 1mW (excluding bias circuit)

	L (um)	VTO (V)	KP (u A/V²)	LAMBDA (1/V)
NMOS	0.35	0.50	94	0.09
NMOS	0.70	0.59	132	0.04
PMOS	0.35	0.72	48	0.12
PMOS	0.70	0.75	52	0.03

HW 1: Differential amplifier

(Make sure that the report do not exceed 10 pages excluding the cover page)

(1) Determine some design parameters from spec using hand analysis.

(Refer the hint at the next page and use the level 1 parameters shown.)

(2) Tweak the design parameters so that SPICE simulation results satisfy the spec. Start from the design parameters determined at the step (1).

(3) Present the SPICE input netlist excluding the model parameter set.

Make sure to include AD, AS, PD, PS in SPICE netlist (refer to the next slide)

(4) Present Sum (Wi x Li) for M1, .., M5 and the spec parameters from SPICE.

(5) Compare the results from hand analysis and SPICE for the following parameters. Use the design parameters of step (2).

1. Low frequency differential mode voltage gain at Vin.cm = 1.65V
2. Low frequency common mode voltage gain at Vin.cm = 1.65V
3. Active input common mode voltage range (min and max values)
4. Dominant pole, non-dominant pole, zero frequency in Hz
5. Input offset voltage with delta L = +- 0.14um @ 3 sigma (use Monte Carlo sim with diff mode DC transfer curve by SPICE, let Vos = diff input voltage when Vout=Vg(M3))
6. Input offset voltage with W1 increased by twice.

HW 1: Differential amplifier

7. Small signal voltage gain of Vout / Vdd (Low frequency value, pole, zero)

8. Small signal voltage gain of Vout / Vss (Low frequency value, pole, zero), Attach 0.5pF capacitor between ns and Vss.

Hints for step (1)

1. Choose L between 0,.35um and 0.70 um.
2. Determine the bias current of tail current source(I(M5)) from SR or power.

   SR = I(M5)/CL   Power = Vdd x I(M5)

3. Calculate Rout and check whether it meets the BW spec.

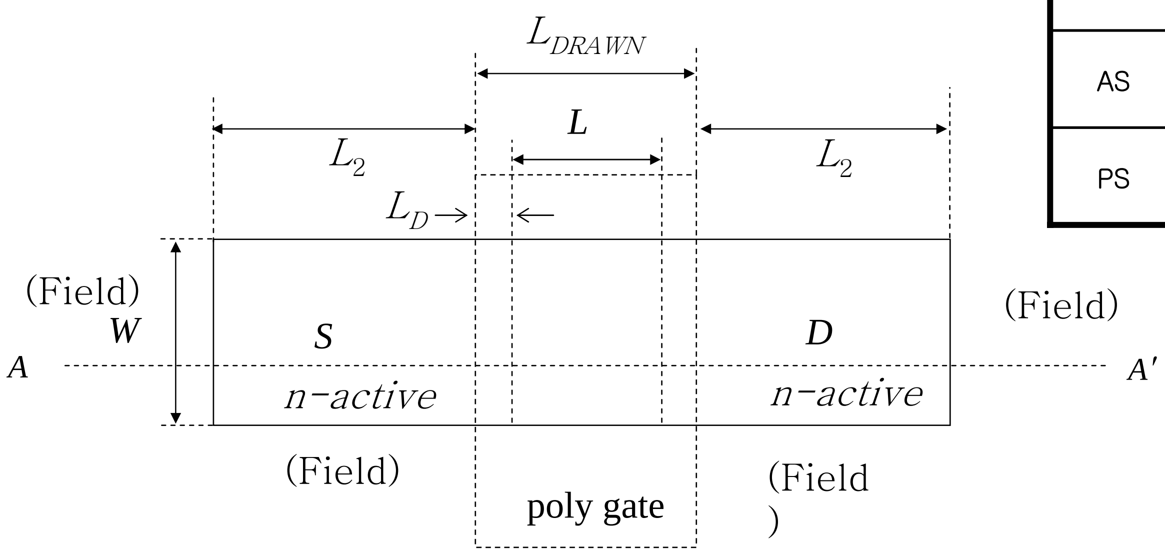
   Rout = 2 / { (LambdaN + LambdaP) x I(M5) }   BW = 1/ (2 pi x Rout x CL)

4. Calculate VDSAT(M1) from the low frequency small signal voltage gain.
5. Calculate VDSAT(M5) from min ICMR.
6. Calculate VDSAT(M3) from max ICMR
7. Calculate W/L from ID = 0.5 x KP x W/L x $VDSAT^2$
8. Iterate until all specs are satisfied.

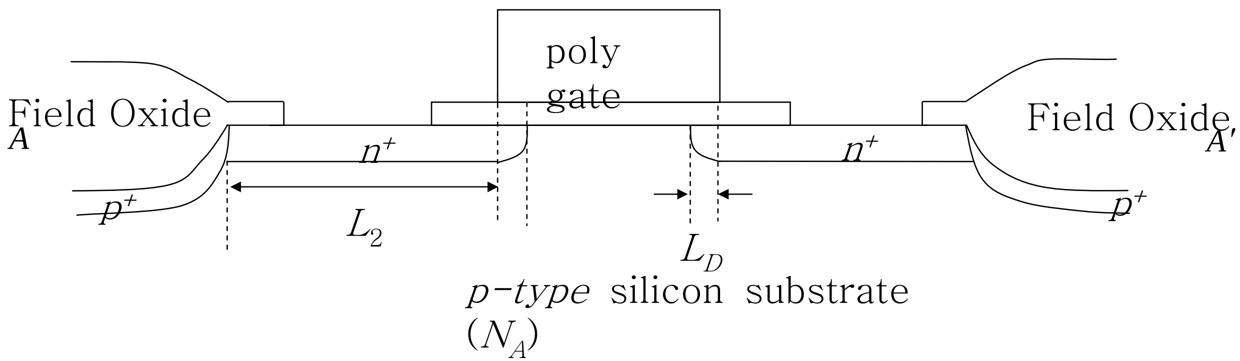
How to decide AD, AS, PD, PS

MOSFET layout & cross section

Name	Meaning	unit	Equation
AD	Drain Jct area	$[m^2]$	$W \cdot (L_2 + LD)$
PD	Drain sidewall length	$[m]$	$W + 2L_2$
AS	Source Jct area	$[m^2]$	$W \cdot (L_2 + LD)$
PS	Source sidewall length	$[m]$	$W + 2L_2$



Assume
L2=0.35 um x 3
LD=0
for a 0.35um process



Hint: SPICE control parameters

```
********************************************
** Common mode DC transfer curve ************
*********************************************
*vsin in inb dc 0
*vsincm incm in dc 0
*vincm incm vss dc 2
*.dc vincm 0 3.3 0.001

*********************************************
** Differential mode DC transfer curve ******
*********************************************
voffset in in1 dc 0
voffset2 inb inb1 0
einb inb1 incm in1 incm -1
vindm in1 incm dc 0
vincm incm vss dc 2
.dc vindm -0.5 0.5 0.001

* Monte Carlo analysis for DC tran curve(diff mode)
*voffset in in1 dc 0
*voffset2 inb inb1 0
*einb inb1 incm in1 incm -1
*vindm in1 incm dc 0
*vincm incm vss dc 2
*.dc vindm -0.5 0.5 0.001 sweep monte=1000
*.param l_e1=gauss(0.7um, 0.20, 3)
```

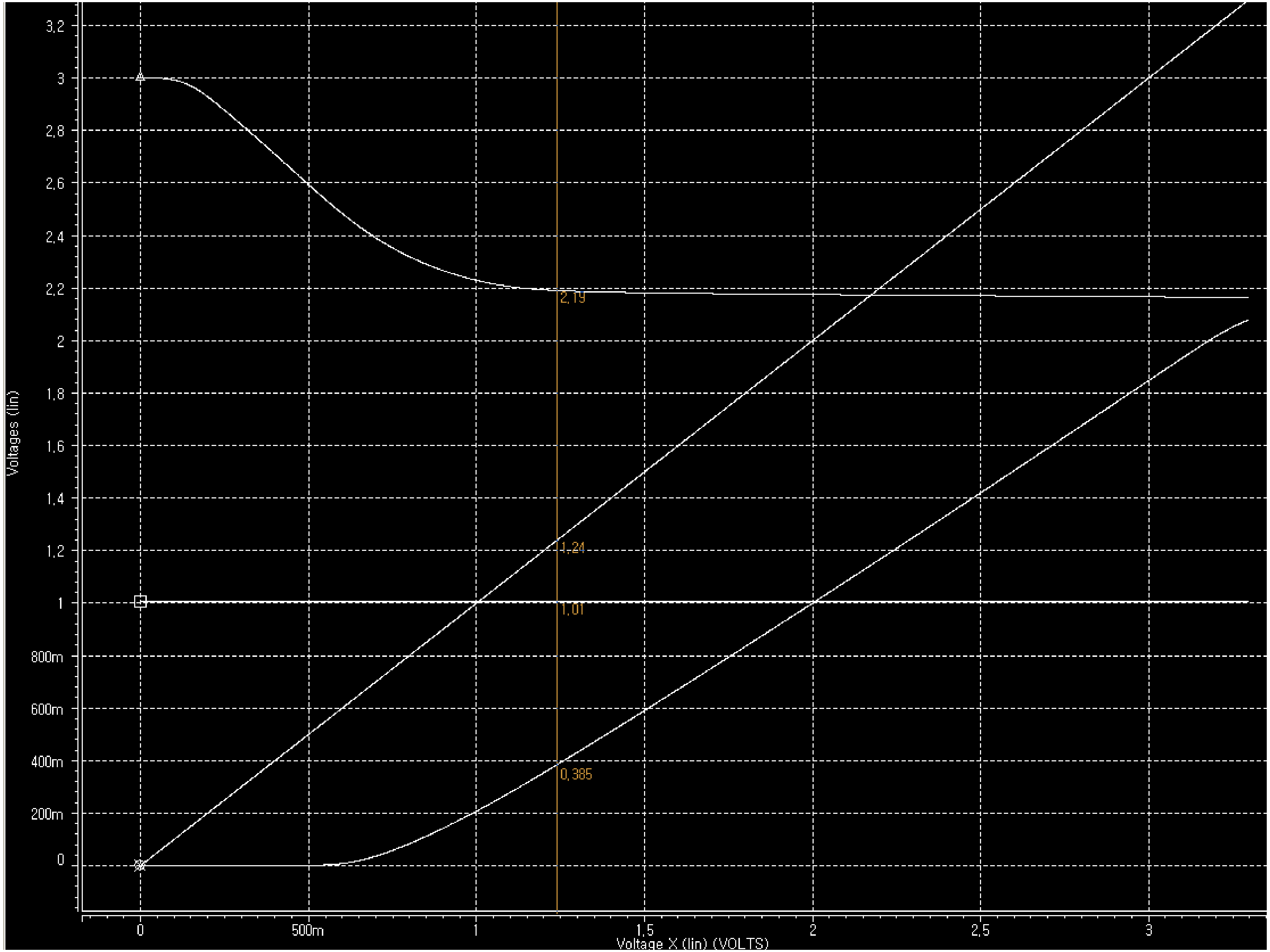
Hint: SPICE control parameters

```
**********************************************
** Differential mode frequency response *****
**********************************************
*vin in vss dc 2 ac 0.5 0
*vinb inb vss dc 2 ac 0.5 180
*.ac dec 10 10K 1000meg
*Cnp1 np1 vss 2p

**********************************************
** Common mode frequency response************
**********************************************
*vin in vss dc 2 ac 1
*vinb inb vss dc 2 ac 1
*.ac dec 10 10K 1000meg

**********************************************
** monte carlo ******************************
** Differential mode frequency response
**********************************************
*vin in vss dc 2 ac 1
*vinb inb vss dc 2 ac 0
*.ac dec 10 1K 1000meg sweep monte=100
*.param l_e1=gauss(0.7um, 0.10, 3)
```

Hint: SPICE control parameters

```
*********************************************
**** d Vout / d Vdd **********************************
*********************************************
*Vdd vdd 0 3.3V ac 1
*vi1 in 0 dc 2
*vi2 inb 0 dc 2
*.ac dec 10 1k 10meg
*
**** d Vout / d Vss **********************************
*********************************************
Vdd vdd 0 3.3V
vss vss 0 dc 0 ac 1
vi1 in 0 dc 2
vi2 inb 0 dc 2
.ac dec 10 1k 1000meg
***************************************
******* Slew rate          ************
***************************************
*vi1 in 0 dc 1.2 pulse 1.2 2.0 0 0 0
*vi2 inb out 0
*.tran 1n 200n
**
.inc "model0p35.txt"
```

Min ICMR determined at Vns=Vbn-Vthn



Max ICMR determined at Vin=Vout+|Vthp|