HSPICE notes

drx
H-1

Hspice manual
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```
p 2-2 (52)  quickAC.sp
8-2 (312)   .OPTIONS LIST NODE POST
9-6 (360)   .OP
11-4 (456)  .AC dec 10 1k 1Meg
7-4 (250)   .print ac v(1) v(2) i(r2) i(c1)
5-6 (152)   v1 1 0 10 ac 1
4-2 (120)   r1 1 2 1k
            r2 2 0 1k
4-4 (122)   c1 2 0 .001u
            .end
```

```
hspice quickAC.sp > quickAC.lis
  quickAC.acφ    binary for GUI output
         .icφ    initial conditions
         .stφ    status
         .lis    output
```

```
2-7 (57)    quickINV.sp                  new statements
10-4 (412)  .tran 200p 20N
17-4 (730)  m1 out in vcc vcc pch L=1U W=20U
            vcc vcc 0 5
5-7 (153)   Vin in 0 0 PULSE .2 4.8 2N 1N 1N 5N 20N
3-29 (87)   .model pch pmos level=1
18-1# (845)
```

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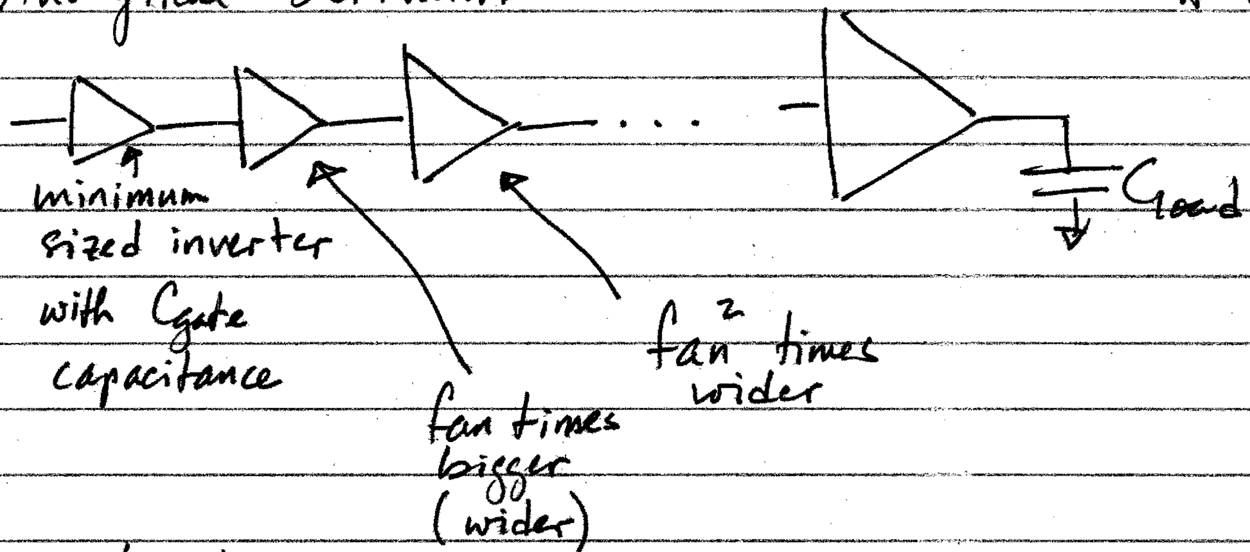
H-2

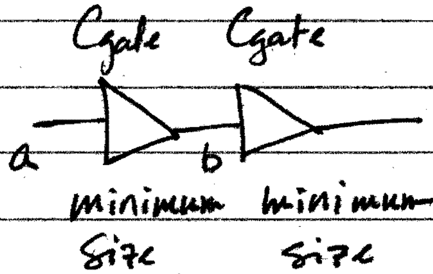
InvChain.sp   new statements

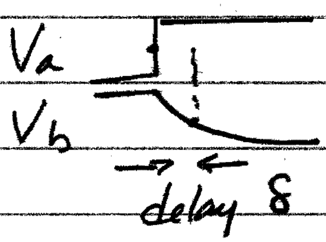
```
3-32 (90)   .lib 'cmoslibrary.lib' nominal
3-19 (77)   .global vcc! gnd!
3-11 (4)    .subckt inv A Z
                m1 Z A gnd! gnd! nmos W=1.4u l=0.35u
                m2 Z A vcc! vcc! pmos W=(1.4u*alpha) l=0.35u
            .ends
3-13 (71)   Xinv1 b c inv M=fan
5-4 (150)   Vin a gnd! 0V PWL 0 0NS 1NS 3 20NS 3
7-35 (281)  .measure TRAN tphl_inv TRIG v(Xinv1.a)
                     VAL=1.5 RISE=1 TARG v(Xinv5.z)
                     VAL=1.5 FALL=1
not in      .OPTION MEASFORM=3
this manual             ^ CSV format
```

Analytical Derivation



N stages





If second gate is fan times wider

→ Delay = fan δ

$$\frac{C_{load}}{C_{gate}} = fan^N$$ for equal delays at each stage

* Ignoring Parasitics

total delay $\equiv D = N\,(\text{fan}\cdot\delta)$

but $\text{fan} = \left(\dfrac{C_{load}}{C_{gate}}\right)^{1/N}$ $\quad R \equiv \dfrac{C_{load}}{C_{gate}}$ 'ratio'

$$D = N R^{1/N} \delta$$

for optimum delay $\dfrac{\partial D}{\partial N} = 0$

$$\frac{\partial}{\partial N}\left(N R^{1/N} \delta\right) = R^{1/N}\delta + \delta N \frac{\partial}{\partial N} R^{1/N}$$

$$\frac{\partial}{\partial N} R^{1/N} = \frac{\partial}{\partial N} e^{\ln R^{1/N}} = \frac{\partial}{\partial N} e^{\frac{1}{N}\ln R}$$

$$= e^{\frac{1}{N}\ln R} \ln R \left(\frac{-1}{N^2}\right) = -R^{1/N} \frac{\ln R}{N^2}$$

So

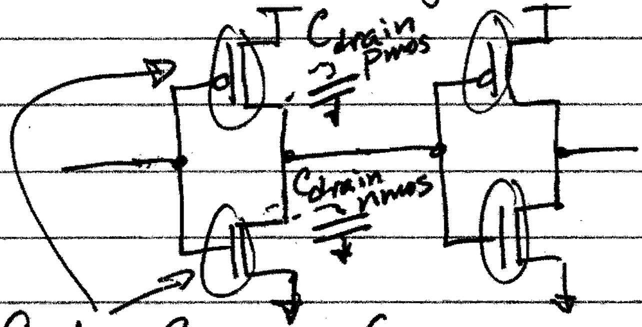
$$\frac{\partial D}{\partial N} = 0 = R^{1/N}\delta - N\delta R^{1/N} \frac{\ln R}{N^2} = R^{1/N}\delta\left(1 - \frac{\ln R}{N}\right)$$

$$\therefore \quad \frac{\ln R}{N} = 1 \qquad \ln R = N \qquad R = e^N$$

$$\boxed{\begin{array}{l} R^{1/N} = e = \text{fan} \\ \& \; N = \ln R \end{array}}$$

But for practical circuits

(1) we cannot ignore parasitics



$C_{gate} = C_{nmos} + C_{pmos}$

(2) using standard cells fan must be an integer

(3) of course N, the number of stages, must be an integer

So, we need to write a python script to run hspice multiple times for slightly different input files searching for an optimum N & fan for a given CMOS technology & C_{load}.