SOLUTION to CHAPTER 2 EXERCISES.

Exercise 2.1.

$R_{eff} = \frac{1}{500} = 2k\Omega \quad R_{eff} = \frac{1}{750} = 1.3k\Omega$

2.2 $C = LWC_{ox} = 1.2pf$

2.3. a) $\frac{2k\Omega}{5} = 400\Omega$

b). $\frac{2k\Omega}{0.28} = 7k\Omega$

2.4. n-channel MOSFET

ON-condition $V_{GS} \geq V_{TN}$

SAT-condition $V_{DS} = V_{GS} - V_{TN}$

2.5 p-channel MOSFET

ON-condition $V_{GS} = V_{TP}$

SAT-condition $V_{DS} = V_{GS} - V_{TP}$

2.6 a) $V_{GT} = 1.2 - 0.3 = 0.9\ V$

b) $I_{DSAT,max} = \frac{900}{2} \times 0.9^2 = 365\ \mu A$

c) $V_{DSAT} = 0.9\ V$

2.7. Subthreshold modeling is important but beyond the scope of the course. However, in subthreshold region:

$I_{DS} = I_{OFF}\, e^{qV_{GS}/nkT}$ where $\frac{kT}{q} = 25mV$ @ RT

Join equations in a point V_0, I_0 where currents and their derivatives are equal.

In saturation

$$\frac{\partial I_{DS}}{\partial V_{GS}} = \frac{k}{2} \times 2V_{GT} = \frac{I_{DS}}{V_{GT}/2}$$

In subthreshold

$$\frac{\partial I_{DS}}{\partial V_{GS}} = \frac{I_{DS}}{nkT/q}$$

Hence, $V_0 = V_T + 2n\frac{kT}{q} = V_T + 0.0875\,V.$

2.8. $$\frac{I_{ON}}{I_{OFF}} = \frac{\frac{k}{2} V_{GT}^2}{\frac{k}{2}\left(2n\frac{kT}{q}\right)^2 \times e^{-\left(V_T + 2n\frac{kT}{q}\right)/n\frac{kT}{q}}}$$

In this example $n = 1.6$ and $n\frac{kT}{q} = 0.04\,V$

Hence

$$\frac{I_{ON}}{I_{OFF}} = \frac{(1.2-0.28)^2}{0.08^2} \times e^{\cancel{10.2}\,9} = \underline{1.07 \cdot 10^6}$$

2.9 Determine V_T for a 28 nm process to reach $I_{ON}/I_{OFF} \geq 10^6$. $n\frac{kT}{q} = 40\,mV$; $V_{DD} = 0.9\,V$

$$\frac{I_{ON}}{I_{OFF}} = \frac{(0.9-x)^2}{0.08^2} \times e^{\frac{x+0.08}{0.04}} \geq 10^6$$

Solving numerically the equation

$$e^{\frac{x+0.08}{0.08}} = \frac{80}{0.9-x}, \text{ i.e. } x = -0.08 + 0.08 \ln \frac{80}{0.9-x}$$

yields $x = 0.31\,V$.

Obviously, V_T is not scaled as much as the V_{DD}. While V_{DD} $1.2 \to 0.9\,V$, V_T $0.28 \to 0.31\,V$.