Project 1: MOSFET Characterization & Differential Amplifier

Project General Rules:

- This project is out of 15 points.
- You work individually.
- Due Date is end of week 9.
- You are required to deliver a soft copy report that contains:
  - Schematic diagrams (snapshots from Multisim showing dimensions and values)
  - Design procedure (hand calculations)
  - Simulation results (snapshots from Multisim)
  - Discussion of your results and conclusions
- Any missing item from the 4 items above will be penalized in the report grading.
- Bad presentation (report document, figures, etc.) of your work is going to affect your grade.
- Any duplicated or late projects will take 0 out of 10.
- The setup of the NMOS and PMOS transistors and their models are given at the end of the document.

Problem (1): Transistor Characterization (4.5 points)

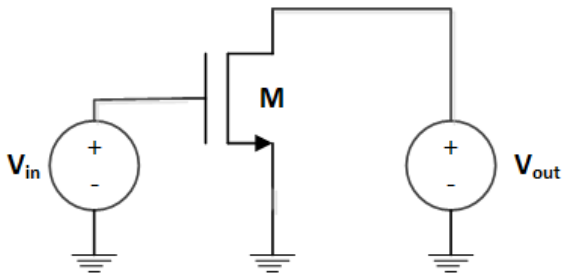


Fig. 1 Transistor Characterization

(a) For the schematic shown in Fig. 1 with W=10µm, L=1µm:
- Perform DC sweep for V_{out} (from 0 to 3V) while V_{in}=2V and plot I_D vs. V_{out}.
- Perform DC sweep for V_{in} (from 0 to 3V) while V_{out}=2V and plot I_D vs. V_{in}.
- From the above curves determine the value of V_{TH}, $\mu_n C_{OX}$, and λ.
- Repeat the above for W=20µm, L=2µm.
- Discuss your results

(b) Repeat (a) for a PMOS device with the same dimensions.
(c) Compare between NMOS and PMOS devices.
(d) Discuss your results

Problem (2): Differential Amplifier (8 points)

(a) Design the differential amplifier shown in Fig. 2 with the following specifications:

- $A_{DM} \geq 5$
- Input linear range $\geq 0.2V$
- Differential output swing $\geq 2.4V_{pp}$ (peak to peak)

(b) Calculate the common-mode input range for your design.

(c) Document the design procedure and the results of the following simulations:

- DC analysis and show the Q-point (I_D, V_{DS}, V_{eff}) of all transistors.
- DC sweep for V_{id} from -1.8V to 1.8V and plot i_{D1}, i_{D2}, and i_{OD}.
- AC analysis and show the small-signal differential gain A_{DM}, conversion gain A_{CM-DM} (due to for 5% mismatch in the two resistors R), and CMRR vs. frequency.
- Transient analysis with
  $V_{in1}=V_{DC}+A.\sin(2\pi ft)+B.\sin(4\pi ft)$, $V_{in2}= V_{DC}-A.\sin(2\pi ft)+B.\sin(4\pi ft)$.
  Plot V_{in1}, V_{in2}, V_P, V_{out1}, V_{out2}, $V_{outd.}$ Where A=10mV, B=10mV, f=1MHz, V_{DC} is a proper DC voltage of your choice.
- Perform Fourier analysis for the case B=0 and plot V_{outd} in the frequency domain. Calculate HD_2, HD_3, and THD.

(d) **Discuss your results**.

Note: The differential inputs V_{in1} and V_{in2} can be generated using an ideal transformer or ideal voltage-controlled voltage source (VCVS).

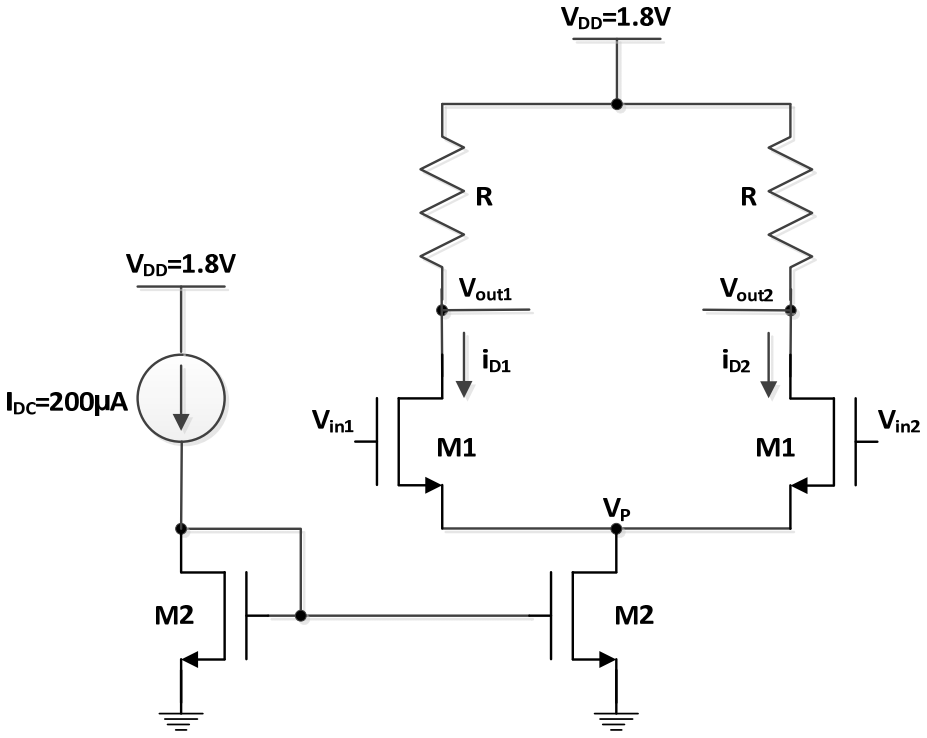
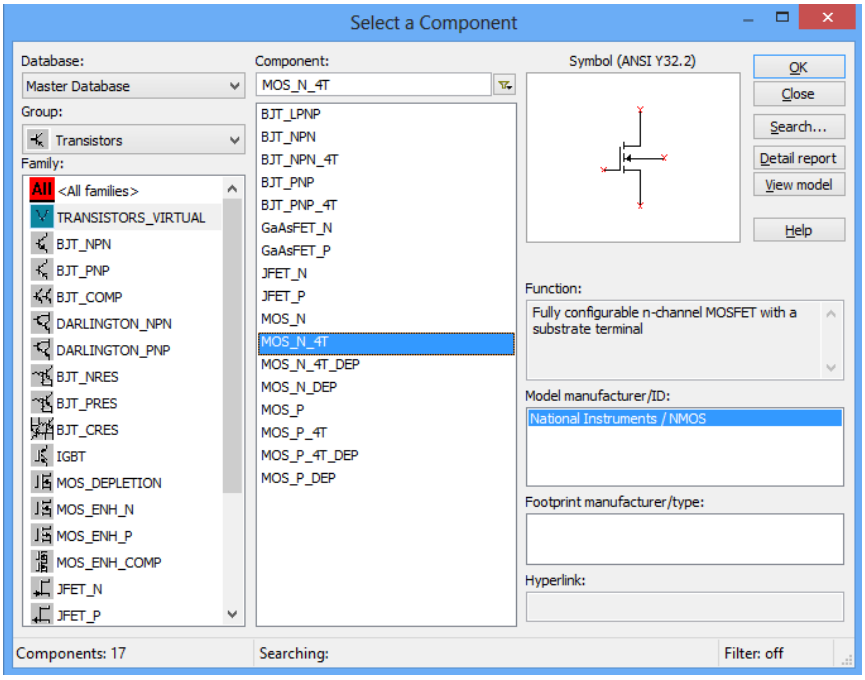


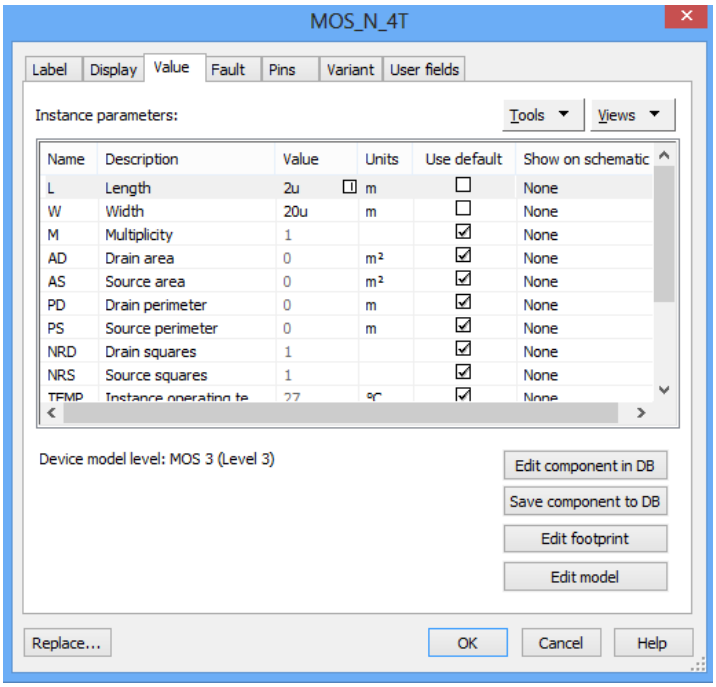
Fig. 2 Differential Amplifier

Setup of the NMOS and PMOS transistors:

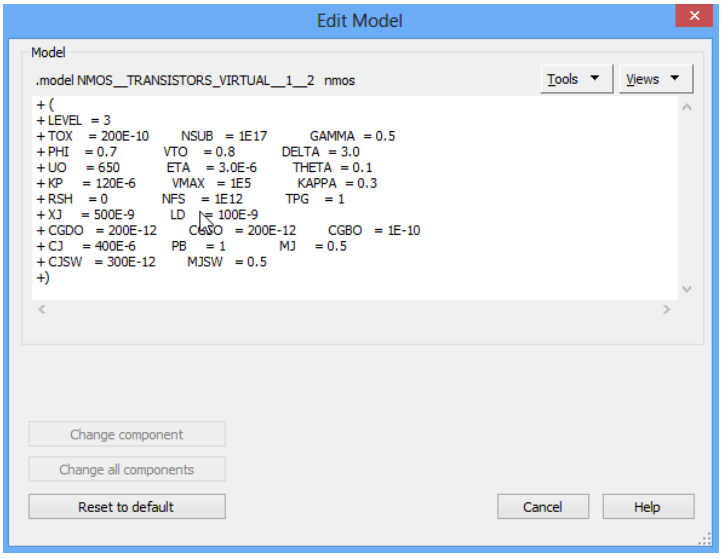
Choose an NMOS_4T from the menu of Place → Component (as shown below) and place it in your schematic.



Double click on the transistor and chosse the tab of "Value". This is where you can change the dimensions (W,L) of the transistor.



Click on the "Edit model" button.
Copy and paste the model of the NMOS (as shown) in the "SPICE view"
Make sure to click on the "Change componnet" button to save changes.



If you need to place another transistor in a schematic, copy the transistor that you have just created to get the correct model and you can then change the dimensions.
Repeat the same for the PMOS transistor (MOS_P_4T).

Minimum length of any transistor is 1µm. The bulk of an NMOS device should be connected to lowest voltage (ground) and that of a PMOS device should be connected to the highest voltage (V_{DD}).

NMOS:

```
+ (
+ LEVEL  = 3
+ TOX    = 200E-10       NSUB   = 1E17         GAMMA  = 0.5
+ PHI    = 0.7           VTO    = 0.7          DELTA  = 3.0
+ UO     = 650           ETA    = 3.0E-6       THETA  = 0.1
+ KP     = 120E-6        VMAX   = 1E5          KAPPA  = 0.3
+ RSH    = 0             NFS    = 1E12         TPG    = 1
+ XJ     = 500E-9        LD     = 100E-9
+ CGDO   = 200E-12       CGSO   = 200E-12      CGBO   = 1E-10
+ CJ     = 400E-6        PB     = 1            MJ     = 0.5
+ CJSW   = 300E-12       MJSW   = 0.5
+)
```

PMOS:

```
+ (
+  LEVEL  = 3
+ TOX    = 200E-10       NSUB   = 1E17         GAMMA  = 0.6
+ PHI    = 0.7           VTO    = -0.8         DELTA  = 0.1
+ UO     = 250           ETA    = 0            THETA  = 0.1
+ KP     = 40E-6         VMAX   = 5E4          KAPPA  = 1
+ RSH    = 0             NFS    = 1E12         TPG    = -1
+ XJ     = 500E-9        LD     = 100E-9
+ CGDO   = 200E-12       CGSO   = 200E-12      CGBO   = 1E-10
+ CJ     = 400E-6        PB     = 1            MJ     = 0.5
+ CJSW   = 300E-12       MJSW   = 0.5
+ )
```