

Digital Integrated Circuit Assignment

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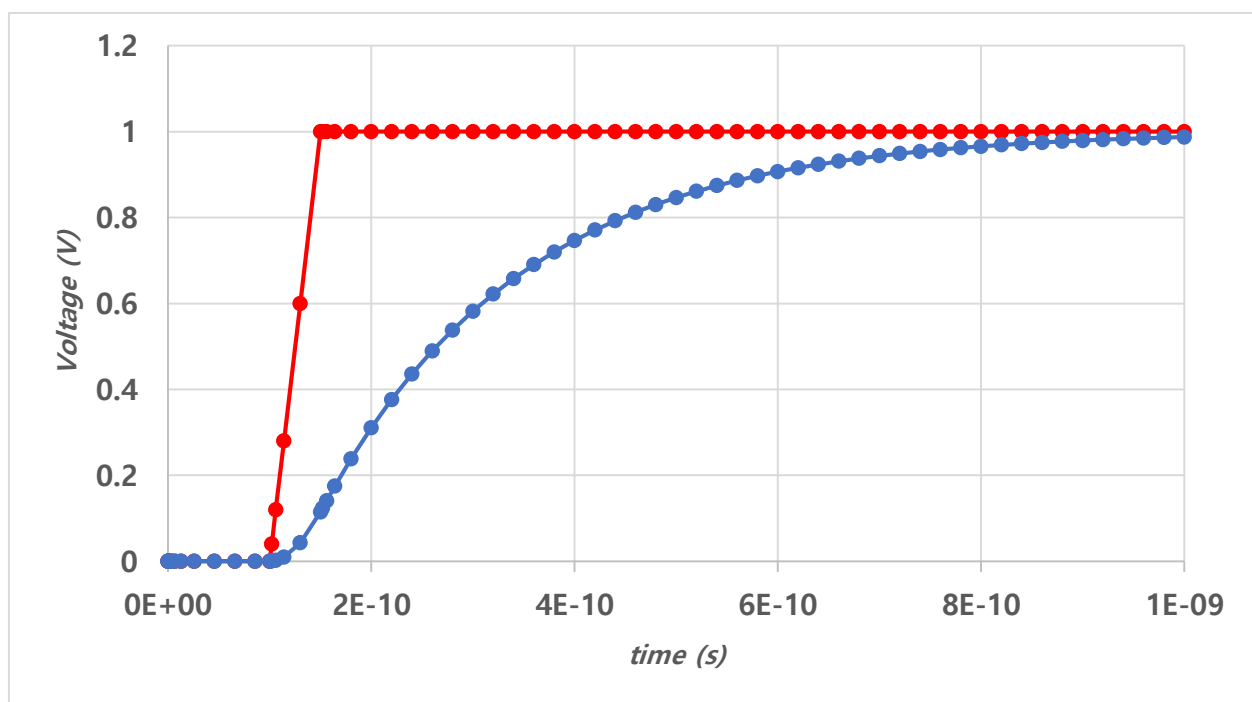


1. RC filter

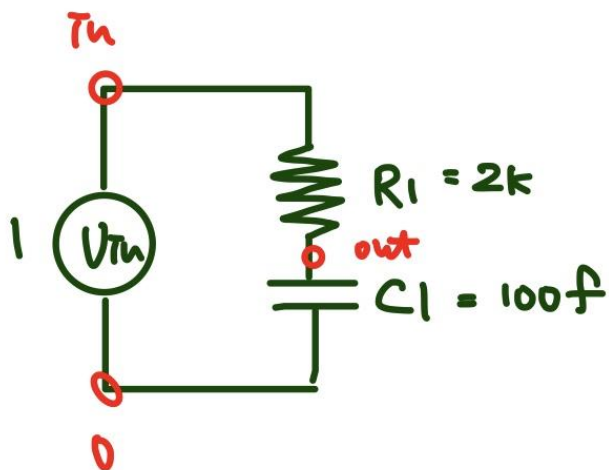
- rc.sp spice code

```
* rc.sp for SPICE3F5  
  
Vin in 0 pwl 0ps 0 100ps 0 150ps 1.0 1ns 1.0  
R1 in out 2k  
C1 out 0 100f  
  
.tran 20ps 1ns  
.print tran v(in) v(out)  
.end
```

- Simulation result



- Circuit based on rc.sp spice code and bw calculation



$$\frac{\frac{1}{sC_1}}{R_1 + \frac{1}{sC_1}} = \frac{1}{1 + sR_1C_1}$$

\therefore Lowpass filter
with $\frac{1}{R_1C_1}$ bandwidth

2. NMOS I-V characteristic curve

- mosiv.sp spice code

```
* mosiv.sp for SPICE3F5

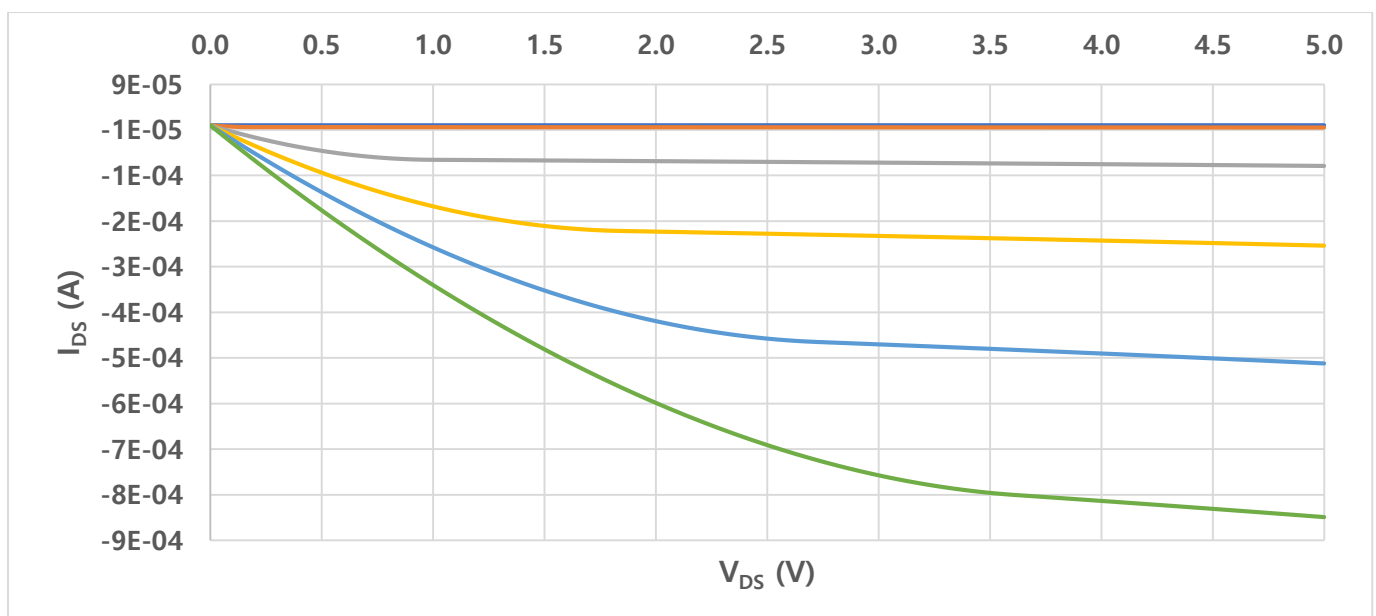
*.include models_1p2mu.sp
.MODEL NMOS NMOS LEVEL=2 LD=0.15U TOX=200.0E-10
+ NSUB=5.36726E+15 VTO=0.743469 KP=8.00059E-05 GAMMA=0.543
+ PHI=0.6 U0=655.881 UEXP=0.157282 UCRIT=31443.8
+ DELTA=2.39824 VMAX=55260.9 XJ=0.25U LAMBDA=0.0367072
+ NFS=1E+12 NEFF=1.001 NSS=1E+11 TPG=1.0 RSH=70.00
+ CGDO=4.3E-10 CGSO=4.3E-10 CJ=0.0003 MJ=0.6585
+ CJSW=8.0E-10 MJSW=0.2402 PB=0.58
* Weff = WDrawn - Delta_W
* The suggested Delta_W is 1.9970E-07

.MODEL PMOS PMOS LEVEL=2 LD=0.15U TOX=200.0E-10
+ NSUB=4.3318E+15 VTO=-0.738861 KP=2.70E-05 GAMMA=0.58
+ PHI=0.6 U0=261.977 UEXP=0.323932 UCRIT=65719.8
+ DELTA=1.79192 VMAX=25694 XJ=0.25U LAMBDA=0.0612279
+ NFS=1E+12 NEFF=1.001 NSS=1E+11 TPG=-1.0 RSH=120.6
+ CGDO=4.3E-10 CGSO=4.3E-10 CJ=0.0005 MJ=0.5052
+ CJSW=1.349E-10 MJSW=0.2417 PB=0.64
* Weff = WDrawn - Delta_W
* The suggested Delta_W is 3.1280E-07

Amazon
Vgs g 0 0
Vds d 0 0
M1 d g 0 0 NMOS W=2.4 L=1.2

.dc Vds 0 5.0 0.05 Vgs 0 5.0 1.0
.plot dc V(g) I(Vds)
.end
```

- Simulation result



- MOSFET current value as V_{ds}

* Without body effect

Triode ① $V_{ds} < V_{gs} - V_{th}$ ② $V_{gs} > V_{th}$

$$I_D = \mu_n C_{ox} \frac{W}{L} \left[(V_{gs} - V_{th}) V_{ds} - \frac{1}{2} V_{ds}^2 \right]$$

Saturation ① $V_{ds} > V_{gs} - V_{th}$ ② $V_{gs} > V_{th}$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{gs} - V_{th})^2$$

3. Inverter voltage transfer characteristic

- inv.sp spice code

```
* inv.sp for SPICE3F5

.MODEL NMOS NMOS LEVEL=2 LD=0.15U TOX=200.0E-10
+ NSUB=5.36726E+15 VTO=0.743469 KP=8.00059E-05 GAMMA=0.543
+ PHI=0.6 U0=655.881 UEXP=0.157282 UCRIT=31443.8
+ DELTA=2.39824 VMAX=55260.9 XJ=0.25U LAMBDA=0.0367072
+ NFS=1E+12 NEFF=1.001 NSS=1E+11 TPG=1.0 RSH=70.00
+ CGDO=4.3E-10 CGSO=4.3E-10 CJ=0.0003 MJ=0.6585
+ CJSW=8.0E-10 MJSW=0.2402 PB=0.58
* Weff = WDrawn - Delta_W
* The suggested Delta_W is 1.9970E-07

.MODEL PMOS PMOS LEVEL=2 LD=0.15U TOX=200.0E-10
+ NSUB=4.3318E+15 VTO=-0.738861 KP=2.70E-05 GAMMA=0.58
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+ NFS=1E+12 NEFF=1.001 NSS=1E+11 TPG=-1.0 RSH=120.6
+ CGDO=4.3E-10 CGSO=4.3E-10 CJ=0.0005 MJ=0.5052
+ CJSW=1.349E-10 MJSW=0.2417 PB=0.64
* Weff = WDrawn - Delta_W
* The suggested Delta_W is 3.1280E-07

vdd vdd 0 5.0
vin a 0 0.0
M1 y a 0 0 NMOS W=2.4 L=1.2
M2 y a vdd vdd PMOS W=2.4 L=1.2

.dc vin 0 5.0 0.01
.print dc V(a) V(y)
.end
```

- Simulation result

