Homework 4 - ECE 1238
Rayan Hassan (4511021)

1 (a) Here, $V_{DS} \geq V_{GS}$, the NMOS will be in saturation

$$\frac{I_D\,(4\text{th row})}{I_D\,(2^{nd}\text{ row})} = \frac{\cancel{\frac{k}{2}(V_{GS}-V_{T_0})^2}(1+\lambda V_{DS(4)})}{\cancel{\frac{k}{2}(V_{GS}-V_{T_0})^2}(1+\lambda V_{DS(2)})}$$

Because we know $V_{GS}(2) = V_{GS}(4) = 0.8V$ (Table)

$$\Rightarrow \frac{I_D(4)}{I_D(2)} = \frac{1+\lambda V_{DS(4)}}{1+\lambda V_{DS(2)}}$$

$$\Rightarrow \frac{60}{59} = \frac{1+\lambda\times 1}{1+\lambda\times 0.8} \Rightarrow 59(1+\lambda) = 60(1+0.8\lambda)$$

$$\Rightarrow 59 + 59\lambda = 60 + 48\lambda$$

$$\Rightarrow 11\lambda = 1 \Rightarrow \boxed{\lambda = 0.0909\ V^{-1}}$$

(b) Now to find V_{T_0}, we want to eliminate the $(1+\lambda V_{DS})$ part of the equation and use the ratio of currents. So let's take row 1 and row 2, where $V_{DS(1)} = V_{DS(2)} = 0.8V$.

$$\frac{I_{D(2)}}{I_{D(1)}} = \frac{\cancel{\frac{k}{2}}(V_{GS(2)}-V_{T_0})^2\cancel{(1+\lambda V_{DS(2)})}}{\cancel{\frac{k}{2}}(V_{GS(1)}-V_{T_0})^2\cancel{(1+\lambda V_{DS(1)})}} = \frac{(V_{GS(2)}-V_{T_0})^2}{(V_{GS(1)}-V_{T_0})^2}$$

$$\Rightarrow \frac{59}{8} = \frac{(0.8-V_{T_0})^2}{(0.6-V_{T_0})^2} \Rightarrow \sqrt{\frac{59}{8}} = \frac{0.8-V_{T_0}}{0.6-V_{T_0}}$$

$$\Rightarrow \quad 2.7156 = \frac{0.8 - V_{TO}}{0.6 - V_{TO}}$$

$$2.7156\left(0.6 - V_{TO}\right) = 0.8 - V_{TO}$$

$$\Rightarrow \quad 1.63 - 2.7156\, V_{TO} = 0.8 - V_{TO}$$

$$\Rightarrow \quad 1.7156\, V_{TO} = 0.83$$

$$\Rightarrow \quad \boxed{V_{TO} \simeq 0.484\ \text{V}}$$

(b) For k, use any row, (let's use row 1)

$$I_{D(sat\,1)} = \frac{k}{2}\left(V_{GS(1)} - V_{TO}\right)^2 \left(1 + \lambda V_{DS(1)}\right)$$

$$8 = \frac{k}{2}\left(0.6 - 0.484\right)^2 \left(1 + 0.0909 \times 0.8\right)$$

$$k = \frac{8}{\frac{1}{2}\left(0.116\right)^2 \left(1.07272\right)}$$

$$\Rightarrow \quad \boxed{k \simeq 1.1\ \text{mA}/\text{V}^2}$$

(d) To find γ let's take row 3

$$37\times10^{-6} = \frac{1.1\times10^{-3}}{2}(0.8-V_T)^2\,(1+0.0909\times0.8)$$

$$\Rightarrow (0.8-V_T)^2 = \frac{37\times10^{-6}}{\frac{1.1\times10^{-3}}{2}(1+0.0909\times0.8)}$$

$$\Rightarrow (0.8-V_T)^2 = 62.7123\times10^{-3}$$

$$\Rightarrow 0.8-V_T = 0.2504$$

$$\Rightarrow V_T = 0.5496\ \text{V}$$

So now: $V_T = V_{T0} + \gamma\left(\sqrt{|-2\phi_F+V_{SB}|} - \sqrt{|2\phi_F|}\right)$

$$\Rightarrow \gamma = \frac{V_T - V_{T0}}{\sqrt{|-2\phi_F+V_{SB}|}-\sqrt{|2\phi_F|}}$$

$$\Rightarrow \gamma = \frac{0.5496-0.484}{\sqrt{|-1.1-0.3|}-\sqrt{|-1.1|}} = \frac{0.0656}{\sqrt{1.4}-\sqrt{1.1}}$$

$$\Rightarrow \boxed{\gamma \approx 0.443\ \text{V}^{1/2}}$$

(e) $$k = k' \frac{W}{L}$$

$$\Rightarrow W = \frac{kL}{k'} = \frac{1.1 \times 4}{0.108}$$

$$\Rightarrow \boxed{W \simeq 40.741 \ \mu m}$$

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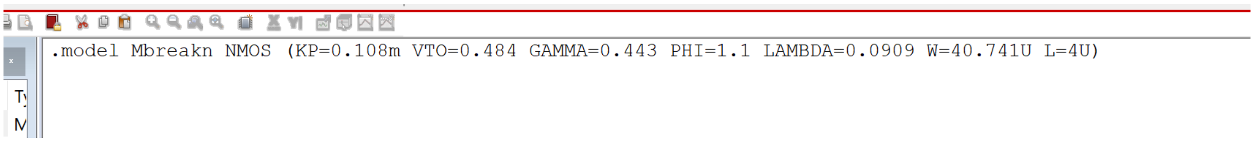
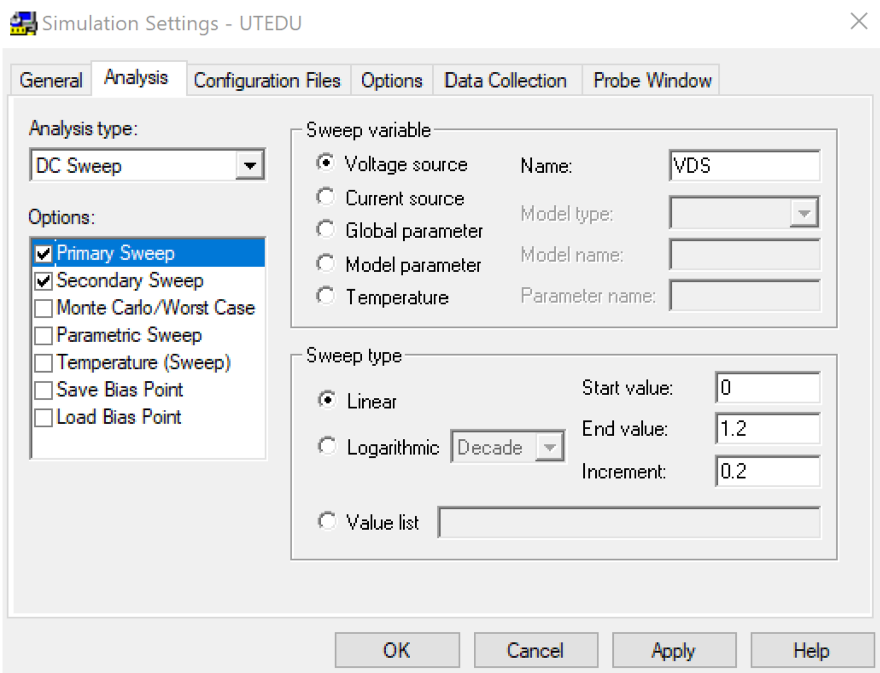
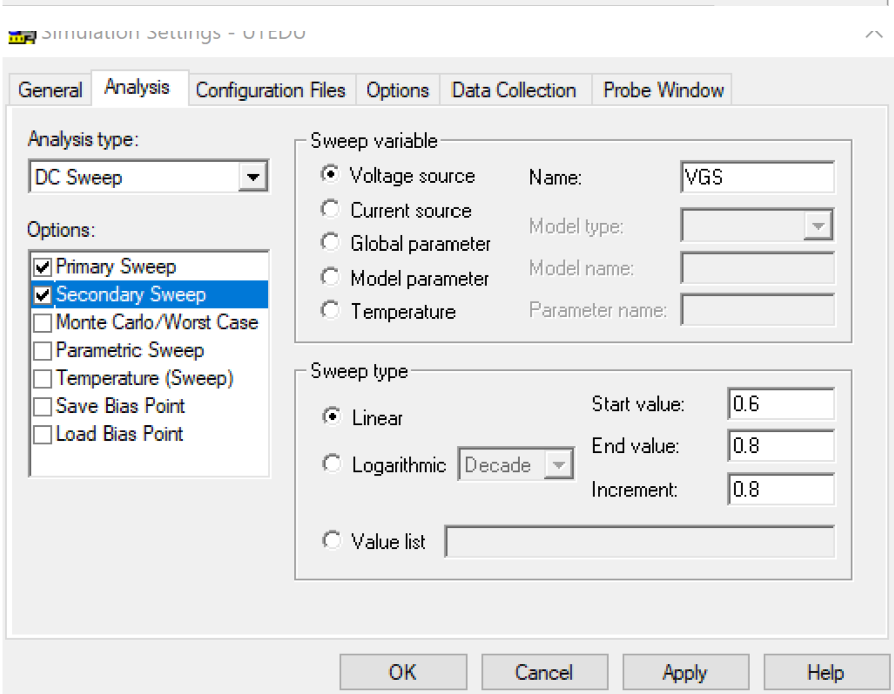
SPICE

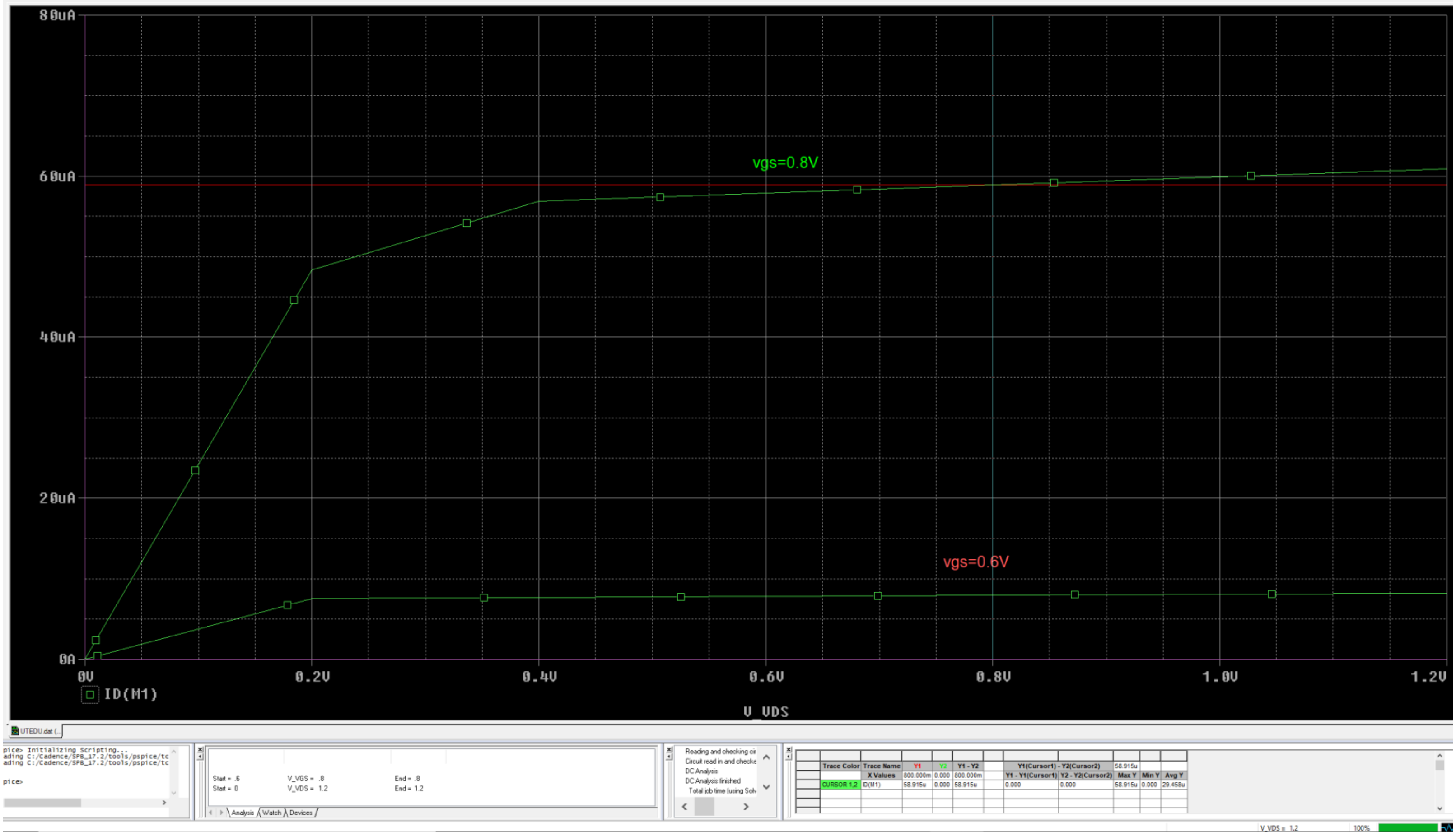






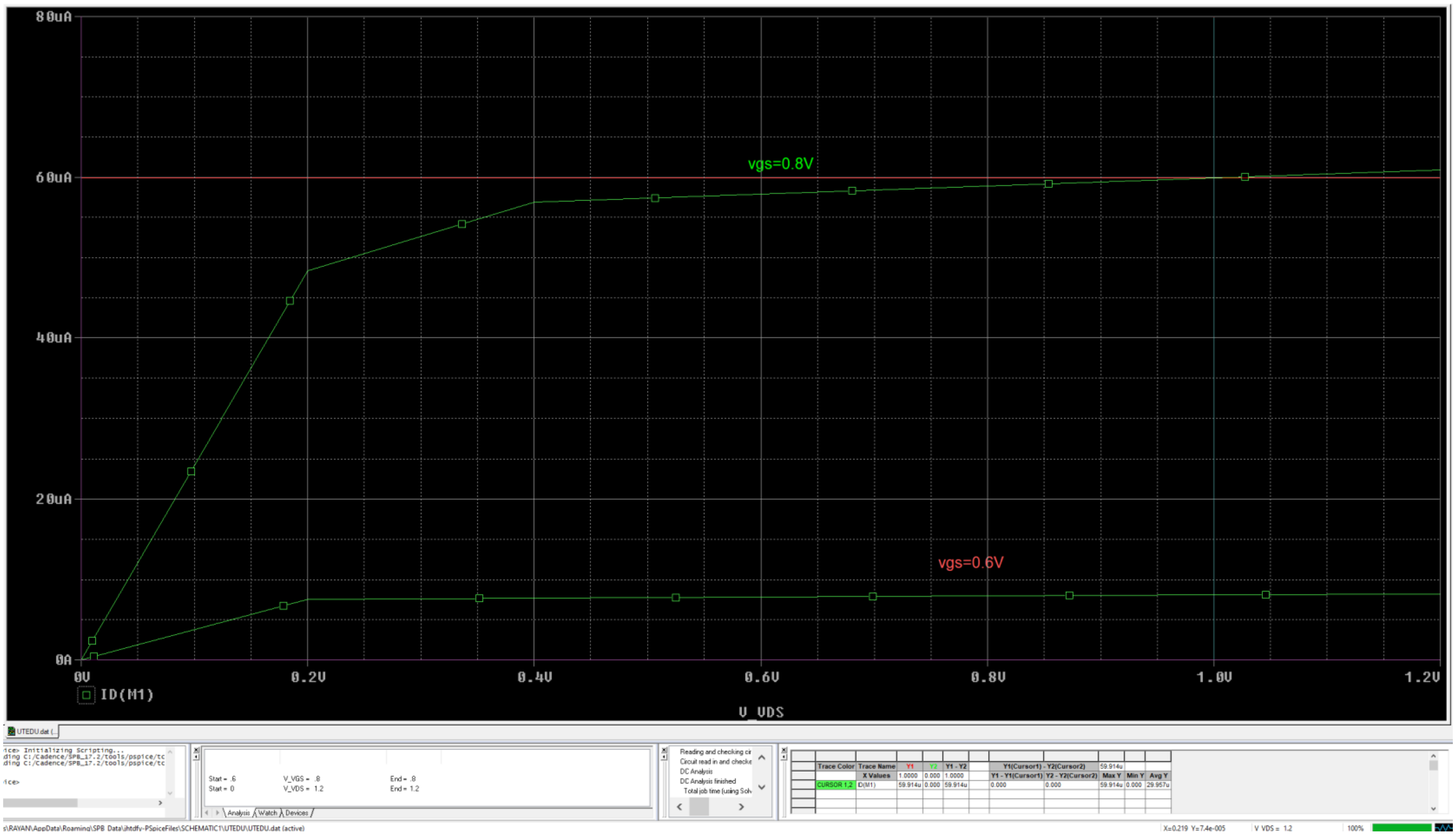
Results:

Vgs = 0.8 V and Vds = 0.8 V



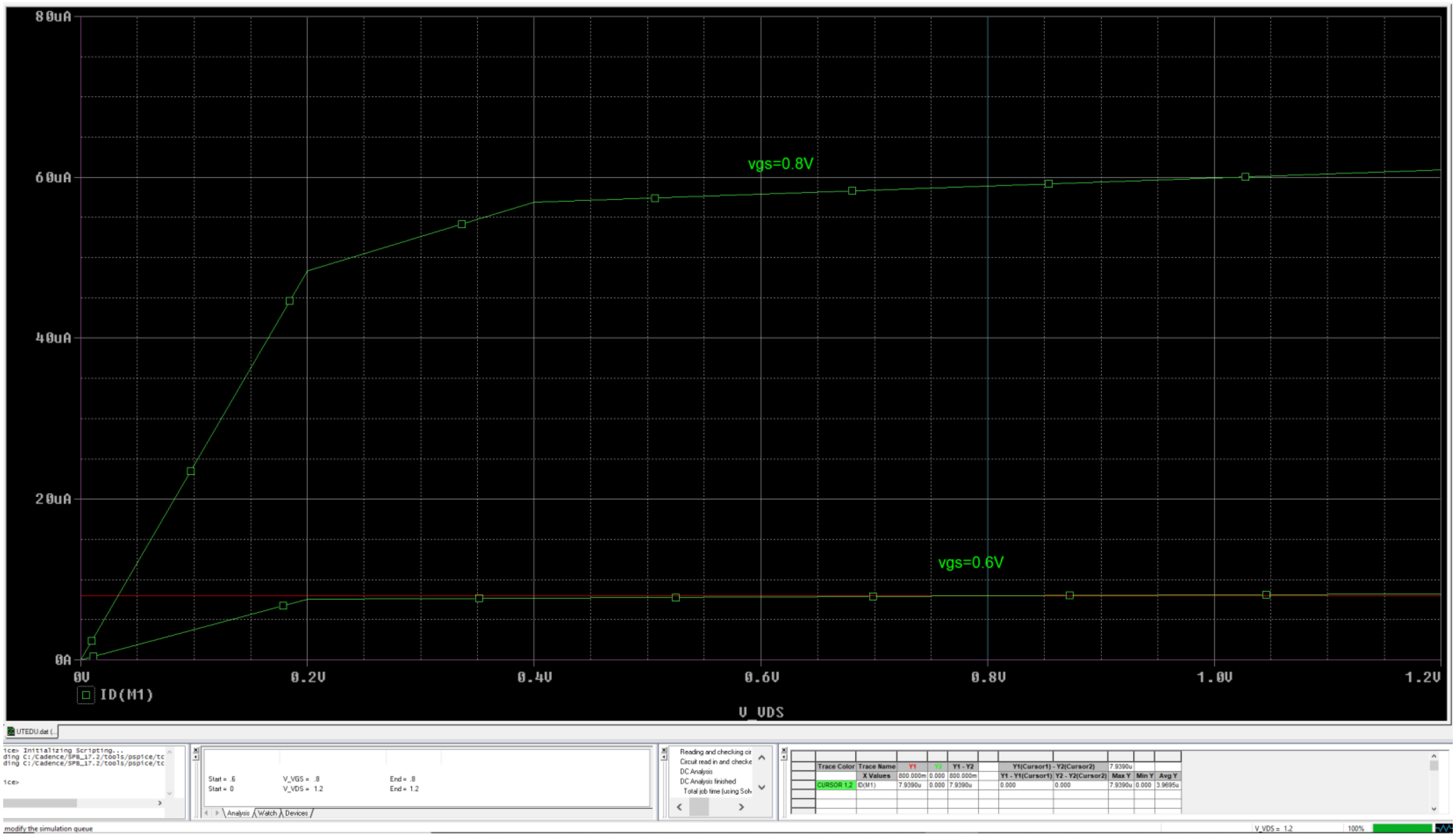
With cursor ON, we can see in the table at the bottom of the simulation window that I(d) = 58.91uA which is almost the same as 59uA (the value in the given table row 2)

Vgs = 0.8 V and Vds = 1 V



Here, I got I(D) = 59.91uA which is almost equal to 60 uA ➔ corresponds to value in given table at row 4

Vgs = 0.6 V and Vds = 0.8 V



Here, I got I(D) = 7.939 uA, which is also almost equal to 8uA ➔ corresponds to value in row 1 of given table

NB. Please note that I didn't get the exact same results because I took approximations when I did my calculations of the device parameters. However, I got very close values which validates the results in the given table.

Report

```
** Creating circuit file "UTEDU.cir"
** WARNING: THIS AUTOMATICALLY GENERATED FILE MAY BE OVERWRITTEN BY SUBSEQUENT SIMULATIONS

*Libraries:
* Profile Libraries :
* Local Libraries :
.LIB "C:/Users/RAYAN/Desktop/JHTDFY.lib"
* From [PSPICE NETLIST] section of C:\Users\RAYAN\AppData\Roaming\SPB_Data\cdssetup\OrCAD_PSpice\17.2.0\PSpice.ini file:
.lib "nomd.lib"

*Analysis directives:
.DC LIN V_VDS 0 1.2 0.2
+ LIN V_VGS 0.6 0.8 0.2
.OPTIONS ADVCONV
.PROBE64 V(alias(*)) I(alias(*)) W(alias(*)) D(alias(*)) NOISE(alias(*))
.INC "..\SCHEMATIC1.net"



**** INCLUDING SCHEMATIC1.net ****
* source JHTDFY
M_M1         N00098 N00091 0 0 Mbreakn
V_VGS         N00091 0 0.8Vdc
V_VDS         N00098 0 1.2Vdc

**** RESUMING UTEDU.cir ****
.END

**** 10/03/21 19:55:15 ******* PSpice Lite (March 2016) ******* ID# 10813 ****

 ** Profile: "SCHEMATIC1-UTEDU"  [ C:\Users\RAYAN\AppData\Roaming\SPB_Data\jhtdfy-PSpiceFiles\SCHEMATIC1\UTEDU.sim ]


 ****     MOSFET MODEL PARAMETERS


******************************************************************************




               Mbreakn
```

```
               Mbreakn
               NMOS
        LEVEL    1
            L    4.000000E-06
            W   40.741000E-06
          VTO     .484
           KP  108.000000E-06
        GAMMA     .443
          PHI    1.1
       LAMBDA      .0909
           IS   10.000000E-15
           JS    0
           PB     .8
         PBSW     .8
           CJ    0
         CJSW    0
         CGSO    0
         CGDO    0
         CGBO    0
          TOX    0
           XJ    0
        UCRIT   10.000000E+03
       DIOMOD    1
          VFB    0
         LETA    0
         WETA    0
           U0    0
         TEMP    0
          VDD    5
        XPART    0



          JOB CONCLUDED

**** 10/03/21 19:55:15 ******* PSpice Lite (March 2016) ******* ID# 10813 ****

 ** Profile: "SCHEMATIC1-UTEDU"  [ C:\Users\RAYAN\AppData\Roaming\SPB_Data\jhtdfy-PSpiceFiles\SCHEMATIC1\UTEDU.sim ]


 ****     JOB STATISTICS SUMMARY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