Homework 2

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Introduction to Library: CIC 0.18um 1.8V/3.3V 1P6M virtual Mixed Mode/RFCMOS Process

Availabe corners: (pmos-nmos)

- TT (typical typical)
- FF (fast fast)
- SS (slow slow)
- FS
- SF

Available MOS Models

- N_18 (1.8v nmos)
- N_BPW_18 (1.8v p-well nmos)
- P_18 (1.8v pmos)
- N_33 (3.3v nmos)
- N_BPW_33
- P_33
- N_LV_18 (low threshold voltage 1.8v nmos)
- P_LV_18
- N_LV_33
- P_LV_33
- N_ZERO_18 (zero Vt 1.8v nmos)
- N_ZERO_33

Design Rule

```
****Layout-Dependent Parasitics Model Parameters****
+   LMIN = 1.8000E-07    LMAX = 5.0000E-05
+   WMIN = 2.5000E-07    WMAX = 1.0000E-04
```

Library Summary

For homework simulation, use:

- `TT` type
- `N_18` and `P_18` for 1.8V nmos and pmos
- `LMIN = 0.18u` and `WMIN = 0.25u`
- assume minimal channel length/width delta = 0.01u
- assume temperature = 27 C

Problem 2-1-1

Initial Guess

Source Code

```
* HW2_1_1.sp
*-------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
Vd  d   gnd 0.9
Vg  g   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.18u
MP1 d g ndd ndd P_18 W=0.25u L=0.18u

*-------------------------------------------------------------------------
* Stimulus
*-------------------------------------------------------------------------
.op
.end
```

Simulation Result

```
...
 element  0:mn1      0:mp1
 model    0:n_18.1   0:p_18.1
 region     Saturati   Saturati
  id        45.7379u  -10.5697u
...
```

We see that `id` of nmos is 4.5 times larger than target (10u), and `id` of pmos is very close to target (10u).
Note:

$$I_D = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{th}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$

pmos: fine-tune `Lp` up one step (0.01u) every time. nmos: change `Ln` to 4.5 times the original (0.81u), then perform fine-tuning.

NMOS Tuning

Source Code

```
* HW2_1_1_b.sp
*-------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
*nmos
Vg  g   gnd 0.9
Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=LN
*MP1 d g ndd ndd P_18 W=0.25u L=LP

*MN1 d g gnd gnd N_18 W=0.25u L=0.18u
*MP1 d g ndd ndd P_18 W=0.25u L=0.18u


*-------------------------------------------------------------------------
* Stimulus
*-------------------------------------------------------------------------

.dc Vdd 0 1.8 1.8 sweep LN 0.81u 1.0u 0.01u
*.dc Vg 0 0.9 0.9 sweep LP 0.18u 0.2u 0.01u

.probe i1(MN1)
*.probe i1(MP1)
.meas DC IMeas find i1(MN1) when v(g)=0.9
*.meas DC IMeas find i1(MP1) when v(g)=0.9
.end
```

Simulation Result:

```
...
 ******
 * hw2_1_1_b.sp
   *** parameter ln =  900.0000n       ***
   imeas=  1.0025E-05
 ******
```

```
 * hw2_1_1_b.sp
   *** parameter ln =  910.0000n       ***
   imeas=  9.9322E-06
 ******
...
```

when Ln parameter `ln = 0.9u`, id is closest to 10uA (1.0025E-05 A).

PMOS Tuning

Source Code: same as above except tune pmos

Simulation Result:

```
...
******
 * hw2_1_1_b.sp
   *** parameter lp =  180.0000n       ***
   imeas= -1.0570E-05
 ******

 * hw2_1_1_b.sp
  *** parameter lp =  190.0000n       ***
   imeas= -9.2225E-06
 ******
...
```

when Lp parameter `lp = 0.18u`, id is closest to 10uA (-1.0570E-05 A)

Result

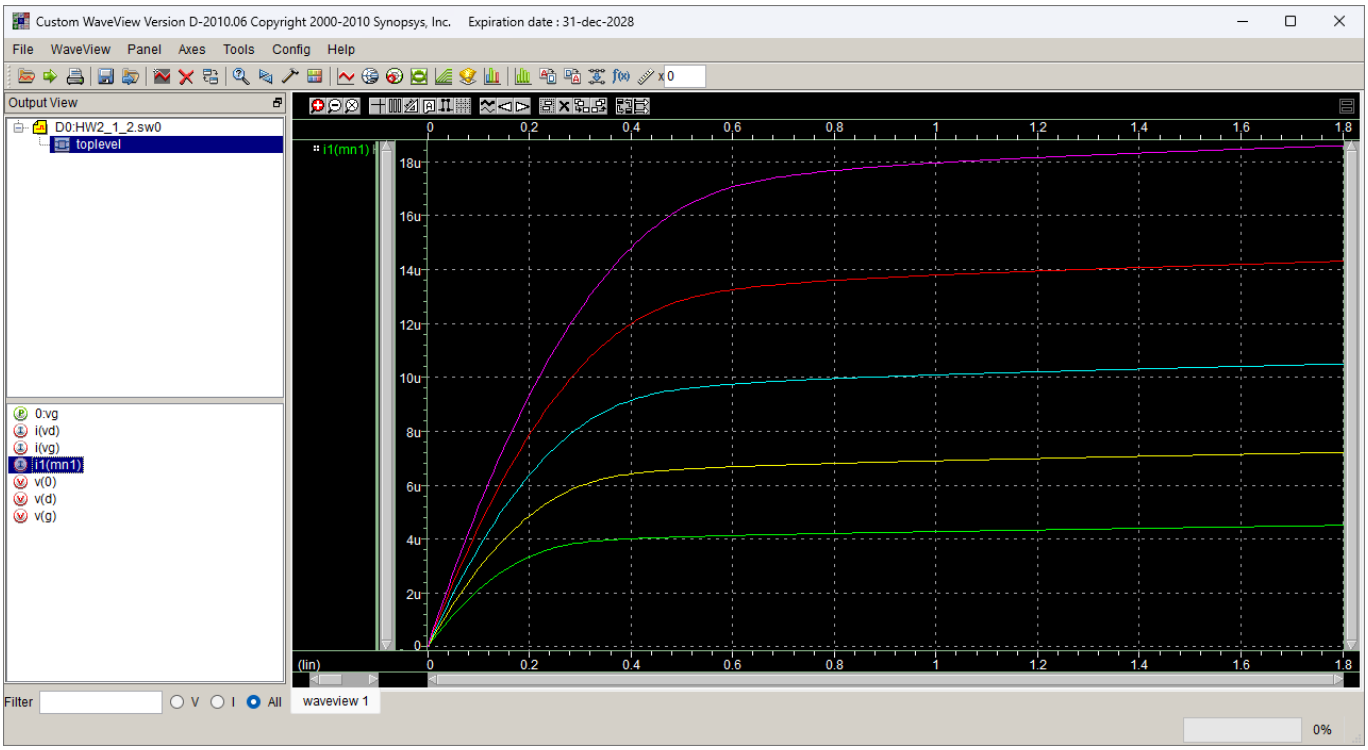
For nmos we choose Wn = 0.25u, Ln = 0.9u.
For pmos we choose Wp = 0.25u, Lp = 0.18u.

Problem 2-1-2

NMOS

```
* HW2_1_2.sp
*-----------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-----------------------------------------------------------------------
* Simulation netlist
*-----------------------------------------------------------------------
Vg  g   gnd 0.9
```

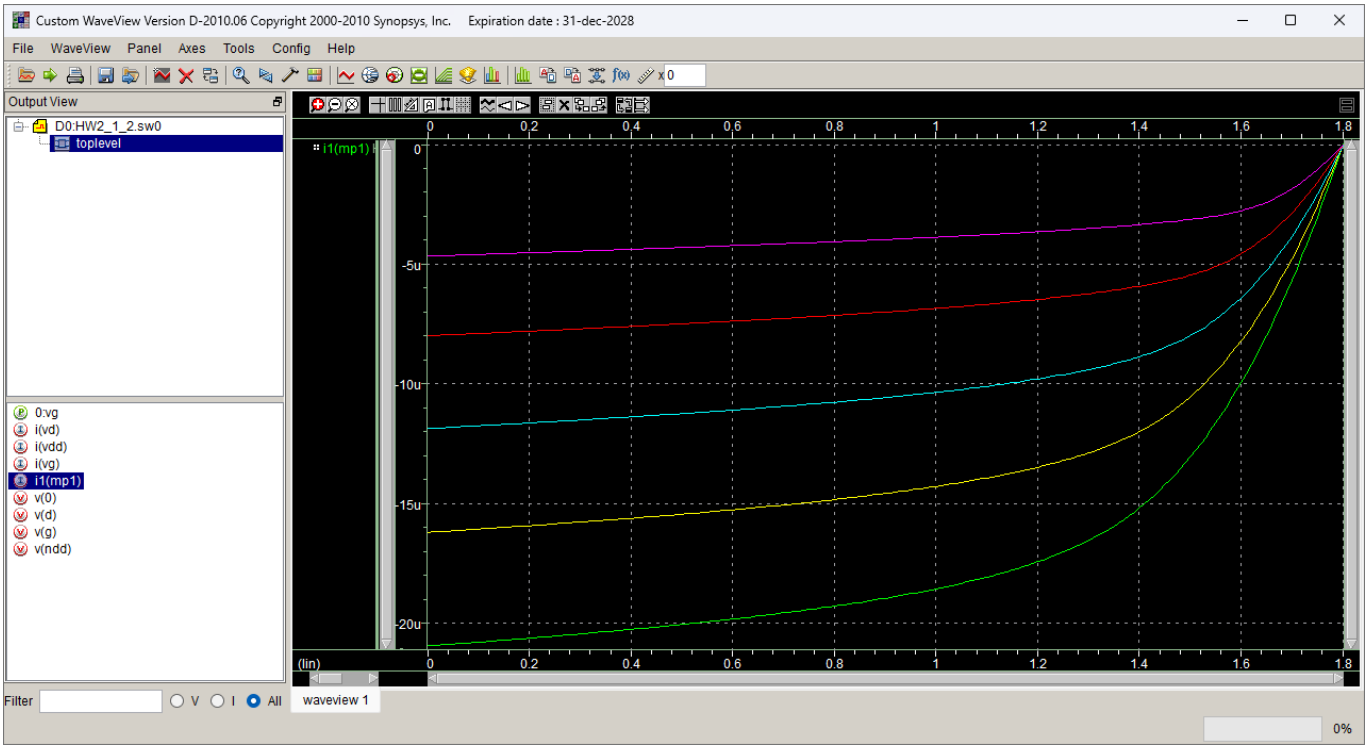
```
Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.9u

*-----------------------------------------------------------------------
* Stimulus
*-----------------------------------------------------------------------
.dc Vd 0 1.8 0.01 sweep Vg 0.7 1.0 0.1
.probe i1(MN1)
```



PMOS

```
* HW2_1_2.sp
*-----------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-----------------------------------------------------------------------
* Simulation netlist
*-----------------------------------------------------------------------
Vg  g   gnd 0.9
Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MP1 d g ndd ndd P_18 W=0.25u L=0.18u

*-----------------------------------------------------------------------
* Stimulus
*-----------------------------------------------------------------------
```

```
.dc Vd 0 1.8 0.01 sweep Vg 0.7 1.0 0.1
.probe i1(MP1)
```



Problem 2-2-1

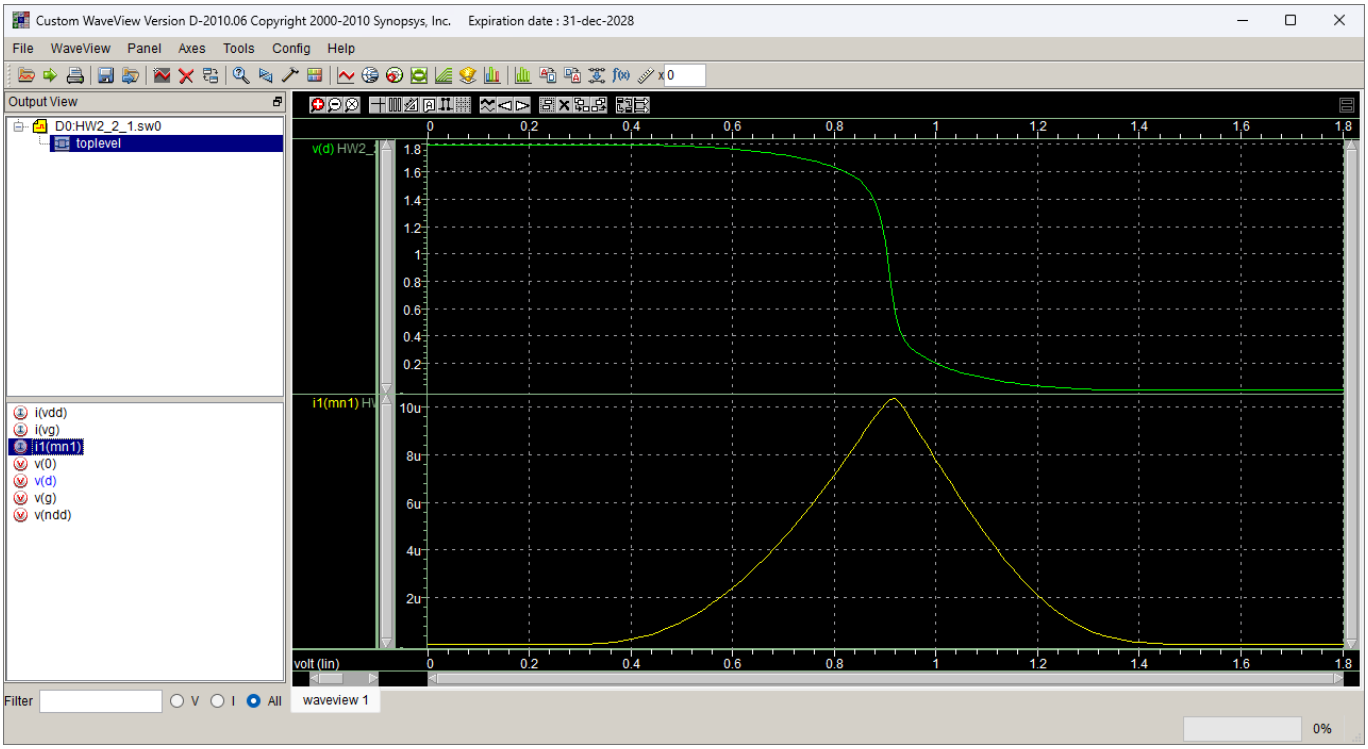
Parallel connecting M nmoses is the equivalent of multiplying Ln by M, thus multiplying Io. The same idea applies to pmos. Therefore, to have Io = 10uA, 20uA, 30uA, we use:

```
*Io = 10u
MN1 d g gnd gnd N_18 W=0.25u L= 0.9u M=1
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=1

*Io = 20u
MN1 d g gnd gnd N_18 W=0.25u L= 0.9u M=2
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=2

*Io = 30u
MN1 d g gnd gnd N_18 W=0.25u L= 0.9u M=3
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=3
```

Io = 10uA (M = 1)

```
* HW2_2_1.sp
*--------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post
```

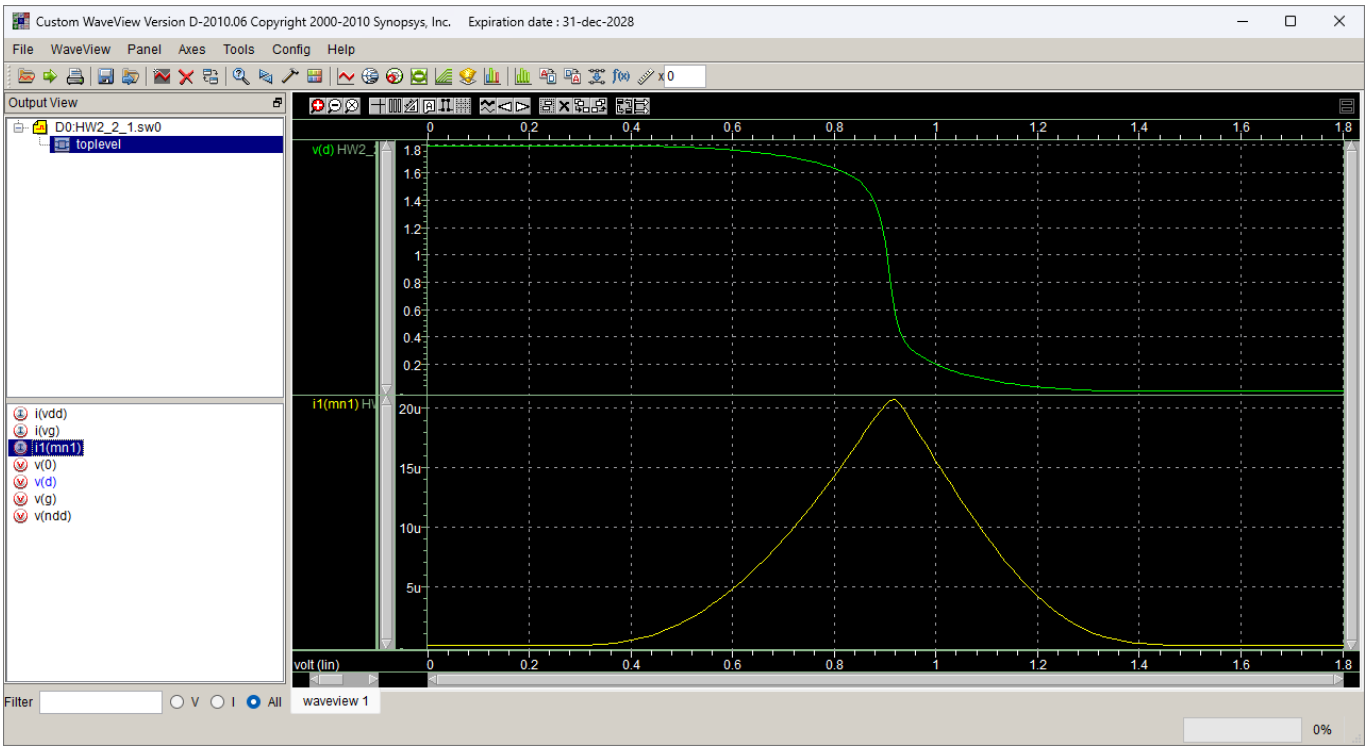
```
*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
Vg  g   gnd
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.90u M=1
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=1

*-------------------------------------------------------------------------
* Stimulus
*-------------------------------------------------------------------------
.dc Vg 0 1.8 0.01
.probe i1(MN1)
.end
```



Io = 20uA (M = 2)

Code same as above, except

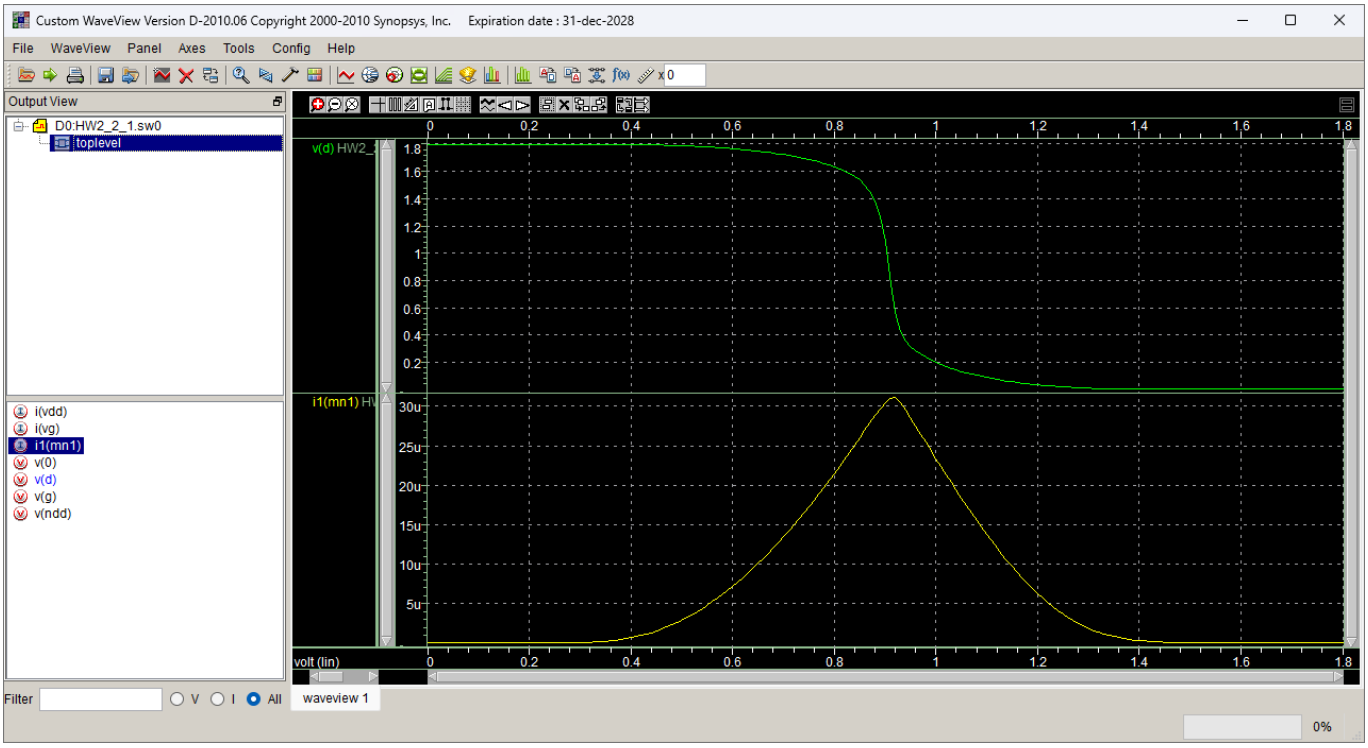
```
MN1 d g gnd gnd N_18 W=0.25u L=0.90u M=2
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=2
```



Io = 30uA (M = 3)

Code same as above, except

```
MN1 d g gnd gnd N_18 W=0.25u L=0.90u M=3
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=3
```



Problem 2-2-2

V1 = 0.7V

Initial Guess

Source Code: same as Problem 2-1-1 except set all `Vg` to 0.7

Simulation Result:

```
element  0:mn1      0:mp1
 model    0:n_18.1   0:p_18.1
 region     Saturati   Saturati
  id        21.5095u  -18.9496u
```

We see that `id` of both nmos and pmos are very close to target (20u).

- pmos: to increase current, fine-tune `Wp` up one step (0.01u) every time.
- nmos: to decrease current, fine-tune `Ln` up one step (0.01u) every time.

NMOS

Simulation Result:

```
...
 * hw2_2_2_07.sp
   *** parameter ln =  180.0000n       ***
   imeas=  2.1509E-05
 ******
 * hw2_2_2_07.sp
   *** parameter ln =  190.0000n       ***
   imeas=  1.9373E-05
...
```

when Ln parameter `ln = 0.19u`, id is closest to 20uA (1.9373E-05 A)

PMOS

Simulation Result:

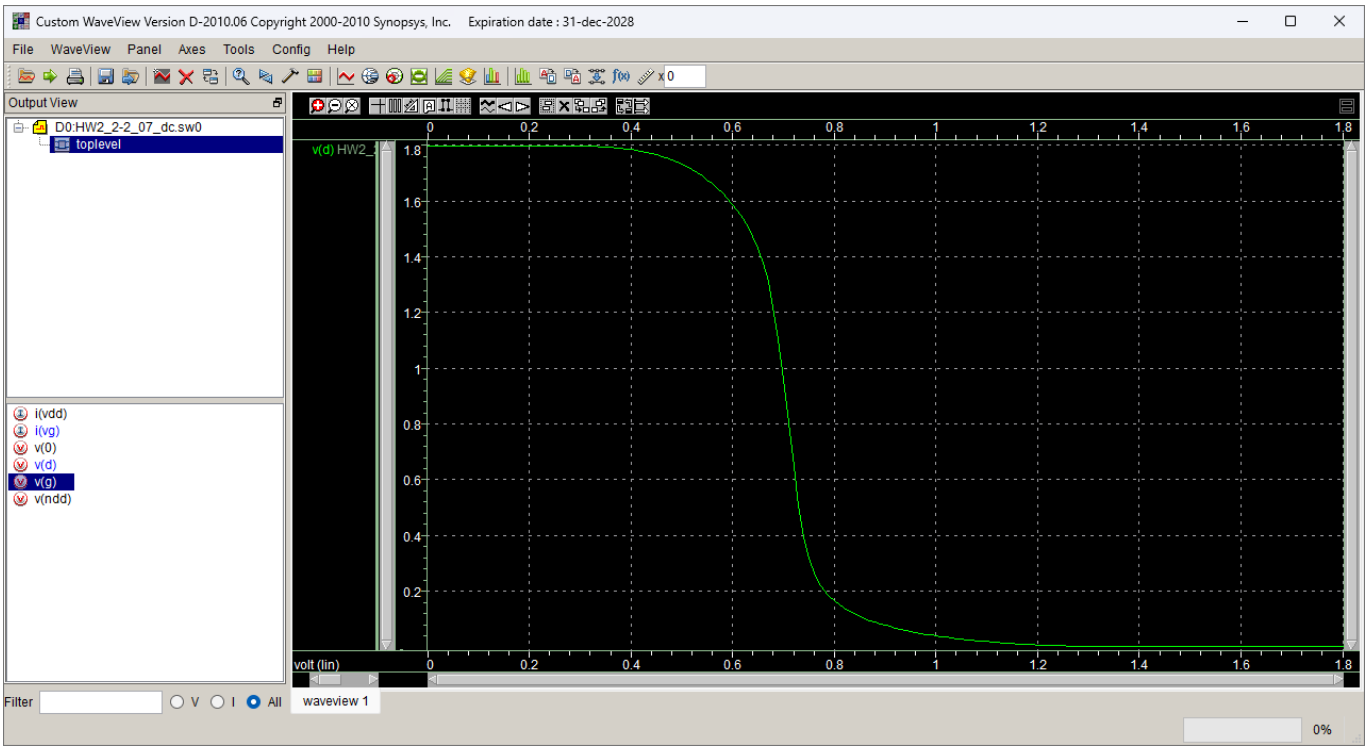
```
...
 * hw2_2_2_07.sp
   *** parameter wp =  260.0000n       ***
    1.80000        -19.9722u
******
 * hw2_2_2_07.sp
   *** parameter wp =  270.0000n       ***
    1.80000        -20.9425u
...
```

when Wp parameter `wp = 0.26u`, id is closest to 20uA (-19.9722u A)

Result

nmos W = 0.25u L = 0.19u
pmos W = 0.26u L = 0.18u

```
* HW2_2_2_07_dc.sp
*-------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
Vg  g   gnd
*Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.19u
MP1 d g ndd ndd P_18 W=0.26u L=0.18u

*-------------------------------------------------------------------------
* Stimulus
*-------------------------------------------------------------------------

.dc Vg 0 1.8 0.01
.op
.end
```



Vg = 0.8

Initial Guess

Source Code: same as Problem 2-1-1 except set all `Vg` to 0.8

Simulation Result:

```
element  0:mn1      0:mp1
model    0:n_18.1   0:p_18.1
region     Saturati   Saturati
 id        33.1641u  -14.5751u
```

We see that `id` of both nmos and pmos are very close to target (20u).

- pmos: to increase current, fine-tune `Wp` up one step (0.01u) every time.
- nmos: to decrease current, multiply `Ln` by 1.2 (0.22u), then fine-tune `Ln` up one step (0.01u) every time.

NMOS

```
* hw2_2_2_08.sp
  *** parameter ln =  260.0000n       ***
  imeas=  2.0368E-05
******
* hw2_2_2_08.sp
  *** parameter ln =  270.0000n       ***
  imeas=  1.9564E-05
```

when Ln parameter `ln = 0.29u`, id is closest to 20uA (2.0368E-05 A)

PMOS

```
 * hw2_2_2_08.sp
   *** parameter wp =  330.0000n       ***
    1.80000        -19.9570u
******
 * hw2_2_2_08.sp
   *** parameter wp =  340.0000n       ***
    1.80000        -20.5651u
```

when Wp parameter `wp = 0.33u`, id is closest to 20uA (-19.9570u A)

Result

nmos W = 0.25u L = 0.29u
pmos W = 0.33u L = 0.18u

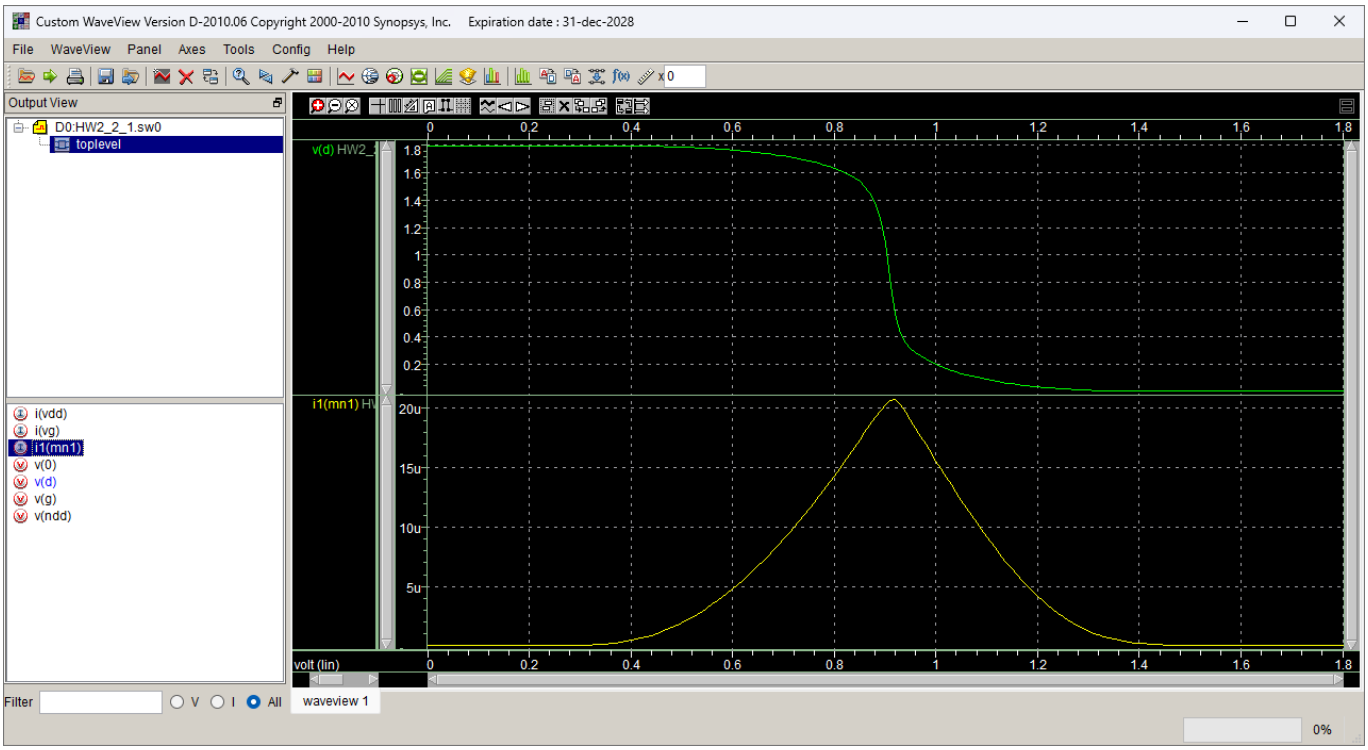
```
* HW2_2_2_08_dc.sp
*--------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*--------------------------------------------------------------------------
* Simulation netlist
*--------------------------------------------------------------------------
Vg  g   gnd
*Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.29u
MP1 d g ndd ndd P_18 W=0.33u L=0.18u

*--------------------------------------------------------------------------
* Stimulus
*--------------------------------------------------------------------------

.dc Vg 0 1.8 0.01
.op
.end
```

![image./pic7.png)

Vg = 0.9

Same as Problem 2-2-1 nmos W = 0.25u L = 0.90u M = 2
pmos W = 0.25u L = 0.18u M = 2

```
* HW2_2_1.sp
*-------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
Vg  g   gnd
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.90u M=2
MP1 d g ndd ndd P_18 W=0.25u L=0.18u M=2

*-------------------------------------------------------------------------
* Stimulus
*-------------------------------------------------------------------------
.dc Vg 0 1.8 0.01
.probe i1(MN1)
.end
```



Vg = 1.0

Initial Guess

Source Code: same as Problem 2-1-1 except set all Vg to 1.0

Simulation Result:

```
element  0:mn1      0:mp1
model    0:n_18.1   0:p_18.1
region     Saturati   Saturati
 id        60.0367u   -6.8436u
```

We see that `id` of nmos is roughly 3 times larger than the target (20uA), and pmos is roughly third of such.

- pmos: to increase current, multiply `Wp` by 2 (0.50u), fine-tune `Wp` up one step (0.01u) every time.
- nmos: to decrease current, multiply `Ln` by 3 (0.75u), then fine-tune `Ln` up one step (0.01u) every time.

NMOS

```
* hw2_2_2_10.sp
*** parameter ln =  570.0000n       ***
   1.80000         20.2303u
******
* hw2_2_2_10.sp
  *** parameter ln =  580.0000n       ***
   1.80000         19.9363u
```

when Ln parameter `ln = 0.58u`, id is closest to 20uA (19.9363u A)

PMOS

```
* hw2_2_2_10.sp
  *** parameter wp =  790.0000n       ***
   1.80000        -19.8113u
******
* hw2_2_2_10.sp
  *** parameter wp =  800.0000n       ***
   1.80000        -20.0495u
```

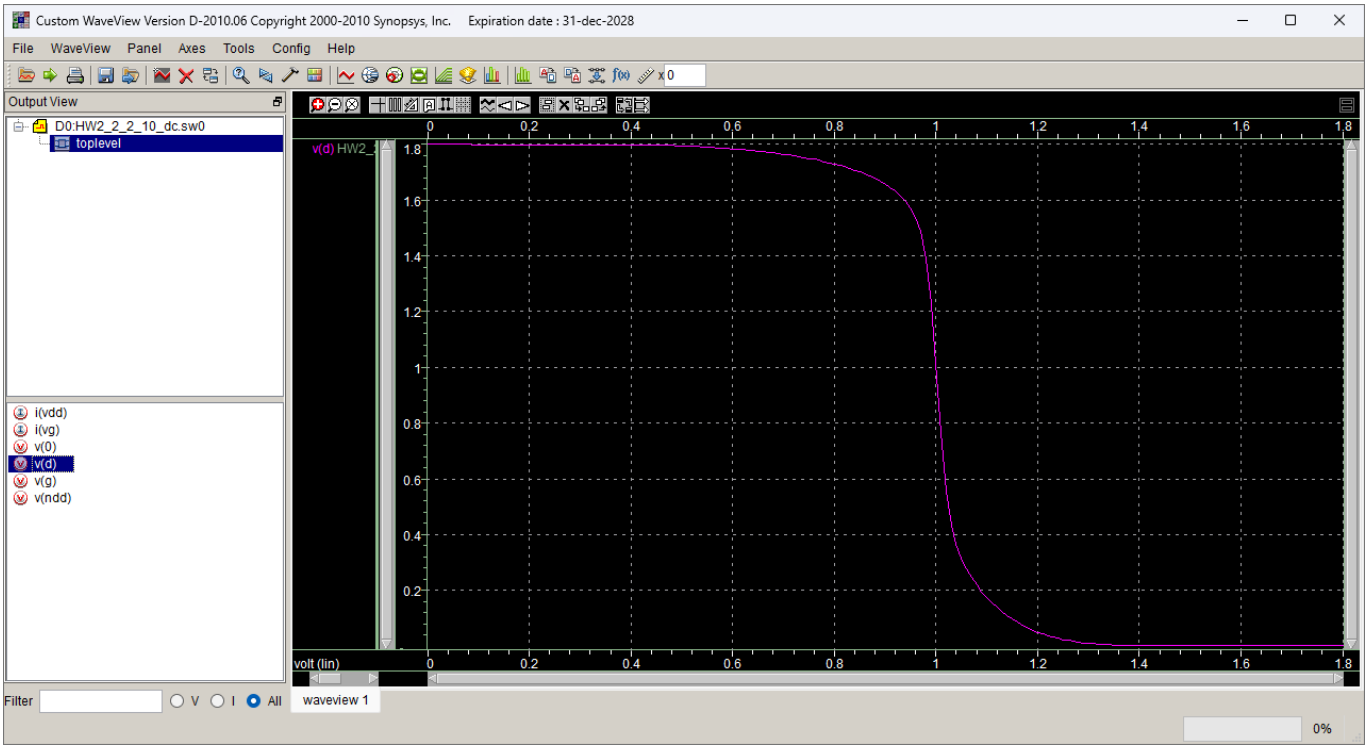
when Wp parameter `wp = 0.80u`, id is closest to 20uA (-20.0495u A)

Result

nmos W = 0.25u L = 0.58u
pmos W = 0.80u L = 0.18u

```
* HW2_2_2_10_dc.sp
*-----------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
```

```
.option post

*--------------------------------------------------------------------------
* Simulation netlist
*--------------------------------------------------------------------------
Vg  g   gnd
*Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.58u
MP1 d g ndd ndd P_18 W=0.80u L=0.18u

*--------------------------------------------------------------------------
* Stimulus
*--------------------------------------------------------------------------

.dc Vg 0 1.8 0.01
.op
.end
```



Vg = 1.1

Initial Guess

Source Code: same as Problem 2-1-1 except set all Vg to 1.1

Simulation Result:

```
element  0:mn1      0:mp1
model    0:n_18.1   0:p_18.1
```

```
region     Saturati   Saturati
 id        73.6641u   -3.8705u
```

We see that `id` of nmos is roughly 3.5 times larger than the target (20uA), and pmos is roughly sixth of such.

- pmos: to increase current, multiply `Wp` by 5 (1.25), fine-tune `Wp` up one step (0.01u) every time.
- nmos: to decrease current, multiply `Ln` by 6 (0.84u), then fine-tune `Ln` up one step (0.01u) every time.

NMOS

```
* hw2_2_2_11.sp
  *** parameter ln =  790.0000n       ***
   1.80000         20.0234u
******
* hw2_2_2_11.sp
  *** parameter ln =  800.0000n       ***
   1.80000         19.8142u
```

when Ln parameter `ln = 0.79u`, id is closest to 20uA (20.0234u A)

PMOS

```
* hw2_2_2_11.sp
  *** parameter wp =    1.6100u       ***
   1.80000        -19.9563u
******
* hw2_2_2_11.sp
  *** parameter wp =    1.6200u       ***
   1.80000        -20.0835u
```

when Wp parameter `wp = 1.61u`, id is closest to 20uA (-19.9563u A)

Result

nmos W = 0.25u L = 0.79u
pmos W = 1.61u L = 0.18u

```
* HW2_2_2_11_dc.sp
*-------------------------------------------------------------------------
.lib 'cic018.l'  tt
.temp 27
.option post

*-------------------------------------------------------------------------
* Simulation netlist
*-------------------------------------------------------------------------
```

```
Vg  g   gnd
*Vd  d   gnd 0.9
Vdd ndd gnd 1.8

MN1 d g gnd gnd N_18 W=0.25u L=0.79u
MP1 d g ndd ndd P_18 W=1.61u L=0.18u

*--------------------------------------------------------------------------
* Stimulus
*--------------------------------------------------------------------------

.dc Vg 0 1.8 0.01
.op
.end
```