

Homework 5 - ECE 1238

Rayan Hassan

5.1 (a) From equation (5.19):

$$V_{OL} = V_{DD} - V_{TO} + \frac{1}{k_n R_L} - \sqrt{\left(V_{DD} - V_{TO} + \frac{1}{k_n R_L}\right)^2 - \frac{2V_{DD}}{k_n R_L}}$$

$$\Rightarrow 0.05 = 1.1 - 0.52 + \frac{1}{2k_n} - \sqrt{\left(1.1 - 0.52 + \frac{1}{2k_n}\right)^2 - \frac{2 \times 1.1}{2}}$$

$$\Rightarrow 0 = 0.53 + \frac{1}{2k_n} - \sqrt{\left(0.58 + \frac{1}{2k_n}\right)^2 - \frac{1.1}{k_n}}$$

$$\Rightarrow \sqrt{\left(0.58 + \frac{1}{2k_n}\right)^2 - \frac{1.1}{k_n}} = 0.53 + \frac{1}{2k_n}$$

$$\Rightarrow \left(0.58 + \frac{1}{2k_n}\right)^2 - \frac{1.1}{k_n} = \left(0.53 + \frac{1}{2k_n}\right)^2$$

$$\Rightarrow 0.58^2 + \frac{0.58}{k_n} + \frac{1}{4k_n^2} - \frac{1.1}{k_n} = 0.53^2 + \frac{0.53}{k_n} + \frac{1}{4k_n^2}$$

$$\Rightarrow 0.58^2 - \frac{0.52}{k_n} = 0.53^2 + \frac{0.53}{k_n}$$

$$\Rightarrow 0.58^2 - 0.53^2 = \frac{1.05}{k_n}$$

$$\Rightarrow 0.0555 = \frac{1.05}{k_n}$$

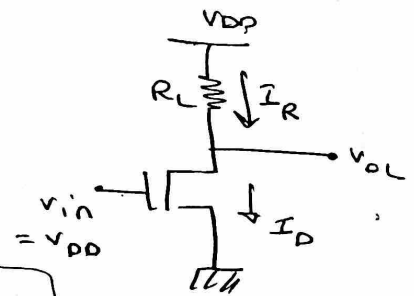
$$\Rightarrow k_n = \frac{1.05}{0.0555} \Rightarrow k_n \approx 18.92 \text{ mA/V}^2$$

$$I_R = I_D$$

Now:

$$\frac{V_{DD} - V_{OL}}{R_L} = \frac{1}{2} K'_n \frac{W}{L} (V_{GS} - V_{TO})^2$$

$V_{GS} = V_{DD}$



where $K_n = K'_n \mu_n C_{ox}$

$$\Rightarrow K'_n = \frac{K_n}{\mu_n C_{ox}} = \frac{18.92(\text{m})}{216(\mu)} \approx 0.088 \text{ mA/V}^2$$

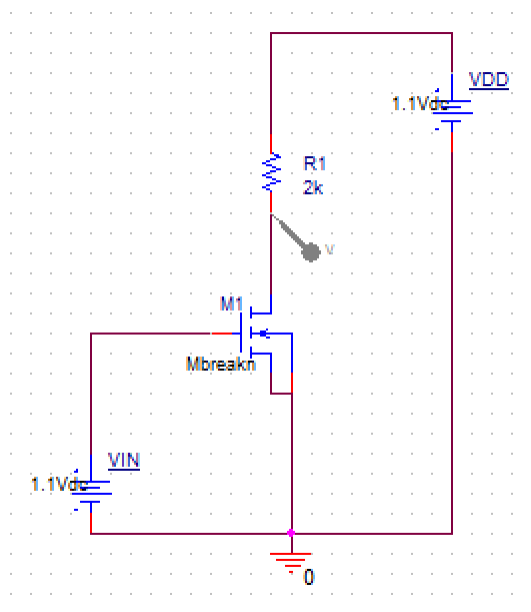
$$\frac{1.1 - 0.05}{2} = \frac{1}{2} \times 0.088 \times \frac{W}{L} (1.1 - 0.52)^2$$

$$0.525 = 0.044 \frac{W}{L} \times 0.3364$$

$$> \frac{W}{L} = \frac{0.525}{0.044 \times 0.3364} \Rightarrow \boxed{\frac{W}{L} \approx 35.47}$$

1) (b)

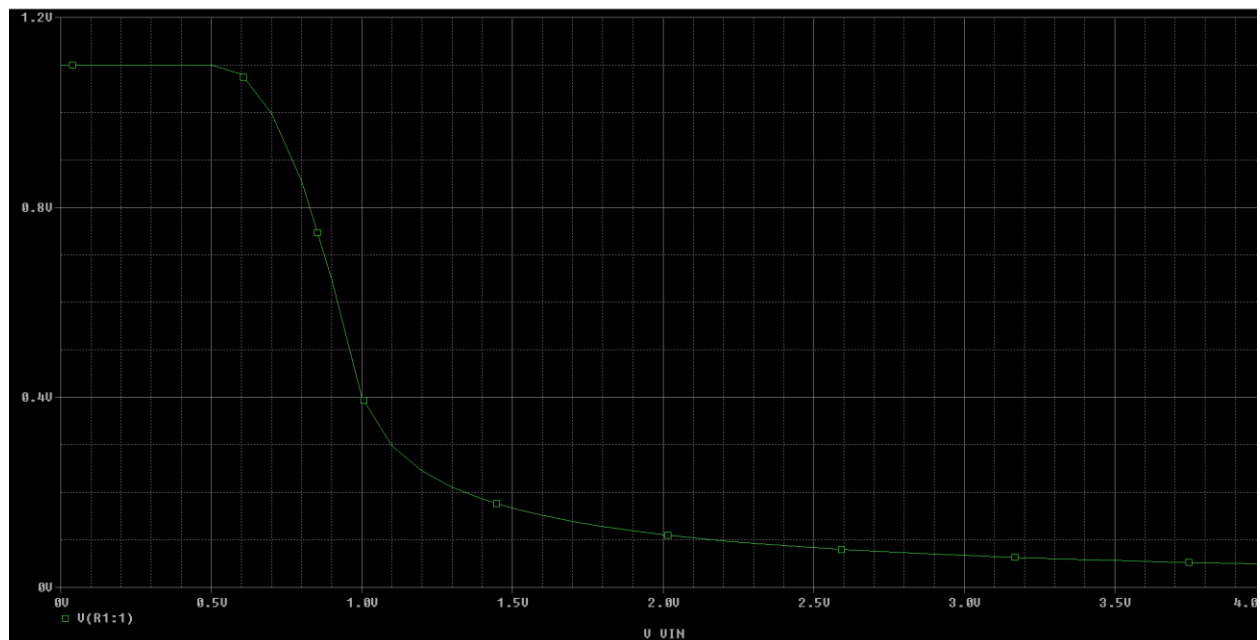
Circuit



Pspice model

```
.model Mbreakn NMOS (KP=0.088m VTO=0.52 GAMMA=0 LAMBDA=0 W=35.47U L=1U)
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General curve



Report

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214 ** Creating circuit file "UYFXC.cir"
215 ** WARNING: THIS AUTOMATICALLY GENERATED FILE MAY BE OVERWRITTEN BY SUBSEQUENT SIMULATIONS
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217 *Libraries:
218 * Profile Libraries :
219 * Local Libraries :
220 .LIB "..\\..\\..\\iuwr-pspicefiles\\iuwr.lib"
221 * From [PSPICE NETLIST] section of C:\\Users\\RAYAN\\AppData\\Roaming\\SPB_Data\\cdssetup\\OrCAD_PSpice\\17.2.0\\PSpice.ini file:
222 .lib "nomd.lib"
223
224 *Analysis directives:
225 .DC LIN V_VIN 0 4 0.1
226 .OPTIONS ADVCONV
227 .PROBE64 V(alias(*)) I(alias(*)) W(alias(*)) D(alias(*)) NOISE(alias(*))
228 .INC "..\\SCHEMATIC1.net"
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232 **** INCLUDING SCHEMATIC1.net ****
233 * source IUWR
234 R_R1 N00123 N00127 2k TC=0.0
235 V_VDD N00127 0 1.1Vdc
236 V_VIN N00116 0 0Vdc
237 M_M1 N00123 N00116 0 0 Mbreakn
238 + L=1u
239 + W=35.47u
240
241 **** RESUMING UYFXC.cir ****
242 .END
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244 **** 10/20/21 03:11:48 ***** PSpice Lite (March 2016) ***** ID# 10813 ****
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246 ** Profile: "SCHEMATIC1-UYFXC" [ C:\\Users\\RAYAN\\AppData\\Roaming\\SPB_Data\\iuwr-PSpiceFiles\\SCHEMATIC1\\UYFXC.sim ]
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249 **** MOSFET MODEL PARAMETERS
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251 *****
252 *****
253 *****
254 *****
255 *****
```

	Mbreakn
	NMOS
LEVEL	1
L	1.000000E-06
W	35.470000E-06
VTO	.52
KP	88.000000E-06
GAMMA	0
PHI	.6
LAMBDA	0
IS	10.000000E-15
JS	0
PB	.8
PBSW	.8
CJ	0
CJSW	0
CGSO	0
CGDO	0
CGBO	0
TOX	0
KJ	0
UCRIT	10.000000E+03
DIOMOD	1
VFB	0
LETA	0
WETA	0
UO	0
TEMP	0
VDD	5
XPART	0

JOB CONCLUDED

*** 10/20/21 03:11:48 ***** PSpice Lite (March 2016) ***** ID# 10813 ****

1) (C)

Using the cursor, I found:

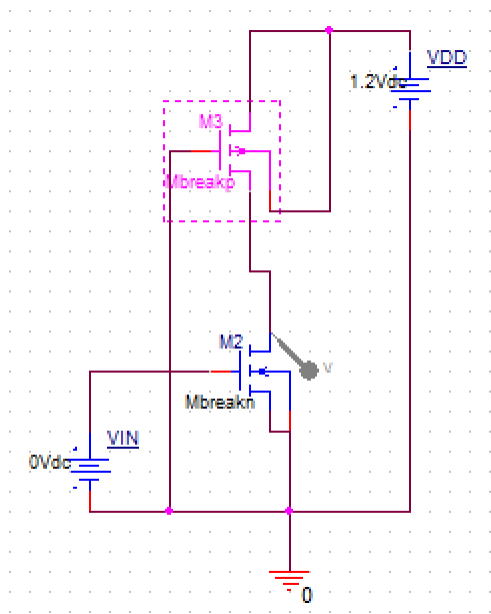
$V_{OH} \approx 1.089 \text{ V}$, $V_{IL} \approx 0.612 \text{ V}$

$V_{OL} \approx 0.389 \text{ V}$, $V_{IH} \approx 1.034 \text{ V}$

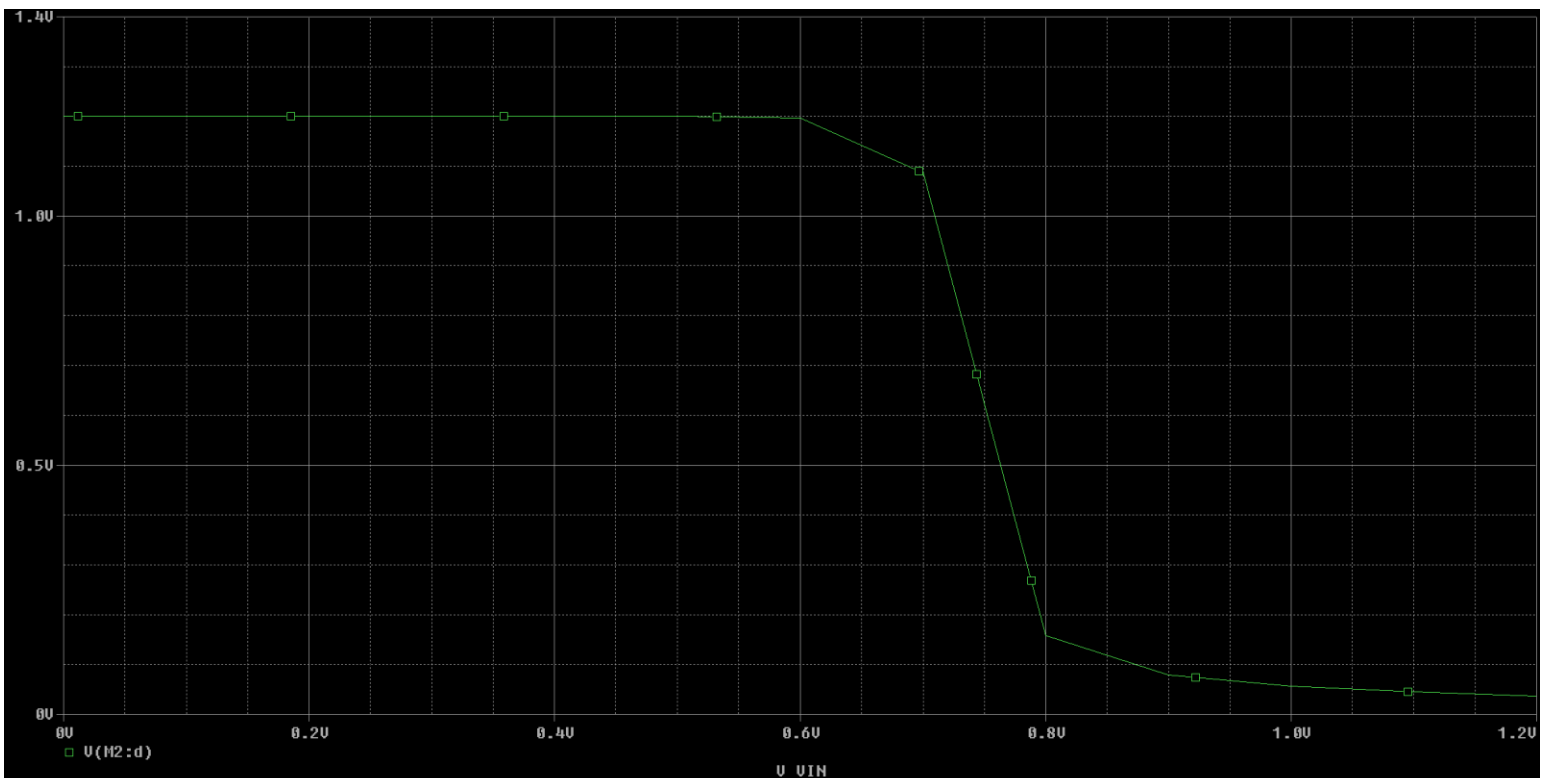
$NMH = V_{OH} - V_{IH} = 1.089 - 1.034 = 0.055 \text{ V}$

$NML = V_{IL} - V_{OL} = 0.612 - 0.389 = 0.223 \text{ V}$

2) (a)



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.model Mbreakn NMOS (KP=94.3U VTO=0.58 W=12U L=1U UO=42.8636 LD=4.00E-8 VSAT=124340)
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.model Mbreakp PMOS (KP=41U VTO=-0.56 W=3U L=1U LD=4.00E-8)
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** Creating circuit file "RG.cir"
** WARNING: THIS AUTOMATICALLY GENERATED FILE MAY BE OVERWRITTEN BY SUBSEQUENT SIMULATIONS

*Libraries:
* Profile Libraries :
* Local Libraries :
.LIB "..\..\kjqed-bspicefiles\kjqed.lib"
* From [PSPICE NETLIST] section of C:\Users\RAYAN\AppData\Roaming\SPB_Data\cdssetup\OrCAD_PSpice\17.2.0\PSpice.ini file:
.lib "nomad.lib"

*Analysis directives:
.DC LIN V VIN 0 1.2 0.1
.OPTIONS ADVCONV
.PROBE64 V(alias(*)) I(alias(*)) W(alias(*)) D(alias(*)) NOISE(alias(*))
.INC "..\SCHEMATIC1.net"

**** INCLUDING SCHEMATIC1.net ****
* source KJQVED
M_M2 N00130 N00123 0 0 Mbreakn
V_VIN N00123 0 0Vdc
V_VDD N00111 0 1.2Vdc
M_M3 N00111 0 N00130 N00111 Mbreakp

**** RESUMING "RG.cir" ****
.END
***** 10/20/21 04:35:15 ***** PSpice Lite (March 2016) ***** ID# 10813 *****
** Profile: "SCHEMATIC1-RG " [ C:\Users\RAYAN\AppData\Roaming\SPB_Data\kjqed-PSpiceFiles\SCHEMATIC1\RG .sim ]

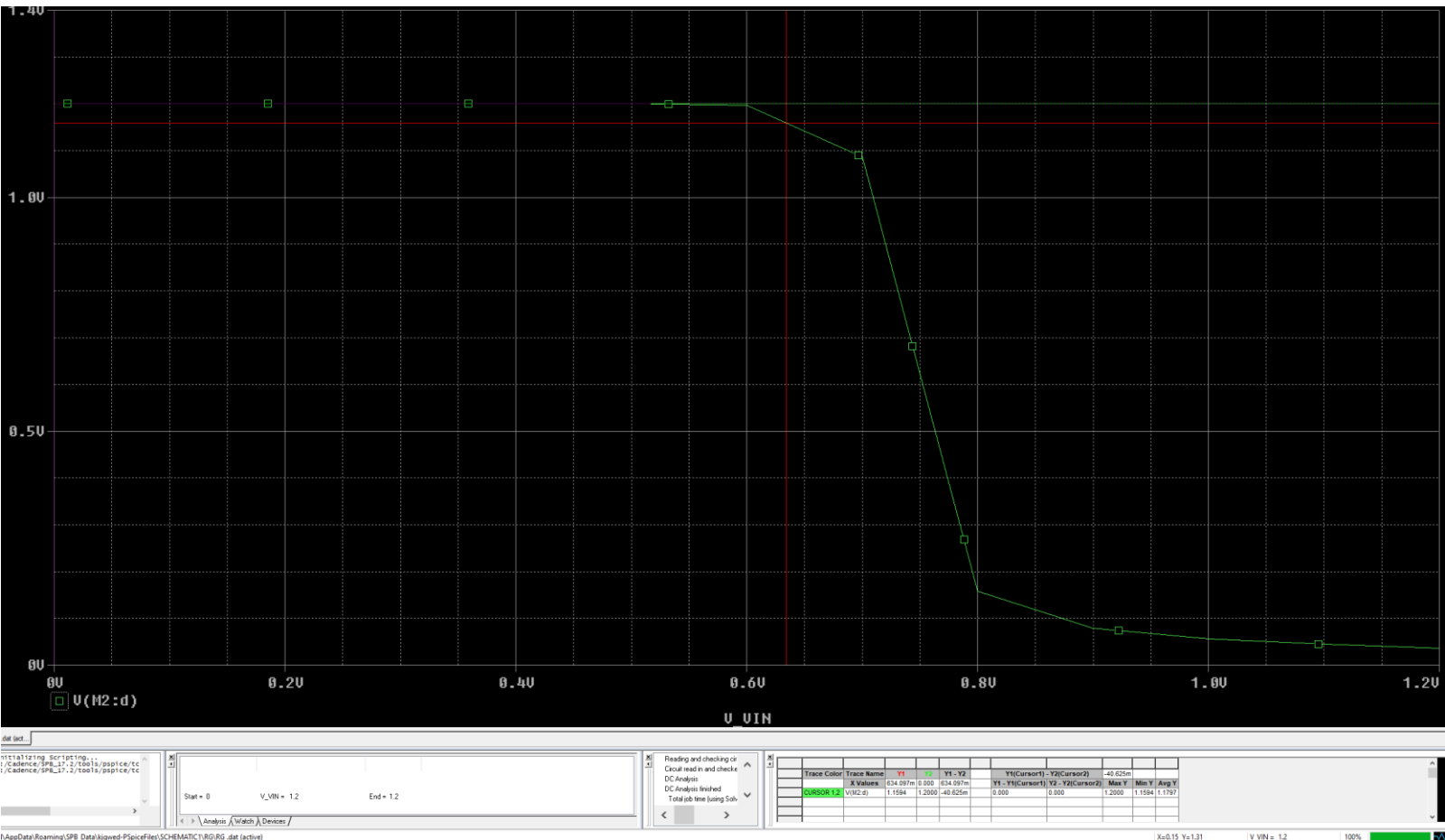
**** MOSFET MODEL PARAMETERS
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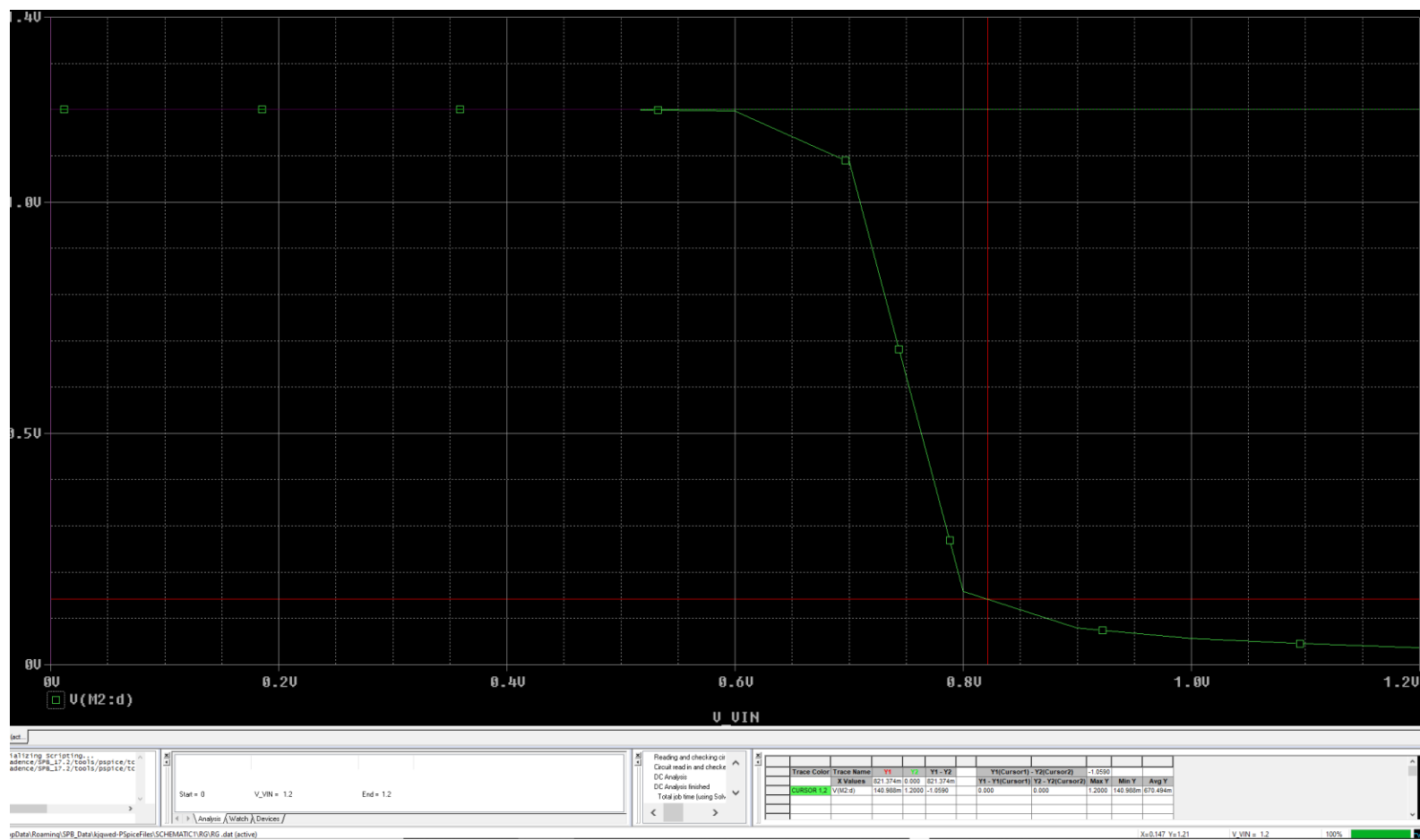
LEVEL      Mbreakn      Mbreakp
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From this we see that:

$V_{OH} = 1.194\text{ V}$ and $V_{IL} = 0.634097\text{ V}$



From this we see that:

$V_{OL} = 0.14V$ and $V_{IH} = 0.82137V$

$NMH = V_{OH} - V_{IH} = 1.194 - 0.82137 = 0.37263 V$

$NML = V_{IL} - V_{OL} = 0.634097 - 0.14 = 0.4941 V$

(b) Results are almost the same as the ones in the calculations