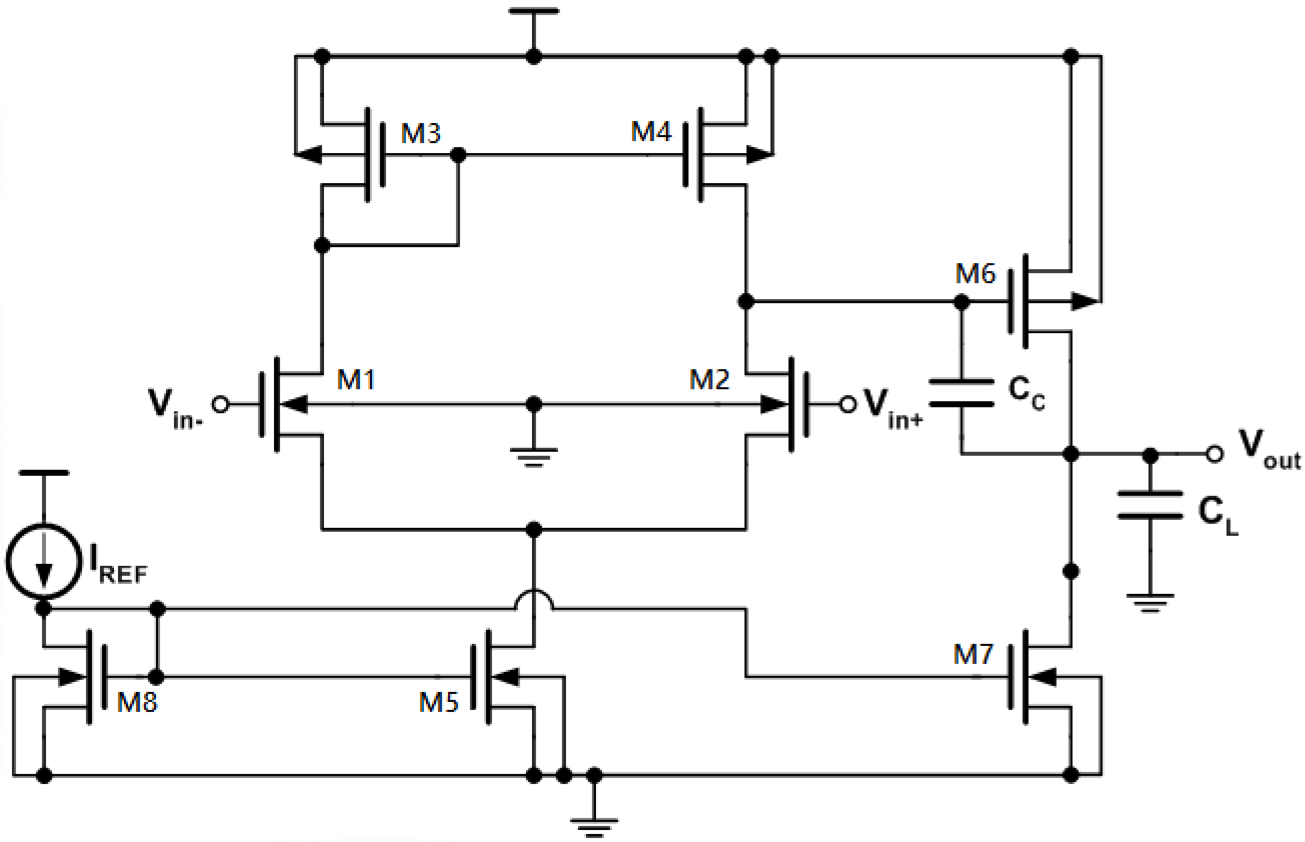
Two stage opamp

Professor: Paul C.-P. Chao

Two stage opamp

- Vdd=1.8V, Vin+=Vin-=0.9V, C_L=4pF



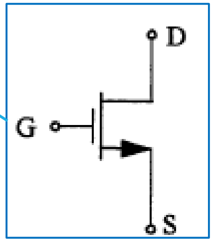
MOS

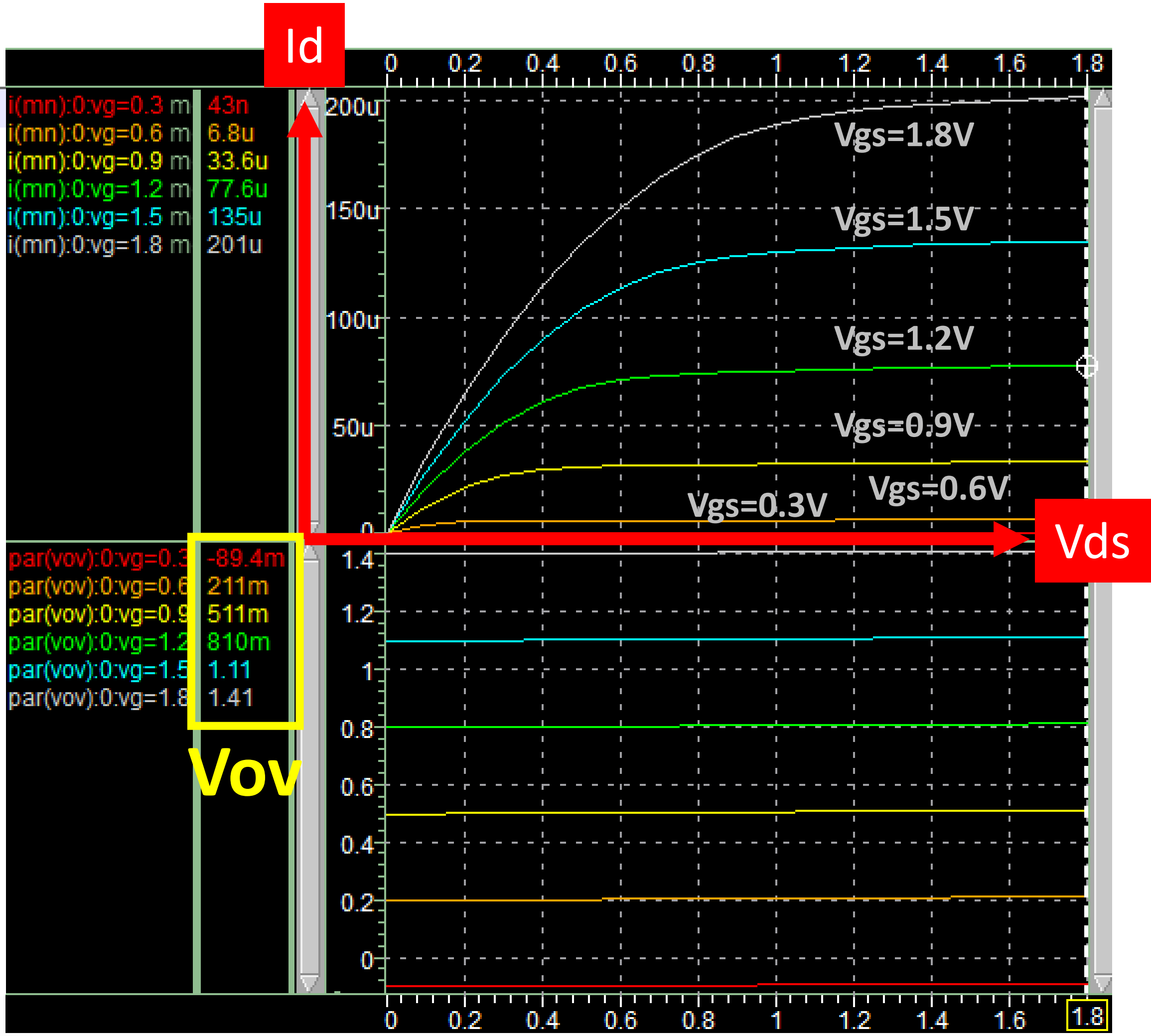
```
****** MOS ******
.option post accurate method=gear
.option probe
.lib 'cic018.l' TT
.temp 27

* Main Circuit
MN   D    G    S    B   N_18   L=1u W=1u

Vd   d    gnd       DC=1.8
Vg   g    gnd       DC=0.9
Vs   s    gnd       DC=0
Vb   b    gnd       DC=0

* Simulation Commands
.op
.dc  vd 0 1.8 0.1 sweep vg 0.3 1.8 0.3
.probe DC  V(*)
.print DC I(MN)
.probe vth = lv9(MN)
.probe vov = par('lx2(MN)-lv9(MN)')
.end
```





MOS

- Calculate by Excel

B6 | f_x | =B2*2/B3*B5/(B4^2)

	A	B	C	D
1	算W			
2	Id	76	(uA)	
3	uCox	240	(uA/V2)	
4	vov=vgs-vth	0.8	(V)	
5	L	1	(u)	
6	W	0.989583	(um)	
7				
8				
9				
10	算uCox			
11	Id	76	(uA)	
12	vov=vgs-vth	0.8	(V)	
13	W	1	(u)	
14	L	1	(u)	
15	uCox	237.5	(uA/V2)	

Operation in the *saturation* region:

- Conditions:

  (1) $v_{GS} \geq V_t \Leftrightarrow v_{OV} \geq 0$

  (2) $v_{GD} \leq V_t \Leftrightarrow v_{DS} \geq v_{GS} - V_t \Leftrightarrow v_{DS} \geq v_{OV}$

- i-v Characteristics:

$$\boxed{i_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(v_{GS} - V_t)^2(1 + \lambda v_{DS})}$$

Threshold voltage:

$$V_t = V_{t0} + \gamma\left(\sqrt{2\phi_f + |V_{SB}|} - \sqrt{2\phi_f}\right)$$

Overdrive voltage:

$$v_{OV} = v_{GS} - V_t$$

$$v_{GS} = V_t + v_{OV}$$

Process parameters:

$C_{ox} = \varepsilon_{ox}/t_{ox}$	$(\mathrm{F/m^2})$
$k'_n = \mu_n C_{ox}$	$(\mathrm{A/V^2})$
$V'_A = (V_A/L)$	$(\mathrm{V/m})$
$\lambda = (1/V_A)$	$(\mathrm{V^{-1}})$
$\gamma = \sqrt{2qN_A\varepsilon_s}/C_{ox}$	$(\mathrm{V^{1/2}})$

Constants:

$$\varepsilon_0 = 8.854 \times 10^{-12}\ \mathrm{F/m}$$

$$\varepsilon_{ox} = 3.9\varepsilon_0 = 3.45 \times 10^{-11}\ \mathrm{F/m}$$

$$\varepsilon_s = 11.7\varepsilon_0 = 1.04 \times 10^{-10}\ \mathrm{F/m}$$

$$q = 1.602 \times 10^{-19}\ \mathrm{C}$$

Hspice netlist

- Circuit description and testbench

```
****** two stage opamp ******
***** model/lib *****
.lib 'cic018.l' TT
***** options *****
.option post accurate method=gear
.option probe
.temp 27
.global vdd gnd
***** Source *****
Vdd     Vdd     gnd     DC=1.8
Iref    vdd     g11
Vinp    vinp    gnd     dc=0.9 ac=1
Vinn    vinn    gnd     dc=0.9

* Main Circuit
M1                  N_18 l=     w=    m=
M2                  N_18 l=     w=    m=
M3                  P_18 l=     w=    m=
M4                  P_18 l=     w=    m=
M5                  N_18 l=     w=    m=
M6                  P_18 l=     w=    m=
M7                  N_18 l=     w=    m=
M8                  N_18 l=     w=    m=
CC v12 vout
CL vout gnd 4p
```

```
***** analysis *****
.op
.ac dec 10 10 1G
.probe vdb(vout) vp(vout)
.meas AC Gain10Hz FIND vdb(vout) AT 10
.meas ac Unit_gain when vdb(vout)=0
.meas ac Phase_mar FIND vp(vout) when vdb(vout)=0

**SLEW RATE**







**ICMR**



**OUTPUT VOLTAGE SWING**








**CMRR**







.end
```

.Measure

(10). MEASURE Statement : AVG, RMS, MIN, MAX, & P-P

- **Syntax :**

```
.MEASURE  DC|AC|TRAN  result  FUNC  out_var  <FROM=val1>  <TO=val2>
+                          <Optimization Option>
```

- result_var : Name Given the Measured Value in HSPICE Output
- FUNC : AVG ----- Average   MAX ----- Maximun   PP ---- Peak-to-Peak
  MIN ------ Minimum   RMS ----- Root Mean Square
- out_var : Name of the Output Variable to be Measured
- <Optimization Option>: <GOAL=val> <MINVAL=val> <WEIGHT=val>

- **Example:**

```
.meas  TRAN  minval      MIN  v(1,2)   from=25ns  to=50ns
.meas  TRAN  tot_power   AVG  power    from=25ns  to=50ns
.meas  TRAN  rms_power   RMS  power
```

.Measure

(11). MEASURE Statement : Find & When Function

- Syntax :

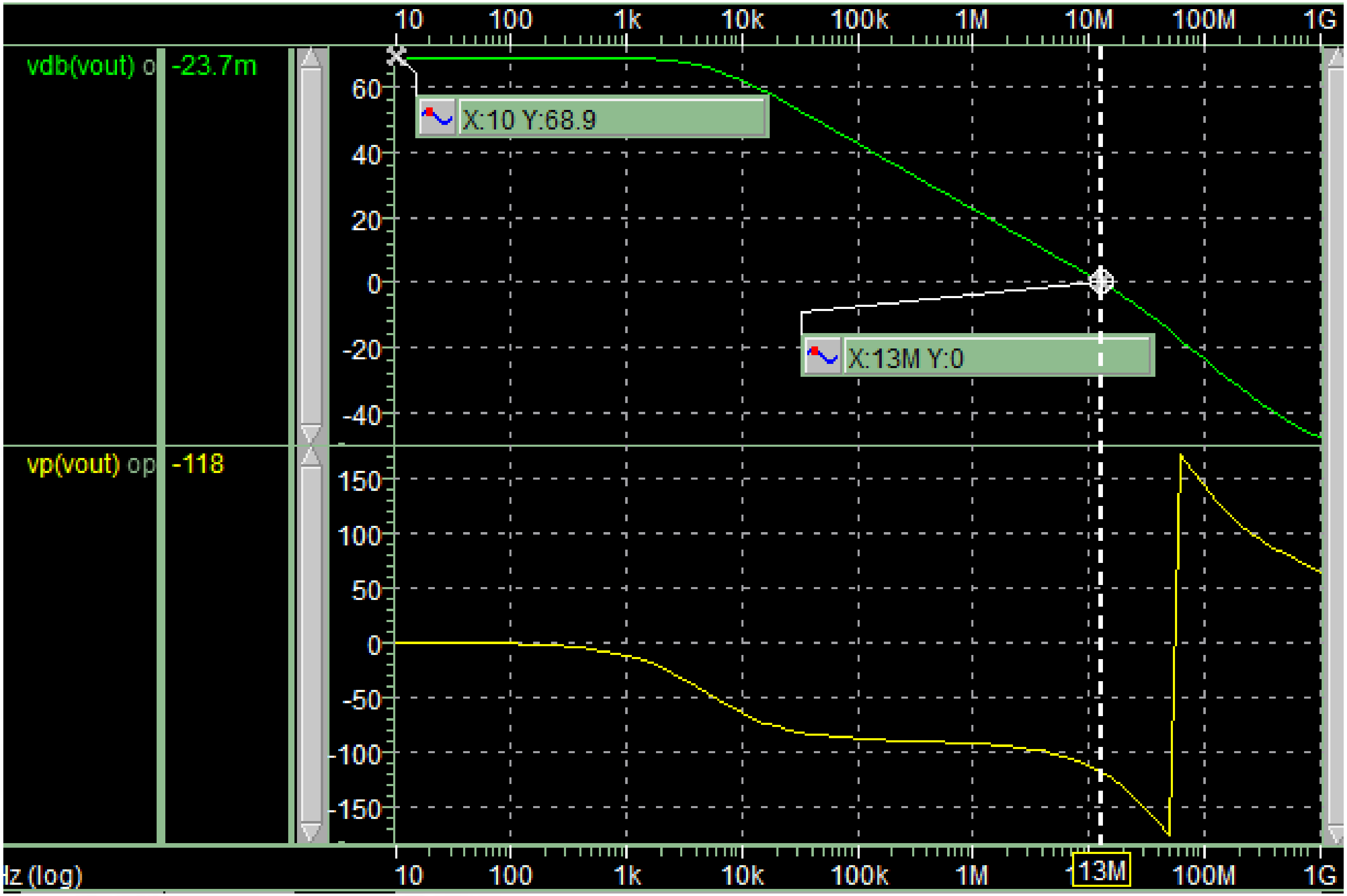
```
.measure  DC|AC|TRAN  result  WHEN  ... <Optimization Option>
.measure  DC|AC|TRAN  result  FIND out_var1 WHEN ...<Optimization Option>
.measure  DC|AC|TRAN  result_var  FIND out_var1 AT=val <Optimization Option>
```

- result : Name Given the Measured Value in HSPICE Output
- WHEN ... : WHEN out_var2=val|out_var3 <TD=time_delay>
  \+ <CROSS=n|LAST> <RISE=r_n|LAST> <FALL=f_n|LAST>
- <Optimization Option> : <GOAL=val> <MINVAL=val> <WEIGHT=val>

- Example:

```
.meas  TRAN  fifth   WHEN v(osc_out)=2.5V rise=5
.meas  TRAN  result  FIND  v(out)  WHEN v(in)=2.5V rise=1
.meas  TRAN  vmin    FIND  v(out)  AT=30ns
```

AC analysis


vdb(vout) o
-23.7m
vp(vout) op
-118
X:10 Y:68.9
X:13M Y:0
10
100
1k
10k
100k
1M
10M
100M
1G
60
40
20
0
-20
-40
150
100
50
0
-50
-100
-150
Hz (log)
13M

.Measure

- **Unity-gain Freq, Phase margin, & DC gain(db/M):**

```
.meas  AC  unitfreq       WHEN  vdb(out)=0    FALL=1
.meas  AC  phase          FIND  vp(out)       WHEN vdb(out)=0
.meas  AC  'gain(db)'     MAX   vdb(out)
.meas  AC  'gain(mag)'    MAX   vm(out)
```

- Analysis command

```
.ac dec 10 10 1G
.probe vdb(vout) vp(vout)
.meas ac Gain10Hz FIND vdb(vout) AT 10
.meas ac Unit_gain when vdb(vout)=0
.meas ac Phase_mar FIND vp(vout) when vdb(vout)=0
```

- Lis file

```
****** two stage opamp ******

 ******  ac analysis tnom=  25.000 temp=  27.000 ******
  gain10hz=  6.8925E+01
  unit_gain=  1.2983E+07
  phase_mar= -1.1773E+02
```