Module 2 Assignment

7nm FinFET Device and Inverter Characterization

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SPICE file used: inverter_assign_2.spice

Sch file used: inverter_assign_2.sch

Extracting the following metrics from simulation results:

- Switching Threshold Voltage (VTC) in mV
- Drain Current (Id) in µA
- Power Consumption (P) in fW (femto watt)
- Propagation Delay (tpd) in ps
- Gain (Av)
- Noise Margin (NM)
- Transconductance (gm) in 10^{-3}
- Frequency (f) in Hz

Characterization Table:

CHARACTERIZATION TABLE

Trial no.	W (PMOS)	W (NMOS)	L (PMOS, NMOS)	W/L (PMOS)	W/L (NMOS)	V_{th} (in mV)	I_d (in uA)	Power (in fW)	t_{pd} (in ps)	Gain / A_v	freq. (in Hz)	Noise margin	Transconductance (gm) x 10^{-3}	O/p resistance (Ro)
1	14	14	7	2	2	344.79	226.07	-1.185	0.4495	6.4284	2.2247	NMH: -0.032019 NML: 0.044396	1.2358	6.428
2	10	14	7	1.4286	2	321.55	226.03	-1.425	0.4426	6.4812	2.2592	NMH: -0.025006 NML: 0.037397	0.96853	6.42842
3	11	14	7	1.5714	2	328.11	201.21	-1.049	0.4432	6.4572	2.2563	NMH: -0.026799 NML: 0.0394854	1.040534	6.457
4	12	14	7	1.7143	2	334.12	210.1	-1.098	0.4438	6.4424	2.2532	NMH: -0.028999 NML: 0.041478	1.108422	6.44233
5	13	14	7	1.8571	2	339.66	218.36	-1.143	0.4445	6.4324	2.2499	NMH: -0.030415 NML: 0.0430194	1.173429	6.43224
6	14	15	7	2	2.1429	340.01	234.52	-1.754	0.4451	6.4326	2.2496	NMH: -0.030590 NML: 0.0429329	1.26179	6.43263
7	13	16	7	1.8571	2.2857	330.42	233.84	-1.221	0.4434	6.4514	2.5515	NMH: -0.027690 NML: 0.0400151	1.218675	6.45133
8	14	17	7	2	2.4286	331.35	250.16	-1.306	0.4352	6.4489	2.2547	NMH: -0.028023 NML: 0.0403602	1.307588	6.44895
9	14	10	7	2	1.4286	367.95	186.75	-1.415	4.4955	6.4529	2.2244	NMH: -0.038091 NML: 0.0507028	1.10319	6.45263
10	14	13	7	2	1.8571	349.91	217.12	-1.141	4.4596	6.4273	2.2424	NMH: -0.032979 NML: 0.0455739	1.207359	6.42807
11	12	11	7	1.7143	1.5714	350.09	184.77	-1.388	4.461	6.4277	2.2416	NMH: -0.033175 NML: 0.0457869	1.030588	6.42762
12	17	13	7	2.4286	1.8571	363.28	236.12	-1.784	4.4849	6.4423	2.2297	NMH: -0.036622 NML: 0.0492198	1.373	6.4422
13	16	11	7	2.2857	1.5714	370.55	208.6	-1.583	4.5019	6.4594	2.2216	NMH: -0.038552 NML: 0.0515534	1.24307	6.45933
14	15	16	7	2.1429	2.2857	340.32	250.69	-1.313	4.4455	6.4318	2.2495	NMH: -0.030307 NML: 0.042819	1.350136	6.43193
15	15	12	7	2.1429	1.7143	360.18	213.86	-1.13	4.4784	6.4369	2.233	NMH: -0.036207 NML: 0.04.8733	1.23082	6.43688

Ensuring Unique Results

Including the following trick in my SPICE deck, adding a dummy voltage source:

Vuniq in 0 DC <your_username_ASCII_sum_in_mV>

Example: My username is Indrani,

➔ convert to ASCII (73+110+100+82+97+110+105 =677)

Using: Vuniq in 0 DC 0.677

[This introduces a small offset in simulation, making your result traceable and unique.]

SPICE code:

```
** sch_path: /home/Desktop/asap_7nm_Xschem/inverter_assign_2.sch
**.subckt inverter_assign_2
Xpfet1 nfet_out nfet_in vdd vdd asap_7nm_pfet l=7e-009 nfin=14
Xnfet1 nfet_out nfet_in GND GND asap_7nm_nfet l=7e-009 nfin=14
V1 nfet_in GND pulse(0 0.7 20p 10p 10p 20p 500p 1)
V2 vdd GND 0.7
Vuniq in 0 DC 0.677

**** begin user architecture code
*.dc v1 0 0.7 1m
*.tran 1e-12 100e-12

.control
   * First run DC
   dc v1 0 0.7 1m
   run
   * DC measurements
   meas dc v_th when nfet_out = nfet_in
   plot nfet_out nfet_in

   let gain_av = abs(deriv(nfet_out))
   meas dc max_gain max gain_av
   let gain_target = max_gain * 0.999
   meas dc vil find nfet_in when gain_av = gain_target cross=1
   meas dc voh find nfet_out when gain_av = gain_target cross=1
   meas dc vih find nfet_in when gain_av = gain_target cross=2
   meas dc vol find nfet_out when gain_av = gain_target cross=2
   let nmh = voh - vih
   let nml = vil - vol
   print v_th max_gain vil voh vih vol nmh nml

   *Transconductance

   let id = v2#branch
   let gm = real(deriv(id, nfet_in))
   meas dc gm_max MAX gm
   plot gm
   let r_out= deriv(nfet_out,id)
   let abs_rout= abs(r_out)
   meas dc max_r_out max abs_rout
   print max_r_out
   plot r_out
```

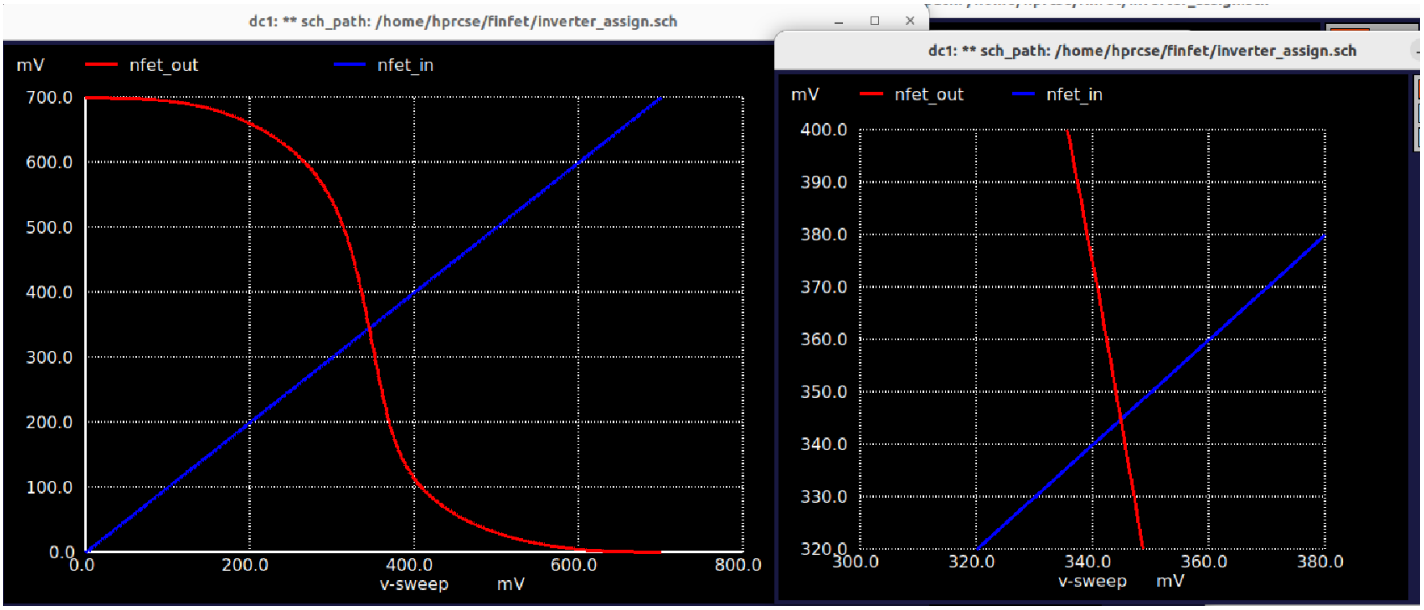
```
   plot id

   * Transient measurements
   tran 1e-12 100e-12
   meas tran tpr when nfet_in = 0.35 rise = 1
   meas tran tpf when nfet_out = 0.35 fall = 1
   let tp = (tpr + tpf) / 2
   let trans_current = v2#branch
   meas tran id_pwr integ trans_current from=2e-11 to=6e-11
   let pwr = id_pwr * 0.7
   let power = abs(pwr / 4e-11)
   print tpr tpf tp id_pwr pwr power

   tran 0.1 100p
   meas tran tr when nfet_in=0.07 RISE=1
   meas tran tf when nfet_out=0.63 FALL=1
   let t_delay = tr + tf
   print t_delay
   let f = 1/t_delay
   print f

.endc




**** end user architecture code
**.ends
.GLOBAL GND
**** begin user architecture code

.subckt asap_7nm_pfet S G D B l=7e-009 nfin=15
          npmos_finfet S G D B BSIMCMG_osdi_P l=7e-009 nfin=15
.ends asap_7nm_pfet

.model BSIMCMG_osdi_P BSIMCMG_va (
+ TYPE = 0

**********************************************************
*                  general                   *
**********************************************************
+version = 107          bulkmod = 1           igcmod  = 1           igbmod  = 0
+gidlmod = 1            iimod   = 0           geomod  = 1           rdsmod  = 0
+rgatemod= 0            rgeomod = 0           shmod   = 0           nqsmod  = 0
+coremod = 0            cgeomod = 0           capmod  = 0           tnom    = 25
```

```
+eot    = 1e-009        eotbox  = 1.4e-007       eotacc  = 3e-010        tfin    = 6.5e-009
+toxp   = 2.1e-009      nbody   = 1e+022        phig    = 4.9278        epsrox  = 3.9
+epsrsub = 11.9         easub   = 4.05          ni0sub  = 1.1e+016      bg0sub  = 1.17
+nc0sub  = 2.86e+025     nsd     = 2e+026        ngate   = 0             nseg    = 5
+l      = 2.1e-008      xl      = 1e-009        lint    = -2.5e-009     dlc     = 0
+dlbin   = 0            hfin    = 3.2e-008      deltaw  = 0             deltawcv= 0
+sdterm  = 0            epsrsp  = 3.9           nfin    = 1
+toxg    = 1.8e-009
**********************************************************
*                  dc                    *
**********************************************************
+cit     = 0            cdsc    = 0.003469      cdscd   = 0.001486      dvt0    = 0.05
+dvt1    = 0.36         phin    = 0.05          eta0    = 0.094         dsub    = 0.24
+k1rsce  = 0            lpe0    = 0             dvtshift= 0             qmfactor= 0
+etaqm   = 0.54         qm0     = 2.183e-012    pqm     = 0.66          u0      = 0.0237
+etamob  = 4            up      = 0             ua      = 1.133         eu      = 0.05
+ud      = 0.0105       ucs     = 0.2672        rdswmin = 0             rdsw    = 200
+wr      = 1            rswmin  = 0             rdwmin  = 0             rshs    = 0
+rshd    = 0            vsat    = 60000         deltavsat= 0.17         ksativ  = 1.592
+mexp    = 2.491        ptwg    = 25            pclm    = 0.01          pclmg   = 1
+pdibl1  = 800          pdibl2  = 0.005704      drout   = 4.97          pvag    = 200
+fpitch  = 2.7e-008     rth0    = 0.15          cth0    = 1.243e-006    wth0    = 2.6e-007
+lcdscd  = 0            lcdscdr = 0             lrdsw   = 1.3           lvsat   = 1441
**********************************************************
*                 leakage                *
**********************************************************
+aigc    = 0.007        bigc    = 0.0015        cigc    = 1             dlcigs  = 5e-009
+dlcigd  = 5e-009       aigs    = 0.006         aigd    = 0.006         bigs    = 0.001944
+bigd    = 0.001944     cigs    = 1             cigd    = 1             poxedge = 1.152
+agidl   = 2e-012       agisl   = 2e-012        bgidl   = 1.5e+008      bgisl   = 1.5e+008
+egidl   = 1.142        egisl   = 1.142
**********************************************************
*                  rf                    *
**********************************************************
**********************************************************
*                 junction               *
**********************************************************
**********************************************************
*               capacitance              *
**********************************************************
+cfs     = 0            cfd     = 0             cgso    = 1.6e-010      cgdo    = 1.6e-010
+cgsl    = 0            cgdl    = 0             ckappas = 0.6           ckappad = 0.6
+cgbo    = 0            cgbl    = 0
**********************************************************
*               temperature              *
```

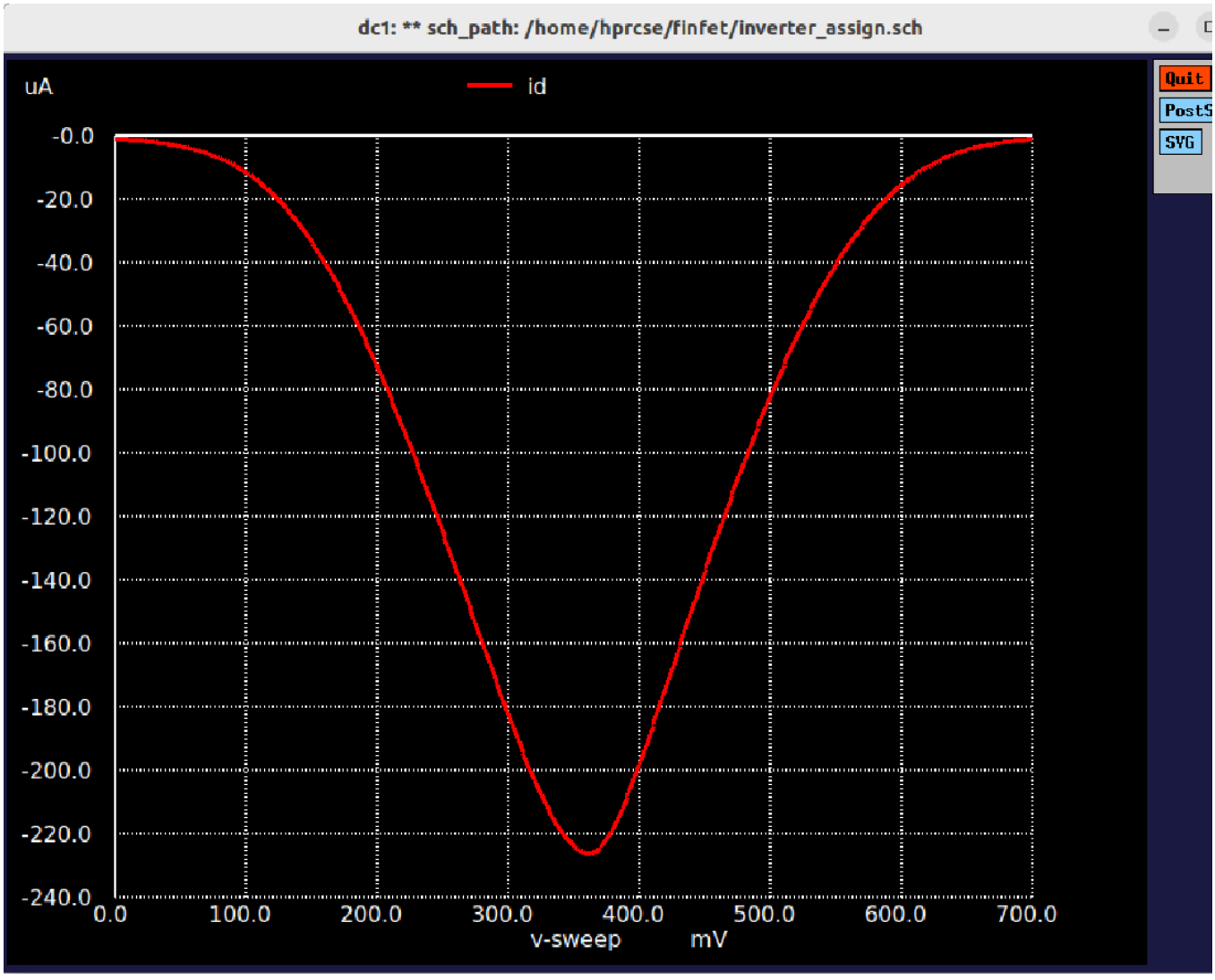
```
**********************************************************
+tbgasub = 0.000473       tbgbsub = 636          kt1    = 0          kt1l   = 0
+ute    = -1.2          utl    = 0            ua1    = 0.001032       ud1    = 0
+ucste  = -0.004775      at     = 0.001        ptwgt  = 0.004        tmexp  = 0
+prt    = 0            tgidl  = -0.007       igt    = 2.5
**********************************************************
*                  noise                    *
**********************************************************
**)
.control
pre_osdi /home/vsduser/Desktop/asap_7nm_Xschem/bsimcmg.osdi
.endc



.subckt asap_7nm_nfet S G D B l=7e-009 nfin=12
        nnmos_finfet S G D B BSIMCMG_osdi_N l=7e-009 nfin=12
.ends asap_7nm_nfet

.model BSIMCMG_osdi_N BSIMCMG_va (
+ TYPE = 1
**********************************************************
*                  general                  *
**********************************************************
+version = 107          bulkmod = 1           igcmod  = 1          igbmod  = 0
+gidlmod = 1           iimod   = 0           geomod  = 1          rdsmod  = 0
+rgatemod= 0           rgeomod = 0           shmod   = 0          nqsmod  = 0
+coremod = 0           cgeomod = 0           capmod  = 0          tnom    = 25
+eot    = 1e-009        eotbox  = 1.4e-007      eotacc  = 1e-010       tfin    = 6.5e-009
+toxp   = 2.1e-009      nbody   = 1e+022        phig    = 4.2466       epsrox  = 3.9
+epsrsub = 11.9         easub   = 4.05         ni0sub  = 1.1e+016      bg0sub  = 1.17
+nc0sub  = 2.86e+025     nsd     = 2e+026        ngate   = 0          nseg    = 5
+l      = 2.1e-008      xl      = 1e-009        lint    = -2e-009      dlc     = 0
+dlbin   = 0           hfin    = 3.2e-008      deltaw  = 0          deltawcv= 0
+sdterm  = 0           epsrsp  = 3.9          nfin    = 1
+toxg    = 1.80e-009
**********************************************************
*                  dc                   *
**********************************************************
+cit    = 0           cdsc    = 0.01         cdscd   = 0.01         dvt0    = 0.05
+dvt1   = 0.47         phin    = 0.05         eta0    = 0.07         dsub    = 0.35
+k1rsce  = 0           lpe0    = 0           dvtshift= 0          qmfactor= 2.5
+etaqm   = 0.54         qm0     = 0.001        pqm     = 0.66         u0      = 0.0303
+etamob  = 2           up      = 0           ua      = 0.55         eu      = 1.2
+ud     = 0           ucs     = 1           rdswmin = 0          rdsw    = 200
```

```
+wr     = 1          rswmin  = 0          rdwmin  = 0          rshs    = 0
+rshd   = 0          vsat    = 70000      deltavsat= 0.2       ksativ  = 2
+mexp   = 4          ptwg    = 30         pclm    = 0.05       pclmg   = 0
+pdibl1  = 0         pdibl2  = 0.002      drout   = 1          pvag    = 0
+fpitch  = 2.7e-008      rth0    = 0.225      cth0    = 1.243e-006     wth0    = 2.6e-007
+lcdscd  = 5e-005     lcdscdr = 5e-005     lrdsw   = 0.2        lvsat   = 0
************************************************************
*                leakage                   *
************************************************************
+aigc    = 0.014      bigc    = 0.005      cigc    = 0.25       dlcigs  = 1e-009
+dlcigd  = 1e-009     aigs    = 0.0115     aigd    = 0.0115     bigs    = 0.00332
+bigd    = 0.00332    cigs    = 0.35       cigd    = 0.35       poxedge = 1.1
+agidl   = 1e-012     agisl   = 1e-012     bgidl   = 10000000   bgisl   = 10000000
+egidl   = 0.35       egisl   = 0.35
************************************************************
*                  rf                    *
************************************************************
************************************************************
*                junction                *
************************************************************
************************************************************
*              capacitance                 *
************************************************************
+cfs     = 0          cfd     = 0          cgso    = 1.6e-010   cgdo    = 1.6e-010
+cgsl    = 0          cgdl    = 0          ckappas = 0.6        ckappad = 0.6
+cgbo    = 0          cgbl    = 0
************************************************************
*              temperature                 *
************************************************************
+tbgasub = 0.000473   tbgbsub = 636        kt1     = 0          kt1l    = 0
+ute     = -0.7       utl     = 0          ua1     = 0.001032   ud1     = 0
+ucste   = -0.004775   at      = 0.001      ptwgt   = 0.004      tmexp   = 0
+prt     = 0          tgidl   = -0.007     igt     = 2.5
************************************************************
*                 noise                    *
************************************************************
**)
.control
pre_osdi /home/vsduser/Desktop/asap_7nm_Xschem/bsimcmg.osdi
.endc


**** end user architecture code
.end
```

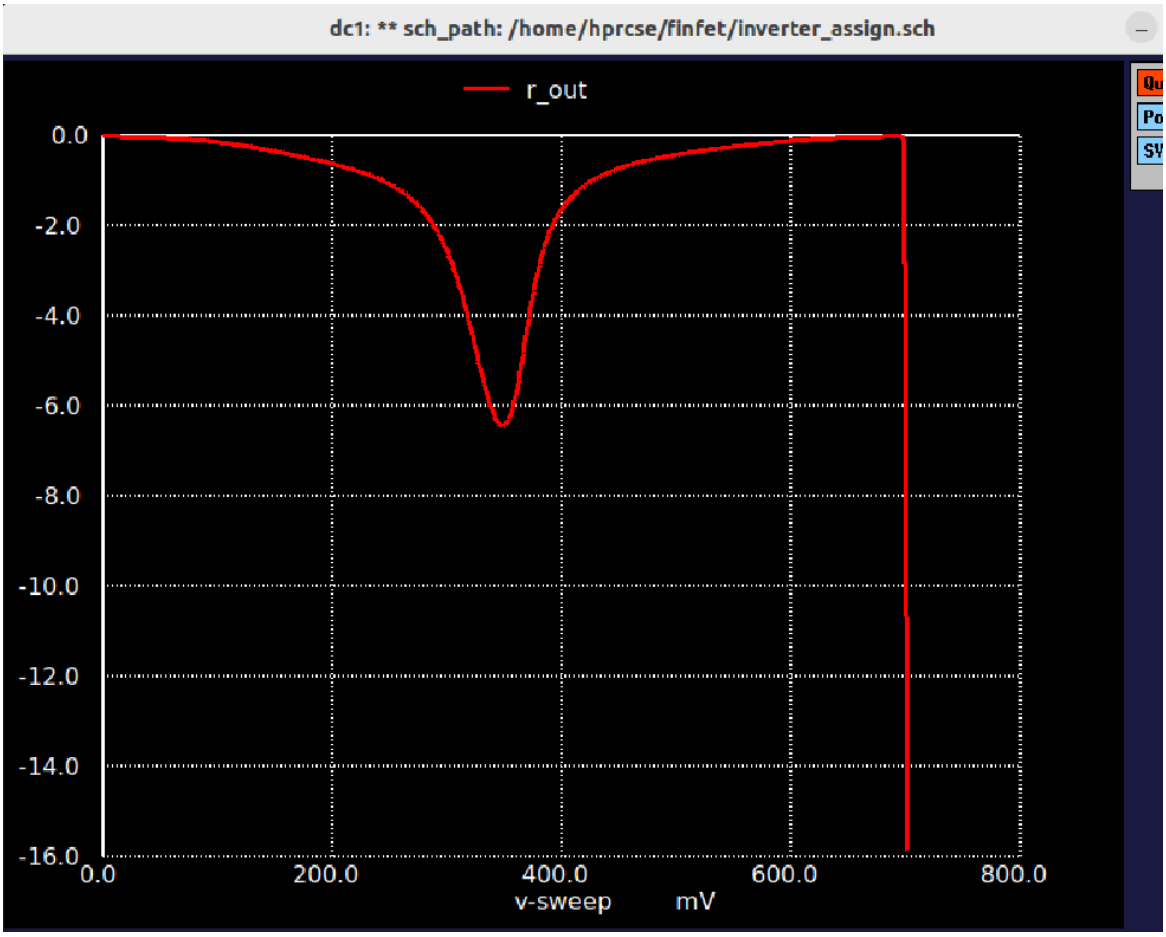
Graphs of VTC, Delay and I_D curves:



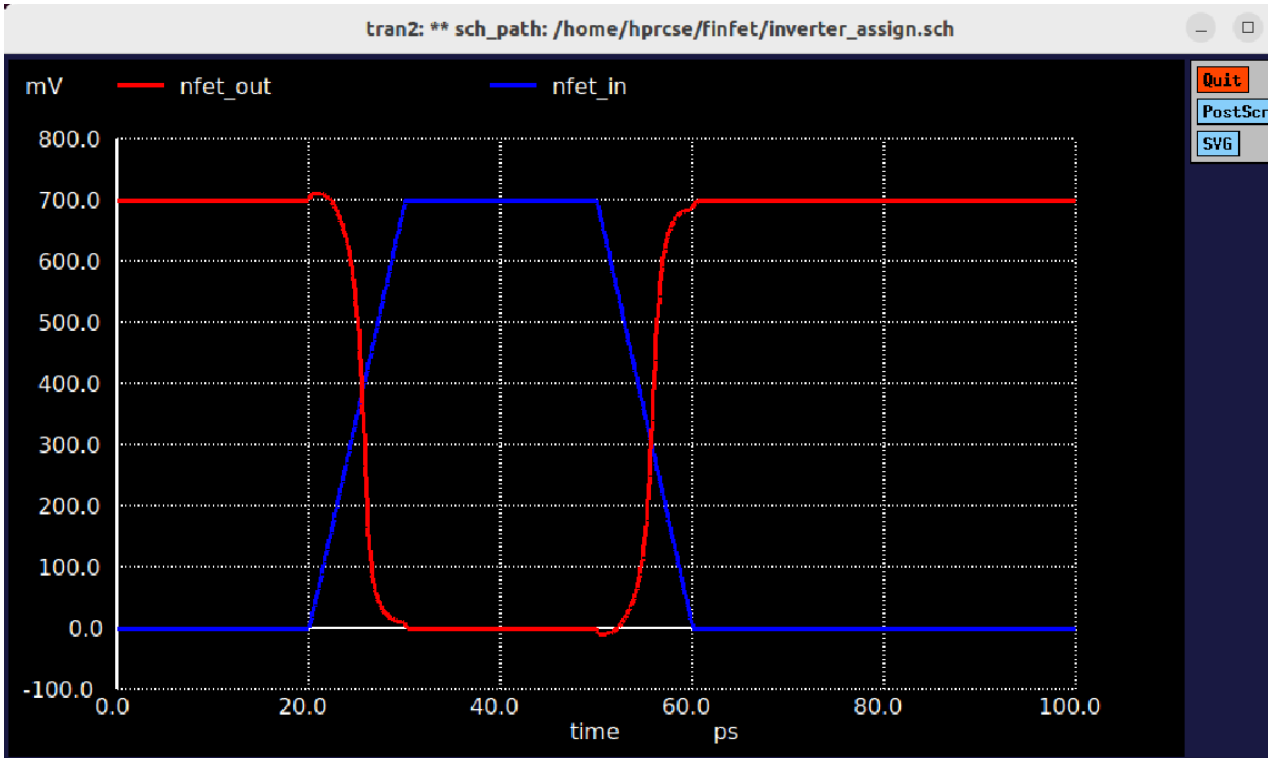
VTC Graph



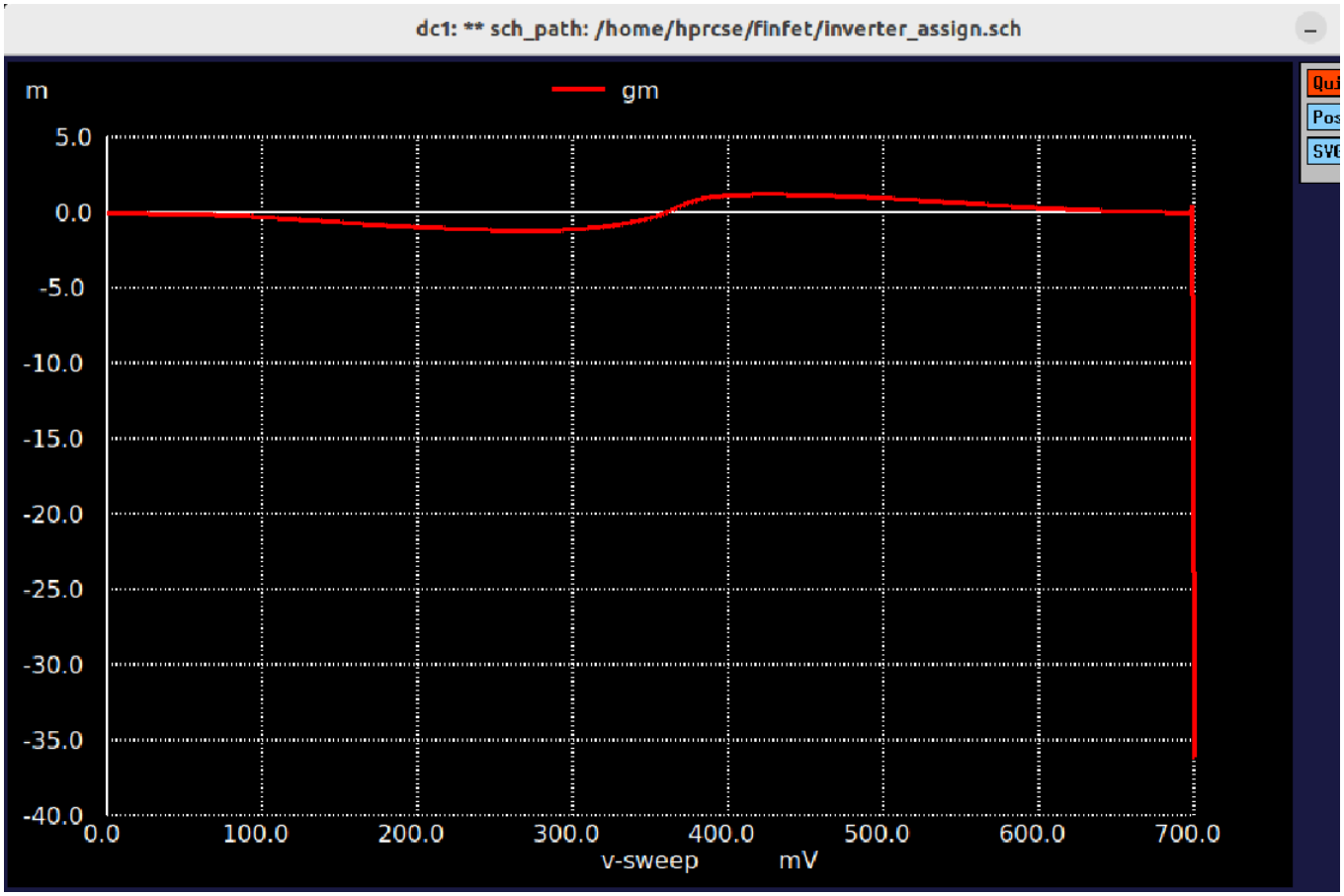
I_D Curve



Output Resistance Graph (r_out)



n-FET output and input plot



Transconductance (Gm) Curve