Spice Model Parametrs

```
*NMOS models

*Typical
.model nch_tt nmos (Level=8
+noimod=1  version=3.3  tnom=27  tox=4.1E-9  xj=1E-7  nch=2.3549E17  vth0=0.362587
+k1=0.5865832  k2=4.152205E-3  k3=1E-3  k3b=2.1824687  w0=1E-7  nlx=1.795622E-7
+lmin=1.8e-7 lmax=1.0e-4 wmin=1.8e-7 wmax=1.0e-4
+dvt0w=0  dvt1w=0  dvt2w=0  dvt0=1.746117  dvt1=0.4409233  dvt2=-3.663487E-4
+u0=262.117234  ua=-1.386325E-9  ub=2.284255E-18  uc=5.506514E-11  vsat=1.04174E5  a0=1.9287698
+ags=0.416466  b0=-1.536637E-9  b1=-1E-7  keta=-7.111387E-3  a1=6.573435E-4  a2=0.8808358
+rdsw=112.5093924  prwg=0.494777  prwb=-0.2  wr=1  wint=7.098292E-9  lint=1.120392E-8
+xl=-2E-8  xw=-1E-8  dwg=-3.812756E-9  dwb=8.690068E-9  voff=-0.0878502  nfactor=2.2975194
+cit=0  cdsc=2.4E-4  cdscd=0  cdscb=0  eta0=3.116078E-3  etab=1
+dsub=0.0226021  pclm=0.7222753  pdiblc1=0.2160258  pdiblc2=2.237807E-3  pdiblcb=0.1  drout=0.8036712
+pscbe1=2.434136E9  pscbe2=4.844371E-8  pvag=0  delta=0.01  rsh=6.8  mobmod=1  prt=0  ute=-1.5
+kt1=-0.11  kt1l=0  kt2=0.022  ua1=4.31E-9  ub1=-7.61E-18  uc1=-5.6E-11  at=3.3E4  wl=0  wln=1  ww=0
+wwn=1  wwl=0  ll=0  lln=1  lw=0  lwn=1  lwl=0  capmod=2  xpart=0.5
+cgdo=6.99E-10  cgso=6.99E-10  cgbo=1E-12  cj=9.840057E-4  pb=0.7342005  mj=0.3623465
+cjsw=2.405513E-10  pbsw=0.4681508  mjsw=0.1  cjswg=3.3E-10  pbswg=0.4681508  mjswg=0.1
+cf=0  pvth0=-7.11401E-4  prdsw=-0.6661763  pk2=5.920718E-4  wketa=2.148339E-4  lketa=-0.0151118
+pu0=3.3563216  pua=-1.30682E-11  pub=0  pvsat=1.25639E3  peta0=1E-4  pketa=6.507934E-4)
```

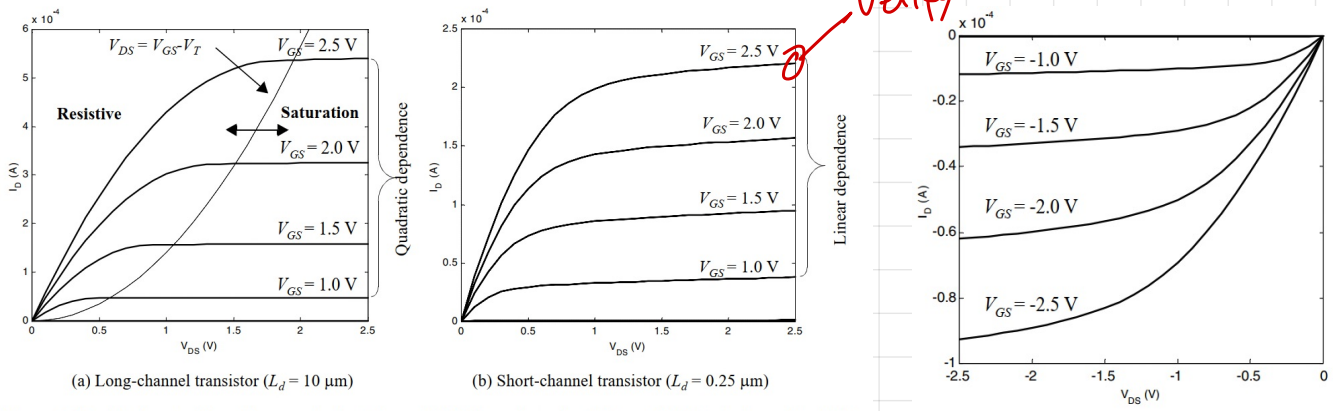
```
*Typical
.model nch_tt nmos (Level=8
+noimod=1  version=3.3  tnom=27  tox=4.1E-9  xj=1E-7  nch=2.3549E17  vth0=0.362587
+k1=0.5865832  k2=4.152205E-3  k3=1E-3  k3b=2.1824687  w0=1E-7  nlx=1.795622E-7
+lmin=1.8e-7 lmax=1.0e-4 wmin=1.8e-7 wmax=1.0e-4
+dvt0w=0  dvt1w=0  dvt2w=0  dvt0=1.746117  dvt1=0.4409233  dvt2=-3.663487E-4
+u0=262.117234  ua=-1.386325E-9  ub=2.284255E-18  uc=5.506514E-11  vsat=1.04174E5  a0=1.9287698  .....

*FF corner
.model nch_ff nmos (level=8
+noimod=1  version=3.3  tnom=27  tox=3.895E-9  xj=1E-7  nch=2.3549E17  vth0=0.262587
+k1=0.5865832  k2=4.152205E-3  k3=1E-3  k3b=2.1824687  w0=1E-7  nlx=1.795622E-7
+lmin=1.8e-7 lmax=1.0e-4 wmin=1.8e-7 wmax=1.0e-4
+dvt0w=0  dvt1w=0  dvt2w=0  dvt0=1.746117  dvt1=0.4409233  dvt2=-3.663487E-4
+u0=288.328957  ua=-1.386325E-9  ub=2.284255E-18  uc=5.506514E-11  vsat=1.04174E5  a0=1.9287698  .....

*SS corner
.model nch_ss nmos (level=8
+noimod=1  version=3.3  tnom=27  tox=4.305E-9  xj=1E-7  nch=2.3549E17  vth0=0.462587
+k1=0.5865832  k2=4.152205E-3  k3=1E-3  k3b=2.1824687  w0=1E-7  nlx=1.795622E-7
+lmin=1.8e-7 lmax=1.0e-4 wmin=1.8e-7 wmax=1.0e-4
+dvt0w=0  dvt1w=0  dvt2w=0  dvt0=1.746117  dvt1=0.4409233  dvt2=-3.663487E-4
+u0=235.905511  ua=-1.386325E-9  ub=2.284255E-18  uc=5.506514E-11  vsat=1.04174E5  a0=1.9287698  .....
```

VLSI Design - Lecture 5

12 - Aug - 2022

Use the generic 0.25 μm CMOS model below for all your work unless otherwise specified. Assume $|2\phi_F| = 0.6\ V$.

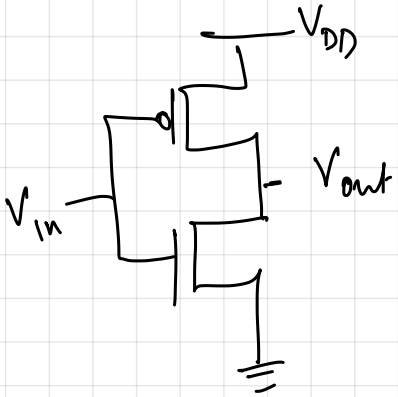
	V_{T0} (V)	γ $(V^{0.5})$	V_{DSAT} (V)	k' (A/V^2)	λ (V^{-1})	R_{eq} $(k\Omega)@V_{DD}$
NMOS	0.43	0.4	0.63	115×10^{-6}	0.06	13
PMOS	-0.4	-0.4	-1	-30×10^{-6}	-0.1	31



(a) Long-channel transistor (L_d = 10 µm) (b) Short-channel transistor (L_d = 0.25 µm)

Figure 3.19 *I-V* characteristics of long- and a short-channel NMOS transistors in a 0.25 µm CMOS technology. The (*W*/*L*) ration of both transistors is identical and equals 1.5

$$I_D = k_n' \frac{W}{L} \left(V_{GS} - V_{Tn} - \frac{V_{DSATn}}{2}\right) V_{DSATn} (1 + \lambda V_{DS})$$



$$I_{dn} = -I_{dp} \Rightarrow I_{dn} + I_{dp} = 0$$

$$k_n'\left(\frac{W}{L}\right)_n \left(V_{IN} - V_{Tn} - \frac{V_{DSATn}}{2}\right) V_{DSATn} + k_p'\left(\frac{W}{L}\right)_p \left(V_{IN} - V_{DD} - V_{Tp} - \frac{V_{DSATp}}{2}\right) V_{DSATp} = 0$$

$k_p'\left(\frac{W}{L}\right)_p$

$$V_M = V_{IN} = V_{out} \qquad r = \frac{k_p V_{DSATp}}{k_n V_{DSATn}}$$

$$V_M - V_{Tn} - \frac{V_{DSATn}}{2} + r\left(V_M - V_{DD} - V_{Tp} - \frac{V_{DSATp}}{2}\right) = 0$$

$$V_M(1 + r) = V_{Tn} + \frac{V_{DSATn}}{2} + r\left(V_{DD} + V_{Tp} + \frac{V_{DSATp}}{2}\right)$$

$$V_M = \frac{V_{Tn} + \frac{V_{DSATn}}{2} + r\left(V_{DD} + V_{TP} + \frac{V_{DSATP}}{2}\right)}{1+r}$$

$$r = \frac{k_p'(W/L)_p \cdot V_{DSATP}}{k_n'(W/L)_n V_{DSATn}}$$

$V_{Tn} = 0.43$ $\quad k_n' = 115\ \mu A/V^2$

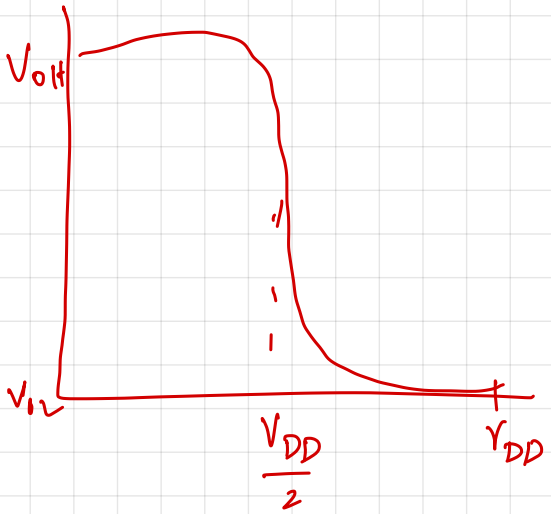
$V_{TP} = -0.4$ $\quad k_p' = -30\ \mu A/V^2$

$V_{DD} = 2.5\ V$

$V_{DSATn} = 0.63$ $\quad V_{DSATP} = -1$

If $r = 1$ $\quad V_M = ?$

$1.17\ V$



$V_M = V_{DD}/2$ $\quad V_M = 1.25$

Assuming $V_{DD} \gg V_{Tn}, V_{DSATn}$
V_{TP} V_{DSATP}

$$V_M = \frac{r V_{DD}}{1+r}$$

$$\left(\frac{W}{L}\right)_p > (W/L)_n$$

$L = L_{min}$ in digital circuits

$L = 0.25\ \mu m$

$L = 0.18\ \mu m$

$(W/L)_{min} = 1.5$ $\quad 0.25 \times 1.5 = 0.375\ \mu m$

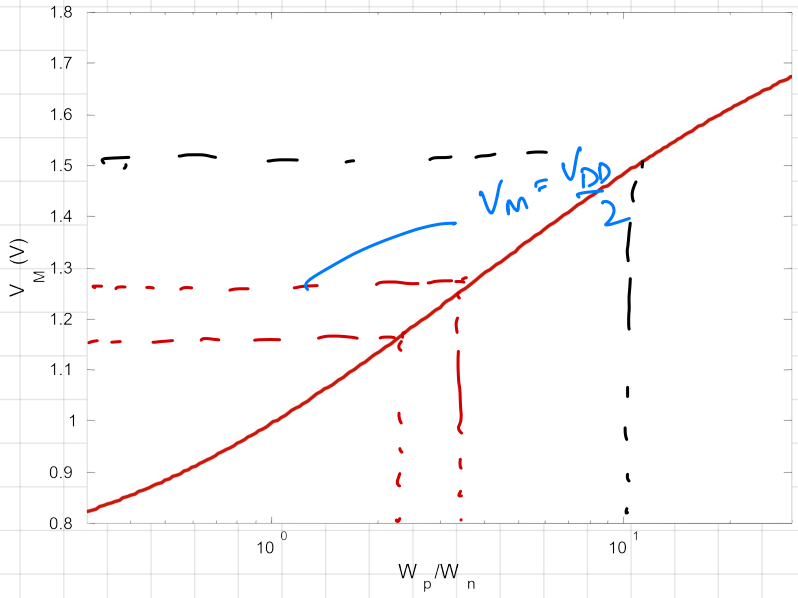
Gain: $\frac{dV_{out}}{dV_{in}}$ Write expression with channel length modulation.

$$g = -\frac{1}{I_D(V_M)} \frac{V_{DSATP} k_p + V_{DSATn} k_n}{\lambda_n - \lambda_p} \sim -30$$

$$I_D = k_n'(W/L)\left(V_M - V_{Tn} - \frac{V_{DSATn}}{2}\right) V_{DSATn}$$

$$115 \times 1.5\left(1.25 - 0.43 - \frac{0.63}{2}\right) 0.63$$

$= 55\ \mu A$ $\quad \sim 59\ \mu A$ with CLM.



$$\left(V_M - V_{Tn} - \frac{V_{DSATN}}{2}\right) + r\left(V_M - V_{DD} - V_{tp} - \frac{V_{DSATD}}{2}\right) = 0$$

r - ? $\quad V_M = V_{DD}/2$

$$\left(1.25 - 0.43 - \frac{0.63}{2}\right) + r\left(-1.25 + 0.4 + 0.5\right) = 0$$

$$r = ? \quad 1.4 = \frac{-30 \times -1}{115 \times 0.63} \times \frac{(W/L)_p}{(W/L)_n}$$

$$\frac{(W/L)_p}{(W/L)_n} = 3.4$$

$$r = 1 \quad \frac{(W/L)_p}{(W/L)_n} = \frac{115 \times 0.63}{30 \times 1} = 2.3$$