Homework 10 Solutions:

14.38 (a) Switch opens at time $t = 0$, thus $v_O(0+) = 0$ V. The capacitor then charge by a constant current I, thus

$$It = Cv_O(t)$$

$$\Rightarrow v_O(t) = \frac{I}{C}t$$

(b) For $I = 1$ mA and $C = 10$ pF the time t for v_O to reach 1 V can be found as

$$1 = \frac{1 \times 10^{-3}}{10 \times 10^{-12}}\, t$$

$$\Rightarrow t = 10^{-8}\ \text{s} = 10\ \text{ns}$$

14.40 $V_{OH} = V_{DD}$

At $t = 0$, v_I goes low and the transistor turns off instantly, thus

$$v_O(0+) = V_{OL}$$

Now capacitor C charges through R towards $v_O(\infty) = V_{DD}$, thus

$$v_O(t) = V_{DD} - (V_{DD} - V_{OL})\, e^{-t/\tau}$$

At $t = t_{PLH}$,

$$v_O = \frac{1}{2}(V_{OL} + V_{OH}) = \frac{1}{2}(V_{OL} + V_{DD}), \text{ thus}$$

$$\frac{1}{2}(V_{OL} + V_{DD}) = V_{DD} - (V_{DD} - V_{OL})e^{-t/\tau}$$

$$\Rightarrow t_{PLH} = 0.69\tau$$

For $R = 10$ kΩ and we wish to limit τ_{PLH} to 100 ps then the maximum value that C can have is found from

$$0.69 \times C \times 10 \times 10^3 = 100 \times 10^{-12}$$

$$\Rightarrow C = 1.45 \times 10^{-14}\ \text{F}$$

$$= 14.5\ \text{fF}$$

14.63 $E = CV_{DD}^2$

$$= 10 \times 10^{-15} \times 1.8^2 = 32.4\ \text{fJ}$$

For 2×10^6 inverters switched at $f = 1$ GHz,

$$P_D = 2 \times 10^6 \times 1 \times 10^9 \times 32.4 \times 10^{-15}$$

$$= 64.8\ \text{W}$$

$$I_{DD} = \frac{P_D}{V_{DD}} = \frac{64.8}{1.8} = 36\ \text{A}$$

14.65 Each cycle, the inverter draws an average current of

$$I_{av} = \frac{60 + 0}{2} = 30\ \mu\text{A}$$

Since $I_{av} = 150$ μA, then the average current corresponding to the dynamic power dissipation is 120 μA. Thus,

$$P_{dyn} = 3.3 \times 120 \times 10^{-6} = 396\ \mu\text{W}$$

But,

$$P_{dyn} = fCV_{DD}^2$$

Thus,

$$396 \times 10^{-6} = 100 \times 10^6 \times 3.3^2 \times C$$

$$\Rightarrow C = 0.36\ \text{pF}$$

14.67 $t_{PLH} = 30$ ns, $t_{PHL} = 50$ ns

$$t_P = \frac{1}{2}(30 + 50) = 40\ \text{ns}$$

$$P_{Dav} = \frac{1}{2}(1 + 0.6) = 0.8\ \text{mW}$$

$$PDP = 0.8 \times 10^{-3} \times 40 \times 10^{-9} = 32\ \text{pJ}$$