

1. zadatak

Rješenje:

a)

$$U_{UL} = U_{PO} \rightarrow K_n \left(U_{PO} - U_{GS0n} - \frac{U_{DSzasn}}{2} \right) U_{DSzasn} = -K_p \left(U_{PO} - U_{DD} - U_{GS0p} - \frac{U_{DSzasp}}{2} \right) U_{DSzasp},$$

$$\rightarrow U_{PO} = 0,895 \text{ V} \rightarrow I_V = K'_n \frac{W_n}{L_n} \left(U_{PO} - U_{GS0n} - \frac{U_{DSzasn}}{2} \right) U_{DSzasn} = 73,5 \text{ } \mu\text{A},$$

$$E_i = \frac{t_r + t_f}{2} U_{DD} I_V = 0,662 \text{ fJ}.$$

b)

$$E_d = C_T U_{DD}^2 = 19,4 \text{ fJ}.$$

2. zadatak

Rješenje:

a)

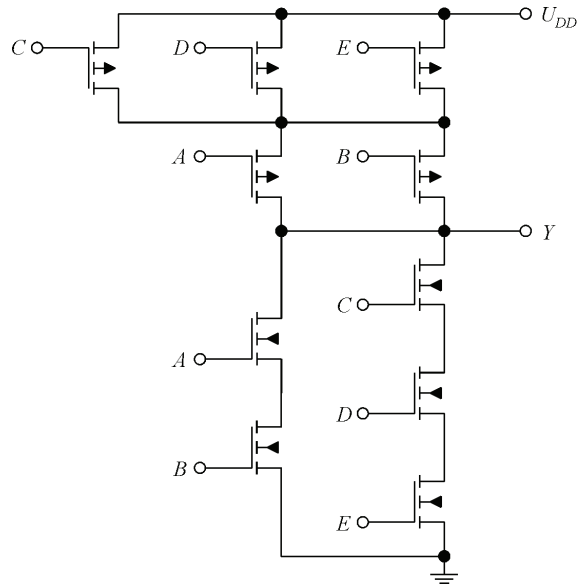
$$C_T = x C_i = S^5 C_i \rightarrow S = \sqrt[5]{x} = \sqrt[5]{\frac{C_T}{C_i}} = 4,96,$$

$$t_d = 5 t_{di} = 5 S t_{dj} = 5 \sqrt[5]{x} t_{dj} = 5 \sqrt[5]{\frac{C_T}{C_i}} t_{dj} = 620 \text{ ps}.$$

b)

$$E_d = (S + S^2 + S^3 + S^4 + S^5) C_i U_{DD}^2 = \frac{S^5 - 1}{S - 1} S C_i U_{DD}^2 = 60,9 \text{ pJ}.$$

3. zadatak



Rješenje:

a)

$$Y = \overline{AB + CDE}.$$

b) $W_{nA} = W_{nB} = 0,6 \mu\text{m}$, $W_{nC} = W_{nD} = W_{nE} = 0,9 \mu\text{m}$ i $W_{pA} = W_{pB} = W_{pC} = W_{pD} = W_{pE} = 1,8 \mu\text{m}$.

c)

$$C_{AE} = (W_{pA} + W_{pB} + W_{pC} + W_{pD} + W_{pE}) \frac{C_{\min}}{W_{\min}} = 15 \text{ fF},$$

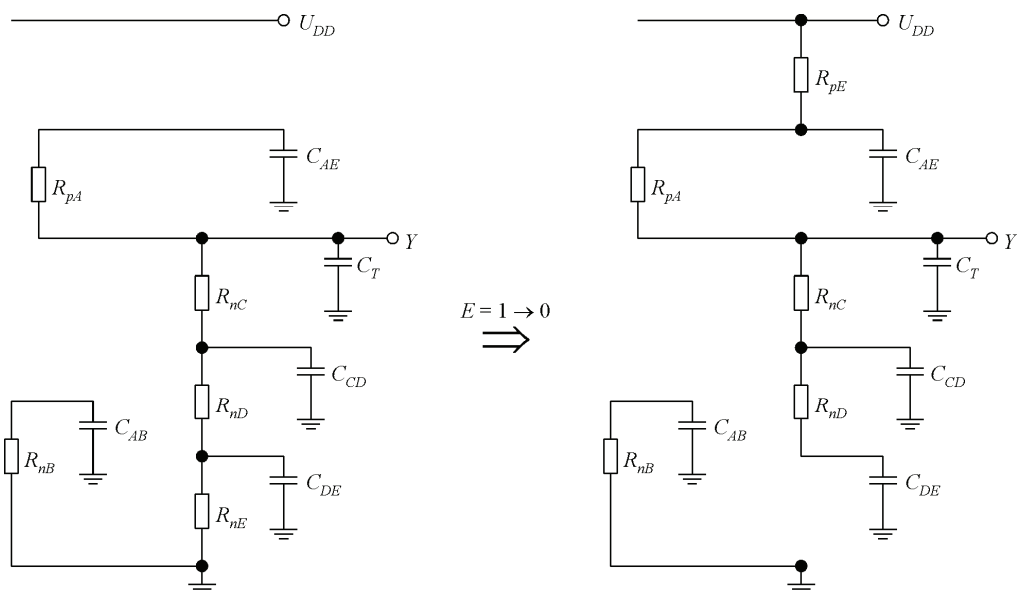
$$C_{AB} = (W_{nA} + W_{nB}) \frac{C_{\min}}{W_{\min}} = 2 \text{ fF},$$

$$C_{CD} = (W_{nC} + W_{nD}) \frac{0,5}{W_{\min}} = 3 \text{ fF}, \quad C_{DE} = (W_{nD} + W_{nE}) \frac{C_{\min}}{W_{\min}} = 3 \text{ fF},$$

$$C_T = (W_{pA} + W_{pB} + W_{nA} + W_{nC}) \frac{C_{\min}}{W_{\min}} = 8,5 \text{ fF},$$

$$R_{pA} = R_{pE} = R_{p\max} \frac{W_{\min}}{W_{pA}} = R_{p\max} \frac{W_{\min}}{W_{pD}} = 2,5 \text{ k}\Omega,$$

$$R_{nC} = R_{nD} = R_{n\max} \frac{W_{\min}}{W_{nD}} = 3 \text{ k}\Omega.$$

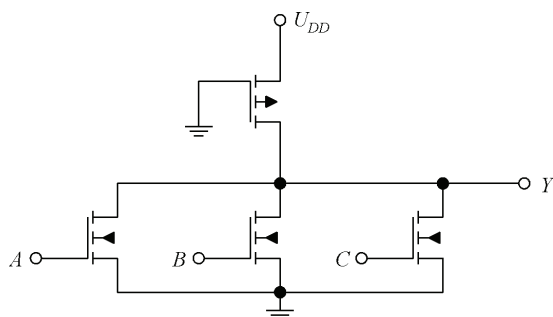


$$\tau_{DY} = R_{pE} C_{AE} + (R_{pE} + R_{pA})(C_{CD} + C_{DE} + C_T) = 110 \text{ ps} .$$

4. zadatak

Rješenje:

a)



b)

$$n K'_n (W/L)_n \left(U_{DD} - U_{GS0n}^0 - \frac{U_0}{2} \right) U_0 = -K'_p (W/L)_p \left(-U_{DD} - U_{GS0p}^0 - \frac{U_{DSzasp}}{2} \right) U_{DSzasp} .$$

n broj nMOS tranzistora s ulaznim naponom $U_{UL} = U_{DD}$. Uz $U_0 \ll 2(U_{DD} - U_{GS0n}^0)$:

$$U_0 = \frac{-K'_p (W/L)_p \left(-U_{DD} - U_{GS0p}^0 - \frac{U_{DSzasp}}{2} \right) U_{DSzasp}}{n K'_n (W/L)_n (U_{DD} - U_{GS0n}^0)} .$$

Najgori slučaj (najveći iznos napona U_0) \rightarrow vodi samo jedan nMOS tranzistor ($n = 1$)

$$\overline{U_0} = \frac{-K'_p (W/L)_p (-U_{DD} - U_{GS0p}^0 - U_{DSzasp}/2) U_{DSzasp}}{n K'_n (W/L)_n (U_{DD} - U_{GS0n}^0)} = 0,131 \text{ V} = 189 \text{ mV}.$$

Najbolji slučaj (najmanji iznos napona U_0) \rightarrow vode sva tri nMOS tranzistora ($n = 3$)

$$\underline{U_0} = \frac{\overline{U_0}}{3} = \frac{189}{3} = 63 \text{ mV}.$$

c) Neovisno o broju uključenih nMOS tranzistora ($n \geq 1$) struju sklopa određuje pMOS tranzistor.

$$I_{Dps} = K'_p (W/L)_p \left(-U_{DD} - U_{GS0p}^0 - \frac{U_{DSzasp}}{2} \right) U_{DSzasp} = -119 \text{ } \mu\text{A},$$

$$P_S = -I_{Dps} U_{DD} = 214 \text{ } \mu\text{W}.$$