Transient Response and VTC

For the circuit in Fig. 3 calculate and draw waveforms at nodes 1, 2, and $V_{out}$. Voltage pulse is applied to the input $V_{in}$ with duration of the pulse $T_1 = 2$ns. CMOS inverters are assumed ideal, with infinite gain around switching point $V_T = V_{dd}/2$. Resistances of MOS transistors and diode are very small (assume zero). Turn-on voltage of the diode is 0V. Known parameters: $R = 10k\Omega$, $C_1 = C_2 = 50fF$, $V_{dd} = 5V$.

Solution:

For $V_{in} = 0$, right before the rising edge of the pulse, we have following state:

$V_1(0^-) = V_2(0^-) = V_{dd} = 5V$  
$V_3(0^-) = 0$  
$V_{C1}(0^-) = V_2(0^-) = 5V$  
$V_{C2}(0^-) = V_2(0^-) - V_3(0^-) = 5V$

At the rising edge of the pulse, $V_1$ drops to 0V and diode turns off. Capacitors $C_1$ and $C_2$ are discharging through resistance $R$ and output of the first inverter, with discharge time constant of $\tau_1 = R(C_1+C_2) = 1$ns (see Fig. A).

At the rising edge of the pulse, $V_1$ drops to 0V and diode turns off. Capacitors $C_1$ and $C_2$ are discharging through resistance $R$ and output of the first inverter, with discharge time constant of $\tau_1 = R(C_1+C_2) = 1$ns (see Fig. A).

Voltage at the output will not change until $V_2$ reaches switching threshold $V_T = V_{dd}/2$. That will occur at the time $t_1 = \tau_1 \ln(2) = 0.69$ns after the rising edge of $V_{in}$. Therefore, $V_2(t_1) = V_{dd}/2$. As soon as $V_2$ has reached $V_{dd}/2$, $V_{out}$ starts rising, but $V_2$ stays at $V_{dd}/2$ due to infinite gain of the inverter. In this regime, fixed current $I_2 = V_{dd}/(2R)$ discharges $C_2$ and $V_{out}$ is a linear ramp. (see Fig. B)
When $V_{\text{out}}$ reaches $V_{\text{dd}}$ at $t_1 + t_2 = 1.69\text{ns}$, $C_1$ starts to discharge as well with time constant $\tau_1$. At time $T_1$, voltage at node 2 has value: 

$$V_2\left(T_1^-\right) = \frac{V_{\text{dd}}}{2}e^{-\frac{T_1^- - (t_1 + t_2)}{\tau_1}} = 1.835\text{V}.$$ 

When $V_{\text{in}}$ undergoes a falling transition, $V_1$ will rise to $V_{\text{dd}}$, diode will turn-on, $V_2$ will rise to $V_{\text{dd}}$, and $V_{\text{out}}$ returns to 0. All these transitions will happen instantaneously since diode conducts with zero resistance. Complete waveforms are shown in Fig. 3s.

![Waveforms](image-url)

Figure 3s.
Problem 2  OSC

\[ V_B = 3.3 \text{V} \rightarrow .65 \]

\[ t_1 = \frac{C \Delta V}{I_{aug}} = \frac{1p (1.65)}{1.83 \mu} \]

\[ t_2 = \frac{C \Delta V}{5.5 \mu A} \]

\[ x, y, z, A, B \]

\[ t_{osc} = ? \]

\[ R_{on} = 0 \]

\[ C_{par} = 0 \]

\[ t_{pu} = 0 \]

\[ V_H = 1.65 \text{V} \]

\[ y(10^-) = 0 \]

\[ z(0^-) = 3.3 \text{V} \]
Problem 3  Monostable Multivibrator

\[ V_t(M_4, M_5, M) = 0.5V \]
\[ V_t(M_1, M_2, M_3) = 0.4V \]
\[ k = 100 \text{ mA} / \text{V}^2 \]
\[ \gamma = 0 \]

\[ V(0) = 0 \]

\[ I = c \frac{dV}{dt} \]

\[ I_{avg} = I_{dsat} (M_5) \frac{k}{2} \frac{w}{l} \]

\[ \Delta V = I_{avg} \text{ pulse width} \]

\[ \text{V}_{\text{out}} \]