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
```
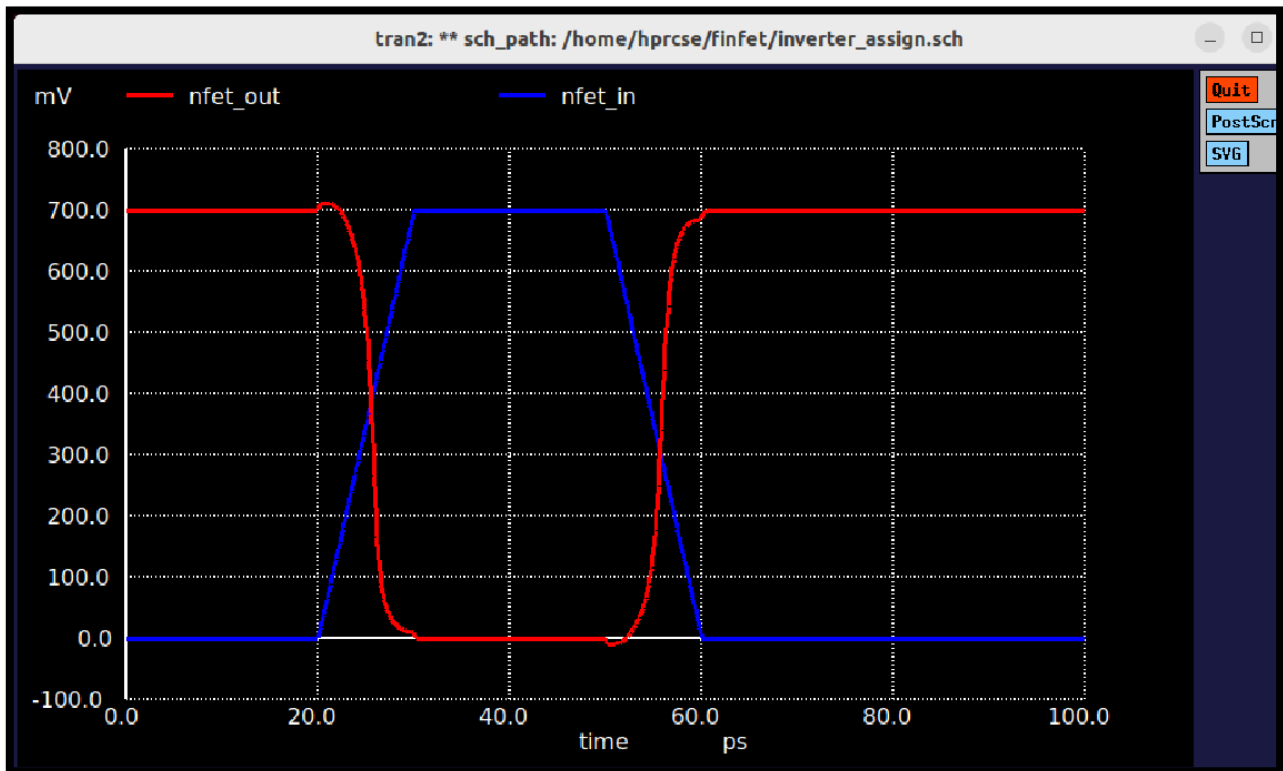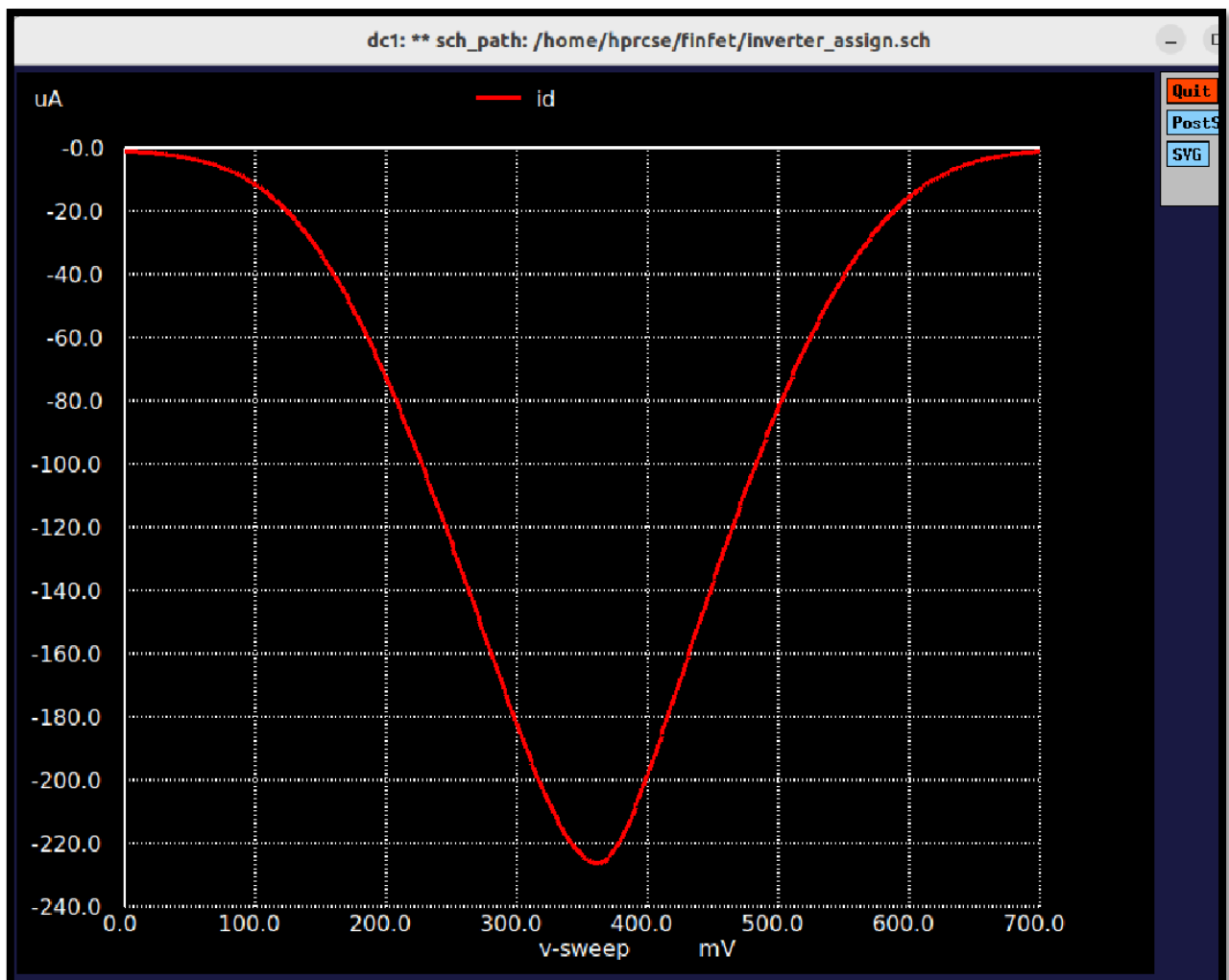
Graphs of VTC, Delay and I_D curves:

VTC: n-FET output and input plot
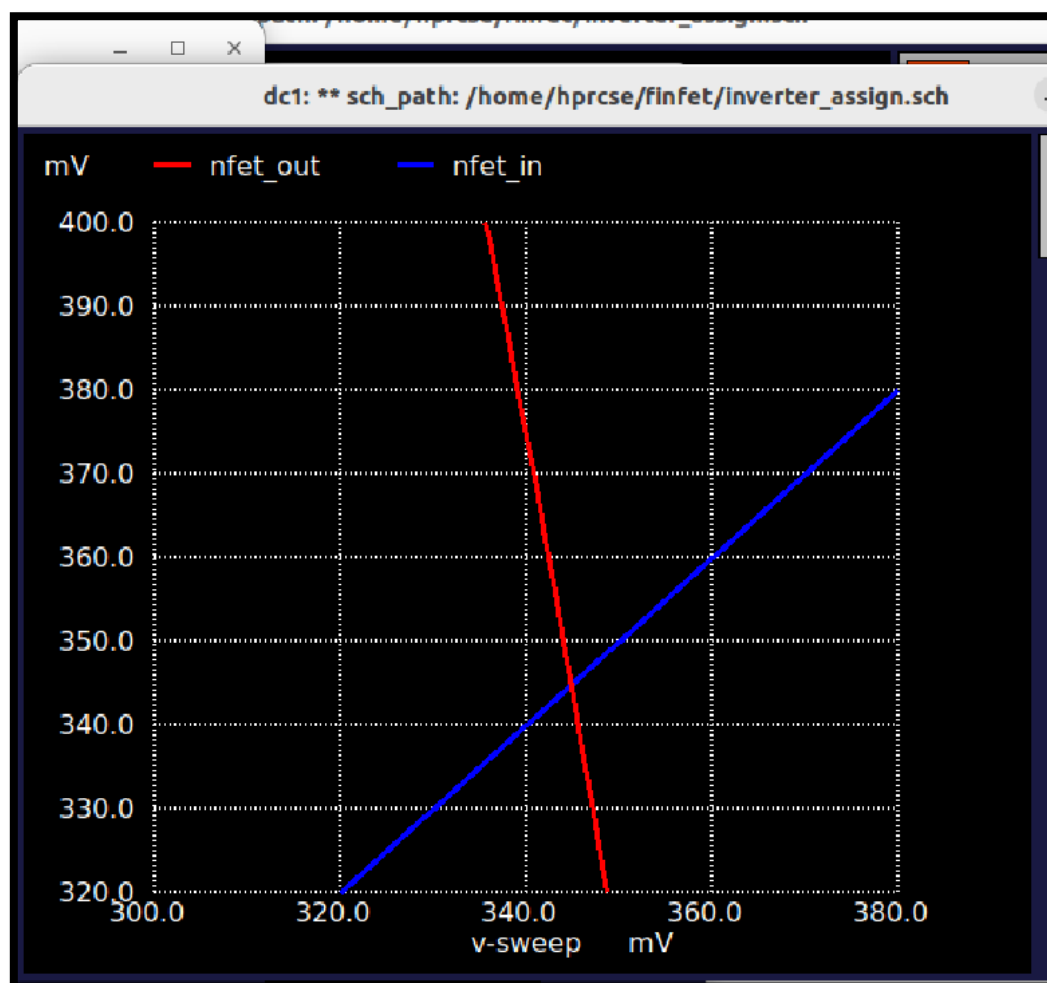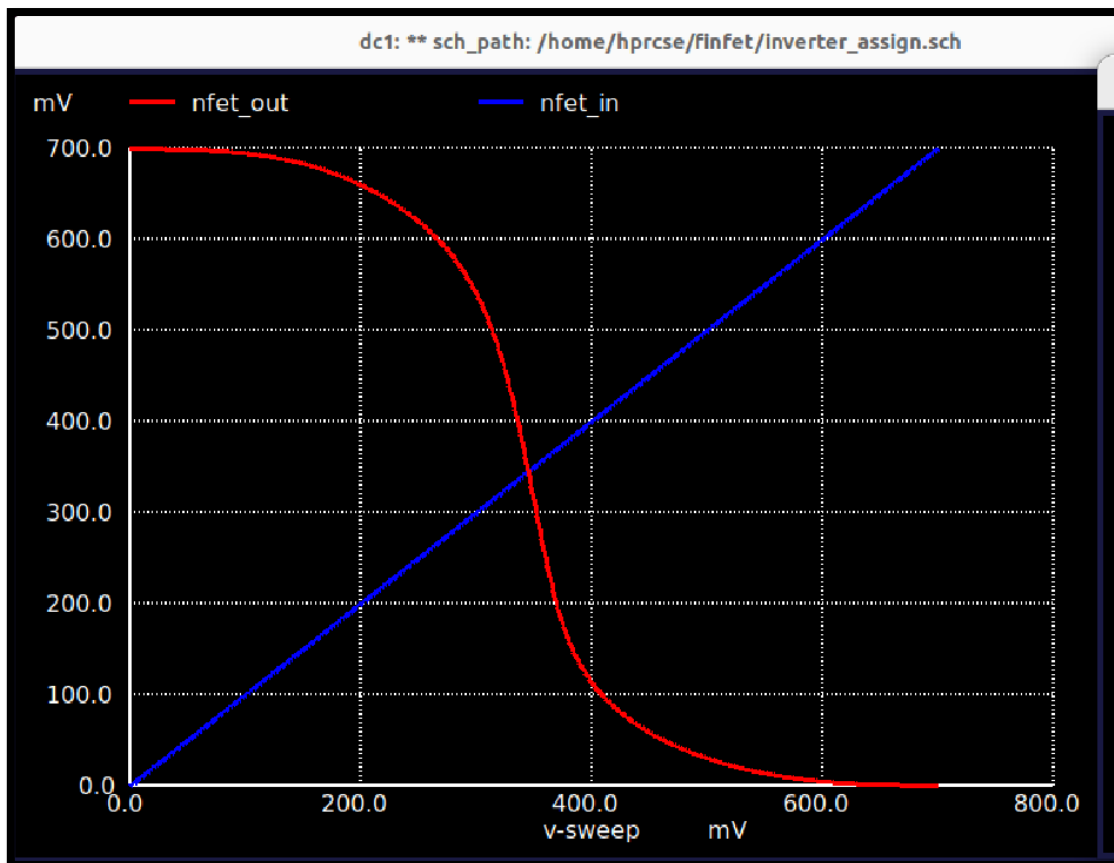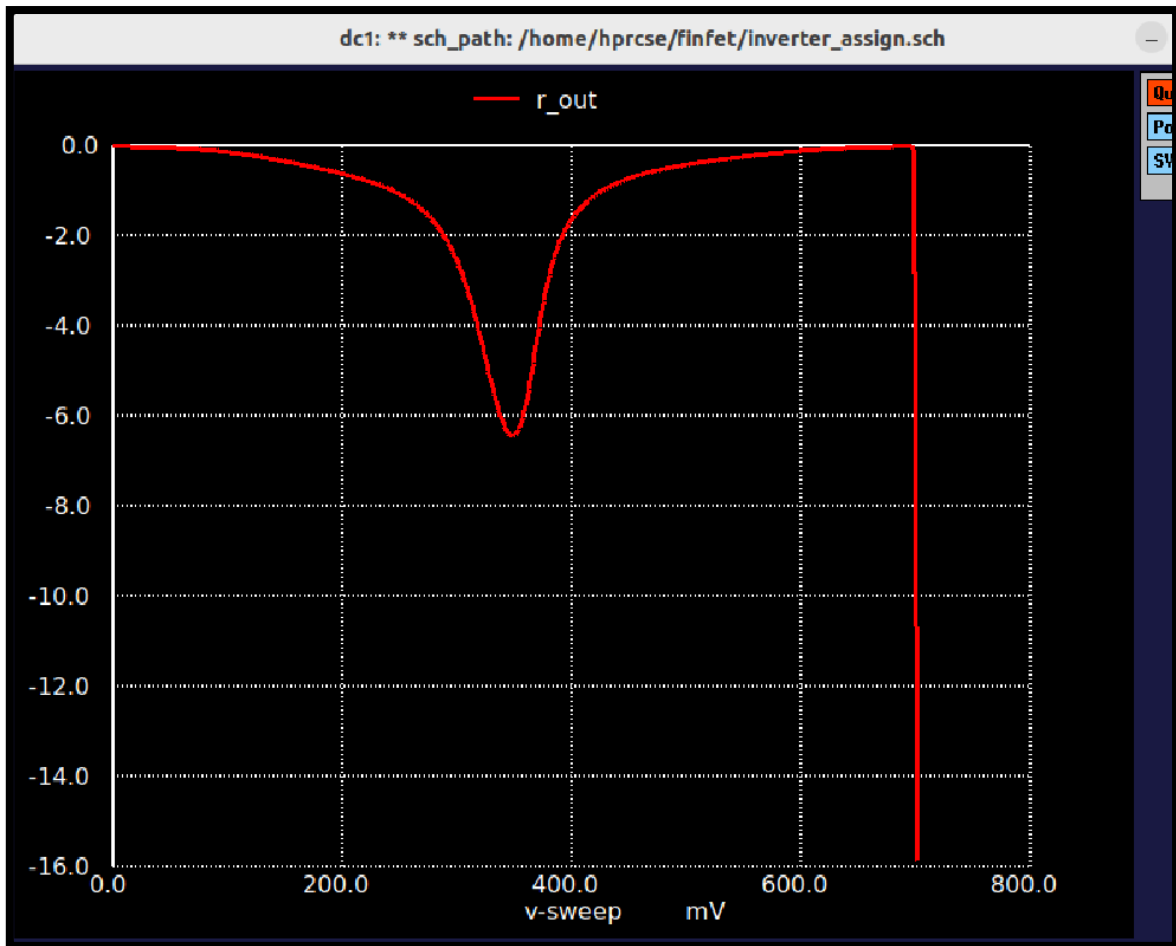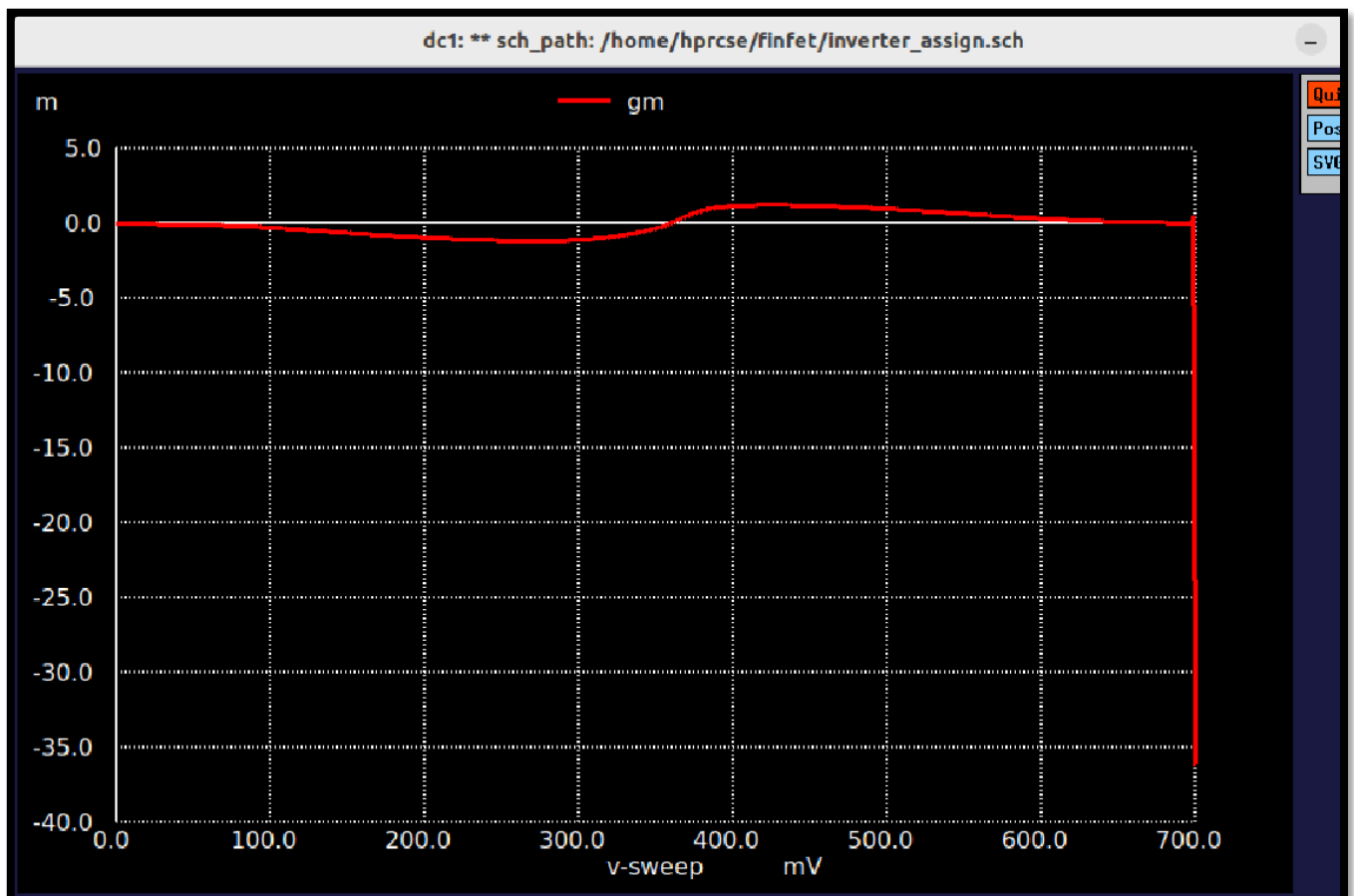

I_D Curve

V$_{Th}$ Graph (with close-up snippet)

Output Resistance Graph (r_out)

Transconductance (Gm) Curve