Problem 1: Use the timing parameters in the table for this problem.

	Setup Time	*clk*-to-*Q* Delay	*D*-to-*Q* Delay	Contamination Delay	Hold Time
Flip-Flops	65 ps	50 ps	n/a	35 ps	30 ps
Latches	25 ps	50 ps	40 ps	35 ps	30 ps

For each of the following sequencing styles, determine the maximum logic propagation delay available when using a 500 ps clock period. Assume there is zero clock skew and no time borrowing takes place. (4 points)

i. Flip-flops
ii. Two-phase transparent latches

Solution:

(a) t_{pd} =500-(t_{pcq} + t_{setup}) = 500 - (50 + 65) = 385 ps;

(b) t_{pd} = 500- 2x t_{pdq} = 500 - 2(40) = 420 ps;

Problem 2: Consider a flip-flop built from a pair of transparent latches using nonoverlapping clocks with no combinational logic in between. Express the setup time and hold time of the flip-flop in terms of the latch timing parameters and $t_{nonoverlap}$. (4 points)

Solution:

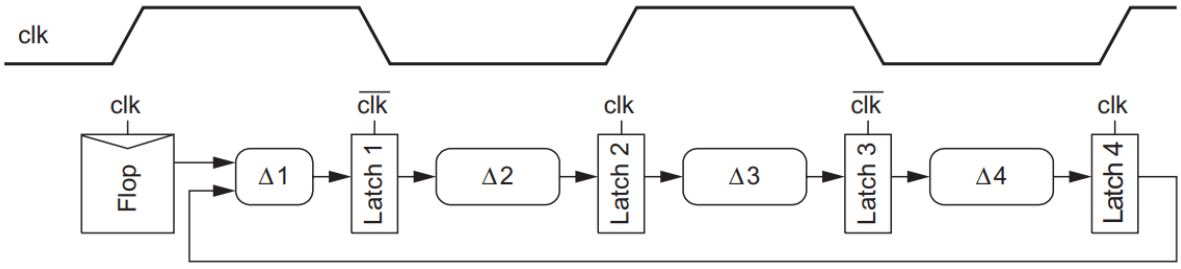
Flop setup time = Latch set up time
+ t nonoverlap time

Flop Hold time = Latch Hold time
− t nonoverlap time

Problem 3: For the path in the figure below, determine which latches borrow time and if any setup time violations occur. Repeat for cycle times of 1200, 1000, and 800 ps. Assume there is zero clock skew and that the latch delays are accounted for in the propagation delay. (12 points)

i. Δ1 = 550 ps; Δ2 = 580 ps; Δ3 = 450 ps; Δ4 = 200 ps

ii. Δ1 = 300 ps; Δ2 = 600 ps; Δ3 = 400 ps; Δ4 = 550 ps



Solution:

$\Delta 1 = 550\,ps,\ \Delta 2 = 580\,ps,\ \Delta 3 = 450\,ps,\ \Delta 4 = 200\,ps$

a) $T_c/2 = 600\,ps$

$\Delta 1, \Delta 2, \Delta 3, \Delta 4 < T_c/2$ (no problem) → no violation

$T_c/2 = 500\,ps$

$\Delta 1 = (T_c/2) + 50$ borrow 50 by Latch 1

$\Delta 2 = (T_c/2) + 80$ borrow (50+80) by Latch 2

$\Delta 3 = (T_c/2) - 50$ borrow (50+80−50) by Latch 3

$\Delta 4 = (T_c/2) - 300$ → all borrow cleared → no violation

$T_c/2 = 400\,ps$

$\Delta 1 = (T_c/2) + 150$ Borrow 150 by Latch 1

$\Delta 2 = (T_c/2) + 180$ Borrow 330 by Latch 2

$\Delta 3 = (T_c/2) + 50$ Borrow 380 by Latch 3

$\Delta 4 = (Tc/2) - 200 \rightarrow$ borrow 180 by latch 4

$\Delta 1 = (Tc/2) + 150 \rightarrow$ borrow 330 by latch1

$\Delta 2 = (Tc/2) + 180 \rightarrow$ borrow 510 by latch2

but $510 > Tc/2 \rightarrow$ violation

b) $\boxed{Tc/2 = 600\ ps}$

$\Delta 1, \Delta 2, \Delta 3, \Delta 4 \leq Tc/2 \rightarrow$ no problem

$Tc/2 = 500\ ps$

$\Delta 1 \leq Tc/2 \rightarrow$ no problem

$\Delta 2 = Tc/2 + 100 \rightarrow$ borrow 100 by Latch 2

$\Delta 3 = Tc/2 - 100 \rightarrow$ borrow 0 $\rightarrow$ borrow cleared

$\Delta 4 = Tc/2 + 50 \rightarrow$ borrow 50 by latch4

But $\Delta 1 = Tc/2 - 200$, so no violation

$T_c = 800, T_c/2 = 400$

$\Delta 1 < T_c/2 \rightarrow$ no violation

$\Delta 2 \leq T_c/2 + 200 \rightarrow$ borrow 200 by latch 2

$\Delta 3 = T_c/2 \rightarrow$ borrow 200 by Latch 3

$\Delta 4 = T_c/2 + 150 \rightarrow$ borrow 350 by Latch 4

$\Delta 1 = T_c/2 - 100 \rightarrow$ borrow 250 by Latch1

$\Delta 2 = T_c/2 + 200 \rightarrow$ borrow 450 by Latch2

but $450 > T_c/2 \rightarrow$ violation