EECT/CE 6325 VLSI Design

Fall 2020

PROJECT #5:

D Flip-Flop

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1. Layout

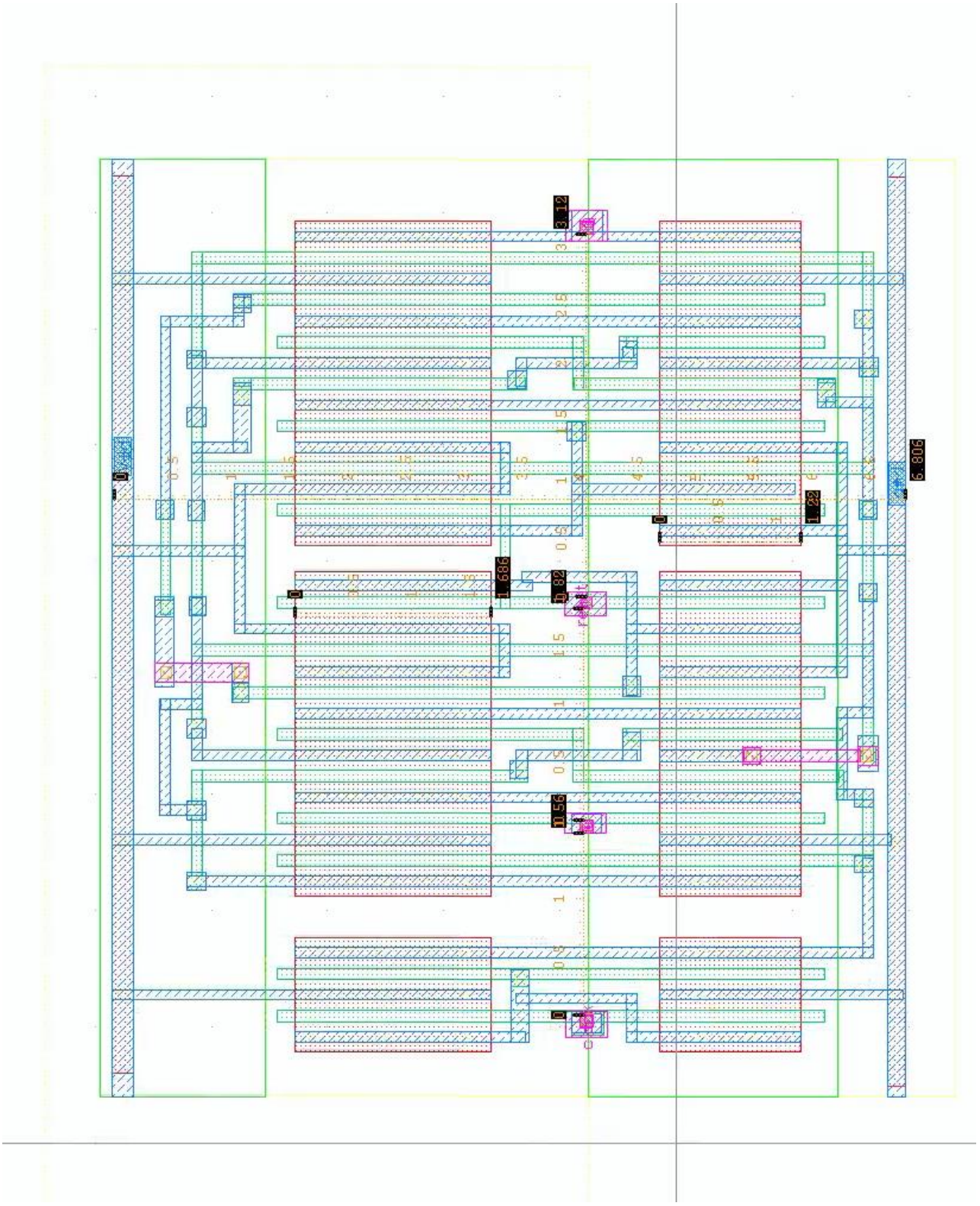


Figure 1 D Flip-Flop layout

Dimensions of the cell:

Height of DFF= 6.806 µm

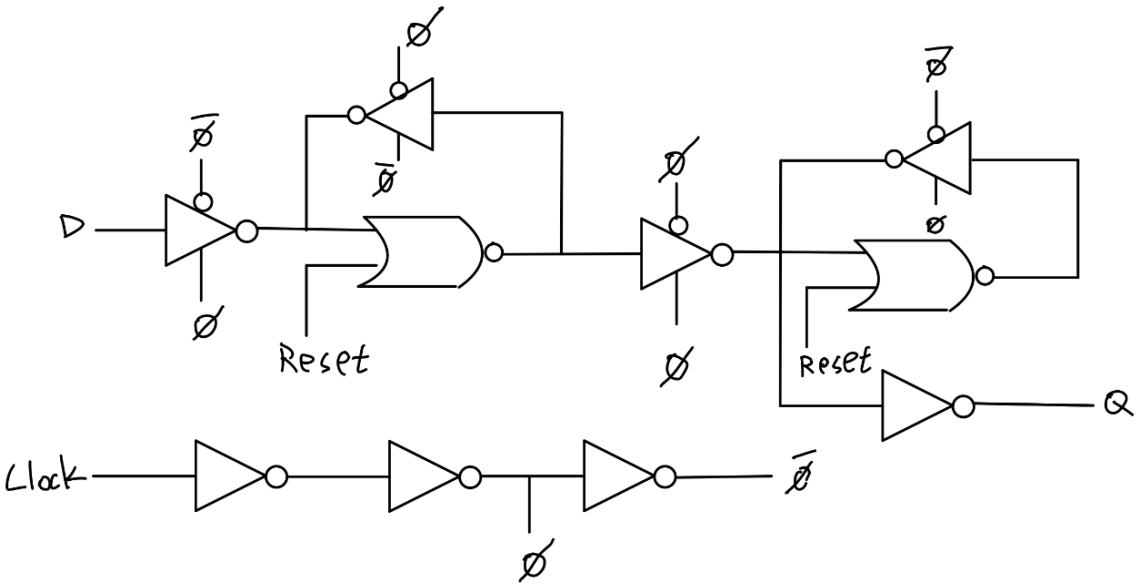
Width of DFF= 8.063 µm

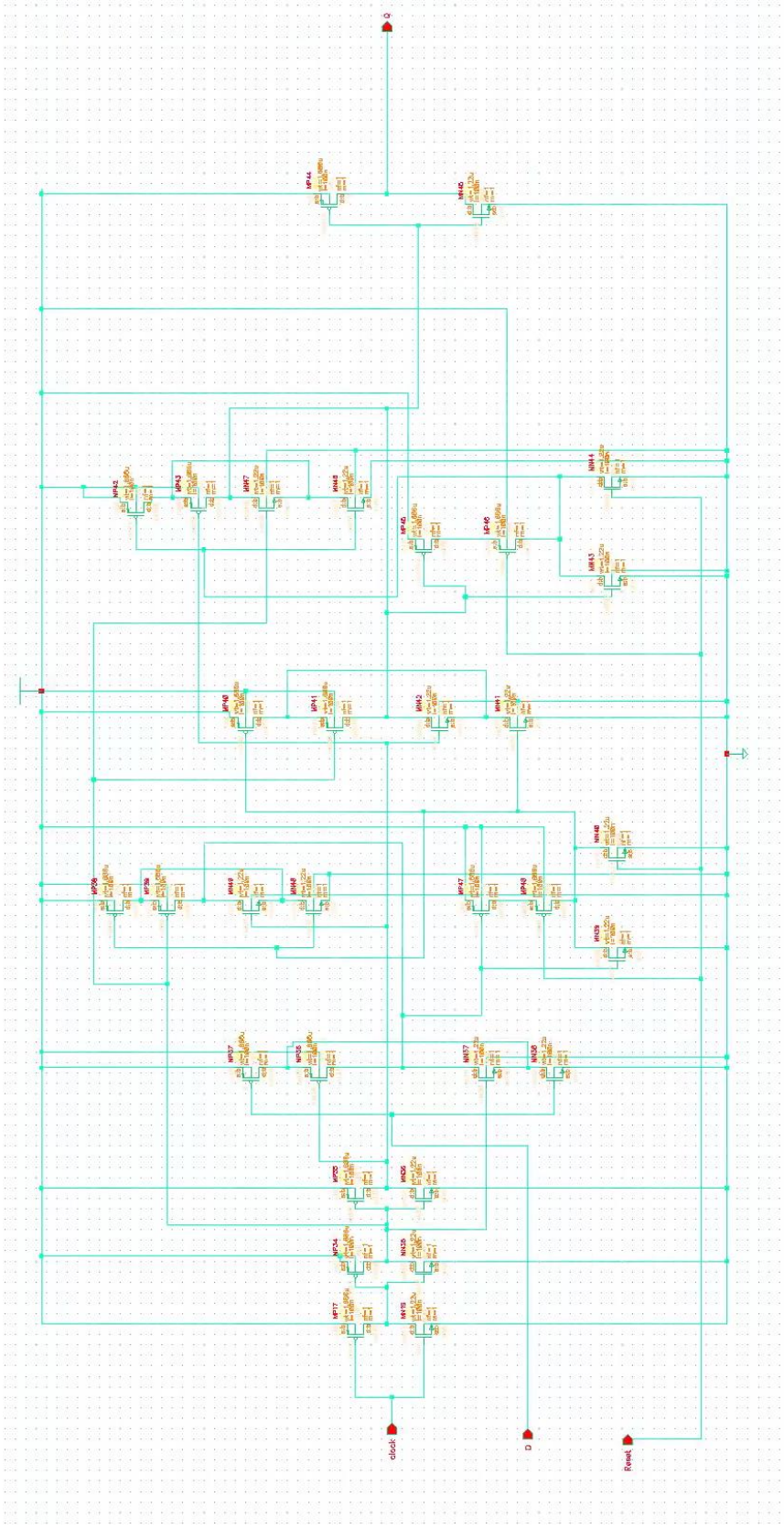
Area of DFF= 54.878 μm^2

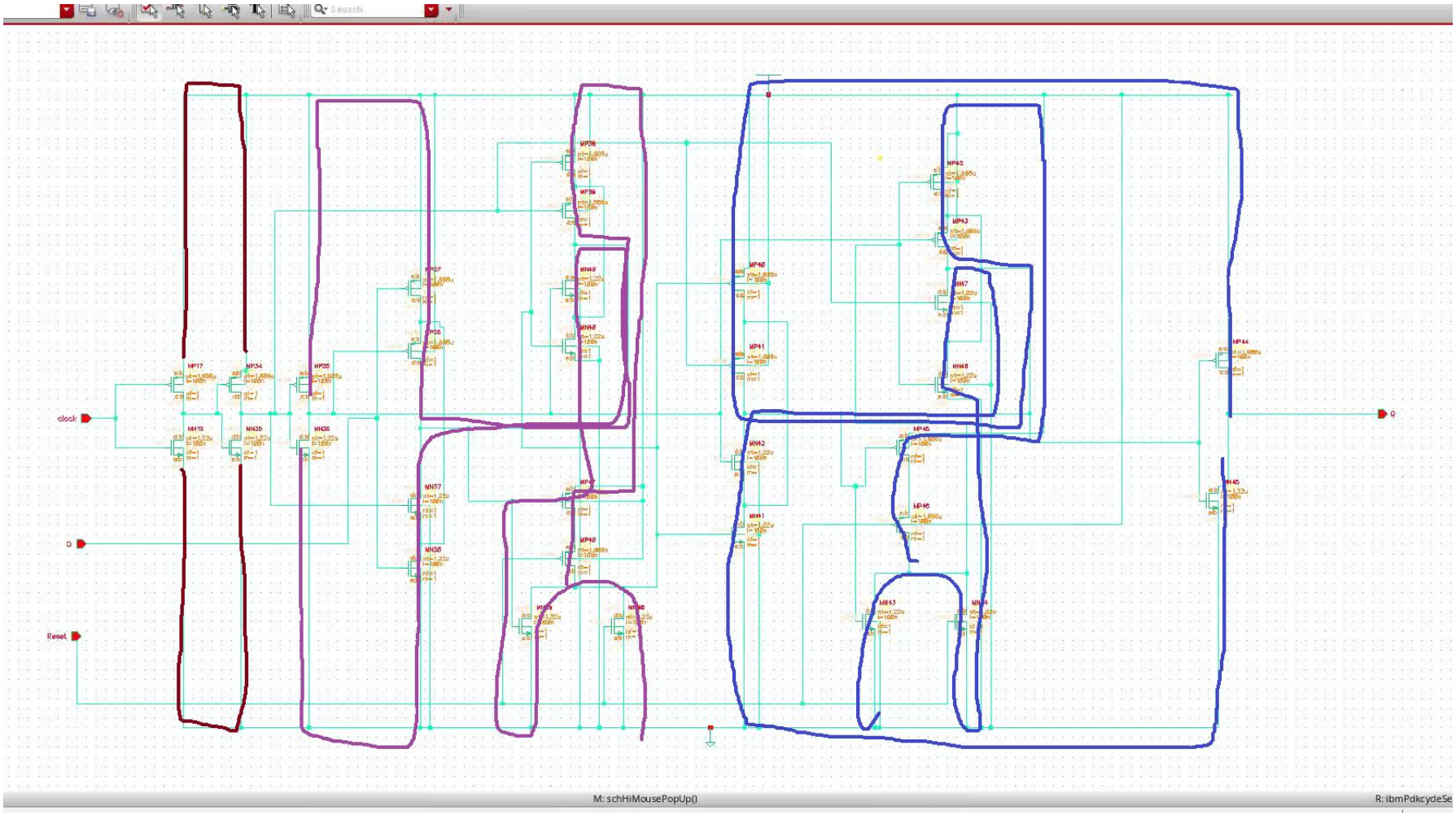
Number of Vertical M2 used in layout = 2

Number of Diffusion break in Layout =2

2. **Schematic**




Q
clock
D
Reset


clock
D
Reset
Q
MP17
MP34
MP35
MP36
MP37
MP38
MP39
MP40
MP41
MP42
MP43
MP44
MP45
MP46
MP47
MP48
MN15
MN35
MN36
MN37
MN38
MN39
MN40
MN41
MN42
MN43
MN44
MN45
MN47
MN48
M: schHiMousePopUp()
R: ibmPdkcycleSe

Euler paths

First trail : clock–$\overline{clock}$

Second trail : ϕ– D – $\bar{\phi}$ – out2– out1–reset

Third trail : Reset – out4 – $\bar{\phi}$ – ϕ – out2 –out3

3. Hspice

Checking the functionality to pass “1”

$example HSPICE setup file

$transistor model

.include "/proj/cad/library/mosis/GF65_LPe/cmos10lpe_CDS_oa_dl064_11_20160415/models/YI-SM00030/Hspice/models/design.inc"

.include DFF.pex.netlist

.global vdd! gnd!

.option post runlvl=5

xi GND! q VDD! clock d reset DFF

```
vdd vdd! gnd! 1.2v

vin clock gnd! pwl(0ns 0v 0.08ns 1.2v 1.5ns 1.2v 1.58ns 0v 3ns 0v 3.08ns 1.2v 4.5ns 1.2v 4.58ns 0v 6ns 0v 6.08ns 1.2v 7.5ns 1.2v 7.58ns 0v 9ns 0v 9.08ns 1.2v 10.5ns 1.2v 10.58ns 0v 12ns 0v)

vin2 d gnd! pwl(0ns 0v t 0v 't+80ps' 1.2v)

vin3 reset gnd! 0v

cout q gnd! 90f


$transient analysis

.tr 0.001ns 12ns sweep t 4.4ns 4.5ns 1ps

.measure tran tsu trig v(d) val=0.6v rise=1 targ v(clock) val=0.6v fall=2

.measure tran tclktoq trig v(clock) val=0.6v fall=2 targ v(q) val=0.6v rise=1

.measure tran td param='tsu+tclktoq'



.end
```

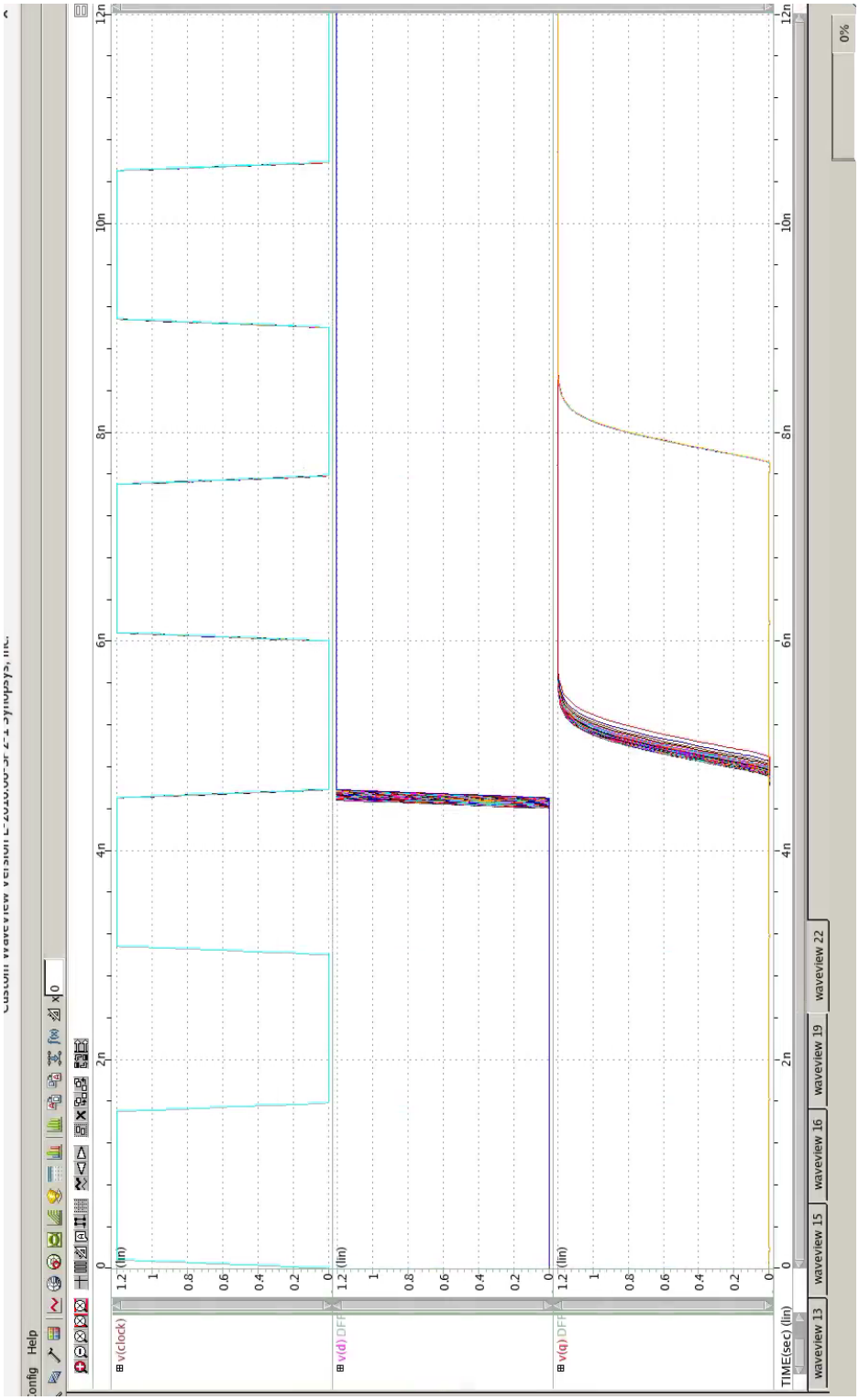
Checking the functionality to pass “0”

```
$example HSPICE setup file


$transistor model

.include
"/proj/cad/library/mosis/GF65_LPe/cmos10lpe_CDS_oa_dl064_11_20160415/models/YI-SM00030/Hspice/models/design.inc"

.include DFF.pex.netlist


.global vdd! gnd!

.option post runlvl=5
```

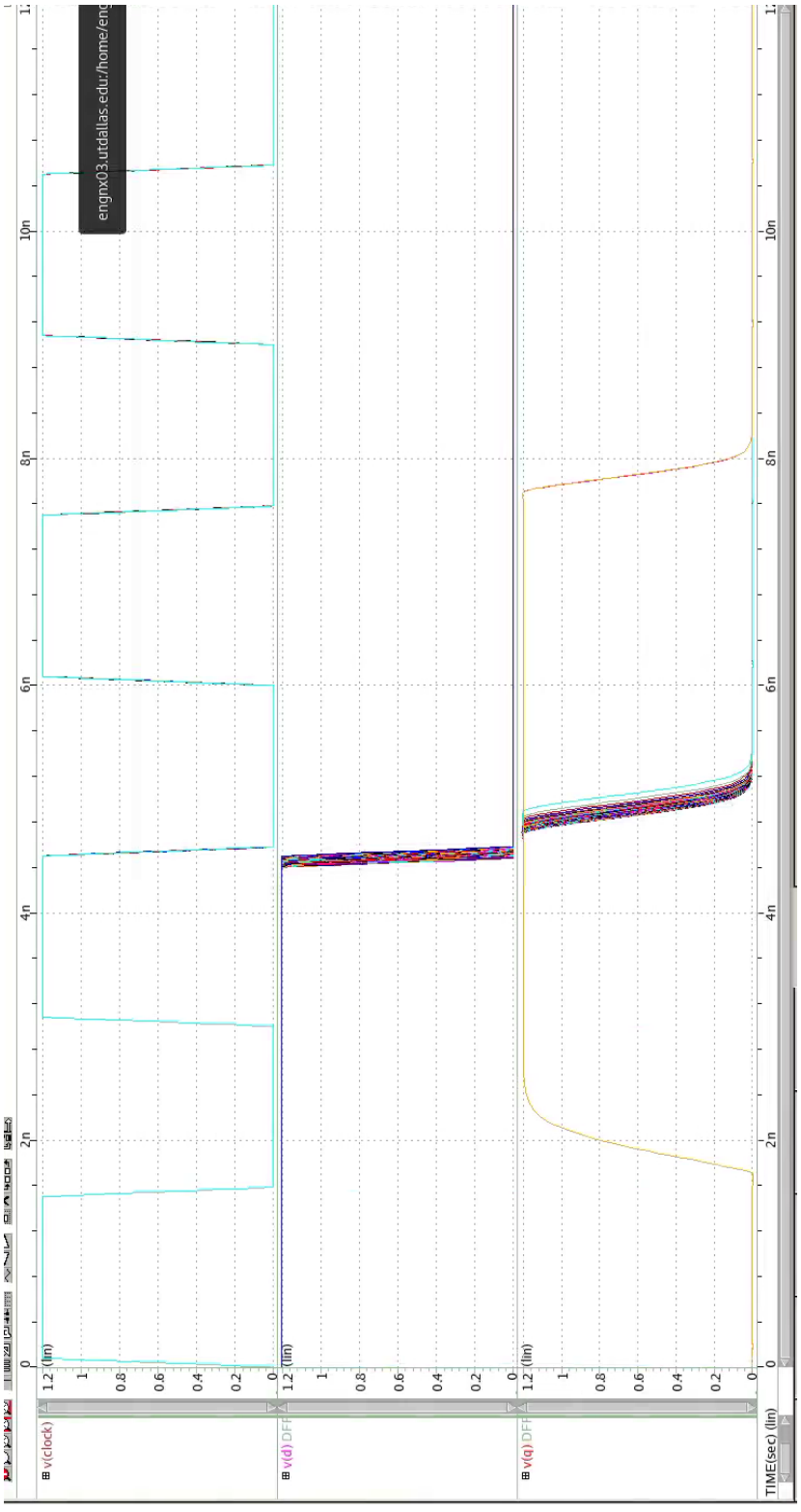
```
xi GND! q VDD! clock d reset DFF


vdd vdd! gnd! 1.2v

vin clock gnd! pwl(0ns 0v 0.08ns 1.2v 1.5ns 1.2v 1.58ns 0v 3ns 0v 3.08ns 1.2v 4.5ns 1.2v 4.58ns 0v 6ns 0v 6.08ns 1.2v 7.5ns 1.2v 7.58ns 0v 9ns 0v 9.08ns 1.2v 10.5ns 1.2v 10.58ns 0v 12ns 0v)

vin2 d gnd! pwl(0ns 1.2v t 1.2v 't+80ps' 0v)

vin3 reset gnd! 0v

cout q gnd! 90f


$transient analysis

.tr 0.001ns 12ns sweep t 4.4ns 4.5ns 1ps

.measure tran tsu trig v(d) val=0.6v fall=1 targ v(clock) val=0.6v fall=2

.measure tran tclktoq trig v(clock) val=0.6v fall=2 targ v(q) val=0.6v fall=1

.measure tran td param='tsu+tclktoq'
```

4. Waveform

Passing “1”



Passing “0”


engnx03.utdallas.edu:/home/eng
v(clock)
v(d) DFF
v(q) DFF
TIME(sec) (lin)
(lin)
0
2n
4n
6n
8n
10n
0.2
0.4
0.6
0.8
1
1.2

5. Measuring T_{su_opt} , T_{su_dd}, $T_{Clk \rightarrow Q}$, T_{delay}, T_{hold}

(1) Drop-dead setup time (T_{su_dd}):

How long before capturing edge that D must be stable

(2) Optimum setup time ($T_{su_{opt}}$):

T_{delay} is given by T_{su} +$T_{Clk \rightarrow Q}$. T_{delay} is minimum is called optimum setup time ($T_{su_{opt}}$)

(3) Hold time (T_{hold}):

How long after capturing edge that D must be stable

(4) Clock to Q time ($T_{Clk \rightarrow Q}$)

How long after capturing edge does the new output appear

Passing “o”

Time	$T_{su}(0)$	$T_{Clk \rightarrow Q}(0)$	$T_{delay}(0)$	$T_{hold}(0)$
$T_{su_{opt}}(0)$	30ps	354ps	384ps	
$T_{su\_dd}(0)$	2ps	517ps	519ps	20ps

DFF.sp | DFF.mt0

```
                25.0000         1
4.484e-09       1.600e-11        3.780e-10       3.940e-10
                25.0000         1
4.485e-09       1.500e-11        3.807e-10       3.957e-10
                25.0000         1
4.486e-09       1.400e-11        3.837e-10       3.977e-10
                25.0000         1
4.487e-09       1.300e-11        3.869e-10       3.999e-10
                25.0000         1
4.488e-09       1.200e-11        3.904e-10       4.024e-10
                25.0000         1
4.489e-09       1.100e-11        3.941e-10       4.051e-10
                25.0000         1
4.490e-09       1.000e-11        3.984e-10       4.084e-10
                25.0000         1
4.491e-09       9.000e-12        4.028e-10       4.118e-10
                25.0000         1
4.492e-09       8.000e-12        4.083e-10       4.163e-10
                25.0000         1
4.493e-09       7.000e-12        4.142e-10       4.212e-10
                25.0000         1
4.494e-09       6.000e-12        4.223e-10       4.283e-10
                25.0000         1
4.495e-09       5.000e-12        4.328e-10       4.378e-10
                25.0000         1
4.496e-09       4.000e-12        4.474e-10       4.514e-10
                25.0000         1
4.497e-09       3.000e-12        4.693e-10       4.723e-10
                25.0000         1
4.498e-09       2.000e-12        5.174e-10       5.194e-10
                25.0000         1
4.499e-09       1.000e-12        3.319e-09       3.320e-09
                25.0000         1
4.500e-09         0.             3.319e-09       3.319e-09
                25.0000         1
```

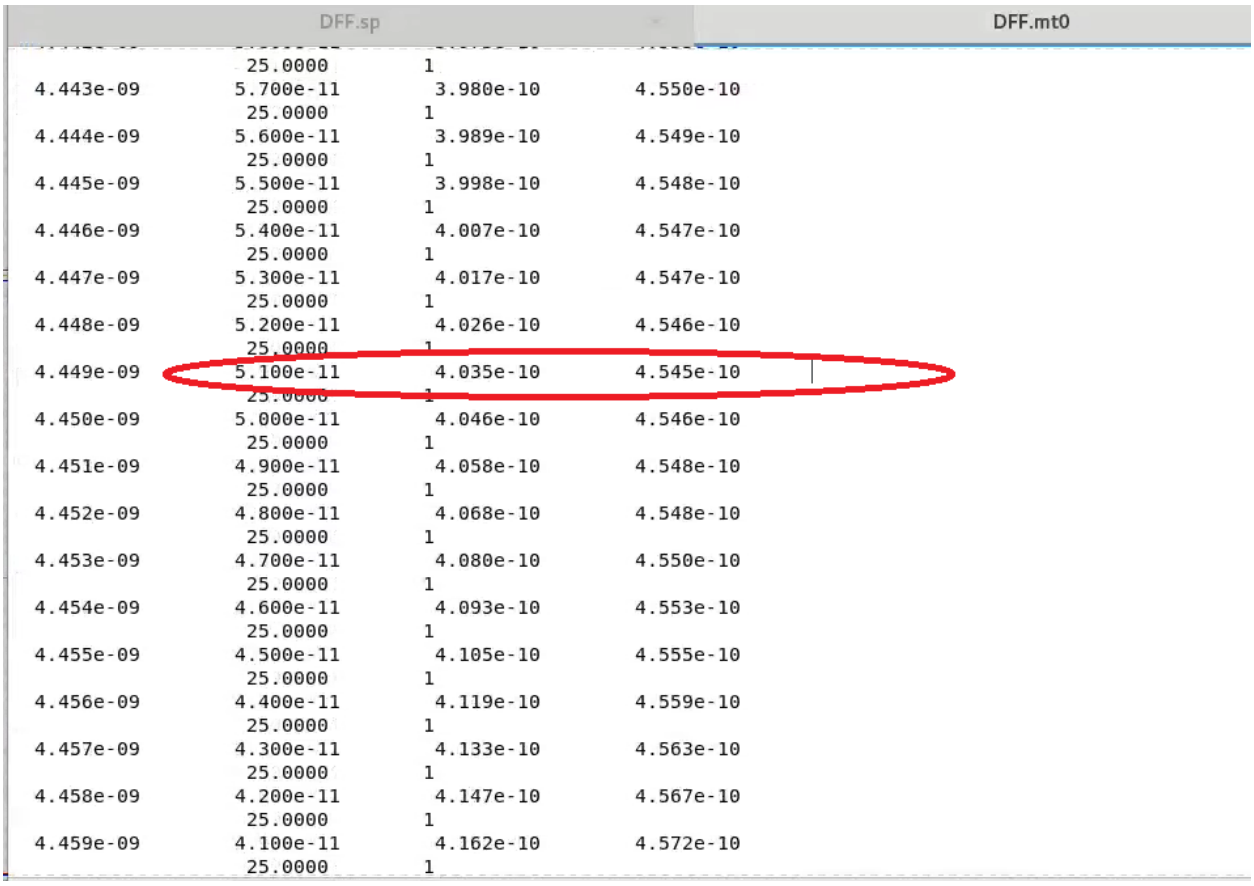
DFF.sp | DFF.mt0

```
4.463e-09       3.700e-11        3.484e-10       3.854e-10
                25.0000         1
4.464e-09       3.600e-11        3.492e-10       3.852e-10
                25.0000         1
4.465e-09       3.500e-11        3.501e-10       3.851e-10
                25.0000         1
4.466e-09       3.400e-11        3.510e-10       3.850e-10
                25.0000         1
4.467e-09       3.300e-11        3.519e-10       3.849e-10
                25.0000         1
4.468e-09       3.200e-11        3.529e-10       3.849e-10
                25.0000         1
4.469e-09       3.100e-11        3.539e-10       3.849e-10
                25.0000         1
4.470e-09       3.000e-11        3.549e-10       3.849e-10
                25.0000         1
4.471e-09       2.900e-11        3.560e-10       3.850e-10
                25.0000         1
4.472e-09       2.800e-11        3.571e-10       3.851e-10
                25.0000         1
4.473e-09       2.700e-11        3.583e-10       3.853e-10
                25.0000         1
4.474e-09       2.600e-11        3.595e-10       3.855e-10
                25.0000         1
4.475e-09       2.500e-11        3.608e-10       3.858e-10
                25.0000         1
4.476e-09       2.400e-11        3.622e-10       3.862e-10
                25.0000         1
4.477e-09       2.300e-11        3.636e-10       3.866e-10
                25.0000         1
4.478e-09       2.200e-11        3.652e-10       3.872e-10
                25.0000         1
4.479e-09       2.100e-11        3.670e-10       3.880e-10
                25.0000         1
4.480e-09       2.000e-11        3.689e-10       3.889e-10
```

Passing “1”

Time	$T_{su}(1)$	$T_{Clk\rightarrow Q}(1)$	$T_{delay}(1)$	$T_{hold}(1)$
$T_{su\_opt}(1)$	51ps	403ps	454ps	
$T_{su\_dd}(1)$	20ps	570ps	590ps	2ps

4.469e-09	3.100e-11	25.0000	4.379e-10	4.689e-10
		1		
4.470e-09	3.000e-11	25.0000	4.415e-10	4.715e-10
		1		
4.471e-09	2.900e-11	25.0000	4.457e-10	4.747e-10
		1		
4.472e-09	2.800e-11	25.0000	4.504e-10	4.784e-10
		1		
4.473e-09	2.700e-11	25.0000	4.553e-10	4.823e-10
		1		
4.474e-09	2.600e-11	25.0000	4.614e-10	4.874e-10
		1		
4.475e-09	2.500e-11	25.0000	4.685e-10	4.935e-10
		1		
4.476e-09	2.400e-11	25.0000	4.777e-10	5.017e-10
		1		
4.477e-09	2.300e-11	25.0000	4.893e-10	5.123e-10
		1		
4.478e-09	2.200e-11	25.0000	5.041e-10	5.261e-10
		1		
4.479e-09	2.100e-11	25.0000	5.272e-10	5.482e-10
		1		
4.480e-09	2.000e-11	25.0000	5.704e-10	5.904e-10
		1		
4.481e-09	1.900e-11	25.0000	3.382e-09	3.401e-09
		1		
4.482e-09	1.800e-11	25.0000	3.382e-09	3.400e-09
		1		
4.483e-09	1.700e-11	25.0000	3.381e-09	3.398e-09
		1		
4.484e-09	1.600e-11	25.0000	3.381e-09	3.397e-09
		1		
4.485e-09	1.500e-11	25.0000	3.382e-09	3.397e-09
		1		
4.486e-09	1.400e-11		3.382e-09	3.396e-09


DFF.sp
DFF.mt0
25.0000 1
4.443e-09 5.700e-11 3.980e-10 4.550e-10
25.0000 1
4.444e-09 5.600e-11 3.989e-10 4.549e-10
25.0000 1
4.445e-09 5.500e-11 3.998e-10 4.548e-10
25.0000 1
4.446e-09 5.400e-11 4.007e-10 4.547e-10
25.0000 1
4.447e-09 5.300e-11 4.017e-10 4.547e-10
25.0000 1
4.448e-09 5.200e-11 4.026e-10 4.546e-10
25.0000 1
4.449e-09 5.100e-11 4.035e-10 4.545e-10
25.0000 1
4.450e-09 5.000e-11 4.046e-10 4.546e-10
25.0000 1
4.451e-09 4.900e-11 4.058e-10 4.548e-10
25.0000 1
4.452e-09 4.800e-11 4.068e-10 4.548e-10
25.0000 1
4.453e-09 4.700e-11 4.080e-10 4.550e-10
25.0000 1
4.454e-09 4.600e-11 4.093e-10 4.553e-10
25.0000 1
4.455e-09 4.500e-11 4.105e-10 4.555e-10
25.0000 1
4.456e-09 4.400e-11 4.119e-10 4.559e-10
25.0000 1
4.457e-09 4.300e-11 4.133e-10 4.563e-10
25.0000 1
4.458e-09 4.200e-11 4.147e-10 4.567e-10
25.0000 1
4.459e-09 4.100e-11 4.162e-10 4.572e-10
25.0000 1