

1. zadatak

Rješenje:

a)

$$t_{dVN} = 0,69 R_n C_T = 49,7 \text{ ps} , \quad t_{dNV} = 0,69 R_p C_T = 33,1 \text{ ps} ,$$

$$t_d = (t_{dVN} + t_{dNV})/2 = 41,4 \text{ ps} .$$

b)

$$R_{nm} = R_n (W_n / W_{\min}) = 6 \text{ k}\Omega , \quad R_{pm} = R_p (W_p / W_{\min}) = 16 \text{ k}\Omega ,$$

$$C_{nm} = C_{pm} = C_T \frac{W_{\min}}{W_n + W_p} = 2,4 \text{ fF} ,$$

$$t_d = 0,345 (R_{nm} + R_{pm} / \beta) (C_{nm} + \beta C_{pm}) ,$$

$$\frac{\partial t_d}{\partial \beta} \equiv 0 \rightarrow \beta_{opt} = \sqrt{\frac{R_{pm}}{R_{nm}} \frac{C_{nm}}{C_{pm}}} = 1,63 ,$$

$$t_{d \min} = 0,345 (R_{nm} + R_{pm} / \beta_{opt}) (C_{nm} + \beta_{opt} C_{pm}) = 34,4 \text{ ps} ,$$

$$t_{dVN} = 0,69 R_{nm} (C_{nm} + \beta_{opt} C_{pm}) = 26,1 \text{ ps} ,$$

$$t_{dNV} = 0,69 R_{pm} / \beta_{opt} (C_{nm} + \beta_{opt} C_{pm}) = 42,8 \text{ ps} .$$

2. zadatak

Rješenje:

a)

$$C_T = x C_i = S^n C_i \rightarrow S^n = x = \frac{C_T}{C_i} = 1250$$

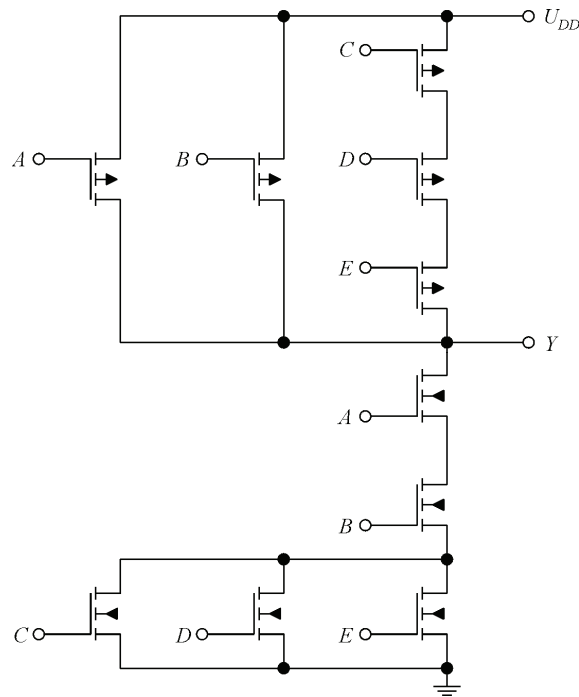
$$t_d = n S t_{dj} \leq t_{d, \max} \rightarrow \frac{t_{d, \max}}{t_{dj}} = 25 \geq n S = n x^{1/n} \rightarrow n = 4$$

$$S = x^{1/n} = 5,95 \approx 6$$

b)

$$E_d = (S + S^2 + \dots + S^n) C_i U_{DD}^2 = \frac{S^n - 1}{S - 1} S C_i U_{DD}^2 = 40,3 \text{ pJ}$$

3. zadatak



Rješenje:

a)

$$Y = \overline{AB(C + D + E)}.$$

b)

$$W_{nA} = W_{nB} = W_{nC} = W_{nD} = W_{nE} = W_{pA} = W_{pB} = 0,9 \mu\text{m} \text{ i } W_{pC} = W_{pD} = W_{pE} = 2,7 \mu\text{m}.$$

c)

$$C_{CD} = (W_{pC} + W_{pD}) \frac{C_{\min}}{W_{\min}} = 7,2 \text{ fF}, \quad C_{DE} = (W_{pD} + W_{pE}) \frac{C_{\min}}{W_{\min}} = 7,2 \text{ fF},$$

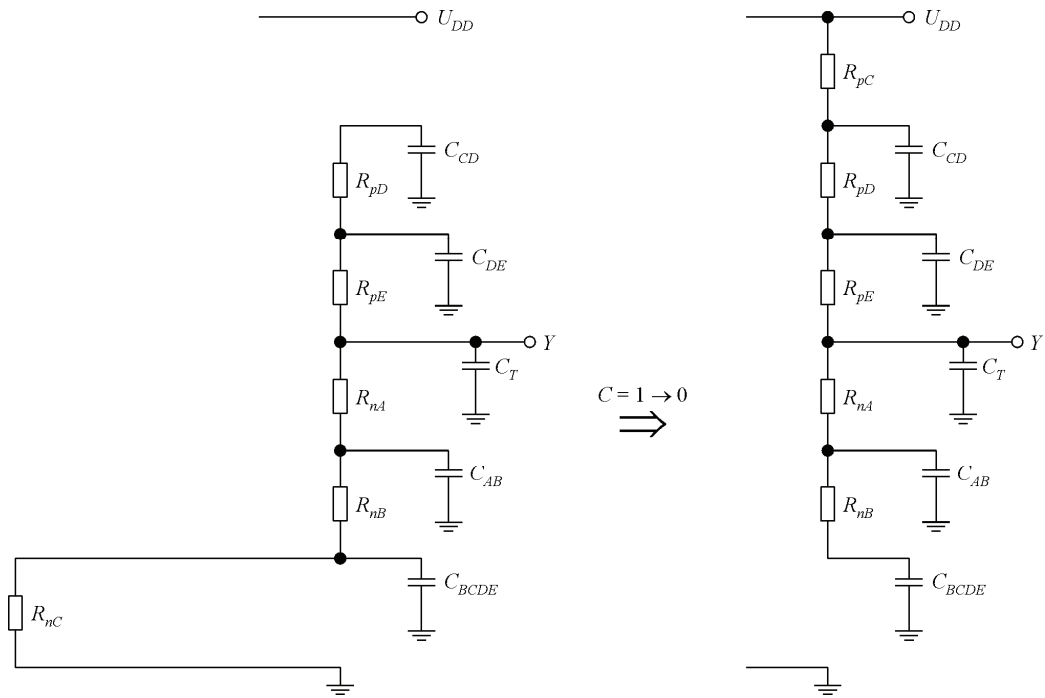
$$C_{AB} = (W_{nA} + W_{nB}) \frac{C_{\min}}{W_{\min}} = 2,4 \text{ fF},$$

$$C_{BCDE} = (W_{nB} + W_{nC} + W_{nD} + W_{nE}) \frac{C_{\min}}{W_{\min}} = 4,8 \text{ fF},$$

$$C_T = (W_{pA} + W_{pB} + W_{pE} + W_{nA}) \frac{C_{\min}}{W_{\min}} = 7,2 \text{ fF},$$

$$R_{pC} = R_{pD} = R_{pE} = R_{p\max} \frac{W_{\min}}{W_{pC}} = R_{p\max} \frac{W_{\min}}{W_{pD}} = R_{p\max} \frac{W_{\min}}{W_{pE}} = 1,5 \text{ k}\Omega,$$

$$R_{nA} = R_{nB} = R_{n\max} \frac{W_{\min}}{W_{nA}} = R_{n\max} \frac{W_{\min}}{W_{nB}} = 2 \text{ k}\Omega.$$

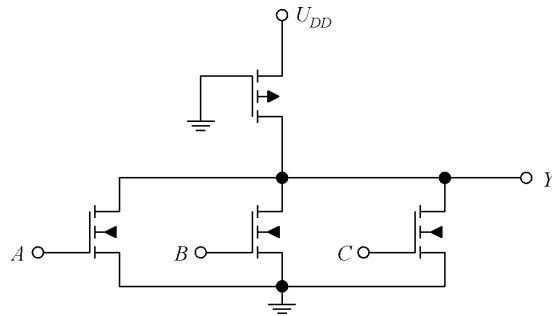


$$\tau_{DY} = R_{pC} C_{CD} + (R_{pC} + R_{pD}) C_{DE} + (R_{pC} + R_{pD} + R_{pE}) (C_{AB} + C_{BCDE} + C_T) = 97,2 \text{ ps}.$$

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 $U_0 \ll 2 (U_{DD} - U_{GS0n}^0)$:

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

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

$$\overline{U_0} = \frac{-K'_p (W/L)_p (-U_{DD} - U_{GS0p}^0 - U_{DSzasp} / 2) U_{DSzasp}}{n K'_n (W/L)_n (U_{DD} - U_{GS0n}^0)} = 0,133 \text{ V} = 133 \text{ mV} .$$

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

$$\overline{U_0} = \frac{\overline{U_0}}{3} = \frac{133}{3} = 44 \text{ mV} .$$

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

$$I_{Dps} = K'_p (W/L)_p \left(-U_{DD} - U_{GS0p}^0 - \frac{U_{DSzasp}}{2} \right) U_{DSzasp} = -92,8 \text{ } \mu\text{A} ,$$

$$P_S = -I_{Dps} U_{DD} = 167 \text{ } \mu\text{W} .$$