FinFet HSPICE Circuit Design and DRAM MATLAB Simulation

Submitted by –

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Content:

The Project Contains screenshots of the HSPICE file, the time datas and the waveforms along with the reported values.

INV 1X

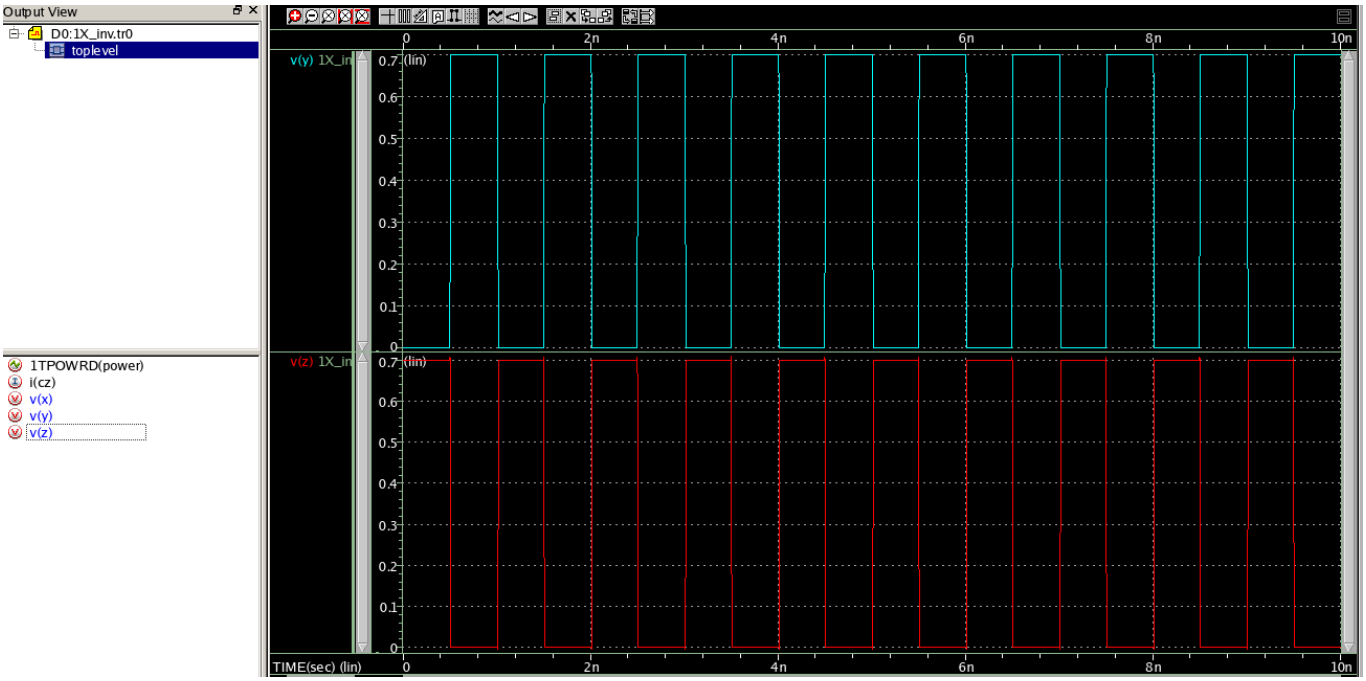
```
.include './hp7nfet.pm'
.include './hp7pfet.pm'
*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 7*number_fin
.param n_fin = 6*number_fin
.param LoadCap = 1f
VSS Gnd 0 'vss'
*add transistors
mp1 Z Y X Y pfet L=lg NFIN=p_fin
mn1 Z Y 0 Y nfet L=lg NFIN=n_fin
*add cap
Cz Z Gnd 'LoadCap'
*add voltage source
VX X 0 'vdd'
VY Y 0 PULSE(0 0.7 0.5n 10p 10p 0.5n 1n)
*define the initial condition of V(Z)
.IC V(Z)='vdd'
*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.01n 10n
*print the V(Z) to waveform file *.tr0
.print V(Z)
.print V(X)
.print V(Y)
.print i(Cz)
.print power(Cz)
*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout
*measurement
.measure tran t_fall_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.35 FALL = 2
.measure tran t_rise_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.35 RISE = 2
.measure tran t_fall_time TRIG V(Z) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.14 FALL = 2
.measure tran t_rise_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.35 RISE = 2
.measure tran t_fall_time TRIG V(Z) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.14 FALL = 2
.measure tran t_rise_time TRIG V(Z) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.56 RISE = 2
.end

```

HSPICE of INV1X

```
t_fall_delay=   2.6286p  targ=   2.5076n   trig=   2.5050n
t_rise_delay=   2.7026p  targ=   2.0177n   trig=   2.0150n
t_fall_time=   3.2181p  targ=   2.5092n   trig=   2.5060n
t_rise_time=   2.9212p  targ=   2.0192n   trig=   2.0162n

        ***** job concluded
```

Report Details of 1X Inverter

PFIN = 7, NFIN =6



1X inverter Waveform

T_Fall_Delay = 2.6286 ps

T_Rise_Delay = 2.7026 ps

T_Fall_Time = 3.2181 ps

T_rise_Time = 2.9212 ps

NAND 1X

```
*************************
*  lab3---1X_nand
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 3*number_fin
.param n_fin = 4*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z1 B X B pfet L=lg NFIN=p_fin
mn1 Z1 A Z2 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z1 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1.1u 2.2u)

*define the initial condition of V(Z)
.IC V(Z1)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
```

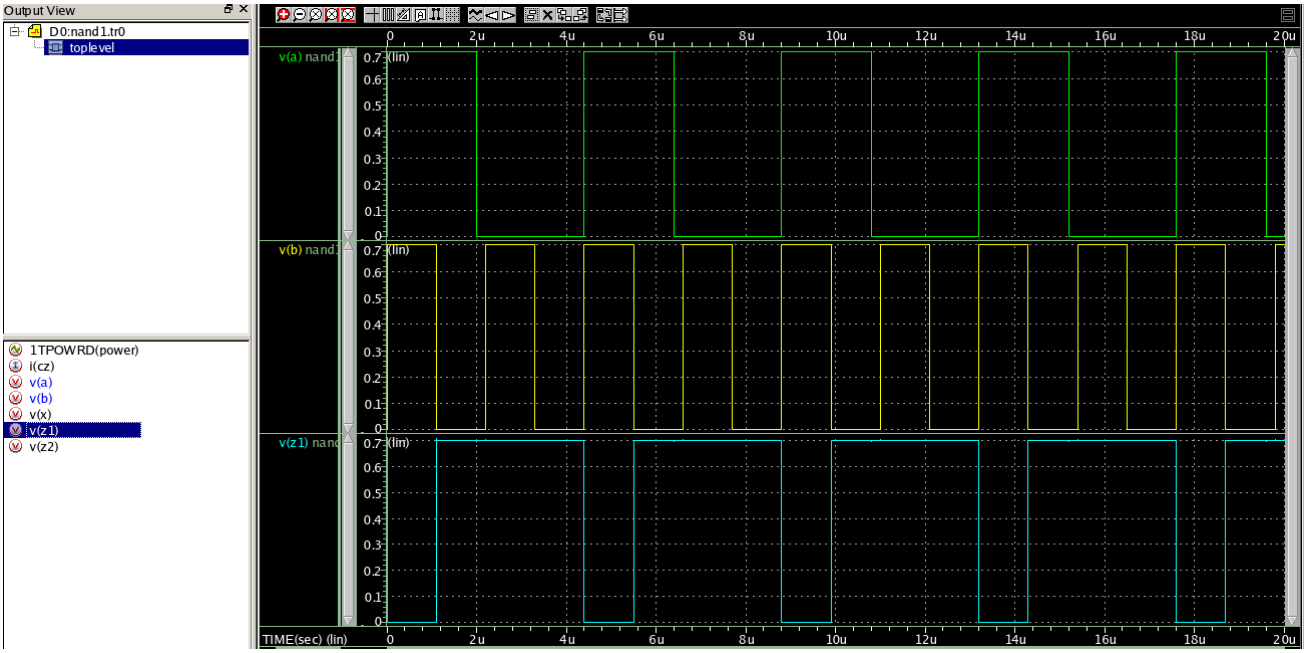
```
39
40  *do transient analysis
41      *syntax: .TRAN tiner tstop START=stval
42      *tiner - time step
43      *tstop - final time
44      *stval - initial time (default 0)
45  .tran 0.1u 20u
46
47  *print the V(Z) to waveform file *.tr0
48  .print V(Z1)
49  .print V(Z2)
50  .print V(X)
51  .print V(A)
52  .print V(B)
53  .print i(Cz)
54  .print power(Cz)
55
56  *simulation options (you can modify this. Post is needed for .tran analysis)
57  .OPTION Post Brief NoMod probe measout
58
59  *measurement
60  .measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
61  + RISE = 2 TARG V(Z1) VAL = 0.35 FALL = 2
62
63  *.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
64  *+ RISE = 3 TARG V(Z1) VAL = 0.35 FALL = 2
65
66  *.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
67  *+ FALL = 2 TARG V(Z1) VAL = 0.35 RISE = 2
68
69  .measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
70  + FALL = 3 TARG V(Z1) VAL = 0.35 RISE = 2
71
72  .measure tran t_fall_time TRIG V(Z1) VAL = 0.56 TD = 1n
73  + FALL = 2 TARG V(Z1) VAL = 0.14 FALL = 2
74
75  .measure tran t_rise_time TRIG V(Z1) VAL = 0.14 TD = 1n
76  + RISE = 2 TARG V(Z1) VAL = 0.56 RISE = 2
77
78  .end
79
```

HSPICE File of NAND1X

PFIN = 3, NFIN =4

```
 t_fall_delay_a=   4.9134p  targ=   8.8000u   trig=   8.8000u
 t_rise_delay_b=   4.5134p  targ=   5.5000u   trig=   5.5000u
 t_fall_time=   4.2712p  targ=   8.8000u   trig=   8.8000u
 t_rise_time=   4.6743p  targ=   5.5000u   trig=   5.5000u

          ***** job concluded
```

Time Details of NAND 1X



Waveform of NAND 1X

T_Fall_Delay = 4.9134 ps

T_Rise_Delay = 4.5134 ps

T_Fall_Time = 4.2712 ps

T_rise_Time 4.6743 ps

NOR 1X

```
**************************
*  lab3---1X_nor
**************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 5*number_fin
.param n_fin = 3*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z2 B Z1 B pfet L=lg NFIN=p_fin
mn1 Z2 A 0 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2.2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1u 2u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'
.IC V(A)='vdd'
.IC V(B)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
```

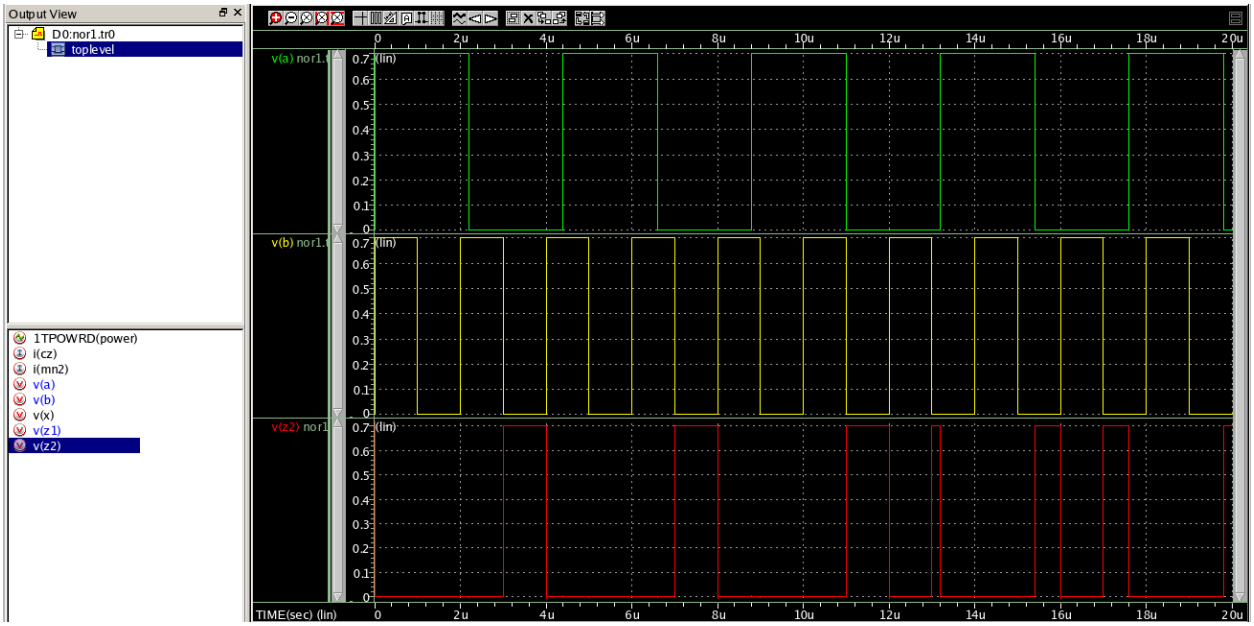
```
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout
*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6

.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.35 FALL = 1

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ FALL = 4 TARG V(Z2) VAL = 0.35 RISE = 5

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.measure tran time1 when V(Z2)=0.14
.measure tran time2 when V(Z2)=0.56
.measure tran switching_power AVG p(Cz) from 'time1' to 'time2'
.measure switching_energy param = 'abs(switching_power * (time2-time1))'
.measure tran leakage_current AVG i(mn2) from 1u to 2u
.measure leakage_power param = 'abs(vdd * leakage_current)'
.end
```

HSPICE of NOR1X

PFIN = 5, NFIN =3

```
 t_fall_delay_a=   4.1131p  targ=  17.6000u   trig=  17.6000u
 t_fall_delay_b=   3.8257p  targ=   4.0000u   trig=   4.0000u
 t_rise_delay_a=   4.3760p  targ=  15.4000u   trig=  15.4000u
 t_rise_delay_b=   4.2590p  targ=   3.0000u   trig=   3.0000u
 t_fall_time=   4.3052p  targ=   8.0000u   trig=   8.0000u
 t_rise_time=   4.8462p  targ=   7.0000u   trig=   7.0000u
```

Time Details of NOR 1X



Waveform of NOR 1X

T_Fall_Delay = 4.1131 ps

T_Rise_Delay = 4.3760 ps

T_Fall_Time = 4.3052 ps

T_rise_Time 4.8462 ps

INV 2X

```
*************************
*  lab3---2X_inv
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 2
.param p_fin = 7*number_fin
.param n_fin = 6*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z Y X Y pfet L=lg NFIN=p_fin
mn1 Z Y 0 Y nfet L=lg NFIN=n_fin

*add cap
Cz Z Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VY Y 0 PULSE(0 0.7 0.5n 10p 10p 0.5n 1n)

*define the initial condition of V(Z)
.IC V(Z)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.01n 10n

*print the V(Z) to waveform file *.tr0
```

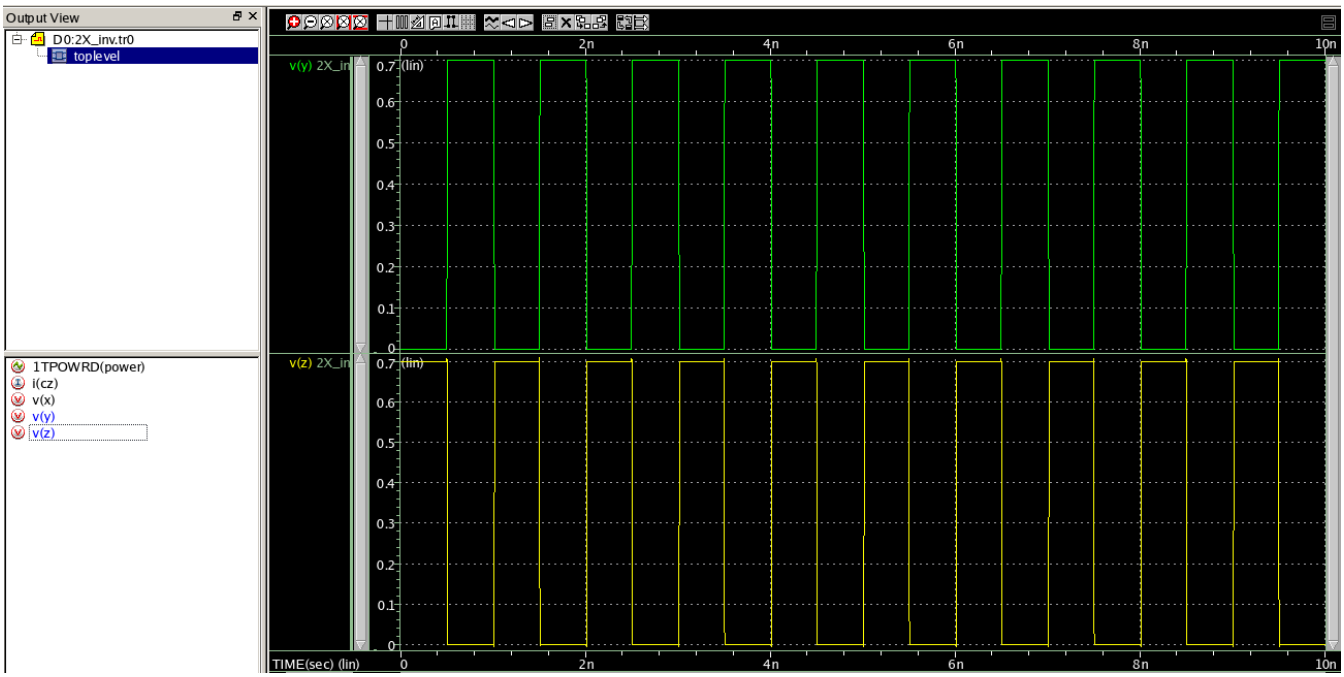
```
*print the V(Z) to waveform file *.tr0
.print V(Z)
.print V(X)
.print V(Y)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.35 FALL = 2

.measure tran t_rise_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.35 RISE = 2

.measure tran t_fall_time TRIG V(Z) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.56 RISE = 2

.end
```

HSPICE OF INVERTER 2X

PFIN = 14, NFIN = 12

```
 t_fall_delay=   1.9953p  targ=   2.5070n   trig=   2.5050n
 t_rise_delay=   2.0015p  targ=   2.0170n   trig=   2.0150n
 t_fall_time=   1.9609p  targ=   2.5078n   trig=   2.5058n
 t_rise_time=   1.9445p  targ=   2.0178n   trig=   2.0159n

          ***** job concluded
```

Time Details of INV 2X



Waveform of INV 2x

T_Fall_Delay = 1.9953 ps

T_Rise_Delay = 2.0015 ps

T_Fall_Time = 1.9609 ps

T_rise_Time =1.9445 ps

INV 4X

```
*************************
*  lab3---4X_inv
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 4
.param p_fin = 7*number_fin
.param n_fin = 6*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z Y X Y pfet L=lg NFIN=p_fin
mn1 Z Y 0 Y nfet L=lg NFIN=n_fin

*add cap
Cz Z Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VY Y 0 PULSE(0 0.7 0.5n 10p 10p 0.5n 1n)

*define the initial condition of V(Z)
.IC V(Z)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.01n 10n

*print the V(Z) to waveform file *.tr0
```

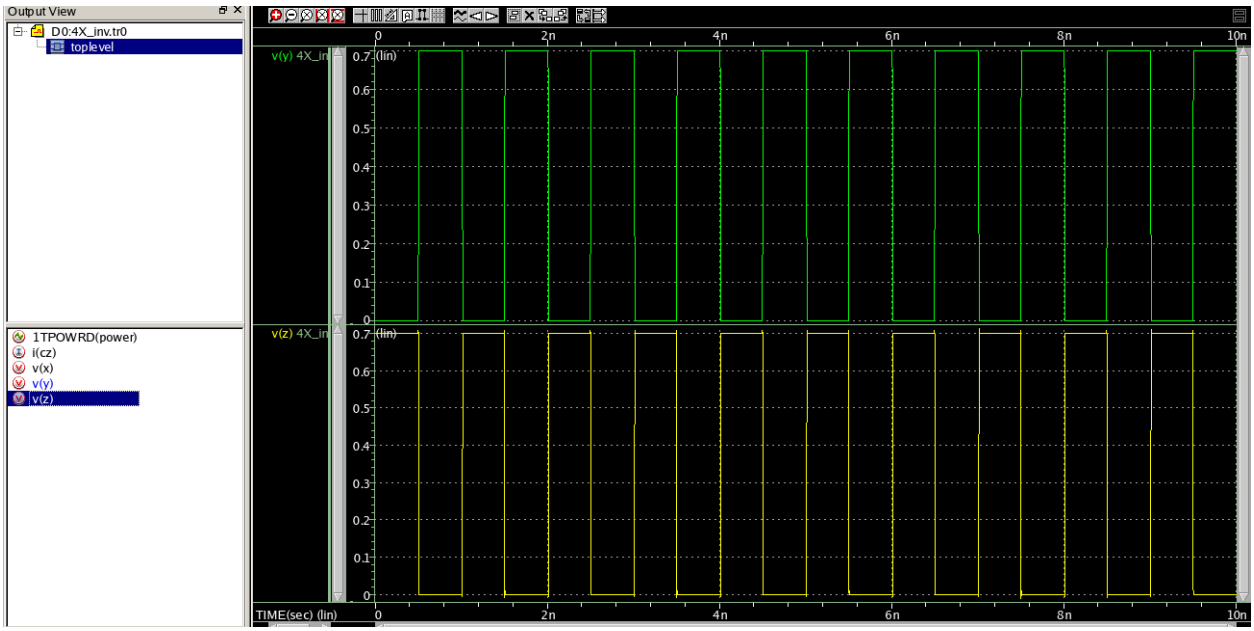
```
*print the V(Z) to waveform file *.tr0
.print V(Z)
.print V(X)
.print V(Y)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.35 FALL = 2

.measure tran t_rise_delay TRIG V(Y) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.35 RISE = 2

.measure tran t_fall_time TRIG V(Z) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z) VAL = 0.56 RISE = 2

.end
```

HSPICE OF INV 4X

PFIN = 28, NFIN = 24

```
 t_fall_delay=   1.3910p  targ=   2.5064n   trig=   2.5050n
 t_rise_delay=   1.4067p  targ=   2.0164n   trig=   2.0150n
 t_fall_time=   1.6118p  targ=   2.5071n   trig=   2.5055n
 t_rise_time=   1.6265p  targ=   2.0172n   trig=   2.0155n

          ***** job concluded
 ......
```

Time Details of INV 4X



Waveform of INV 4X

T_Fall_Delay = 1.3910 ps

T_Rise_Delay = 1.4067 ps

T_Fall_Time = 1.6118 ps

T_rise_Time =1.6265 ps

NOR 2X

```
1  **************************
2  *  lab3---2X_nor
3  **************************
4
5  .include './hp7nfet.pm'
6  .include './hp7pfet.pm'
7
8  *define parameters
9  .param vdd=0.7
10 .param vss=0
11 .param fin_height=18n
12 .param fin_width=7n
13 .param lg=11n
14 .param number_fin = 2
15 .param p_fin = 5*number_fin
16 .param n_fin = 3*number_fin
17 .param LoadCap = 1f
18
19 VSS Gnd 0 'vss'
20
21
22 *add transistors
23 mp1 Z1 A X A pfet L=lg NFIN=p_fin
24 mp2 Z2 B Z1 B pfet L=lg NFIN=p_fin
25 mn1 Z2 A 0 A nfet L=lg NFIN=n_fin
26 mn2 Z2 B 0 B nfet L=lg NFIN=n_fin
27
28 *add cap
29 Cz Z2 Gnd 'LoadCap'
30
31 *add voltage source
32 VX X 0 'vdd'
33
34 VA A 0 PULSE(0 0.7 0 10p 10p 2.2u 4.4u)
35 VB B 0 PULSE(0 0.7 0 10p 10p 1u 2u)
36
37 *define the initial condition of V(Z)
38 .IC V(Z2)='vdd'
39
40 *do transient analysis
41     *syntax: .TRAN tiner tstop START=stval
42     *tiner - time step
43     *tstop - final time
44     *stval - initial time (default 0)
```

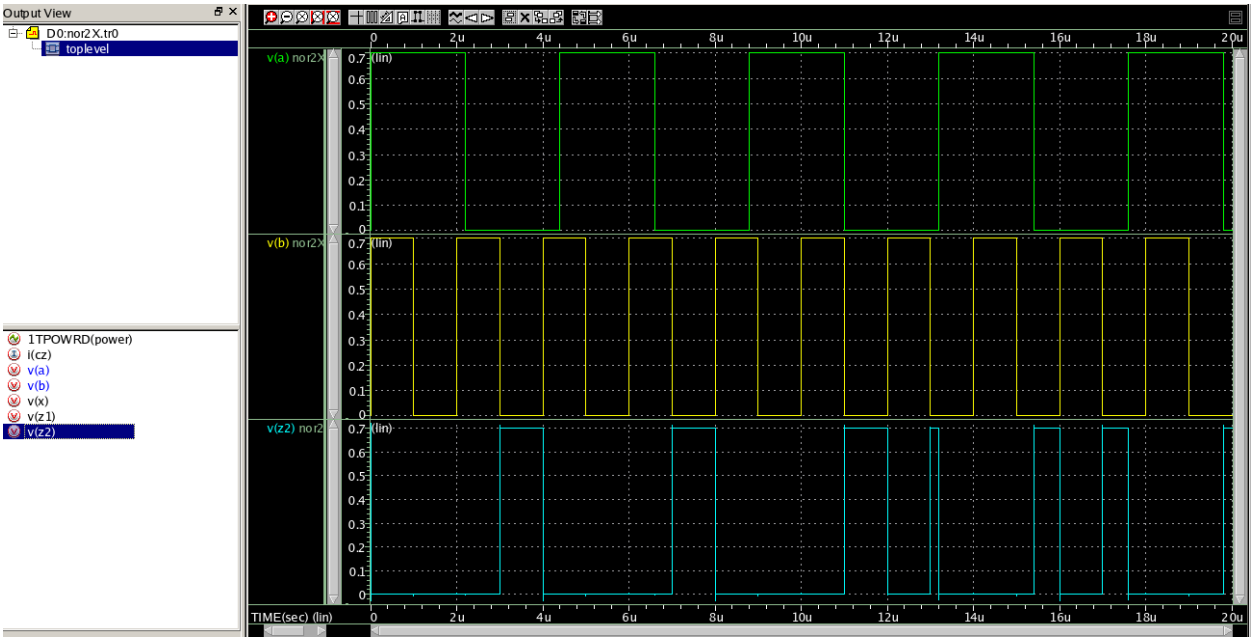
```
    *stval - initial time (default 0)
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6

.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.35 FALL = 1

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ FALL = 4 TARG V(Z2) VAL = 0.35 RISE = 5

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.end
```

HSPICE Of NOR 2X

PFIN = 10, NFIN = 6

```
 t_fall_delay_a=   3.3821p  targ=  17.6000u   trig=  17.6000u
 t_fall_delay_b=   3.2519p  targ=   4.0000u   trig=   4.0000u
 t_rise_delay_a=   3.5824p  targ=  15.4000u   trig=  15.4000u
 t_rise_delay_b=   3.4677p  targ=   3.0000u   trig=   3.0000u
 t_fall_time=   3.9124p  targ=   8.0000u   trig=   8.0000u
 t_rise_time=   4.3289p  targ=   7.0000u   trig=   7.0000u

          ***** job concluded
```

Time Details of NOR2X



Waveform of NOR 2X

T_Fall_Delay = 3.3821ps

T_Rise_Delay = 3.2519 ps

T_Fall_Time = 3.9124 ps

T_rise_Time =4.3289 ps

NOR 4X

```
*************************
*  lab3---4X_nor
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 4
.param p_fin = 5*number_fin
.param n_fin = 3*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z2 B Z1 B pfet L=lg NFIN=p_fin
mn1 Z2 A 0 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2.2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1u 2u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
```

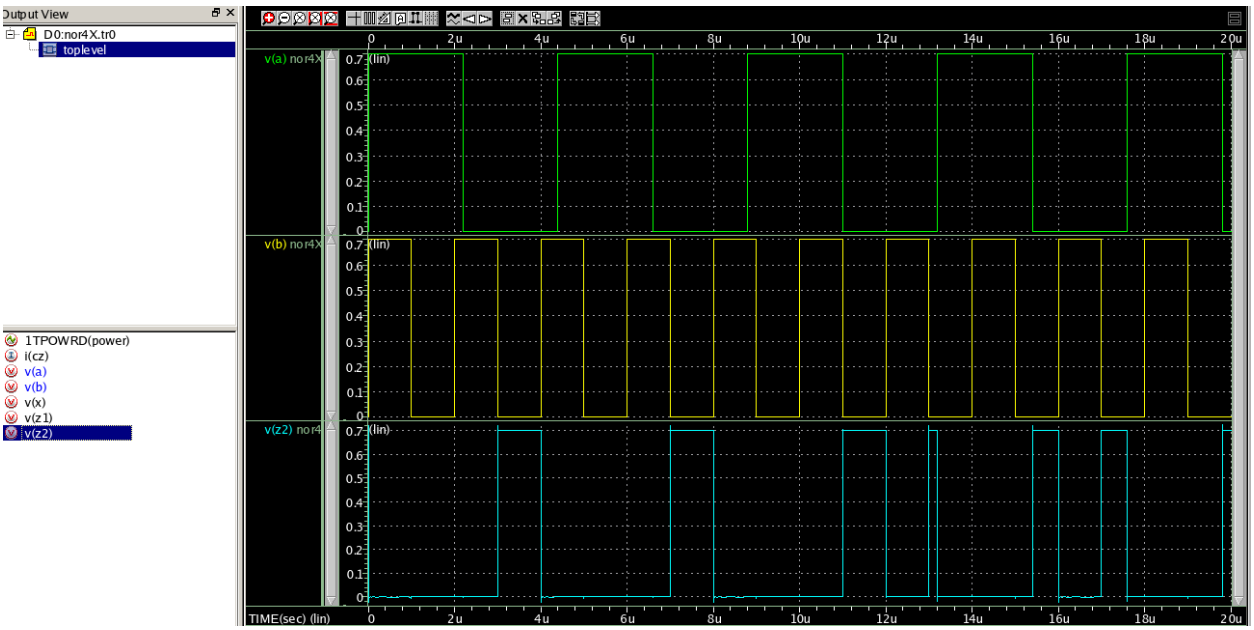
```
    *stval - initial time (default 0)
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6

.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.35 FALL = 1

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ FALL = 4 TARG V(Z2) VAL = 0.35 RISE = 5

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.end
```

HSPICE OF NOR 4X

PFIN = 20, NFIN = 12

```
 t_fall_delay_a=   3.1527p  targ=  17.6000u   trig=  17.6000u
 t_fall_delay_b=   2.9954p  targ=   4.0000u   trig=   4.0000u
 t_rise_delay_a=   3.2195p  targ=  15.4000u   trig=  15.4000u
 t_rise_delay_b=   3.0902p  targ=   3.0000u   trig=   3.0000u
 t_fall_time=   3.8008p  targ=   8.0000u   trig=   8.0000u
 t_rise_time=   4.1813p  targ=   7.0000u   trig=   7.0000u

          ***** job concluded
```

Time Details of NOR 4X



Waveform of NOR 4X

T_Fall_Delay = 3.1527 ps

T_Rise_Delay = 3.2195 ps

T_Fall_Time = 3.8008 ps

T_rise_Time =4.1813 ps

NAND 2X

```
*************************
*  lab3---2X_nand
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 2
.param p_fin = 3*number_fin
.param n_fin = 4*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z1 B X B pfet L=lg NFIN=p_fin
mn1 Z1 A Z2 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z1 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1.1u 2.2u)

*define the initial condition of V(Z)
.IC V(Z1)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
```

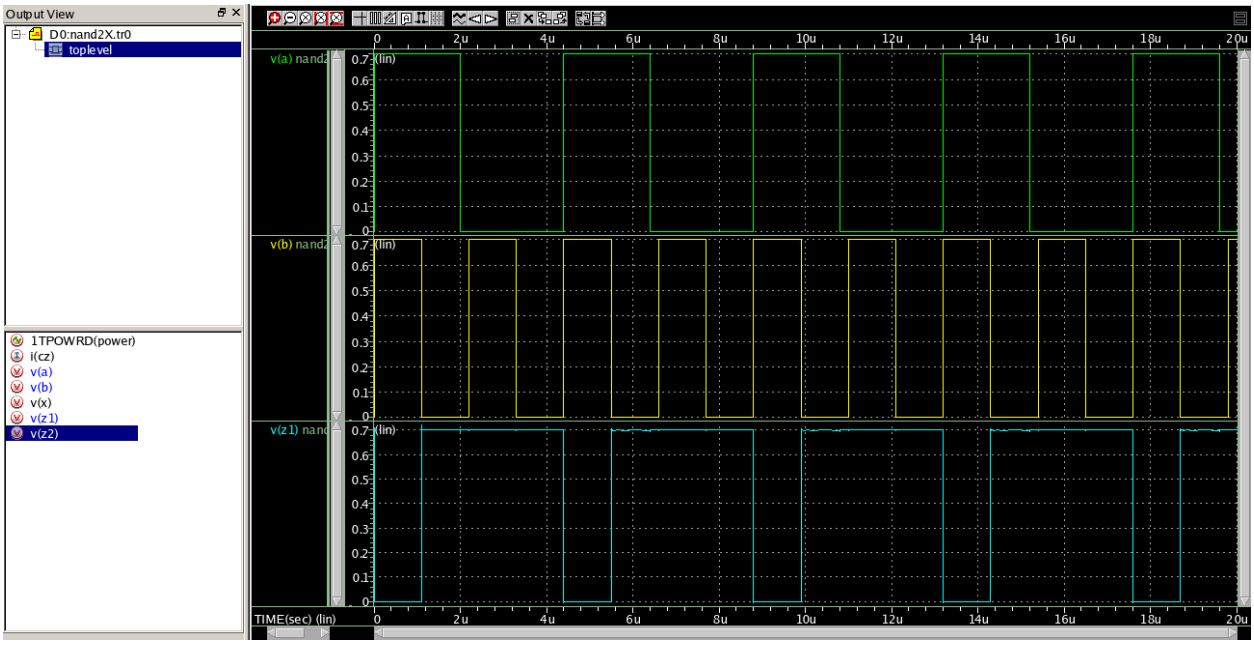
```
    *stval - initial time (default 0)
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z1) VAL = 0.35 FALL = 2

*.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
*+ RISE = 3 TARG V(Z1) VAL = 0.35 FALL = 2

*.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
*+ FALL = 2 TARG V(Z1) VAL = 0.35 RISE = 2

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 3 TARG V(Z1) VAL = 0.35 RISE = 2

.measure tran t_fall_time TRIG V(Z1) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z1) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z1) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z1) VAL = 0.56 RISE = 2

.end
```

HSPICE of NAND2X

PFIN = 6, NFIN = 8

```
t_fall_delay_a=   3.1527p  targ=  17.6000u   trig=  17.6000u
t_fall_delay_b=   2.9954p  targ=   4.0000u   trig=   4.0000u
t_rise_delay_a=   3.2195p  targ=  15.4000u   trig=  15.4000u
t_rise_delay_b=   3.0902p  targ=   3.0000u   trig=   3.0000u
t_fall_time=   3.8008p  targ=   8.0000u   trig=   8.0000u
t_rise_time=   4.1813p  targ=   7.0000u   trig=   7.0000u

          ***** job concluded
```

Time Details of NAND 2X



Waveform of NAND 2X

T_Fall_Delay = 3.1527 ps

T_Rise_Delay = 3.2195 ps

T_Fall_Time = 3.8008 ps

T_rise_Time =4.1813 ps

NAND 4X

```
*************************
*  lab3---4X_nand
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 4
.param p_fin = 3*number_fin
.param n_fin = 4*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z1 B X B pfet L=lg NFIN=p_fin
mn1 Z1 A Z2 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z1 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1.1u 2.2u)

*define the initial condition of V(Z)
.IC V(Z1)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
```

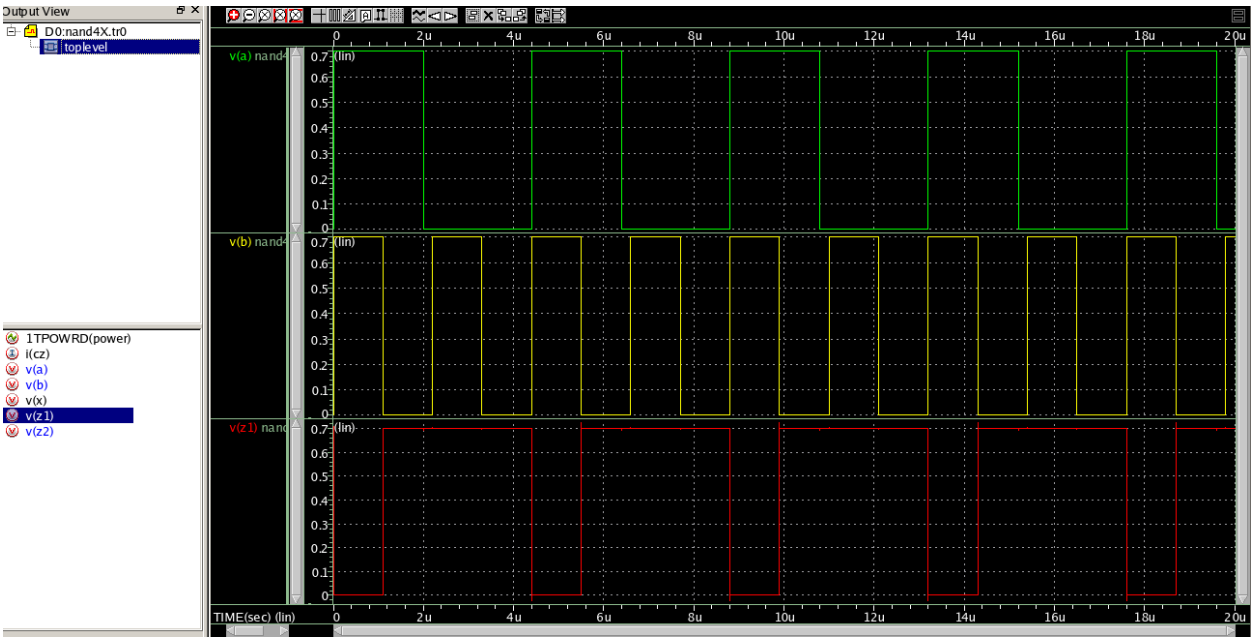
```
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z1) VAL = 0.35 FALL = 2

*.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
*+ RISE = 3 TARG V(Z1) VAL = 0.35 FALL = 2

*.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
*+ FALL = 2 TARG V(Z1) VAL = 0.35 RISE = 2

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 3 TARG V(Z1) VAL = 0.35 RISE = 2

.measure tran t_fall_time TRIG V(Z1) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z1) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z1) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z1) VAL = 0.56 RISE = 2

.end
```

HSPICE OF NAND4X

PFIN = 12, NFIN = 16

```
 t_fall_delay_a=   3.5135p  targ=   8.8000u   trig=   8.8000u
 t_rise_delay_b=   3.2647p  targ=   5.5000u   trig=   5.5000u
 t_fall_time=   3.4808p  targ=   8.8000u   trig=   8.8000u
 t_rise_time=   3.8396p  targ=   5.5000u   trig=   5.5000u

          ***** job concluded
```

Time Detail of NAND 4X



Waveform of NAND 4X

T_Fall_Delay = 3.5135 ps

T_Rise_Delay = 3.2647 ps

T_Fall_Time = 3.4808 ps

T_rise_Time =3.8396 ps

NOR_SG

```
*************************
*  lab3---1X_nor
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 5*number_fin
.param n_fin = 3*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z2 B Z1 B pfet L=lg NFIN=p_fin
mn1 Z2 A 0 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2.2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1u 2u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'
.IC V(A)='vdd'
.IC V(B)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
```

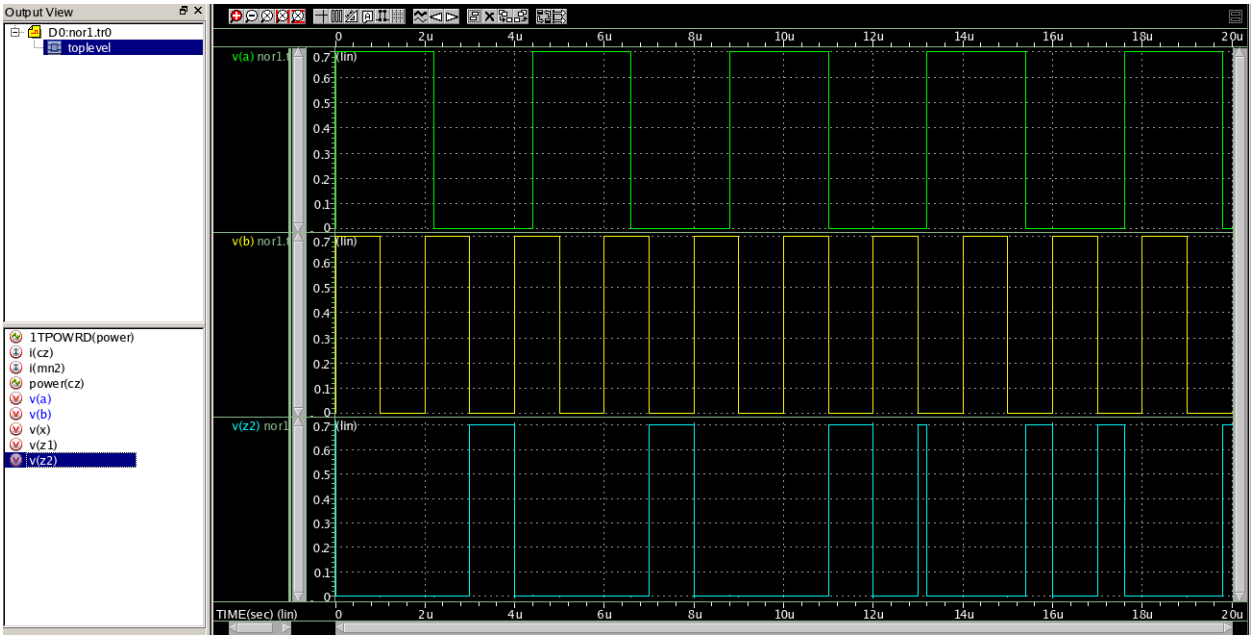
```
45      *tstop - final time
46      *stval - initial time (default 0)
47  .tran 0.1u 20u
48
49  *print the V(Z) to waveform file *.tr0
50  .print V(Z1)
51  .print V(Z2)
52  .print V(X)
53  .print V(A)
54  .print V(B)
55  .print i(Cz)
56  .print power(Cz)
57
58  *simulation options (you can modify this. Post is needed for .tran analysis)
59  .OPTION Post Brief NoMod probe measout
60  *measurement
61  .measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
62  + RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6
63
64  .measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
65  + RISE = 2 TARG V(Z2) VAL = 0.35 FALL = 1
66
67  .measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
68  + FALL = 4 TARG V(Z2) VAL = 0.35 RISE = 5
69
70  .measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
71  + FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1
72
73  .measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
74  + FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2
75
76  .measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
77  + RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2
78
79  .measure tran time1 when V(Z2)=0.14
80  .measure tran time2 when V(Z2)=0.56
81  .measure tran switching_power AVG p(Cz) from 'time1' to 'time2'
82  .measure switching_energy param = 'abs(switching_power * (time2-time1))'
83  .measure tran leakage_current AVG i(mn2) from 1u to 2u
84  .measure leakage_power param = 'abs(vdd * leakage_current)'
85  .end
```

HSPICE OF NOR_SG

PFIN = 5, NFIN = 3

```
t_fall_delay_a=    4.1131p  targ=  17.6000u   trig=  17.6000u
t_fall_delay_b=    3.8257p  targ=   4.0000u   trig=   4.0000u
t_rise_delay_a=    4.3760p  targ=  15.4000u   trig=  15.4000u
t_rise_delay_b=    4.2590p  targ=   3.0000u   trig=   3.0000u
t_fall_time=    4.3052p  targ=    8.0000u   trig=    8.0000u
t_rise_time=    4.8462p  targ=    7.0000u   trig=    7.0000u
time1=    8.9025p
time2=    6.1202p
switching_power= -50.4293u  from=    6.1202p     to=    8.9025p
switching_energy= 140.3077a
leakage_current=    7.1374p  from=    1.0000u     to=    2.0000u
leakage_power=    4.9962p

          ***** job concluded
.......
```

Time Details of NOR 1X SG



Waveform of NOR 1X SG

T_Fall_Delay = 4.1131 ps

T_Rise_Delay = 4.3760 ps

T_Fall_Time = 4.3052 ps

T_rise_Time =4.8462 ps

Switching power = -50.4293uW

Switching energy = 140.3077aJ

Leakage current = 7.1374pAmp

Leakage power = 4.9962pW

NOR_IG

```
*************************
*  lab3---1X_nor_IG
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 6*number_fin
.param n_fin = 2*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z2 A X B pfet L=lg NFIN=p_fin
mn1 Z2 A 0 A nfet L=lg NFIN=n_fin
mn2 Z2 B 0 B nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 1.2u 2.2u)
VB B 0 PULSE(0 0.7 0 10p 10p 0.5u 1.1u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.1u 20u
```

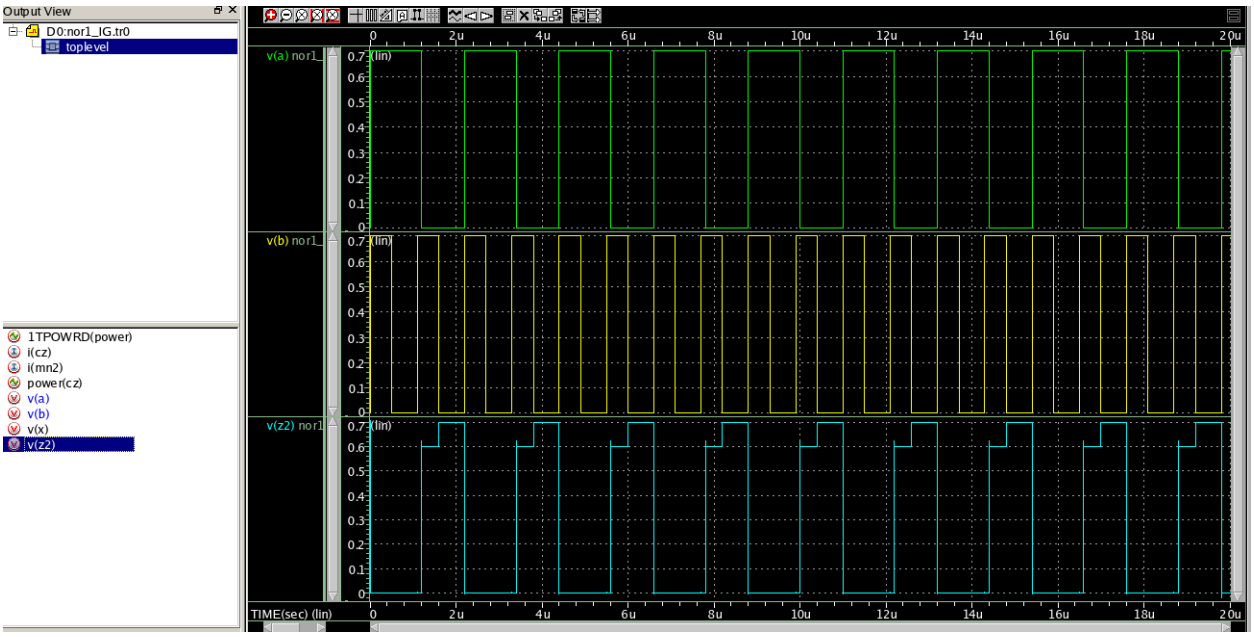
```
*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
*.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35
*+ RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6

.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35
+ RISE = 3 TARG V(Z2) VAL = 0.35 FALL = 2

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 2

*.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
*+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.measure tran time1 when V(Z2)=0.14
.measure tran time2 when V(Z2)=0.56
.measure tran switching_power AVG p(Cz) from 'time1' to 'time2'
.measure switching_energy param = 'abs(switching_power * (time2-time1))'


.measure tran leakage_current AVG i(mn2) from 1.1u to 2.2u
.measure leakage_power param = 'abs(vdd * leakage_current)'

.end
```

HSPICE File of NOR 1_IG

PFIN = 6, NFIN = 2

```
t_fall_delay_b=   3.4841p  targ=   2.2000u   trig=   2.2000u
t_rise_delay_a=   3.8528p  targ=   3.4000u   trig=   3.4000u
t_fall_time=   4.1208p  targ=   4.4000u   trig=   4.4000u
t_rise_time=   4.9263p  targ=   3.4000u   trig=   3.4000u
time1=   9.8130p
time2=   6.7983p
switching_power= -50.2411u  from=   6.7983p     to=   9.8130p
switching_energy= 151.4615a
leakage_current=  57.8165u  from=   1.1000u     to=   2.2000u
leakage_power=  40.4715u

        ***** job concluded
******
```

Time Details of NOR 1X IG



Waveform of NOR 1X IG

T_Fall_Delay = 3.4841 ps

T_Rise_Delay = 3.8528 ps

T_Fall_Time = 4.1208 ps

T_rise_Time =4.9263 ps

Switching power = -50.241uW

Switching energy = 151.4615aJ

Leakage current = 57.8165 uAmp

Leakage power = 40.4715 uW

NOR_LP

```
**************************
*  lab3---1X_nor_LP
**************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 5*number_fin
.param n_fin = 3*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X X pfet L=lg NFIN=p_fin
mp2 Z2 B Z1 X pfet L=lg NFIN=p_fin
mn1 Z2 A 0 0 nfet L=lg NFIN=n_fin
mn2 Z2 B 0 0 nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 2.2u 4.4u)
VB B 0 PULSE(0 0.7 0 10p 10p 1u 2u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
```

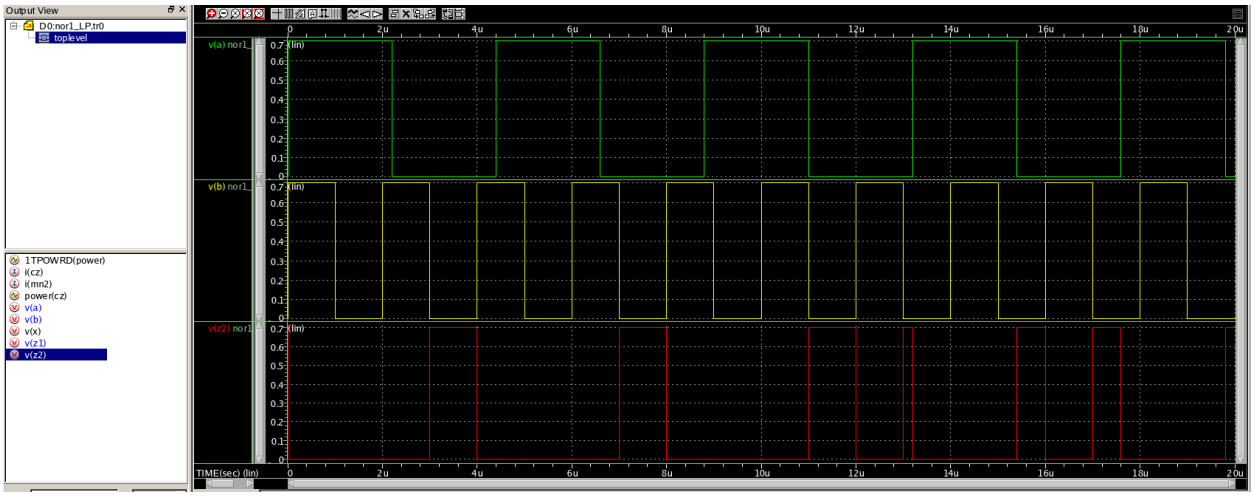
```
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ RISE = 4 TARG V(Z2) VAL = 0.35 FALL = 6

.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.35 FALL = 1

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35 TD = 1n
+ FALL = 4 TARG V(Z2) VAL = 0.35 RISE = 5

.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.measure tran time1 when V(Z2)=0.14
.measure tran time2 when V(Z2)=0.56
.measure tran switching_power AVG p(Cz) from 'time1' to 'time2'
.measure switching_energy param = 'abs(switching_power * (time2-time1))'


.measure tran leakage_current AVG i(mn2) from 1u to 2u
.measure leakage_power param = 'abs(vdd * leakage_current)'

.end
```

HSPICE OF NOR1X_LP

PFIN = 5, NFIN = 3

```
y
 t_fall_delay_a=   4.1131p  targ=  17.6000u   trig=  17.6000u
 t_fall_delay_b=   3.8257p  targ=   4.0000u   trig=   4.0000u
 t_rise_delay_a=   4.3760p  targ=  15.4000u   trig=  15.4000u
 t_rise_delay_b=   4.2590p  targ=   3.0000u   trig=   3.0000u
 t_fall_time=   4.3047p  targ=   8.0000u   trig=   8.0000u
 t_rise_time=   4.8460p  targ=   7.0000u   trig=   7.0000u
 time1=   8.9025p
 time2=   6.1202p
 switching_power= -50.4293u  from=   6.1202p     to=   8.9025p
 switching_energy= 140.3077a
 leakage_current=   7.1383p  from=   1.0000u     to=   2.0000u
 leakage_power=   4.9968p

         ***** job concluded
```

Time Details of NOR 1X LP



Waveform of NOR 1X LP

T_Fall_Delay = 4.1131 ps

T_Rise_Delay = 3.8257 ps

T_Fall_Time = 4.3760 ps

T_rise_Time =4.2590 ps

Switching power = -50.4293uW

Switching energy = 140.3077 aJ

Leakage current = 7.1383 pAmp

Leakage power = 4.9968 pW

NOR_LP_IG

```
*************************
*  lab3---1X_nor_IG_LP
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 6*number_fin
.param n_fin = 2*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z2 A X B pfet L=lg NFIN=p_fin
mn1 Z2 A 0 0 nfet L=lg NFIN=n_fin
mn2 Z2 B 0 0 nfet L=lg NFIN=n_fin

*add cap
Cz Z2 Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 1.2u 2.2u)
VB B 0 PULSE(0 0.7 0 10p 10p 0.5u 1.1u)

*define the initial condition of V(Z)
.IC V(Z2)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.1u 20u
```

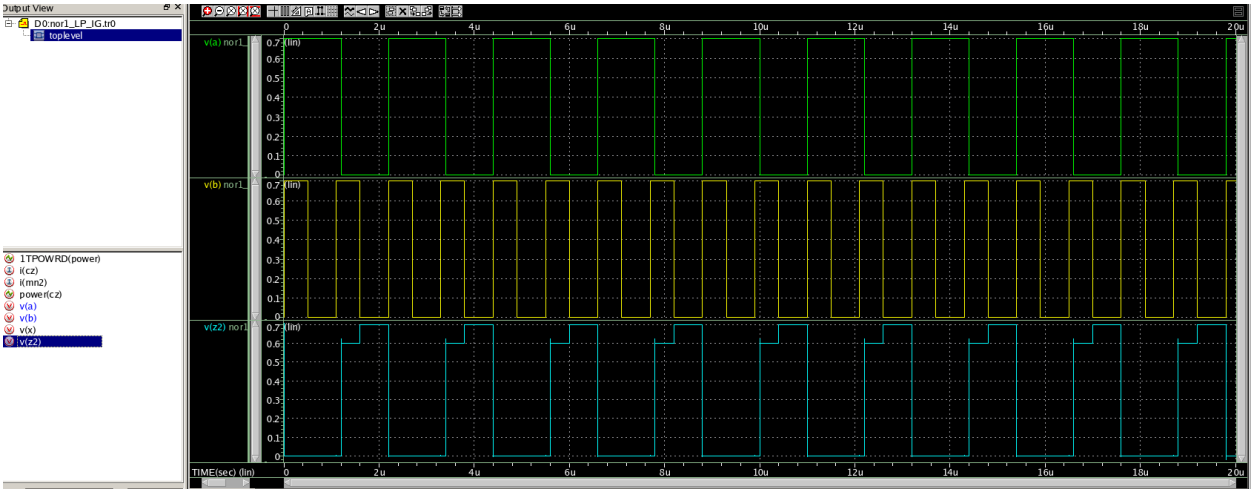
```
.tran 0.1u 20u

*print the V(Z) to waveform file *.tr0
.print V(Z1)
.print V(Z2)
.print V(X)
.print V(A)
.print V(B)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_B TRIG V(B) VAL = 0.35
+ RISE = 3 TARG V(Z2) VAL = 0.35 FALL = 2

.measure tran t_rise_delay_A TRIG V(A) VAL = 0.35
+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 2

*.measure tran t_rise_delay_B TRIG V(B) VAL = 0.35 TD = 1n
*+ FALL = 2 TARG V(Z2) VAL = 0.35 RISE = 1

.measure tran t_fall_time TRIG V(Z2) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Z2) VAL = 0.14 FALL = 2

.measure tran t_rise_time TRIG V(Z2) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Z2) VAL = 0.56 RISE = 2

.measure tran time1 when V(Z2)=0.14
.measure tran time2 when V(Z2)=0.56
.measure tran switching_power AVG p(Cz) from 'time1' to 'time2'
.measure switching_energy param = 'abs(switching_power * (time2-time1))'


.measure tran leakage_current AVG i(mn2) from 1u to 2u
.measure leakage_power param = 'abs(vdd * leakage_current)'

.end
```

HSPICE Command of NOR 1X LP_IG

PFIN = 6, NFIN = 2

```
y
 t_fall_delay_b=   3.4841p  targ=   2.2000u   trig=   2.2000u
 t_rise_delay_a=   3.8528p  targ=   3.4000u   trig=   3.4000u
 t_fall_time=   4.1207p  targ=   4.4000u   trig=   4.4000u
 t_rise_time=   4.9263p  targ=   3.4000u   trig=   3.4000u
 time1=   9.8130p
 time2=   6.7983p
 switching_power= -50.2411u  from=   6.7983p     to=   9.8130p
 switching_energy= 151.4615a
 leakage_current=  63.5980u  from=   1.0000u     to=   2.0000u
 leakage_power=  44.5186u

         ***** job concluded
```

Time Details of NOR 1X LP_IG



Waveform of NOR 1X LP_IG

T_Fall_Delay = 3.4841 ps

T_Rise_Delay = 3.8528 ps

T_Fall_Time = 4.1207 ps

T_rise_Time =4.9263 ps

Switching power = -50.2411 uW

Switching energy = 151.4615 aJ

Leakage current = 63.5980 uAmp

Leakage power = 44.5186 uW

1_BIT_Full_ Adder

```
*************************
*  lab3---1Bit_Full_Adder
*************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param number_fin = 1
.param p_fin = 1*number_fin
.param n_fin = 1*number_fin
.param LoadCap = 1f

VSS Gnd 0 'vss'


*add transistors
mp1 Z1 A X A pfet L=lg NFIN=p_fin
mp2 Z1 B X B pfet L=lg NFIN=p_fin
mp3 Z3 C Z1 C pfet L=lg NFIN=p_fin
mp4 Z3 B Z2 B pfet L=lg NFIN=p_fin
mp5 Z2 A X A pfet L=lg NFIN=p_fin

mn1 Z3 C Z5 C nfet L=lg NFIN=n_fin
mn2 Z3 B Z4 B nfet L=lg NFIN=n_fin
mn3 Z5 A 0 A nfet L=lg NFIN=n_fin
mn4 Z5 B 0 B nfet L=lg NFIN=n_fin
mn5 Z4 A 0 A nfet L=lg NFIN=n_fin

mp6 Z6 Z3 Z8 Z3 pfet L=lg NFIN=p_fin
mp7 Z8 A X A pfet L=lg NFIN=p_fin
mp8 Z8 B X B pfet L=lg NFIN=p_fin
mp9 Z8 C X C pfet L=lg NFIN=p_fin
mp10 Z12 A X A pfet L=lg NFIN=p_fin
mp11 Z11 B Z12 B pfet L=lg NFIN=p_fin
mp12 Z6 C Z11 C pfet L=lg NFIN=p_fin

mn6 Z6 Z3 Z7 Z3 nfet L=lg NFIN=n_fin
mn7 Z7 A 0 A nfet L=lg NFIN=n_fin
```

```
mn7 Z7 A 0 A nfet L=lg NFIN=n_fin
mn8 Z7 B 0 B nfet L=lg NFIN=n_fin
mn9 Z7 C 0 C nfet L=lg NFIN=n_fin
mn10 Z6 A Z9 A nfet L=lg NFIN=n_fin
mn11 Z9 B Z10 B nfet L=lg NFIN=n_fin
mn12 Z10 C 0 C nfet L=lg NFIN=n_fin

mp13 Cout Z3 X Z3 pfet L=lg NFIN=p_fin
mn13 Cout Z3 0 Z3 nfet L=lg NFIN=n_fin

mp14 Sum Z6 X Z6 pfet L=lg NFIN=p_fin
mn14 Sum Z6 0 Z6 nfet L=lg NFIN=n_fin

*add cap
Cz Sum Gnd 'LoadCap'
Cz1 Cout Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd'

VA A 0 PULSE(0 0.7 0 10p 10p 4.5u 9u)
VB B 0 PULSE(0 0.7 0 10p 10p 2.2u 4.2u)
VC C 0 PULSE(0 0.7 0 10p 10p 1u 2u)

*define the initial condition of V(Z)
.IC V(Sum)='vdd'
.IC V(Cout)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.1u 30u

*print the V(Z) to waveform file *.tr0
.print V(Sum)
.print V(Cout)
.print V(X)
.print V(A)
.print V(B)
.print V(C)
.print i(Cz)
```

```
*print the V(Z) to waveform file *.tr0
.print V(Sum)
.print V(Cout)
.print V(X)
.print V(A)
.print V(B)
.print V(C)
.print i(Cz)
.print power(Cz)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement
.measure tran t_fall_delay_Cout TRIG V(B) VAL = 0.35 TD = 1n
+ RISE = 4 TARG V(Cout) VAL = 0.35 FALL = 7

.measure tran t_fall_delay_Sum TRIG V(C) VAL = 0.35 TD = 1n
+ RISE = 2 TARG V(Sum) VAL = 0.35 FALL = 3

.measure tran t_rise_delay_Cout TRIG V(C) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Cout) VAL = 0.35 RISE = 1

.measure tran t_rise_delay_Sum TRIG V(C) VAL = 0.35 TD = 1n
+ FALL = 2 TARG V(Sum) VAL = 0.35 RISE = 2

.measure tran t_fall_time_Cout TRIG V(Cout) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Cout) VAL = 0.14 FALL = 2

.measure tran t_rise_time_Cout TRIG V(Cout) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Cout) VAL = 0.56 RISE = 2

.measure tran t_fall_time_Sum TRIG V(Sum) VAL = 0.56 TD = 1n
+ FALL = 2 TARG V(Sum) VAL = 0.14 FALL = 2

.measure tran t_rise_time_Sum TRIG V(Sum) VAL = 0.14 TD = 1n
+ RISE = 2 TARG V(Sum) VAL = 0.56 RISE = 2

.end
```

HSPICE File of 1_Bit_Adder

PFIN = 1, NFIN = 1

```
y
 t_fall_delay_cout= 200.0213n  targ=  17.0000u   trig=  16.8000u
 t_fall_delay_sum=  13.1167p  targ=   4.0000u   trig=   4.0000u
 t_rise_delay_cout=   1.0000u  targ=   4.0000u   trig=   3.0000u
 t_rise_delay_sum=  14.6975p  targ=   3.0000u   trig=   3.0000u
 t_fall_time_cout=   7.3886p  targ=   5.0000u   trig=   5.0000u
 t_rise_time_cout=   8.1876p  targ=   6.0000u   trig=   6.0000u
 t_fall_time_sum=   6.9551p  targ=   2.2000u   trig=   2.2000u
 t_rise_time_sum=   7.9708p  targ=   3.0000u   trig=   3.0000u

          ***** job concluded
```

Time Details of 1 Bit Adder

Waveform of 1 Bit Full Adder

T_Fall_Delay = 13.117 ps

T_Rise_Delay = 14.6975 ps

COUT_T_Fall_Time = 7.3886 ps

COUT_T_rise_Time =8.1876 ps

SUM_T_Fall_Time = 6.9551 ps

SUM_T_rise_Time =7.9708 ps

Verification

A	B	Cin	Sum	Cout
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Hence all the values are verified, and the result is checked to receive a positive correlation.

Conclusion

The Hspice files of all the respective Compound gates were successfully designed using HSPICE command and the time delays and the rise and fall times were calculated and the logic was verified using the waveform.

Simple DRAM Simulation in HSPICE

```
**************************
*  lab3 sample hspice
**************************

.include './hp7nfet.pm'
.include './hp7pfet.pm'

*define parameters
.param vdd=0.7
.param vss=0
.param fin_height=18n
.param fin_width=7n
.param lg=11n
.param p_fin = 1

VSS Gnd 0 'vss'

.param LoadCap = 1f

*name drain frontgate source backgate
*add transistors
mp1 Z vdd X vdd pfet L=lg NFIN=p_fin

*add cap
Cz Z Gnd 'LoadCap'

*add voltage source
VX X 0 'vdd/2'
VY Y 0 'vdd'

*define the initial condition of V(Z)
.IC V(Z)='vdd'

*do transient analysis
    *syntax: .TRAN tiner tstop START=stval
    *tiner - time step
    *tstop - final time
    *stval - initial time (default 0)
.tran 0.5m 2050m SWEEP data=table

.data table
p_fin LoadCap
1       1f
2       1f
```

```
.data table
p_fin LoadCap
1       1f
2       1f
3       1f
4       1f
5       1f
*50000^0.1 = 2.9505
1       2.9505f
2       2.9505f
3       2.9505f
4       2.9505f
5       2.9505f
*50000^0.2 = 8.70551
1       8.70551f
2       8.70551f
3       8.70551f
4       8.70551f
5       8.70551f
*50000^0.3 = 25.6857
1       25.6857f
2       25.6857f
3       25.6857f
4       25.6857f
5       25.6857f
*50000^0.4 = 75.7858
1       75.7858f
2       75.7858f
3       75.7858f
4       75.7858f
5       75.7858f
*50000^0.5 = 223.607
1       223.607f
2       223.607f
3       223.607f
4       223.607f
5       223.607f
*50000^0.6 = 659.754
1       659.754f
2       659.754f
3       659.754f
4       659.754f
5       659.754f
```

```
*50000^0.7 = 1946.61
1       1946.61f
2       1946.61f
3       1946.61f
4       1946.61f
5       1946.61f
*50000^0.8 = 5743.49
1       5743.49f
2       5743.49f
3       5743.49f
4       5743.49f
5       5743.49f
*50000^0.9 = 16946.2
1       16946.2f
2       16946.2f
3       16946.2f
4       16946.2f
5       16946.2f
*50000^1.0 = 50000
1       50000f
2       50000f
3       50000f
4       50000f
5       50000f


*print the V(Z) to waveform file *.tr0
*.print V(X)
*.print V(Y)
.print V(Z)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement --> These are samples of measurements. Modify as per your requirement.
.measure tran RTL TRIG AT=0 TARG v(Z) VAL=0.355 FALL=1
.measure tran avg_current AVG I(Cz) from 0 to 'RTL'
.measure tran avg_power AVG p(Cz)



.end
```

HSPICE Command of 1T DRAM Cell using Fin FET

```
1  ************************
2  *  lab3 sample hspice
3  ************************
4
5  .include './lp32nm.pm'
6
7  *define parameters
8  .param vdd=1.0
9  .param vss=0
10 .param multiplier = 1
11 .param wd=120n*multiplier
12 .param lg=32n
13
14 VSS Gnd 0 'vss'
15
16 .param LoadCap = 1f
17
18 *name drain frontgate source backgate
19 *add transistors
20 mp1 Z vdd X vdd pmos L=lg W=wd
21
22 *add cap
23 Cz Z Gnd 'LoadCap'
24
25 *add voltage source
26 VX X 0 'vdd/2'
27 VY Y 0 'vdd'
28
29 *define the initial condition of V(Z)
30 .IC V(Z)='vdd'
31
32 *do transient analysis
33     *syntax: .TRAN tiner tstop START=stval
34     *tiner - time step
35     *tstop - final time
36     *stval - initial time (default 0)
37 .tran 0.5m 7550m SWEEP data=table
38
39 .data table
40 multiplier LoadCap
41 1          1f
42 2          1f
43 3          1f
44 4          1f
```

```
40  Multiplier Loadcap
41  1       1f
42  2       1f
43  3       1f
44  4       1f
45  5       1f
46  6       1f
47  7       1f
48  8       1f
49  9       1f
50  10      1f
51  11      1f
52  12      1f
53  13      1f
54  14      1f
55  15      1f
56  16      1f
57  *50000^0.1 = 2.9505
58  1       2.9505f
59  2       2.9505f
60  3       2.9505f
61  4       2.9505f
62  5       2.9505f
63  6       2.9505f
64  7       2.9505f
65  8       2.9505f
66  9       2.9505f
67  10      2.9505f
68  11      2.9505f
69  12      2.9505f
70  13      2.9505f
71  14      2.9505f
72  15      2.9505f
73  16      2.9505f
74  *50000^0.2 = 8.70551
75  1       8.70551f
76  2       8.70551f
77  3       8.70551f
78  4       8.70551f
79  5       8.70551f
80  6       8.70551f
81  7       8.70551f
82  8       8.70551f
83  9       8.70551f
```

```
 76  2       8.70551f
 77  3       8.70551f
 78  4       8.70551f
 79  5       8.70551f
 80  6       8.70551f
 81  7       8.70551f
 82  8       8.70551f
 83  9       8.70551f
 84  10      8.70551f
 85  11      8.70551f
 86  12      8.70551f
 87  13      8.70551f
 88  14      8.70551f
 89  15      8.70551f
 90  16      8.70551f
 91  *50000^0.3 = 25.6857
 92  1       25.6857f
 93  2       25.6857f
 94  3       25.6857f
 95  4       25.6857f
 96  5       25.6857f
 97  6       25.6857f
 98  7       25.6857f
 99  8       25.6857f
100  9       25.6857f
101  10      25.6857f
102  11      25.6857f
103  12      25.6857f
104  13      25.6857f
105  14      25.6857f
106  15      25.6857f
107  16      25.6857f
108  *50000^0.4 = 75.7858
109  1       75.7858f
110  2       75.7858f
111  3       75.7858f
112  4       75.7858f
113  5       75.7858f
114  6       75.7858f
115  7       75.7858f
116  8       75.7858f
117  9       75.7858f
118  10      75.7858f
119  11      75.7858f
```

```
10      75.7858f
11      75.7858f
12      75.7858f
13      75.7858f
14      75.7858f
15      75.7858f
16      75.7858f
*50000^0.5 = 223.607
1       223.607f
2       223.607f
3       223.607f
4       223.607f
5       223.607f
6       223.607f
7       223.607f
8       223.607f
9       223.607f
10      223.607f
11      223.607f
12      223.607f
13      223.607f
14      223.607f
15      223.607f
16      223.607f
*50000^0.6 = 659.754
1       659.754f
2       659.754f
3       659.754f
4       659.754f
5       659.754f
6       659.754f
7       659.754f
8       659.754f
9       659.754f
10      659.754f
11      659.754f
12      659.754f
13      659.754f
14      659.754f
15      659.754f
16      659.754f
*50000^0.7 = 1946.61
1       1946.61f
2       1946.61f
```

```
1       1946.61f
2       1946.61f
3       1946.61f
4       1946.61f
5       1946.61f
6       1946.61f
7       1946.61f
8       1946.61f
9       1946.61f
10      1946.61f
11      1946.61f
12      1946.61f
13      1946.61f
14      1946.61f
15      1946.61f
16      1946.61f
*50000^0.8 = 5743.49
1       5743.49f
2       5743.49f
3       5743.49f
4       5743.49f
5       5743.49f
6       5743.49f
7       5743.49f
8       5743.49f
9       5743.49f
10      5743.49f
11      5743.49f
12      5743.49f
13      5743.49f
14      5743.49f
15      5743.49f
16      5743.49f
*50000^0.9 = 16946.2
1       16946.2f
2       16946.2f
3       16946.2f
4       16946.2f
5       16946.2f
6       16946.2f
7       16946.2f
8       16946.2f
9       16946.2f
10      16946.2f
```

```
7       16946.2f
8       16946.2f
9       16946.2f
10      16946.2f
11      16946.2f
12      16946.2f
13      16946.2f
14      16946.2f
15      16946.2f
16      16946.2f
*50000^1.0 = 50000
1       50000f
2       50000f
3       50000f
4       50000f
5       50000f
6       50000f
7       50000f
8       50000f
9       50000f
10      50000f
11      50000f
12      50000f
13      50000f
14      50000f
15      50000f
16      50000f

*print the V(Z) to waveform file *.tr0
*.print V(X)
*.print V(Y)
.print V(Z)

*simulation options (you can modify this. Post is needed for .tran analysis)
.OPTION Post Brief NoMod probe measout

*measurement --> These are samples of measurements. Modify as per your requirement.
.measure tran RTL TRIG AT=0 TARG v(Z) VAL=0.55 FALL=1
.measure tran avg_current AVG I(Cz) from 0 to 'RTL'
.measure tran avg_power AVG p(Cz)

.end
```

HSPICE Command of 1T DRAM using MOS

After running the HSPICE files of the FinFet being designed using Fin Fet and MOS, we receive the .mt0 file. In order to automate the process and the draw the graph, we read the mt0 file and generate a list of data to be fed into matlab to plot the desired output.

Below is the python code which I used to extract the datas from the .mto file and pass on to the matlab code.

```
f = open("./DRAM_Sweep.mt0", "r")
a = f.read()
b=a.split('\n')
#print(len(b))
pfin=[]
loadcap=[]
rtl=[]
avg_current=[]
avg_power=[]

for i in range(0,len(b)-1,3):
    if(i>4):
        #print(i,b[i-1])
        list=[]
        t=b[i-1].split(" ")
        for i1 in t:
            if(i1):
                list.append(i1)
        pfin.append(list[1])
        loadcap.append(list[2])
        rtl.append(list[3])

        list1=[]
        #print(b[i])
        t1=b[i].split(" ")
        for j in t1:
            if (j):
                list1.append(j)
        avg_current.append(list1[0])
        avg_power.append(list1[1])
#print ("avg_current array", avg_current)
```

```
                list.append(i1)
        pfin.append(list[1])
        loadcap.append(list[2])
        rtl.append(list[3])

        list1=[]
        #print(b[i])
        t1=b[i].split(" ")
        for j in t1:
            if (j):
                list1.append(j)
        avg_current.append(list1[0])
        avg_power.append(list1[1])
#print ("avg_current array", avg_current)
#print('\n')
#print ("Pfin array " , pfin)
#print('\n')
#print ("loadcap array", loadcap)
#print('\n')
#print ("avg_power array", avg_power)
#print('\n')
#print ("rtl array", rtl)

f=open("dram_finfet.txt","w")
f1=open("dram_finfet.csv","w")
f.write("pfin,avg_current,loadcap,avg_power,rtl\n")
f1.write("pfin,avg_current,loadcap,avg_power,rtl\n")
for i in range(len(pfin)):
    f.write(str(pfin[i])+","+str(avg_current[i])+','+str(loadcap[i])+","+str(avg_power[i])+','+str(rtl[i])+'\n')
    f1.write(str(pfin[i])+","+str(avg_current[i])+','+str(loadcap[i])+","+str(avg_power[i])+','+str(rtl[i])+'\n')
f.close()
f1.close()
```

Python code to make the input file for matlab plot – Fin Fet

```
f = open("./DRAM_MOSFET_Sweep.mt0", "r")
a = f.read()
b=a.split('\n')
#print(len(b))
multiplier=[]
loadcap_mos=[]
rtl_mos=[]
avg_current_mos=[]
avg_power_mos=[]

for i in range(0,len(b)-1,3):
    if(i>4):
        #print(i,b[i-1])
        list=[]
        t=b[i-1].split(" ")
        for i1 in t:
            if(i1):
                list.append(i1)
        multiplier.append(list[1])
        loadcap_mos.append(list[2])
        rtl_mos.append(list[3])

        list1=[]
        #print(b[i])
        t1=b[i].split(" ")
        for j in t1:
            if (j):
                list1.append(j)
        avg_current_mos.append(list1[0])
        avg_power_mos.append(list1[1])
print ("avg_current_Mosfet array", avg_current_mos)
print('\n')
print ("Multiplier array " , multiplier)
```

```
        multiplier.append(list[1])
        loadcap_mos.append(list[2])
        rtl_mos.append(list[3])

        list1=[]
        #print(b[i])
        t1=b[i].split(" ")
        for j in t1:
            if (j):
                list1.append(j)
        avg_current_mos.append(list1[0])
        avg_power_mos.append(list1[1])
print ("avg_current_Mosfet array", avg_current_mos)
print('\n')
print ("Multiplier array " , multiplier)
print('\n')
print ("loadcap_Mosfet array", loadcap_mos)
print('\n')
print ("avg_power_Mosfet array", avg_power_mos)
print('\n')
print ("rtl_Mosfet array", rtl_mos)

f=open("mosfet_finfet.txt","w")
f1=open("mosfet_finfet.csv","w")
f.write("multiplier,avg_current,loadcap,avg_power,rtl\n")
f1.write("multiplier,avg_current,loadcap,avg_power,rtl\n")
print(len(multiplier))
for i in range(len(multiplier)):
    f.write(str(multiplier[i])+","+str(avg_current_mos[i])+','+str(loadcap_mos[i])+","+str(avg_power_mos[i])+','+str(rtl_mos[i])+'\n')
    f1.write(str(multiplier[i])+","+str(avg_current_mos[i])+','+str(loadcap_mos[i])+","+str(avg_power_mos[i])+','+str(rtl_mos[i])+'\n')
f.close()
f1.close()
```

Python code to make the input file for matlab plot – MOS

After running he above file, we are generating the .text file, which is being used to feed to the matlab, as well as the we use the data to find the asked statistics of the DRAM File.

```
from statistics import stdev
from statistics import mean

file = open("./DRAM_Sweep.mt0", "r")
file1= open("./DRAM_MOSFET_Sweep.mt0", "r")
data = file.read()
data1 = file1.read()
b=data.split('\n')
b1=data.split('\n')
p_fin = []
mul = []
avg_current = []
avg_current_mos = []
loadcap = []
loadcap_mos = []
avg_power = []
avg_power_mos = []
rtl = []
rtl_mos = []


for i in range(0, len(b)-1, 3):
    if(i > 4):
        #print (b[i-1])
        list = []
        temp1 = b[i-1].split(" ")
        for var in temp1:
            if(var):
                list.append(float(var))
        p_fin.append(list[1])
        loadcap.append(list[2])
        rtl.append(list[3])
```

```
        p_rtl.append(list[1])
        loadcap.append(list[2])
        rtl.append(list[3])

        #i
        list1 = []
        temp1 = b[i].split(" ")
        for var in temp1:
            if(var):
                list1.append(float(var))
        #print (list)
        avg_current.append(list1[0])
        avg_power.append(list1[1])

print("Maximum value of RTL "+str(max(rtl)))
print("Minimum value of RTL "+str(min(rtl)))
print("Standard Deviation of RTL "+str(stdev(rtl)))
print("Average value of RTL "+str(mean(rtl)))
print("Average value of Average Current "+str(mean(avg_current)))
print("Maximum value of Average Current "+str(max(avg_current)))
print("Minimum value of Average Current "+str(min(avg_current)))
print("Standard Deviation of Average Current "+str(stdev(avg_current)))
print("Maximum value of average power "+str(max(avg_power)))
print("Minimum value of average power "+str(min(avg_power)))
print("Standard Deviation of average power "+str(stdev(avg_power)))
print("Average value of average power "+str(mean(avg_power)))


for i in range(0, len(b1)-1, 3):
    if(i > 4):
        #print (b[i-1])
        list2 = []
        temp2 = b1[i-1].split(" ")
```

```
        #print (b[i-1])
        list2 = []
        temp2 = b1[i-1].split(" ")
        for var1 in temp2:
            if(var1):
                list2.append(float(var1))
        mul.append(list2[1])
        loadcap_mos.append(list2[2])
        rtl_mos.append(list2[3])

        #i
        list3 = []
        temp3 = b[i].split(" ")
        for var2 in temp3:
            if(var2):
                list3.append(float(var2))
        #print (list)
        avg_current_mos.append(list3[0])
        avg_power_mos.append(list3[1])

print("Maximum value of RTL MOS "+str(max(rtl_mos)))
print("Minimum value of RTL MOS"+str(min(rtl_mos)))
print("Standard Deviation of RTL MOS "+str(stdev(rtl_mos)))
print("Average value of RTL MOS"+str(mean(rtl_mos)))
print("Average value of Average Current MOS"+str(mean(avg_current_mos)))
print("Maximum value of Average Current MOS"+str(max(avg_current_mos)))
print("Minimum value of Average Current MOS"+str(min(avg_current_mos)))
print("Standard Deviation of Average Current MOS"+str(stdev(avg_current_mos)))
print("Maximum value of average power MOS"+str(max(avg_power_mos)))
print("Minimum value of average power MOS"+str(min(avg_power_mos)))
print("Standard Deviation of average power MOS"+str(stdev(avg_power_mos)))
print("Average value of average power MOS"+str(mean(avg_power_mos)))
```

```
print("Standard Deviation of average power MOS"+str(stdev(avg_power_mos)))
print("Average value of average power MOS"+str(mean(avg_power_mos)))
```

```
Maximum value of RTL 0.007382
Minimum value of RTL 1.598e-08
Standard Deviation of RTL 0.0012369681126332022
Average value of RTL 0.00049078344
Average value of Average Current -6.695218181818182e-09
Maximum value of Average Current -1.122e-09
Minimum value of Average Current -5.206e-08
Standard Deviation of Average Current 7.517518443217e-09
Maximum value of average power -7.357e-17
Minimum value of average power -4.148e-12
Standard Deviation of average power 1.162797944700218e-12
Average value of average power -5.20267938e-13
Maximum value of RTL MOS 0.007382
Minimum value of RTL MOS1.598e-08
Standard Deviation of RTL MOS 0.0012369681126332022
Average value of RTL MOS0.00049078344
Average value of Average Current MOS-6.695218181818182e-09
Maximum value of Average Current MOS-1.122e-09
Minimum value of Average Current MOS-5.206e-08
Standard Deviation of Average Current MOS7.517518443217e-09
Maximum value of average power MOS-7.357e-17
Minimum value of average power MOS-4.148e-12
Standard Deviation of average power MOS1.162797944700218e-12
Average value of average power MOS-5.20267938e-13
```

Python Code and the Output Statistics Calculated.

The above diagrams are representing the python code and the statistics calculated for the DRAM, the obtained statistics are verified and the reported.

Below is the Matlab code and the further documentation of DRAM using FinFET

```
input_data = importdata(strcat(pwd,"./dram_finfet.txt"));
Fin = input_data.data(:,1);
Capacitance_FINFET = input_data.data(:,3);
RTL_FINFET=input_data.data(:,5);
avgcurrent_FINFET=input_data.data(:,2);
avgPower_FINFET=input_data.data(:,4);

AverageCurrent_FINFET=[];
AveragePower_FINFET=[];
RtlPlotFinfet=[];

for i=1:11
    RtlPlotFinfet=horzcat(RtlPlotFinfet,RTL_FINFET(1+5*(i-1):5*i));
    AverageCurrent_FINFET=horzcat(AverageCurrent_FINFET,avgcurrent_FINFET(1+5*(i-1):5*i));
    AveragePower_FINFET=horzcat(AveragePower_FINFET,avgPower_FINFET(1+5*(i-1):5*i));
end

figure
surf(unique(Capacitance_FINFET),unique(Fin),RtlPlotFinfet)
title('DRAM FINFET Refresh Time Limit Plot')
xlabel('Capacitance_Load (fF)')
ylabel('PFins')
zlabel('RTL(sec)')

figure
surf(unique(Capacitance_FINFET),unique(Fin),AverageCurrent_FINFET)
title('DRAM FINFET Average Current Plot')
xlabel('Capacitance_Load (fF)')
```

```
xlabel('Capacitance_Load (fF)')
ylabel('Fins')
zlabel('Average_Current (Amp)')

figure
surf(unique(Capacitance_FINFET),unique(Fin),AveragePower_FINFET)
title('DRAM FINFET Average Power Plot')
xlabel('Capacitance_Load (fF)')
ylabel('Fins')
zlabel('Average_Power (Watt)')
```

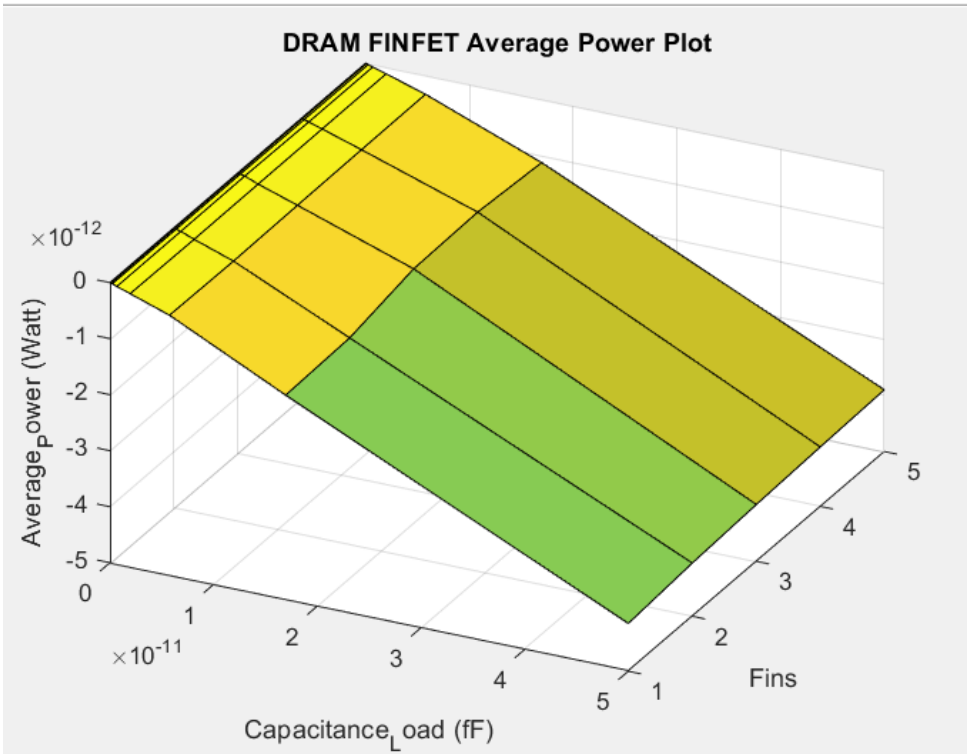
MATLAB code for DRAM_FinFet

dram_finfet.txt

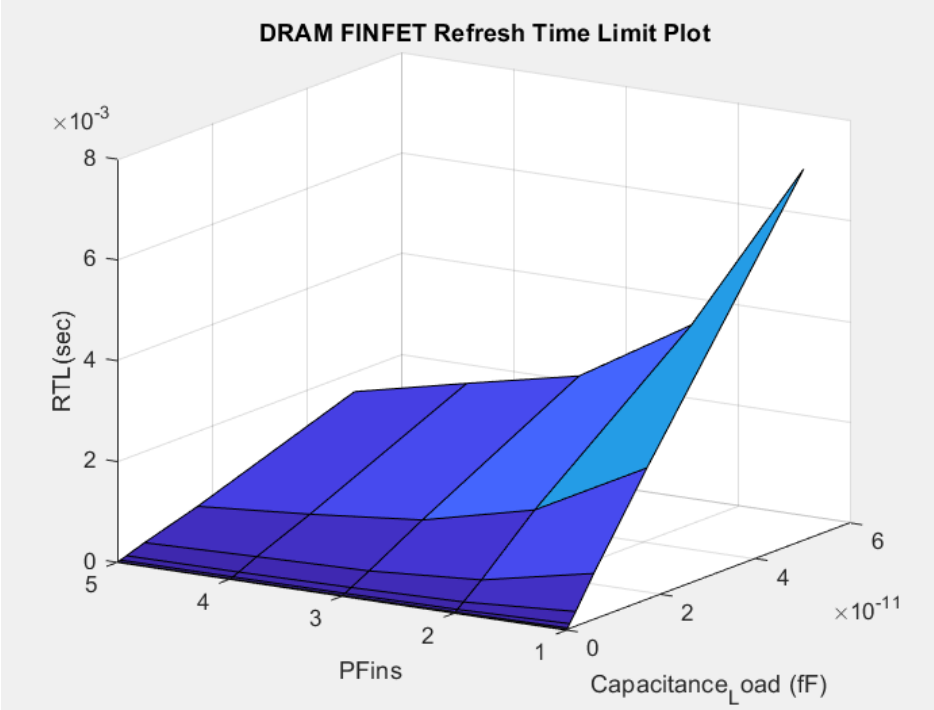
Input to the MATLAB File

```
pfin,avg_current,loadcap,avg_power,rtl
1.0000,-1.947e-09,1.000e-15,-7.890e-17,1.589e-07
2.0000,-3.566e-09,1.000e-15,-8.191e-17,8.532e-08
3.0000,-4.740e-09,1.000e-15,-8.531e-17,5.497e-08
4.0000,-6.222e-09,1.000e-15,-7.357e-17,4.095e-08
5.0000,-1.923e-08,1.000e-15,-1.725e-16,1.598e-08
1.0000,-1.687e-09,2.951e-15,-1.973e-16,4.814e-07
2.0000,-3.273e-09,2.951e-15,-1.839e-16,2.350e-07
3.0000,-5.781e-09,2.951e-15,-2.330e-16,1.579e-07
4.0000,-7.318e-09,2.951e-15,-2.561e-16,1.239e-07
5.0000,-9.306e-09,2.951e-15,-2.563e-16,9.668e-08
1.0000,-1.710e-09,8.706e-15,-5.627e-16,1.366e-06
2.0000,-2.976e-09,8.706e-15,-5.395e-16,7.495e-07
3.0000,-5.013e-09,8.706e-15,-5.806e-16,4.779e-07
4.0000,-6.816e-09,8.706e-15,-5.662e-16,3.424e-07
5.0000,-7.906e-09,8.706e-15,-5.738e-16,2.919e-07
1.0000,-1.589e-09,2.569e-14,-1.593e-15,4.216e-06
2.0000,-3.442e-09,2.569e-14,-1.735e-15,2.062e-06
3.0000,-5.076e-09,2.569e-14,-1.661e-15,1.357e-06
4.0000,-6.174e-09,2.569e-14,-1.624e-15,1.100e-06
5.0000,-7.871e-09,2.569e-14,-1.574e-15,8.435e-07
1.0000,-1.887e-09,7.579e-14,-4.979e-15,1.128e-05
2.0000,-1.890e-08,7.579e-14,-6.833e-15,1.549e-06
3.0000,-4.943e-09,7.579e-14,-5.163e-15,4.385e-06
4.0000,-6.451e-09,7.579e-14,-5.021e-15,3.296e-06
5.0000,-9.844e-09,7.579e-14,-5.812e-15,2.368e-06
1.0000,-1.122e-09,2.236e-13,-1.095e-14,3.459e-05
2.0000,-3.683e-09,2.236e-13,-1.539e-14,1.755e-05
3.0000,-5.618e-09,2.236e-13,-1.467e-14,1.117e-05
4.0000,-2.186e-08,2.236e-13,-2.088e-14,3.955e-06
5.0000,-5.206e-08,2.236e-13,-2.049e-14,1.649e-06
1.0000,-1.676e-09,6.598e-13,-4.284e-14,1.053e-04
2.0000,-3.275e-09,6.598e-13,-3.971e-14,5.060e-05
3.0000,-3.390e-09,6.598e-13,-3.220e-14,3.360e-05
4.0000,-8.195e-09,6.598e-13,-4.734e-14,2.373e-05
5.0000,-9.337e-09,6.598e-13,-4.623e-14,2.071e-05
1.0000,-1.679e-09,1.947e-12,-1.213e-13,3.005e-04
2.0000,-3.472e-09,1.947e-12,-1.316e-13,1.539e-04
3.0000,-4.985e-09,1.947e-12,-1.263e-13,1.044e-04
4.0000,-6.825e-09,1.947e-12,-1.224e-13,7.406e-05
5.0000,-8.039e-09,1.947e-12,-1.194e-13,6.194e-05

1.0000,-1.641e-09,5.743e-12,-3.589e-13,9.216e-04
2.0000,-3.374e-09,5.743e-12,-3.737e-13,4.574e-04
3.0000,-4.983e-09,5.743e-12,-3.575e-13,2.987e-04
4.0000,-5.964e-09,5.743e-12,-3.458e-13,2.457e-04
5.0000,-7.650e-09,5.743e-12,-3.367e-13,1.866e-04
1.0000,-2.068e-09,1.695e-11,-1.352e-12,2.618e-03
2.0000,-3.728e-09,1.695e-11,-1.310e-12,1.448e-03
3.0000,-4.881e-09,1.695e-11,-1.058e-12,9.134e-04
4.0000,-6.309e-09,1.695e-11,-1.026e-12,6.912e-04
5.0000,-8.966e-09,1.695e-11,-1.123e-12,5.107e-04
1.0000,-2.189e-09,5.000e-11,-4.148e-12,7.382e-03
2.0000,-4.078e-09,5.000e-11,-4.050e-12,3.949e-03
3.0000,-6.144e-09,5.000e-11,-3.986e-12,2.601e-03
4.0000,-7.555e-09,5.000e-11,-3.938e-12,2.118e-03
5.0000,-9.823e-09,5.000e-11,-3.899e-12,1.617e-03
```

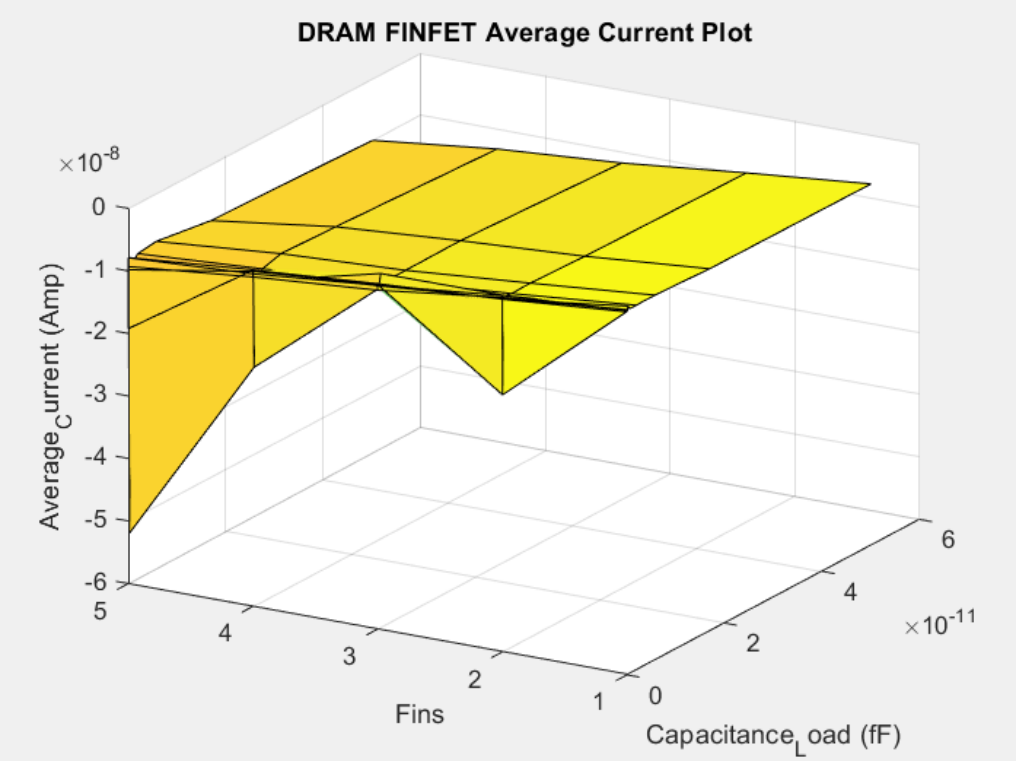
Dram_finfet.txt Input Data Set to the matlab



DRAM FINFET Average Power Plot



DRAM FINFET Refresh Time Limit Plot



DRAM FINFET Average Current Plot

Below is the Matlab code and the further documentation of DRAM using Mos

```
MOS_data = importdata(strcat(pwd,"./mosfet_finfet.txt"));
Multiplier = MOS_data.data(:,1);
Cap_MOS = MOS_data.data(:,3);
RTL_MOS=MOS_data.data(:,5);
avg_I_MOS=MOS_data.data(:,2);
avg_P_MOS=MOS_data.data(:,4);

RTL_plot_MOS=[];
I_avg_MOS=[];
P_avg_MOS=[];

for i=1:11
    RTL_plot_MOS=horzcat(RTL_plot_MOS,RTL_MOS(1+16*(i-1):16*i));
    I_avg_MOS=horzcat(I_avg_MOS,avg_I_MOS(1+16*(i-1):16*i));
    P_avg_MOS=horzcat(P_avg_MOS,avg_P_MOS(1+16*(i-1):16*i));
end

figure
surf(unique(Cap_MOS),unique(Multiplier),RTL_plot_MOS)
title('DRAM MOS RTL Plot')
xlabel('Capacitance Load (fF)')
ylabel('Multiplier')
zlabel('Refresh Time Limit (sec)')

figure
surf(unique(Cap_MOS),unique(Multiplier),I_avg_MOS)
title('DRAM MOS Average Current Plot')
xlabel('Capacitance Load (fF)')
ylabel('Multiplier')
zlabel('Average Current (Amp)')

figure
surf(unique(Cap_MOS),unique(Multiplier),P_avg_MOS)
title('DRAM MOS Average Power Plot')
xlabel('Capacitance Load (fF)')
ylabel('Multiplier')
zlabel('Average Power (Watt)')
```

MATLAB code for DRAM_Mos

mosfet_finfet.txt

Input to the MATLAB File

```
multiplier,avg_current,loadcap,avg_power,rtl
1.0000,-7.493e-13,1.000e-15,-4.755e-17,5.340e-04
2.0000,-7.445e-13,1.000e-15,-4.784e-17,5.422e-04
3.0000,-6.940e-13,1.000e-15,-4.859e-17,5.828e-04
4.0000,-6.398e-13,1.000e-15,-4.918e-17,6.363e-04
5.0000,-5.911e-13,1.000e-15,-4.887e-17,6.940e-04
6.0000,-5.555e-13,1.000e-15,-4.911e-17,7.404e-04
7.0000,-5.279e-13,1.000e-15,-5.050e-17,7.797e-04
8.0000,-5.052e-13,1.000e-15,-5.079e-17,8.149e-04
9.0000,-4.847e-13,1.000e-15,-5.097e-17,8.501e-04
10.0000,-4.613e-13,1.000e-15,-5.036e-17,8.973e-04
11.0000,-4.433e-13,1.000e-15,-4.968e-17,9.364e-04
12.0000,-4.282e-13,1.000e-15,-4.934e-17,9.707e-04
13.0000,-4.153e-13,1.000e-15,-4.953e-17,1.002e-03
14.0000,-4.041e-13,1.000e-15,-4.983e-17,1.030e-03
15.0000,-3.941e-13,1.000e-15,-5.040e-17,1.056e-03
16.0000,-3.852e-13,1.000e-15,-5.072e-17,1.081e-03
1.0000,-1.163e-12,2.951e-15,-1.472e-16,1.035e-03
2.0000,-1.443e-12,2.951e-15,-1.462e-16,8.342e-04
3.0000,-1.427e-12,2.951e-15,-1.467e-16,8.477e-04
4.0000,-1.365e-12,2.951e-15,-1.473e-16,8.875e-04
5.0000,-1.299e-12,2.951e-15,-1.479e-16,9.334e-04
6.0000,-1.213e-12,2.951e-15,-1.489e-16,1.009e-03
7.0000,-1.151e-12,2.951e-15,-1.492e-16,1.067e-03
8.0000,-1.102e-12,2.951e-15,-1.487e-16,1.116e-03
9.0000,-1.062e-12,2.951e-15,-1.487e-16,1.158e-03
10.0000,-1.029e-12,2.951e-15,-1.502e-16,1.195e-03
11.0000,-9.999e-13,2.951e-15,-1.532e-16,1.229e-03
12.0000,-9.740e-13,2.951e-15,-1.554e-16,1.260e-03
13.0000,-9.477e-13,2.951e-15,-1.576e-16,1.296e-03
14.0000,-9.164e-13,2.951e-15,-1.583e-16,1.346e-03
15.0000,-8.897e-13,2.951e-15,-1.580e-16,1.389e-03
16.0000,-8.671e-13,2.951e-15,-1.573e-16,1.427e-03

1.0000,-1.459e-12,8.706e-15,-4.558e-16,2.500e-03
2.0000,-2.315e-12,8.706e-15,-4.481e-16,1.555e-03
3.0000,-2.591e-12,8.706e-15,-4.469e-16,1.396e-03
4.0000,-2.631e-12,8.706e-15,-4.472e-16,1.380e-03
5.0000,-2.585e-12,8.706e-15,-4.479e-16,1.408e-03
6.0000,-2.520e-12,8.706e-15,-4.487e-16,1.444e-03
7.0000,-2.447e-12,8.706e-15,-4.493e-16,1.485e-03
8.0000,-2.361e-12,8.706e-15,-4.506e-16,1.541e-03
9.0000,-2.255e-12,8.706e-15,-4.513e-16,1.625e-03
10.0000,-2.169e-12,8.706e-15,-4.533e-16,1.695e-03
11.0000,-2.099e-12,8.706e-15,-4.533e-16,1.754e-03
12.0000,-2.045e-12,8.706e-15,-4.529e-16,1.801e-03
13.0000,-1.996e-12,8.706e-15,-4.522e-16,1.844e-03
14.0000,-1.952e-12,8.706e-15,-4.510e-16,1.883e-03
15.0000,-1.913e-12,8.706e-15,-4.499e-16,1.919e-03
16.0000,-1.878e-12,8.706e-15,-4.493e-16,1.953e-03
1.0000,-1.603e-12,2.569e-14,-1.405e-15,6.938e-03
2.0000,-2.901e-12,2.569e-14,-1.375e-15,3.771e-03
3.0000,-3.848e-12,2.569e-14,-1.364e-15,2.821e-03
4.0000,-4.345e-12,2.569e-14,-1.360e-15,2.500e-03
5.0000,-4.588e-12,2.569e-14,-1.358e-15,2.372e-03
6.0000,-4.668e-12,2.569e-14,-1.357e-15,2.336e-03
7.0000,-4.660e-12,2.569e-14,-1.357e-15,2.343e-03
8.0000,-4.608e-12,2.569e-14,-1.357e-15,2.370e-03
9.0000,-4.539e-12,2.569e-14,-1.357e-15,2.406e-03
10.0000,-4.472e-12,2.569e-14,-1.357e-15,2.441e-03
11.0000,-4.394e-12,2.569e-14,-1.357e-15,2.480e-03
12.0000,-4.319e-12,2.569e-14,-1.356e-15,2.519e-03
13.0000,-4.250e-12,2.569e-14,-1.357e-15,2.554e-03
14.0000,-4.108e-12,2.569e-14,-1.358e-15,2.658e-03
15.0000,-3.988e-12,2.569e-14,-1.358e-15,2.749e-03
16.0000,-3.885e-12,2.569e-14,-1.359e-15,2.830e-03
```

```
1.0000,-1.697e-12,7.579e-14,-4.273e-15,1.975e-02
2.0000,-3.260e-12,7.579e-14,-4.199e-15,1.014e-02
3.0000,-4.555e-12,7.579e-14,-4.159e-15,7.227e-03
4.0000,-5.730e-12,7.579e-14,-4.135e-15,5.707e-03
5.0000,-6.631e-12,7.579e-14,-4.121e-15,4.918e-03
6.0000,-7.232e-12,7.579e-14,-4.111e-15,4.515e-03
7.0000,-7.658e-12,7.579e-14,-4.105e-15,4.265e-03
8.0000,-7.939e-12,7.579e-14,-4.100e-15,4.114e-03
9.0000,-8.099e-12,7.579e-14,-4.096e-15,4.033e-03
10.0000,-8.173e-12,7.579e-14,-4.094e-15,3.998e-03
11.0000,-8.182e-12,7.579e-14,-4.091e-15,3.996e-03
12.0000,-8.151e-12,7.579e-14,-4.089e-15,4.013e-03
13.0000,-8.093e-12,7.579e-14,-4.085e-15,4.043e-03
14.0000,-8.023e-12,7.579e-14,-4.083e-15,4.078e-03
15.0000,-7.943e-12,7.579e-14,-4.082e-15,4.119e-03
16.0000,-7.858e-12,7.579e-14,-4.080e-15,4.162e-03
1.0000,-1.708e-12,2.236e-13,-1.277e-14,5.871e-02
2.0000,-3.375e-12,2.236e-13,-1.268e-14,2.951e-02
3.0000,-4.932e-12,2.236e-13,-1.259e-14,2.010e-02
4.0000,-6.420e-12,2.236e-13,-1.252e-14,1.536e-02
5.0000,-7.866e-12,2.236e-13,-1.248e-14,1.247e-02
6.0000,-9.107e-12,2.236e-13,-1.244e-14,1.075e-02
7.0000,-1.010e-11,2.236e-13,-1.241e-14,9.689e-03
8.0000,-1.099e-11,2.236e-13,-1.239e-14,8.901e-03
9.0000,-1.178e-11,2.236e-13,-1.237e-14,8.300e-03
10.0000,-1.246e-11,2.236e-13,-1.235e-14,7.837e-03
11.0000,-1.298e-11,2.236e-13,-1.233e-14,7.512e-03
12.0000,-1.344e-11,2.236e-13,-1.232e-14,7.244e-03
13.0000,-1.380e-11,2.236e-13,-1.231e-14,7.051e-03
14.0000,-1.405e-11,2.236e-13,-1.230e-14,6.917e-03
15.0000,-1.425e-11,2.236e-13,-1.229e-14,6.819e-03
16.0000,-1.434e-11,2.236e-13,-1.228e-14,6.773e-03

1.0000,-1.723e-12,6.598e-13,-3.789e-14,0.1725
2.0000,-3.462e-12,6.598e-13,-3.777e-14,8.543e-02
3.0000,-5.104e-12,6.598e-13,-3.765e-14,5.795e-02
4.0000,-6.692e-12,6.598e-13,-3.755e-14,4.412e-02
5.0000,-8.366e-12,6.598e-13,-3.746e-14,3.513e-02
6.0000,-9.974e-12,6.598e-13,-3.738e-14,2.939e-02
7.0000,-1.135e-11,6.598e-13,-3.731e-14,2.583e-02
8.0000,-1.273e-11,6.598e-13,-3.725e-14,2.303e-02
9.0000,-1.396e-11,6.598e-13,-3.720e-14,2.098e-02
10.0000,-1.517e-11,6.598e-13,-3.715e-14,1.929e-02
11.0000,-1.636e-11,6.598e-13,-3.711e-14,1.787e-02
12.0000,-1.754e-11,6.598e-13,-3.708e-14,1.662e-02
13.0000,-1.871e-11,6.598e-13,-3.705e-14,1.554e-02
14.0000,-1.965e-11,6.598e-13,-3.703e-14,1.478e-02
15.0000,-2.039e-11,6.598e-13,-3.700e-14,1.425e-02
16.0000,-2.107e-11,6.598e-13,-3.696e-14,1.379e-02
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2.0000,-3.490e-12,1.947e-12,-1.119e-13,0.2507
3.0000,-5.163e-12,1.947e-12,-1.118e-13,0.1698
4.0000,-6.860e-12,1.947e-12,-1.117e-13,0.1277
5.0000,-8.558e-12,1.947e-12,-1.116e-13,0.1022
6.0000,-1.030e-11,1.947e-12,-1.114e-13,8.471e-02
7.0000,-1.200e-11,1.947e-12,-1.113e-13,7.258e-02
8.0000,-1.354e-11,1.947e-12,-1.112e-13,6.440e-02
9.0000,-1.503e-11,1.947e-12,-1.111e-13,5.804e-02
10.0000,-1.648e-11,1.947e-12,-1.110e-13,5.294e-02
11.0000,-1.795e-11,1.947e-12,-1.109e-13,4.859e-02
12.0000,-1.944e-11,1.947e-12,-1.108e-13,4.480e-02
13.0000,-2.094e-11,1.947e-12,-1.107e-13,4.153e-02
14.0000,-2.243e-11,1.947e-12,-1.107e-13,3.871e-02
15.0000,-2.394e-11,1.947e-12,-1.106e-13,3.620e-02
16.0000,-2.534e-11,1.947e-12,-1.106e-13,3.417e-02
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3.0000,-5.222e-12,5.743e-12,-3.303e-13,0.4948
4.0000,-6.911e-12,5.743e-12,-3.302e-13,0.3744
5.0000,-8.594e-12,5.743e-12,-3.301e-13,0.3013
6.0000,-1.031e-11,5.743e-12,-3.300e-13,0.2510
7.0000,-1.205e-11,5.743e-12,-3.298e-13,0.2146
8.0000,-1.379e-11,5.743e-12,-3.297e-13,0.1872
9.0000,-1.561e-11,5.743e-12,-3.295e-13,0.1652
10.0000,-1.720e-11,5.743e-12,-3.294e-13,0.1501
11.0000,-1.879e-11,5.743e-12,-3.293e-13,0.1374
12.0000,-2.035e-11,5.743e-12,-3.292e-13,0.1270
13.0000,-2.185e-11,5.743e-12,-3.291e-13,0.1183
14.0000,-2.341e-11,5.743e-12,-3.290e-13,0.1104
15.0000,-2.499e-11,5.743e-12,-3.289e-13,0.1034
16.0000,-2.662e-11,5.743e-12,-3.288e-13,9.699e-02
1.0000,-1.726e-12,1.695e-11,-9.415e-13,4.4184
2.0000,-3.465e-12,1.695e-11,-9.702e-13,2.2013
3.0000,-5.180e-12,1.695e-11,-9.739e-13,1.4743
4.0000,-6.927e-12,1.695e-11,-9.743e-13,1.1018
5.0000,-8.624e-12,1.695e-11,-9.745e-13,0.8855
6.0000,-1.044e-11,1.695e-11,-9.745e-13,0.7306
7.0000,-1.213e-11,1.695e-11,-9.745e-13,0.6292
8.0000,-1.379e-11,1.695e-11,-9.745e-13,0.5539
9.0000,-1.548e-11,1.695e-11,-9.744e-13,0.4934
10.0000,-1.721e-11,1.695e-11,-9.744e-13,0.4438
11.0000,-1.899e-11,1.695e-11,-9.743e-13,0.4018
12.0000,-2.082e-11,1.695e-11,-9.743e-13,0.3660
13.0000,-2.253e-11,1.695e-11,-9.742e-13,0.3382
14.0000,-2.414e-11,1.695e-11,-9.742e-13,0.3160
15.0000,-2.576e-11,1.695e-11,-9.743e-13,0.2964
16.0000,-2.739e-11,1.695e-11,-9.744e-13,0.2787

1.0000,-2.739e-11,5.000e-11,-2.380e-12,8.4228
2.0000,-3.450e-12,5.000e-11,-2.670e-12,6.5208
3.0000,-5.186e-12,5.000e-11,-2.781e-12,4.3380
4.0000,-6.914e-12,5.000e-11,-2.830e-12,3.2548
5.0000,-8.643e-12,5.000e-11,-2.853e-12,2.6038
6.0000,-1.038e-11,5.000e-11,-2.863e-12,2.1675
7.0000,-1.212e-11,5.000e-11,-2.869e-12,1.8568
8.0000,-1.385e-11,5.000e-11,-2.872e-12,1.6250
9.0000,-1.552e-11,5.000e-11,-2.873e-12,1.4517
10.0000,-1.724e-11,5.000e-11,-2.874e-12,1.3073
11.0000,-1.902e-11,5.000e-11,-2.874e-12,1.1842
12.0000,-2.087e-11,5.000e-11,-2.875e-12,1.0777
13.0000,-2.252e-11,5.000e-11,-2.875e-12,0.9993
14.0000,-2.416e-11,5.000e-11,-2.875e-12,0.9323
15.0000,-2.583e-11,5.000e-11,-2.875e-12,0.8723
16.0000,-2.754e-11,5.000e-11,-2.875e-12,0.8183
```
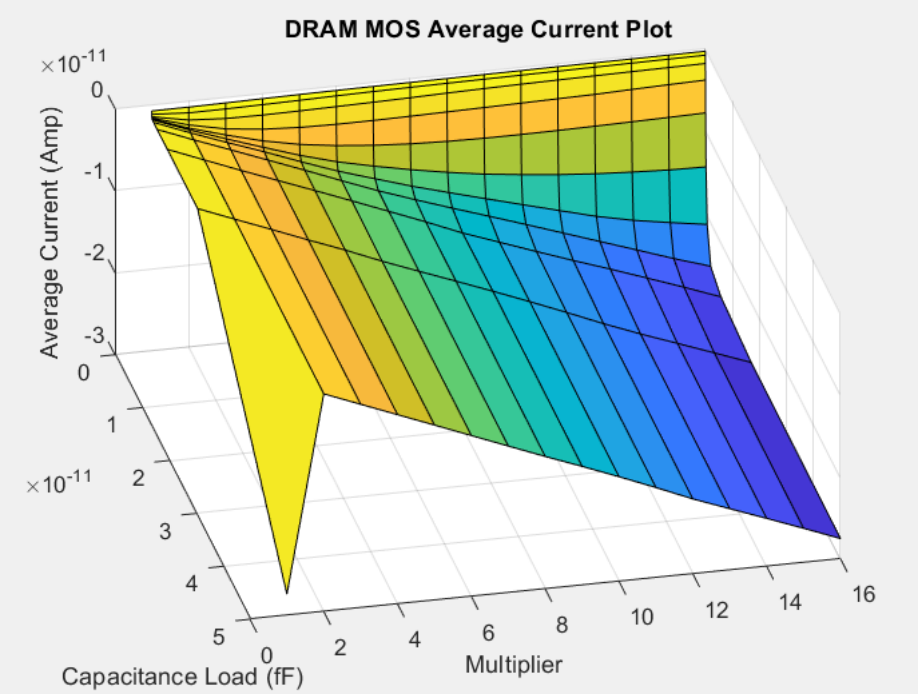
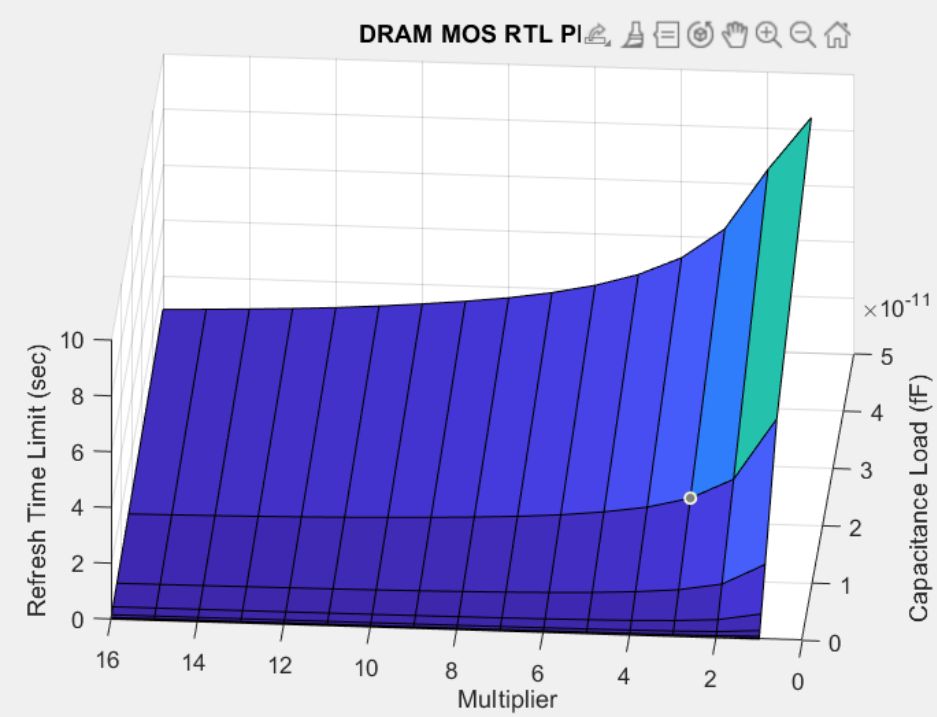
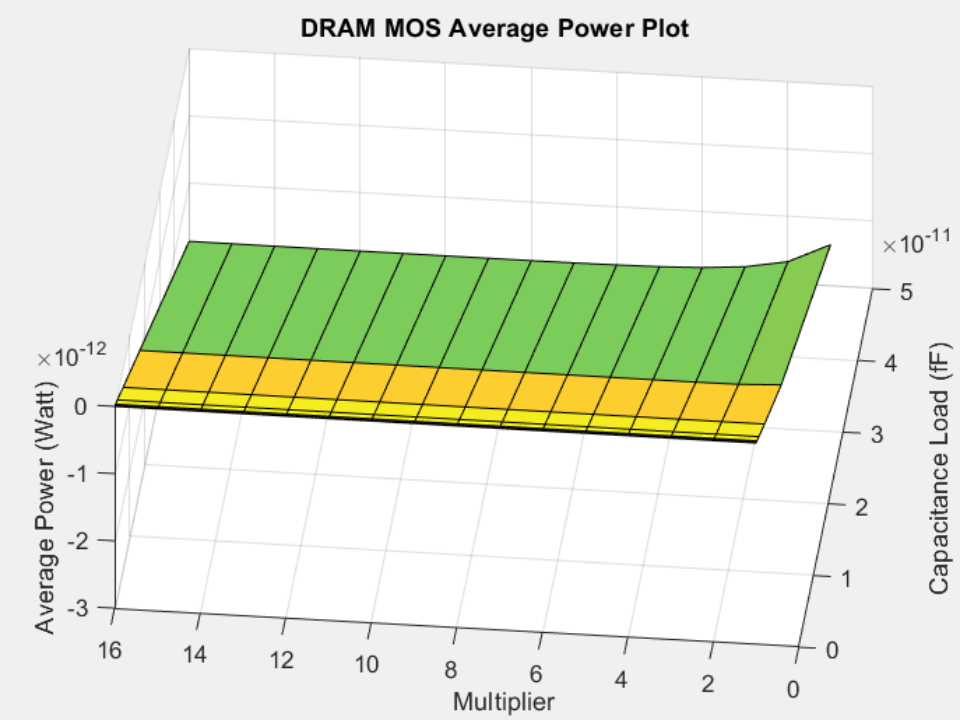

Dram_mos.txt Input Data Set to the matlab



DRAM MOS Average Power Plot



DRAM MOS Average Power Plot



DRAM MOS Average Power Plot

CONCLUSION

Hence the Hspice file was generated for the DRAM using Fin Fet and MOS, after running the HSPICE file, we received a mt0 file and we used a python to extract the mt0 file and generate relevant data, we pass that data into MATLAB and then plot the required 3D graphs, for the statistics regarding the min, max, mean and standard deviation, I am using the python code to extract all the re quired values.