

Problem Set 4 Solutions

CS 230, Spring 2023

1. B) $T_1 \geq T_2$

In pipelined CPU, there will be buffer delay and stage delay. So for 1 instruction nonpipelined CPU takes less time compared to pipelined CPU.

2. **Pipeline A (Uniform Delay)**

$$K = 8, t_p = 2ns, n=100$$

$$ET_A = (k + n - 1)t_p$$

$$= (8+100-1)2$$

$$= 214ns$$

Pipeline B (Non-uniform Delay)

$$k = 5, t_p = \max(2, 4, 6, 3, 2) = 6ns, n=100$$

$$ET_B = (k + n - 1)t_p$$

$$= (5+100-1)6$$

$$= 624ns$$

$$\text{Time saved} = 624 - 214 = 410ns$$

3. $k = 4$

$$t_p = \max(\text{stage delay} + \text{buffer delay})$$

$$= \max(22, 42, 32, 50) \text{ [Last stage does not have a buffer]}$$

$$= 50ns$$

$$t_n = 20 + 40 + 30 + 50 = 140ns$$

$$\text{Speedup (S)} = \frac{t_n}{t_p} = \frac{140}{50} = 2.8$$

$$\text{Efficiency } (\eta) = \frac{S}{k} = \frac{2.8}{4} = 70\%$$

4. $k = 4$

$$t_p = \max(\text{stagedelay} + \text{bufferdelay})$$

$$= \max(5, 7, 4, 12) \text{ [Here buffer is given at last stage explicitly]}$$

$$= 12ns$$

$$t_n = 4 + 6 + 3 + 11 = 24ns$$

$$\text{Speedup} = \frac{t_n}{t_p} = \frac{24}{12} = 2$$

5. We have the following data dependencies:

$$I3 \rightarrow I2$$

$$I4 \rightarrow I3$$

With Operand Forwarding

	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10	CC11	CC12	CC13
I1	IF	ID	EX	EX	EX	EX	EX	WB					
I2		IF	ID	ID	ID	ID	ID	EX	EX	EX	WB		
I3			IF	IF	IF	IF	IF	ID	ID	ID	EX	WB	
I4								IF	IF	IF	ID	EX	WB

= 13 cycles

Without Operand Forwarding

	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10	CC11	CC12	CC13	CC14	CC15	CC16	CC17
I1	IF	ID	EX	EX	EX	EX	EX	WB									
I2		IF	ID	ID	ID	ID	ID	EX	EX	EX	WB						
I3			IF	IF	IF	IF	IF	ID	ID	ID	ID	ID	EX	WB			
I4								IF	IF	IF	IF	IF	ID	ID	ID	EX	WB

= 17 cycles

Thus, 4 cycles are saved

$$6. \text{ \#stalls/Instruction} = 0.3 \cdot 0.6 \cdot 4 + 0.3 \cdot 0.4 \cdot 0.4 \cdot 4$$

$$= 0.192$$

$$\text{Avg Instruction } ET_{\text{pipeline}} = (1 + \text{\#stalls/instruction})t_p$$

$$= (1 + 0.192)2\text{ns}$$

$$= 3.82\text{ns}$$

$$\text{Speedup} = \frac{k}{1 + \text{\#stalls/instruction}} = \frac{5}{1.192} = 2.61$$