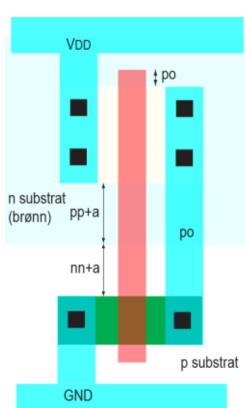
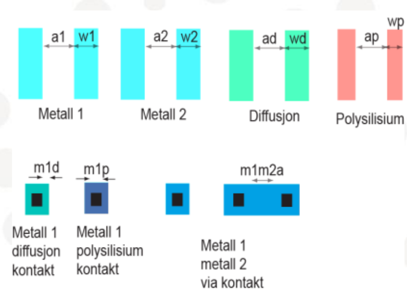
INF3400 Del 4
Moderne MOS transistor modell, transient simulering og enkle utleggsregler

Introduksjon til utleggsregler

Enkle utleggsregler:



Inverter



Enkle MOS kapasitans modeller

Gatekapasitens:

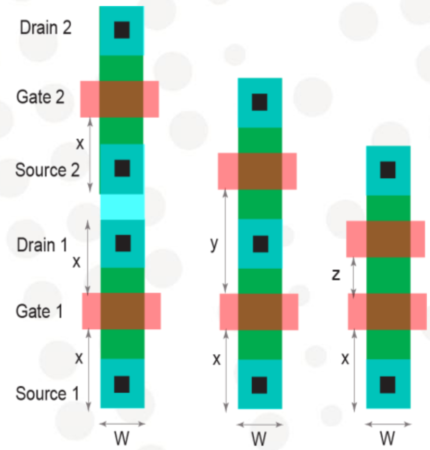
$$C_g = C_{ox}WL$$

der

$$C_g = C_{permicron}W$$

der

$$C_{permicron} = C_{ox}L$$



Oppgave 2.4

En transistor med lengde 90*nm* har en tykkelse på gateoksid(t_{ox}) lik 16Å.
Hva blir gatekapasitans per mikrometer?

Løsning:

$$C_{permicron} = C_{ox}L$$

$$= \frac{\varepsilon_{ox}}{t_{ox}} L$$

$$= \frac{3.9 \cdot 8.85 \cdot 10^{-14}}{16 \cdot 10^{-8}} \frac{F}{cm} \left(90 \cdot 10^{-7}\, cm\right)$$

$$= 1.94 \frac{fF}{\mu m}$$

Gatekapasitans detaljer

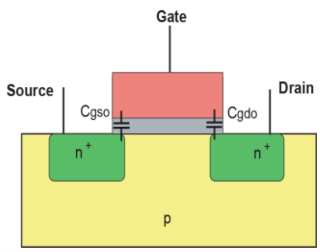
Ubiasert gatekapasitans:

$$C_0 = C_{ox} W L$$

Overlappskapasitanser (statiske):

$$C_{gs0} = C_{gsol} W$$

$$C_{gd0} = C_{gdol} W$$



Operasjonsområde **AV**:

$$C_{gb} = C_0$$

Operasjonsområde **LINEÆR**:

$$C_{gs} = C_{gd} = \frac{C_0}{2}$$

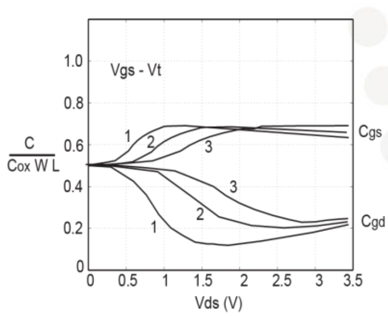
Operasjonsområde **METNING**:

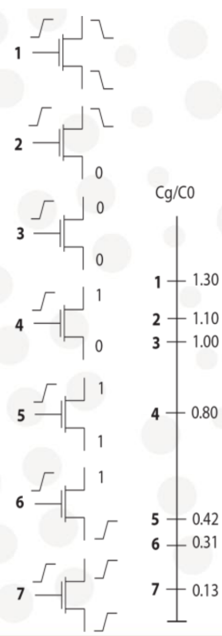
$$C_{gs} = \frac{2C_0}{3}$$

$$C_{gd} = 0$$

Gatekapasitans:

$$C_g = C_{gs} + C_{gd} + C_{gb} \approx C_0$$





Diffusjonskapasitans detaljer

Diffusjonskapasitans source:

$$C_{sb} = AS \cdot C_{jbs} + PS \cdot C_{jbssw}$$

der:

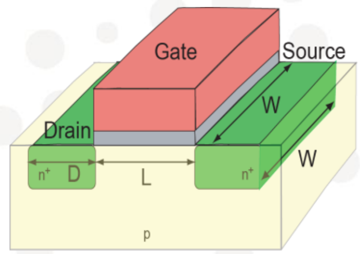
$$AS = W \cdot D$$

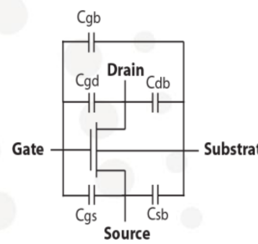
$$PS = 2W + 2D$$

$$C_{jbs} = C_j \left(1 + \frac{V_{sb}}{\Psi_0}\right)^{-M_J}$$

$$\Psi_0 = V_T \ln \frac{N_A N_D}{n_i^2}$$

$$C_{jbssw} = C_{JSW} \left(1 + \frac{V_{sb}}{\Psi_0}\right)^{-M_{JSW}}$$





Oppgave 2.5

Beregn diffusjonskapasitans C_{db} for en transistor med en (minimum) kontakt på drain i en 0.6μm prosess når drainspenningen er 0V og VDD = 5V . Anta at substratet er jordet. Parameterverdier er C_J = 0.42$fF/\mu m2$, M_J = 0.44, C_{JSW} = 0.33$fF/\mu m$, M_{JSW} = 0.12 og Ψ_0 = 0.98V ved romtemperatur.

Løsning:

$$C_{db}(0V) = AD \cdot C_{jbs} + PD \cdot C_{jbssw}$$

$$= (1.8\mu m^2)\left(0.42 \frac{fF}{\mu m^2}\right) + (5.4\mu m)\left(0.33 \frac{fF}{\mu m}\right)$$

$$= 2.54\ fF$$

$$C_{db}(5V) = AD \cdot C_{jbs} + PD \cdot C_{jbssw}$$

$$= (1.8)C_J\left(1 + \frac{V_{db}}{\Psi_0}\right)^{-M_J} + (5.4\mu m)C_{JSW}\left(1 + \frac{V_{db}}{\Psi_0}\right)^{-MJSW}$$

$$= (1.8\mu m^2)(0.42)\left(1 + \frac{5}{0.98}\right)^{-0.44} + (5.4\mu m)(0.33)\left(1 + \frac{5}{0.98}\right)^{-0.12}$$

$$= 1.78\ fF$$

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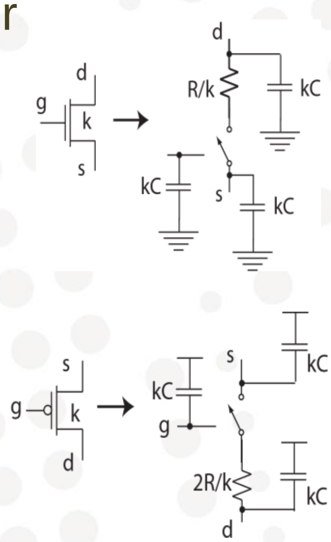
ENKLE RC modeller

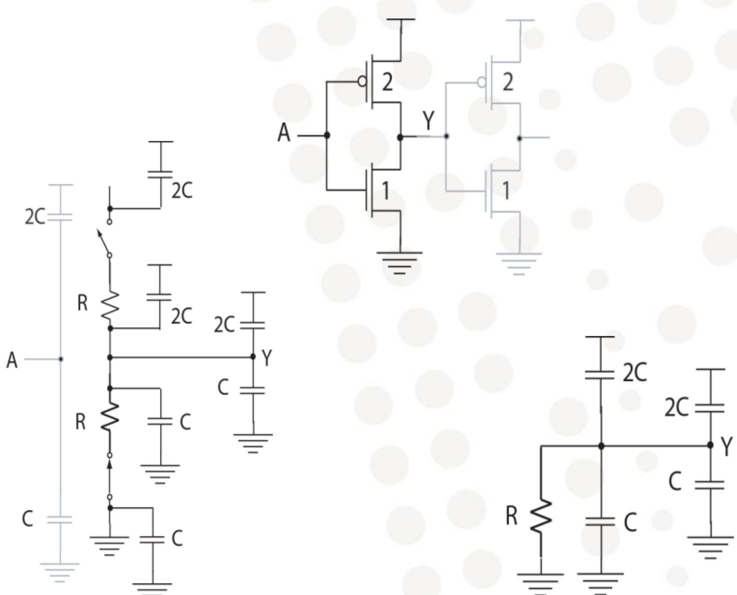
Motstand i transistor:

$$R = \left(\frac{\partial I_{ds}}{\partial V_{ds}}\right)^{-1}$$

$$\approx \left(\beta\left(V_{gs} - V_t\right)\right)^{-1}$$

$$\approx \frac{1}{\mu C_{ox}} \frac{L}{W} \left(V_{gs} - V_t\right)^{-1}$$





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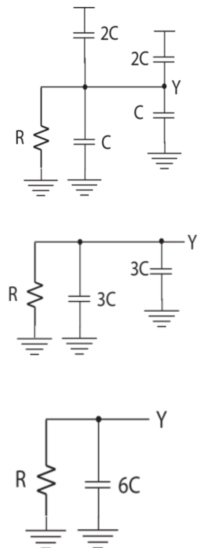
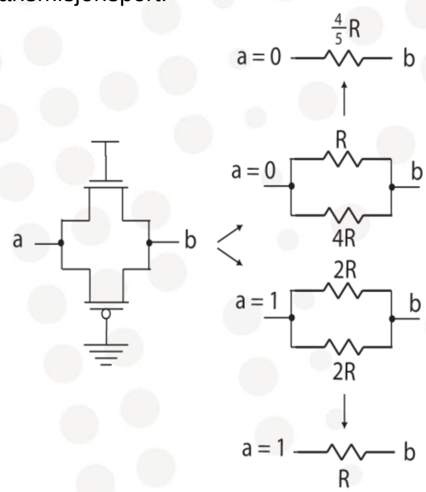
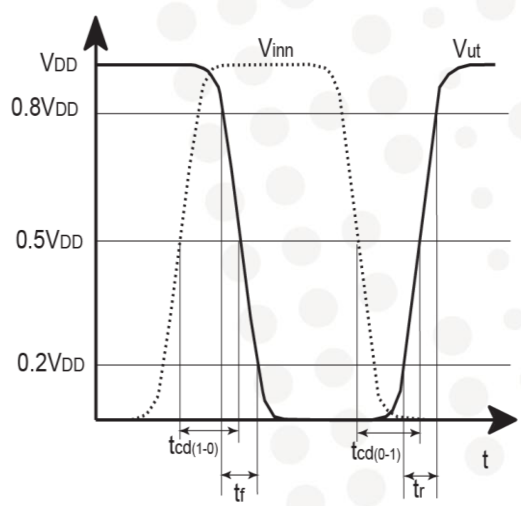


Transmisjonsport:



RC forsinkelsesmodeller



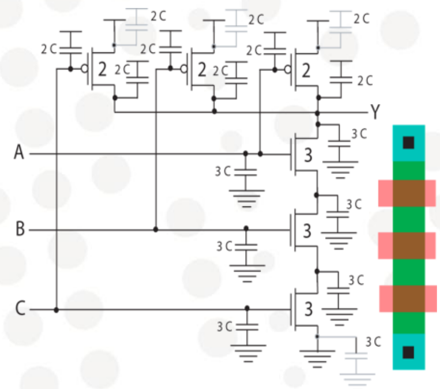
Seriekobling av transistorer:

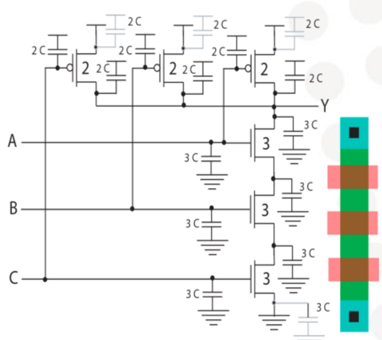
$$R_{effektiv} = \sum_{i=1}^{n} \frac{R}{k_i}$$

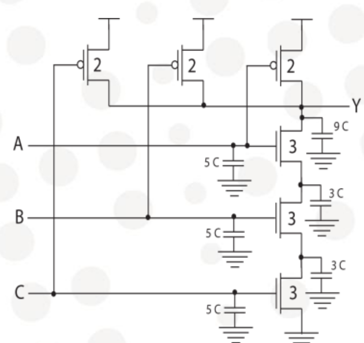
Parallellkobling av transistorer:

$$R_{effektiv} = R \| R = \frac{R}{2}$$

Eksempel NAND3:







Transisjon fra 0 til 1:

$$R_{effektiv} = \frac{2R}{2} = R$$

Transisjon fra 1 til 0:

$$R_{effektiv} = \left(\frac{1}{3} + \frac{1}{3} + \frac{1}{3}\right)R = R$$

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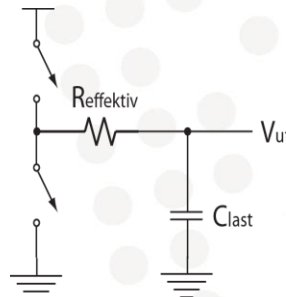
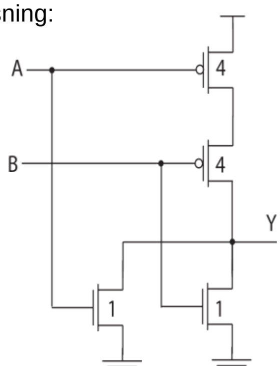
RC modell



Oppgave C

Tegn transistorskjematikk for en toinngangs NOR port med transistor bredder slik at effektiv motstand i nedtrekket blir lik en enhetsinverter. Beregn stige og fall forsinkelse når porten skal drive *h* identiske NOR porter ved å bruke enkle RC modeller.

Løsning:



$$R_{opptrekk} = \frac{2R}{4} + \frac{2R}{4} = R$$

$$C_{parasitic} = 2C + 4C + 4C = 10C$$

$$t_{parasitic} = R \cdot 10C = \frac{10}{3}\tau$$

$$t_{pd} = (10C + h \cdot 5C)R = (2 + h)5RC = (2 + h)\frac{5}{3}\tau$$

Hastighetsmetning

Hastigheten til ladningsbærere:

$$v = \frac{\mu E_{lat}}{1+\frac{E_{lat}}{E_{sat}}}$$

der:

$$E_{lat} = \frac{V_{ds}}{L}$$

AV $\quad I_{ds} = 0$

LINEÆR $\quad I_{ds} = P_c \frac{\beta}{2}(V_{gs}-V_t)^{\alpha}\frac{V_{ds}}{V_{dsat}}(1+\lambda V_{ds})$

METNING $\quad I_{ds} = P_c \frac{\beta}{2}(V_{gs}-V_t)^{\alpha}(1+\lambda V_{ds})$

Transistormodeller:

$$I_{ds} = 0 \qquad \text{AV}$$

$$I_{ds} = P_c \frac{\beta}{2}(V_{gs}-V_t)^{\alpha}\frac{V_{ds}}{V_{dsat}} \qquad \text{LINEÆR}$$

$$I_{ds} = P_c \frac{\beta}{2}(V_{gs}-V_t)^{\alpha} \qquad \text{METNING}$$

Metningsspenning

$$V_{dsat} = P_v (V_{gs}-V_t)^{\alpha/2}$$

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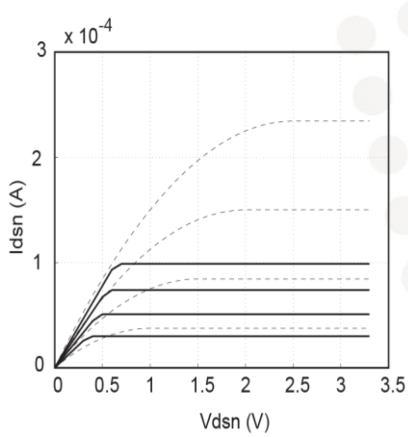

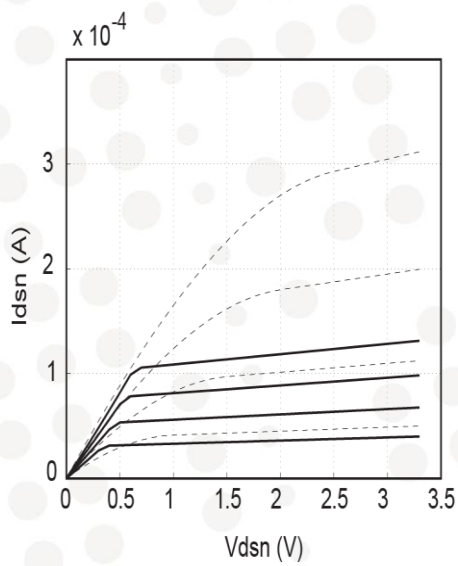

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