VLSI HW3 105061213

(a)

先根據.captab 可以得到第一個 inverter 的 input capacitance

```
   node     =     cap
+0:in       =   3.9284f
```

$$d = f + p$$

$$p = 1, \text{for inverter}$$

$$F = GH = 38183$$

$$G = 1, \text{for inverter chain}$$

$$H = \frac{c_{out}}{c_{in}} = \frac{150pf}{3.9284ff} = 38183$$

$$F = GH = 38183$$

$$f = \sqrt[n]{F} = \sqrt[n]{38183}$$

n	f	D = n(f+p)
3	33.67	104.02
5	8.29	46.24
7	4.51	38.60
9	3.23	38.06
11	2.61	39.7

所以最後選 n=9，f = 3.23

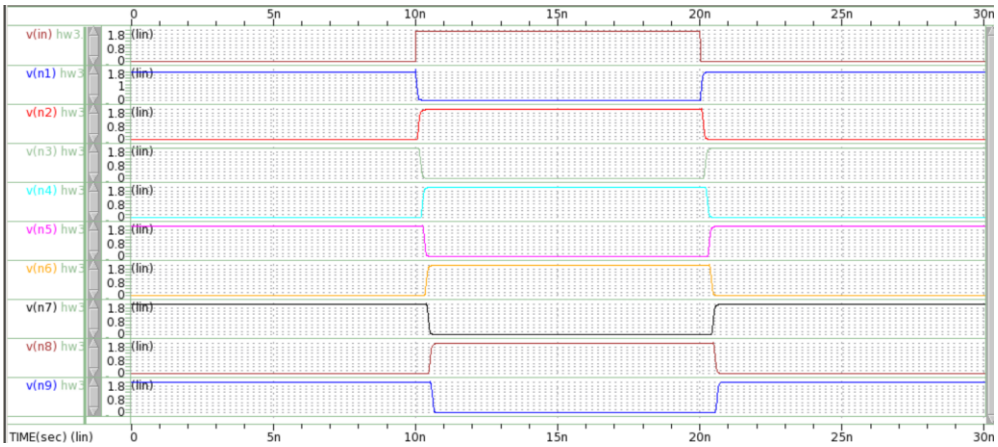
$$\frac{W_{inv\_2}}{W_{inv\_1}} = \frac{W_{inv\_3}}{W_{inv\_2}} = \frac{W_{inv\_4}}{W_{inv\_3}} = \frac{W_{inv\_5}}{W_{inv\_4}} = \frac{W_{inv\_6}}{W_{inv\_5}} = \frac{W_{inv\_7}}{W_{inv\_6}} = \frac{W_{inv\_8}}{W_{inv\_7}} = \frac{W_{inv\_9}}{W_{inv\_8}} = 3.23$$

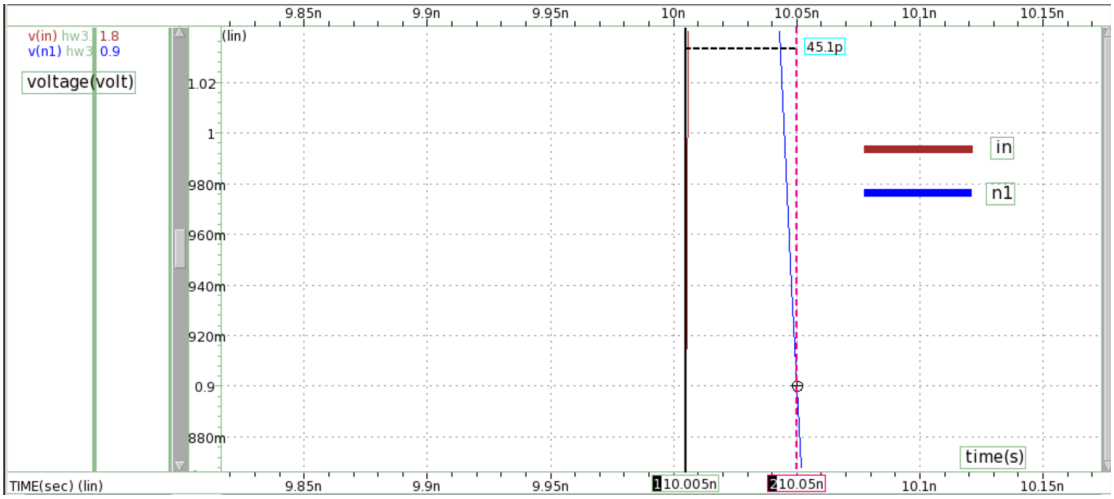
(b)

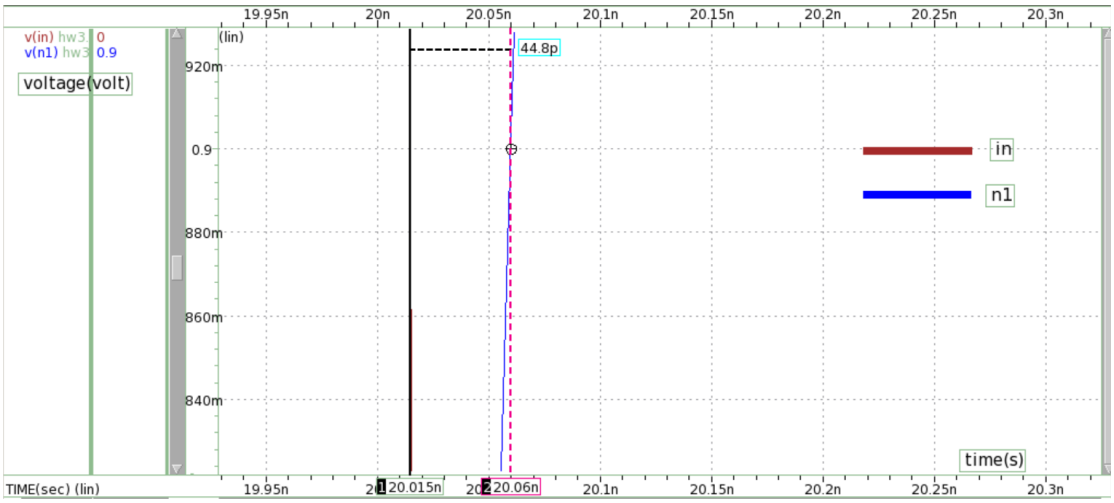
設定 n1 是 inverter_1 的 drain ；n2 是 inverter_2 的 drain ……以此類推

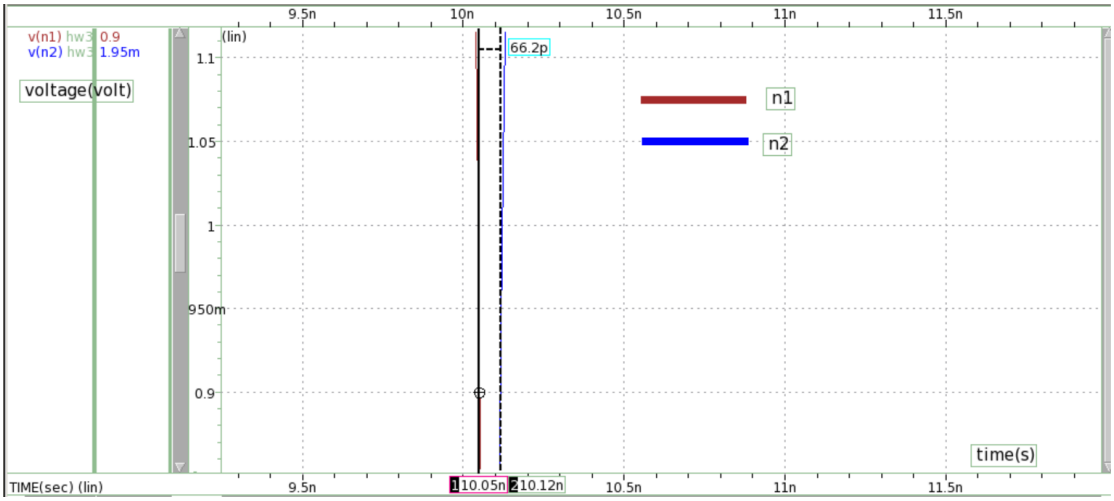
n9 是 inverter_9 的 drain

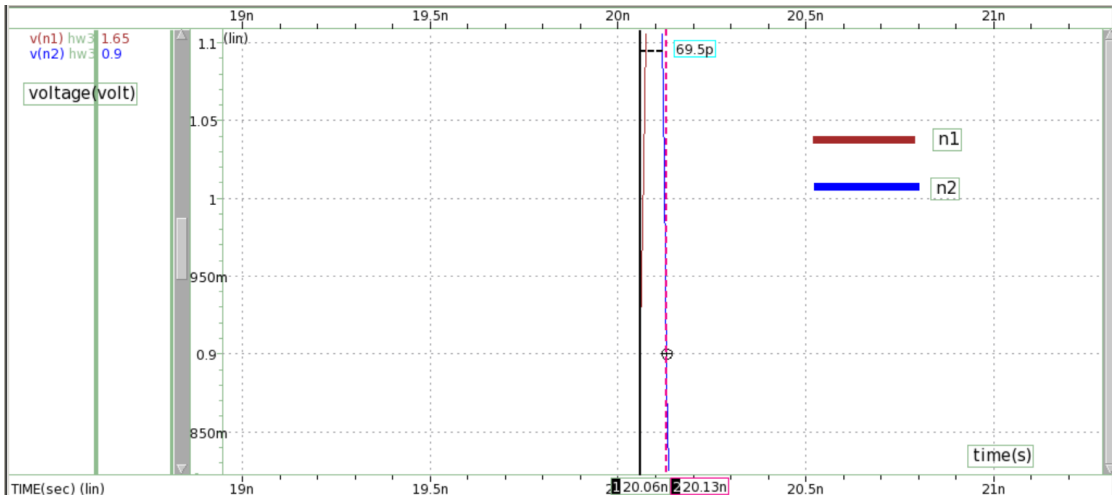
waveforms:

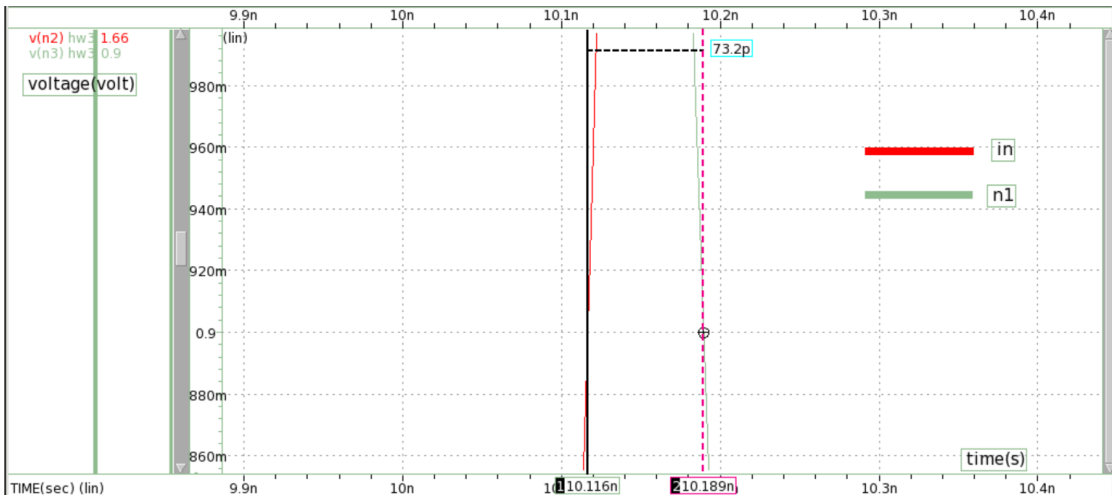


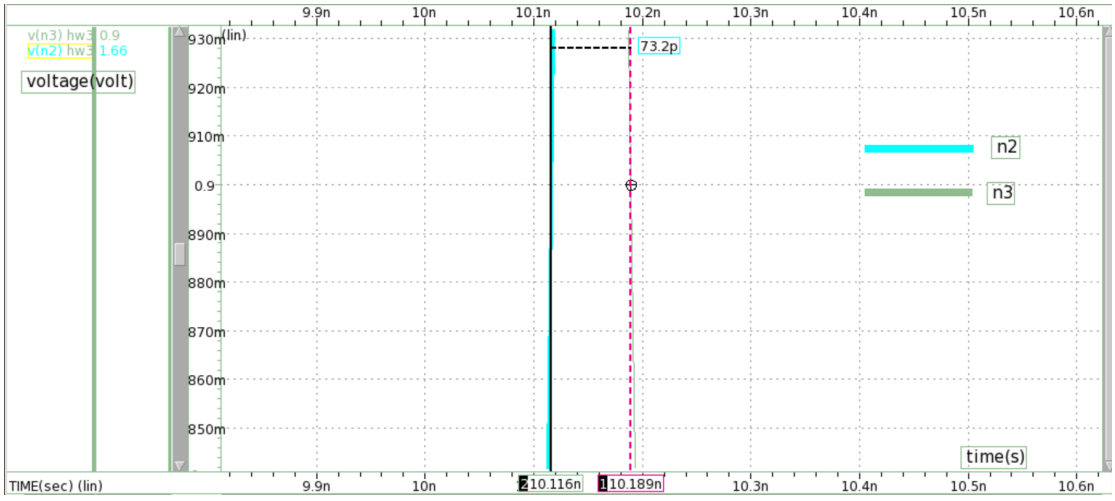

v(in) hw3 1.8
v(n1) hw3 0.9
voltage(volt)
(lin)
45.1p
in
n1
time(s)
TIME(sec) (lin)
10.005n
10.05n

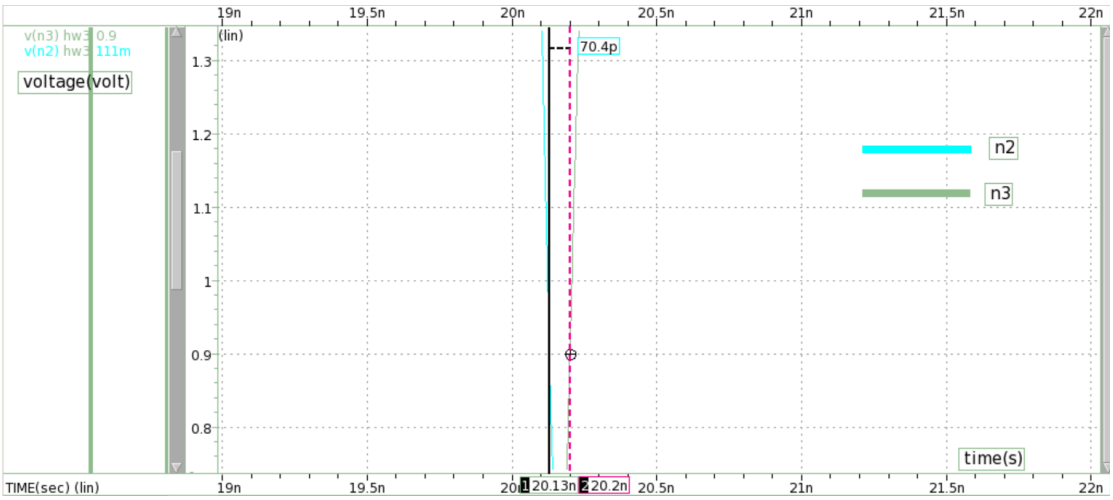

v(in) hw3 0
v(n1) hw3 0.9
voltage(volt)
(lin)
44.8p
in
n1
time(s)
TIME(sec) (lin)
20.015n
20.06n

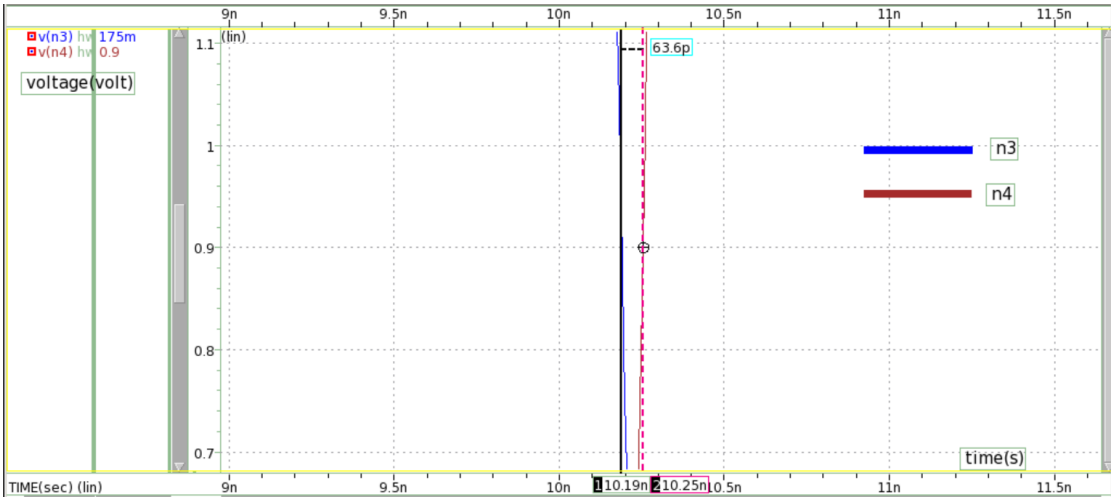

v(n1) hw3 0.9
v(n2) hw3 1.95m
voltage(volt)
(lin)
66.2p
n1
n2
time(s)
TIME(sec) (lin)
10.05n
10.12n

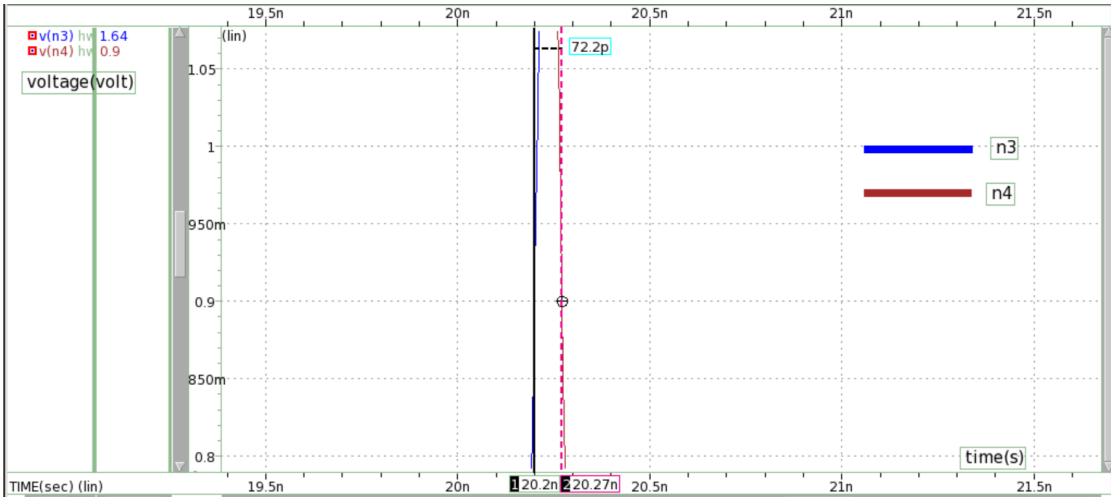

v(n1) hw3 1.65
v(n2) hw3 0.9
voltage(volt)
(lin)
69.5p
n1
n2
time(s)
TIME(sec) (lin)
20.06n
20.13n

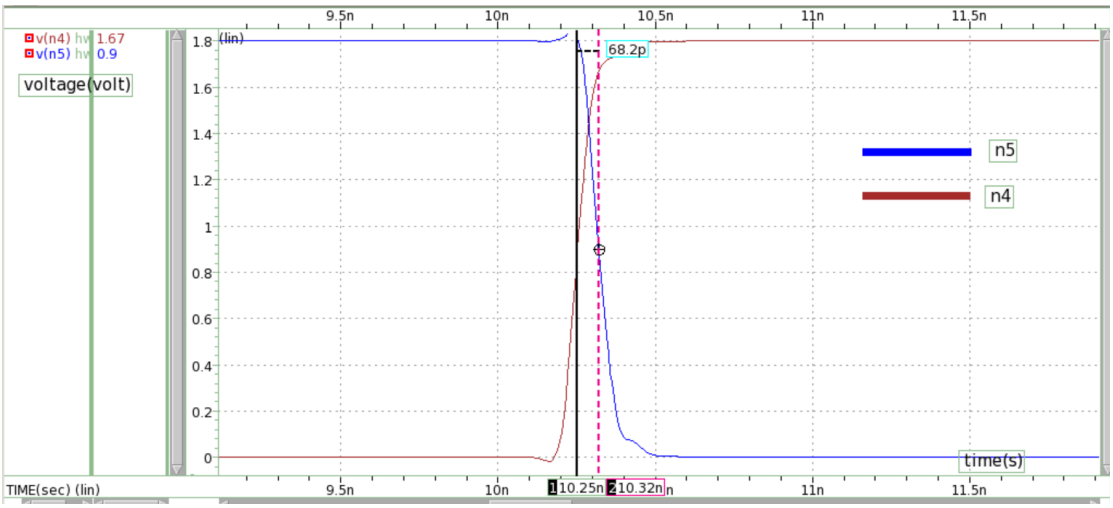

v(n2) hw3 1.66
v(n3) hw3 0.9
voltage(volt)
(lin)
73.2p
in
n1
time(s)
TIME(sec) (lin)
10.116n
10.189n

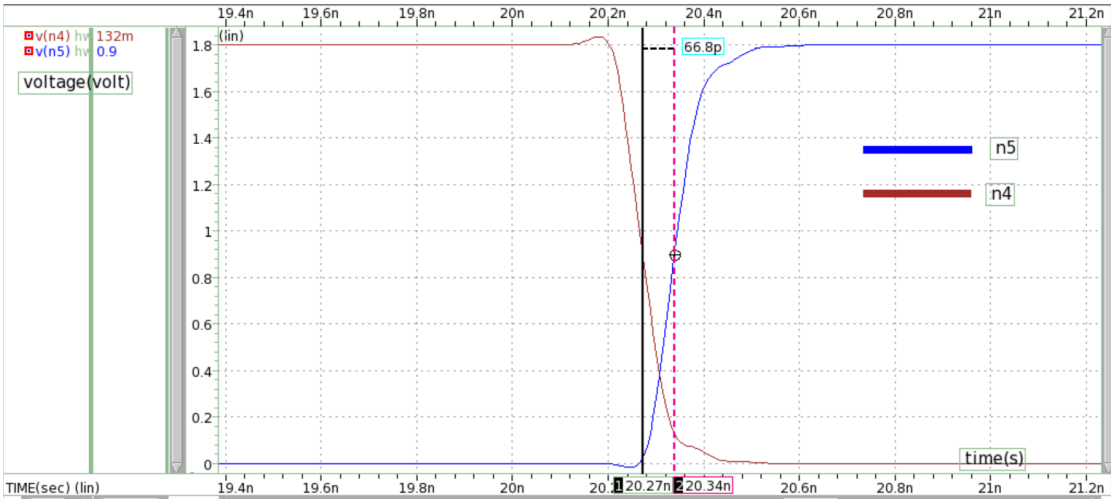

v(n3) hw3 0.9
v(n2) hw3 1.66
voltage(volt)
(lin)
73.2p
n2
n3
time(s)
TIME(sec) (lin)
10.116n
10.189n

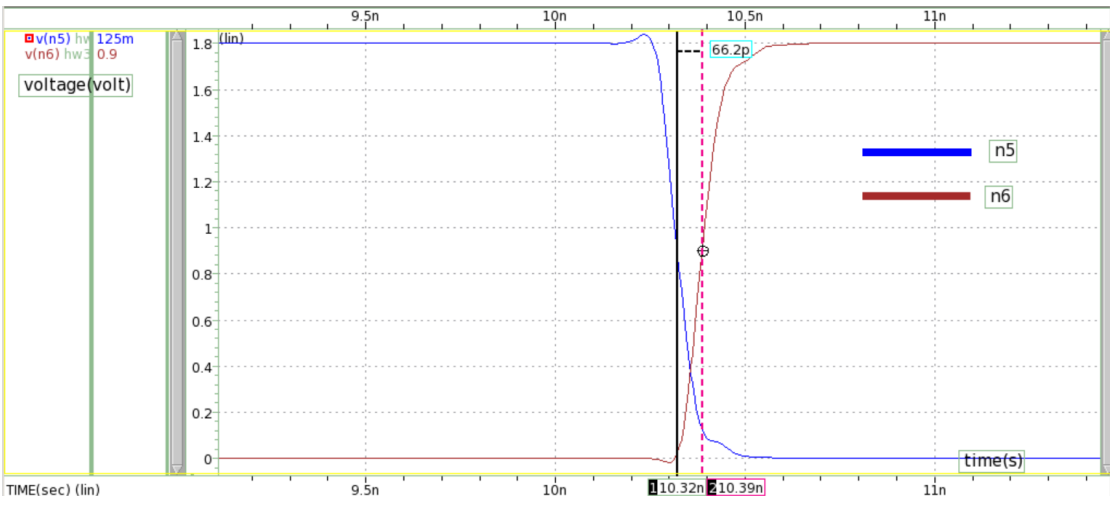

v(n3) hw3 0.9
v(n2) hw3 111m
voltage(volt)
(lin)
70.4p
n2
n3
time(s)
TIME(sec) (lin)
1 20.13n 2 20.2n

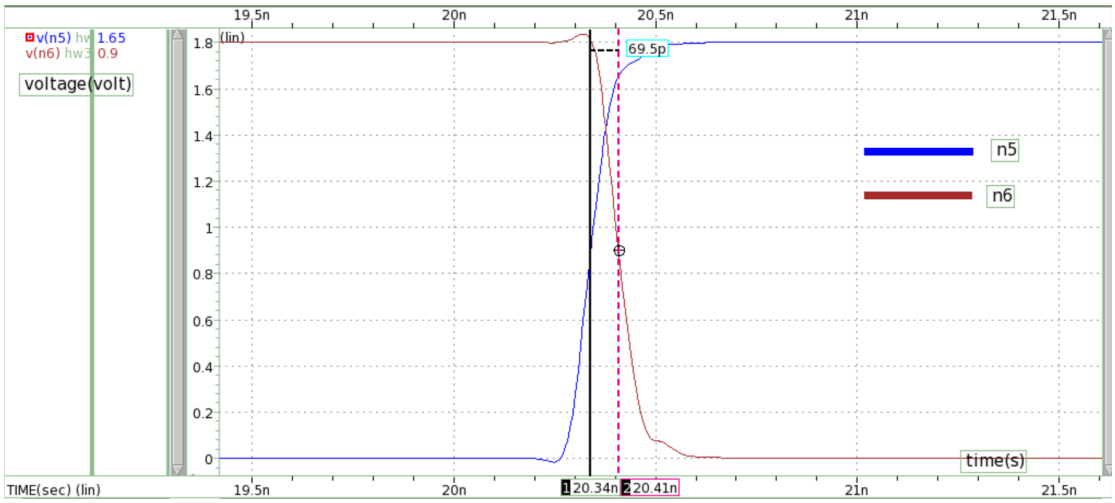

v(n3) hw 175m
v(n4) hw 0.9
voltage(volt)
(lin)
63.6p
n3
n4
time(s)
TIME(sec) (lin)
1 10.19n 2 10.25n

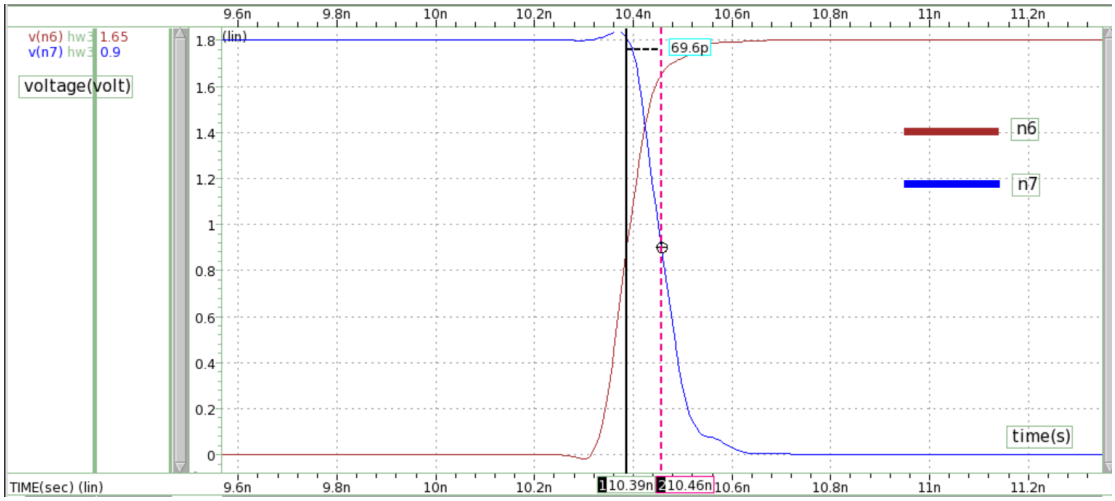

v(n3) hw 1.64
v(n4) hw 0.9
voltage(volt)
(lin)
72.2p
n3
n4
time(s)
TIME(sec) (lin)
1 20.2n 2 20.27n

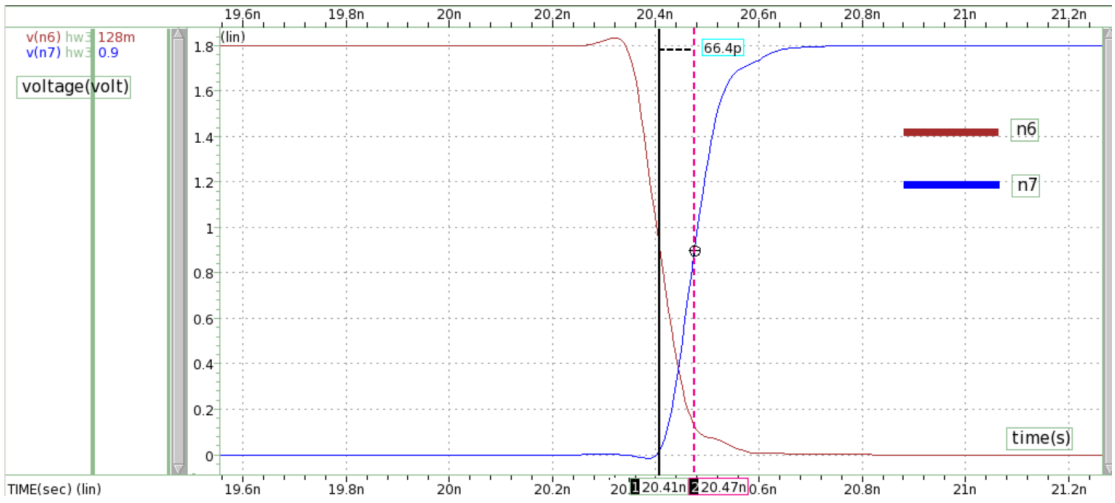

v(n4) hw 1.67
v(n5) hw 0.9
voltage(volt)
(lin)
68.2p
n5
n4
time(s)
TIME(sec) (lin)
10.25n
10.32n

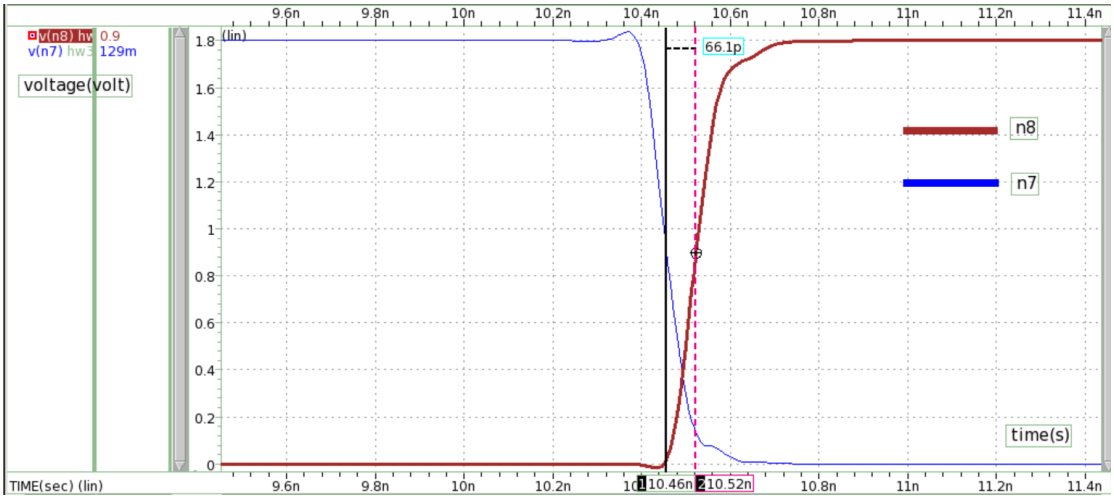

v(n4) hw 132m
v(n5) hw 0.9
voltage(volt)
(lin)
66.8p
n5
n4
time(s)
TIME(sec) (lin)
20.27n
20.34n

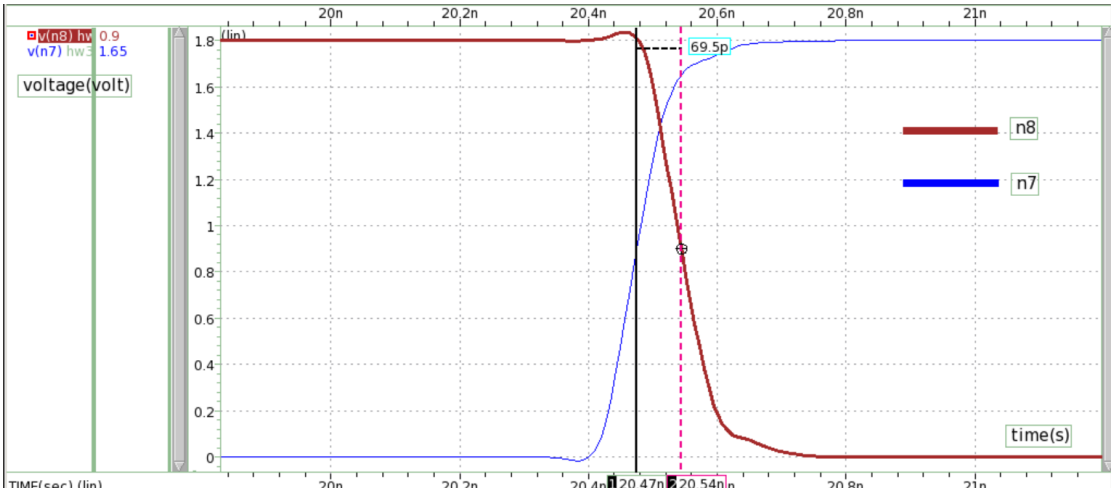

v(n5) hw 125m
v(n6) hw 0.9
voltage(volt)
(lin)
66.2p
n5
n6
time(s)
TIME(sec) (lin)
10.32n
10.39n

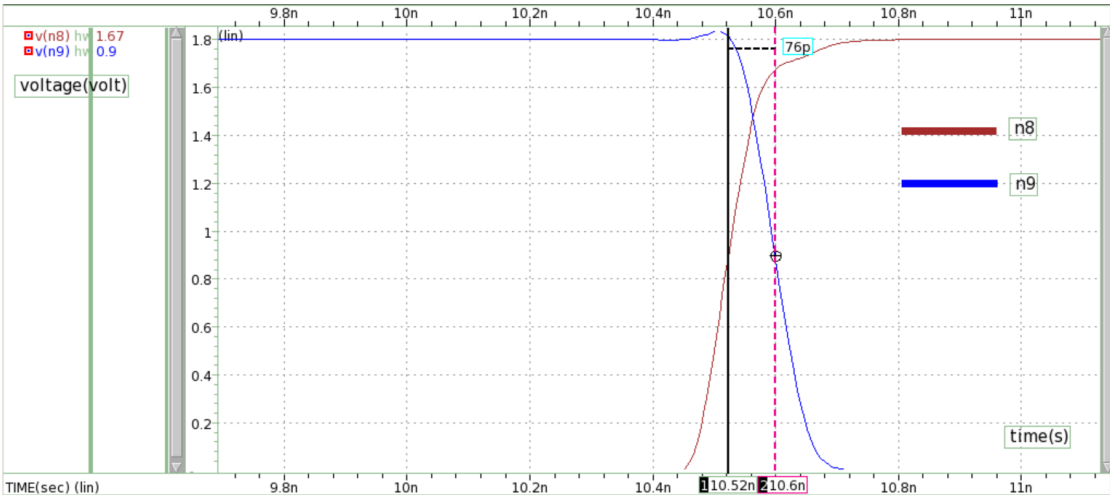

v(n5) hw 1.65
v(n6) hw 0.9
voltage(volt)
(lin)
69.5p
n5
n6
time(s)
TIME(sec) (lin)
1 20.34n 2 20.41n

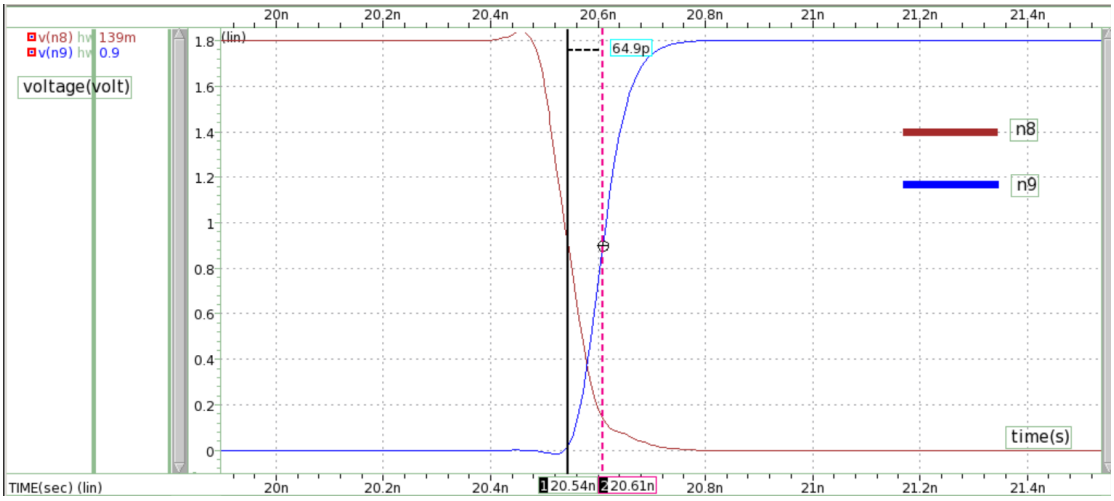

v(n6) hw 1.65
v(n7) hw 0.9
voltage(volt)
(lin)
69.6p
n6
n7
time(s)
TIME(sec) (lin)
1 10.39n 2 10.46n


v(n6) hw 128m
v(n7) hw 0.9
voltage(volt)
(lin)
66.4p
n6
n7
time(s)
TIME(sec) (lin)
1 20.41n 2 20.47n


v(n8) hw 0.9
v(n7) hw 129m
voltage(volt)
9.6n 9.8n 10n 10.2n 10.4n 10.6n 10.8n 11n 11.2n 11.4n
(lin)
66.1p
n8
n7
time(s)
TIME(sec) (lin)
10.46n
10.52n


v(n8) hw 0.9
v(n7) hw 1.65
voltage(volt)
20n 20.2n 20.4n 20.6n 20.8n 21n
(lin)
69.5p
n8
n7
time(s)
20.47n
20.54n


v(n8) hw 1.67
v(n9) hw 0.9
voltage(volt)
9.8n 10n 10.2n 10.4n 10.6n 10.8n 11n
(lin)
76p
n8
n9
time(s)
TIME(sec) (lin)
10.52n
10.6n



Delay:

```
n1_r=   44.9183p   targ=   20.0599n    trig=   20.0150n
n1_f=   45.0634p   targ=   10.0501n    trig=   10.0050n
n2_r=   66.2357p   targ=   10.1163n    trig=   10.0501n
n2_f=   69.4684p   targ=   20.1294n    trig=   20.0599n
n3_r=   66.8090p   targ=   20.1962n    trig=   20.1294n
n3_f=   70.2107p   targ=   10.1865n    trig=   10.1163n
n4_r=   67.0512p   targ=   10.2536n    trig=   10.1865n
n4_f=   69.5781p   targ=   20.2658n    trig=   20.1962n
n5_r=   66.7778p   targ=   20.3326n    trig=   20.2658n
n5_f=   69.5702p   targ=   10.3231n    trig=   10.2536n
n6_r=   66.7783p   targ=   10.3899n    trig=   10.3231n
n6_f=   69.5423p   targ=   20.4021n    trig=   20.3326n
n7_r=   66.6951p   targ=   20.4688n    trig=   20.4021n
n7_f=   69.5812p   targ=   10.4595n    trig=   10.3899n
n8_r=   66.6785p   targ=   10.5262n    trig=   10.4595n
n8_f=   69.5133p   targ=   20.5383n    trig=   20.4688n
n9_r=   65.1093p   targ=   20.6034n    trig=   20.5383n
n9_f=   75.9664p   targ=   10.6021n    trig=   10.5262n
in_to_n9_r= 588.4115p   targ=   20.6034n    trig=   20.0150n
in_to_n9_f= 597.1356p   targ=   10.6021n    trig=   10.0050n
```

除了 n1 的 delay 受到 input 的上升和下降斜率影響外，其他 delay 都很接近。

把每一級 delay 相加得到 in_to_n9_r 和 in_to_n9_f

Capacitance:

```
+0:in       =    3.9284f 0:n1       =   14.4755f 0:n2       =   51.0287f
+0:n3       =  148.2031f 0:n4       =  530.2817f 0:n5       =    1.5455p
+0:n6       =    5.5322p 0:n7       =   16.1235p 0:n8       =   57.7151p
+0:n9       =  210.0739p 0:vd       =  126.3472p
```

(c)

因為拿掉電壓源後的 n9 要接回到 in 的點
可以用還沒拿掉電壓源的 in 到 n9 的 rise_delay 和 fall_delay 相加得到拿掉電壓源後的周期
根據(b)的結果，in_to_n9_rise_delay = 588.4115p,in_to_n9_fall_delay = 597.1356p
所以週期 T= 597.1356p+588.4115p = 1185.5471ps

Frequency = $\frac{1}{1185.5471p} \cong 0.843(GHZ)$

(d)

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
t=   1.2283n  targ=  12.3942n   trig=  11.1659n
```

週期 T= 1.2283ns

Frequency = $\frac{1}{1.2283n} \cong 0.814(GHZ)$

手算值 = $0.843(GHZ)$

誤差百分比 = $\frac{0.843-0.814}{0.814} \times 100\% = 3.56\%$

因為 inver_chain 的最後面(n9)要接回到最前面，所以對 n9 而言會看到比原本還要多的電容，因此充放電的時間比較久，頻率也下降了。

(e)

Dynamic power:

根據$\mathrm{P} = \alpha \mathrm{C} V^2 f$

因為每個 node 的值都是一起變的所以$\alpha = 1$

然後把每一個 node 的電容值加起來得到$\mathrm{C} = 236.792\mathrm{ps}$

根據(d)小題 $\mathrm{f} = 0.814(\mathrm{GHZ})$

$$\mathrm{P} = \alpha \mathrm{C} V^2 f = 0.6229(W)$$

因為 static power 相較 dynamic power 過於微小，所以省略

(f)

```
****** transient analysis tnom=  25.000 temp=  25.000 ***
t=   1.2283n  targ=  12.3942n   trig=  11.1659n
avg_power= 769.0878m  from=  11.1659n     to=  12.3942n
```

模擬的值 = 769.0878(mW)

手算 dynamic power 值 = 0.6229(W)

誤差百分比 = $\frac{0.7691-0.6229}{0.7691} \times 100\% = 19\%$

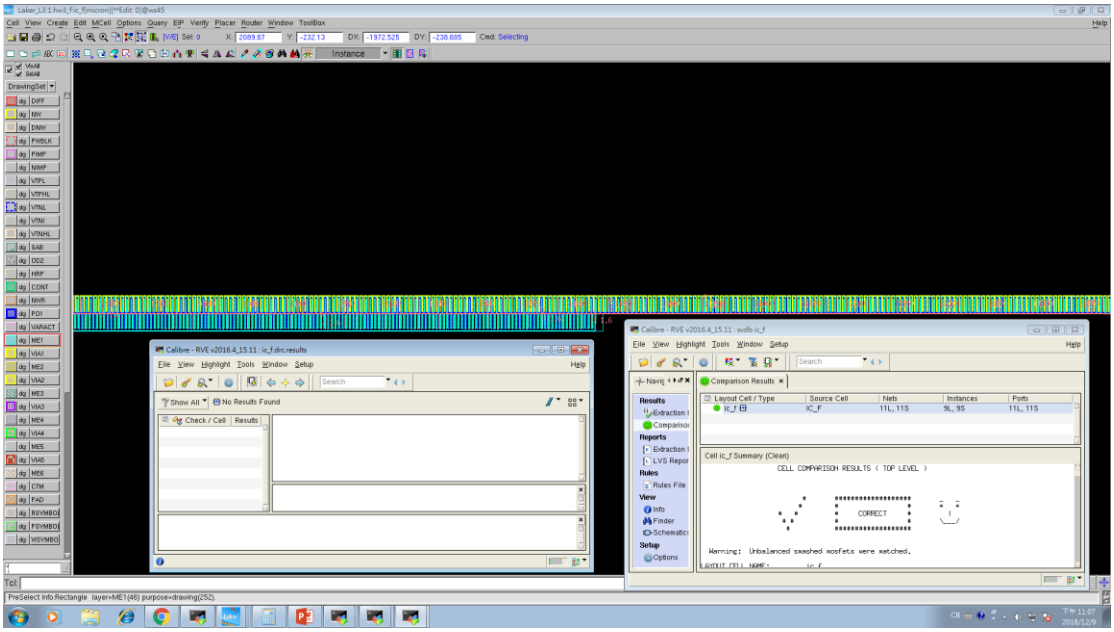
(i)手算值只有算到 dynamic_power 而忽略了 static_power。

(ii)其實 VDD 這個點也有寄生電容充放電會消耗能量，但是我們手算的都只有算 mos 的 drain 的電容消耗的能量。

綜上兩點，手算的數值與模擬值有出入

(g)

Drc&lvs



當我在畫 layout 的時候把每個 mos 都畫得很近，減少 metal(線)的長度，為了能減少 parasitic capacitor 和 resistor。

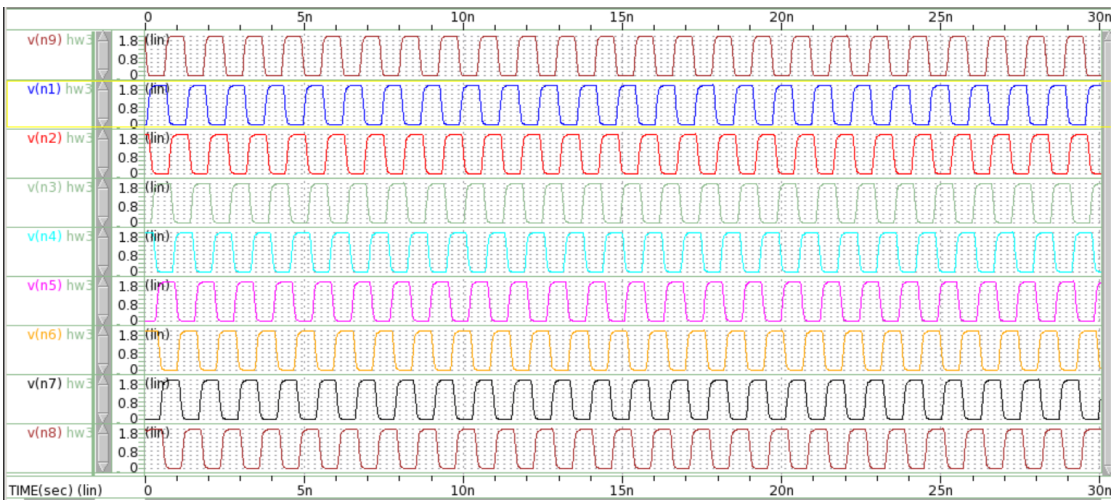
但是兩條平行的 metal 卻不能離太近，避免有 cross delay。

正常來說，我們都會把所有並聯的 mos 擺在同一塊 diffusion region 上，減少寄生電容。但是因為要方便做作業的關係，只能採取一塊 diffusion region 上只並聯兩個 mos。

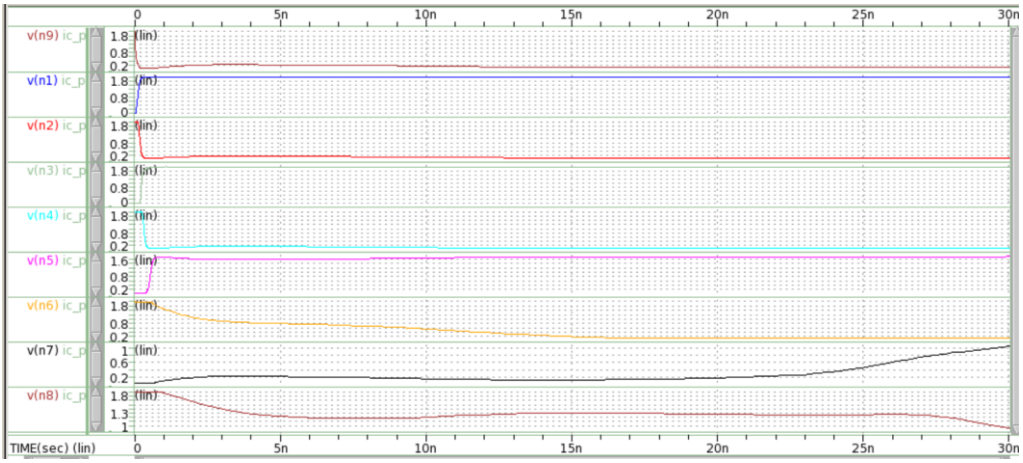
可能是 delay 太久了，所以找不到頻率和 power comsuption。

由於導線太長、並聯的畫法不是最佳的等種種原因，所以這個 oscillation_frequency 相當的低，波型看起來也不正常，跟 presim 的結果天差地遠。

Presim:



Posim:


0
5n
10n
15n
20n
25n
30n
v(n9) ic_p
v(n1) ic_p
v(n2) ic_p
v(n3) ic_p
v(n4) ic_p
v(n5) ic_p
v(n6) ic_p
v(n7) ic_p
v(n8) ic_p
1.8 (lin)
0.8
0.2
0
1.6 (lin)
1 (lin)
0.6
1.3
1
TIME(sec) (lin)