

Homework 2 Solutions

a) Timing diagram is given below with explanations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1 SUB R1, R1, R2	IF	DR	EX	ME	WB																									
2 NOOP		IF	DR	EX	ME	WB																								
3 ADD R2, \$02, R3			IF	DR	EX	ME	WB																							
4 ADD R2, \$06, R4				IF	DR	EX	ME	WB																						
5 NOOP					IF	DR	EX	ME	WB																					
6 SUB R4, \$03, R6						IF	DR	EX	ME	WB																				
7 ADD R5, R3, R5							IF	DR	EX	ME	WB																			
8 NOOP								IF	DR	EX	ME	WB																		
9 STL \$07(R5), R6									IF	DR	EX	ME	WB																	
10 SUB R3, \$01, R3										IF	DR	EX	ME	WB																
11 BNZ LOOP											IF	DR	EX	ME	WB															
12 NOOP												IF	DR	EX	ME	WB														
13 NOOP													IF	DR	EX	ME	WB													
14 SUB R4, \$03, R6														IF	DR	EX	ME	WB												
15 ADD R5, R3, R5															IF	DR	EX	ME	WB											
16 NOOP																	IF	DR	EX	ME	WB									
17 STL \$07(R5), R6																		IF	DR	EX	ME	WB								
18 SUB R3, \$01, R3																			IF	DR	EX	ME	WB							
19 BNZ LOOP																				IF	DR	EX	ME	WB						
20 NOOP																					IF	DR	EX	ME	WB					
21 NOOP																						IF	DR	EX	ME	WB				
22 SUB R5, \$02, R5																						IF	DR	EX	ME	WB				
23 BRU DONE																							IF	DR	EX	ME	WB			
24 NOOP																								IF	DR	EX	ME	WB		
25 NOOP																									IF	DR	EX	ME	WB	
26 LDL \$03(R4), R2																										IF	DR	EX	ME	WB

1 NOOP introduced between 1st and 3rd instructions since the value of R2 will be computed at the end of ME phase of 1st instruction.

1 NOOP introduced between 4th and 6th instructions since the value of R4 will be computed at the end of ME phase of 4th instruction.

1 NOOP introduced between 7th and 9th instructions since the value of R5 will be computed at the end of ME phase of 7th instruction.

2 NOOPs introduced after 11th instruction. (branch)

1 NOOP introduced between 15th and 17th instructions since the value of R5 will be computed at the end of ME phase of 15th instruction.

2 NOOPs introduced after 19th instruction. (branch)

2 NOOPs introduced after 23rd instruction. (branch)

- d) The optimized solution is given below. Instruction order is changed so that the number of NOOPs is reduced. The instructions must be arranged accordingly to the number of iterations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 SUB R1, R1, R2	IF	DR	EX	ME	WB																			
2 NOOP		IF	DR	EX	ME	WB																		
3 ADD R2, \$06, R4			IF	DR	EX	ME	WB																	
4 ADD R2, \$02, R3				IF	DR	EX	ME	WB																
5 LOOP SUB R4, \$03, R6					IF	DR	EX	ME	WB															
6 ADD R5, R3, R5						IF	DR	EX	ME	WB														
7 SUB R3, \$01, R3							IF	DR	EX	ME	WB													
8 BNZ LOOP								IF	DR	EX	ME	WB												
9 STL \$07(R5), R6									IF	DR	EX	ME	WB											
10 NOOP										IF	DR	EX	ME	WB										
11 LOOP SUB R4, \$03, R6											IF	DR	EX	ME	WB									
12 ADD R5, R3, R5												IF	DR	EX	ME	WB								
13 SUB R3, \$01, R3													IF	DR	EX	ME	WB							
14 BNZ LOOP														IF	DR	EX	ME	WB						
15 STL \$07(R5), R6															IF	DR	EX	ME	WB					
16 NOOP																IF	DR	EX	ME	WB				
17 BRU DONE																	IF	DR	EX	ME	WB			
18 NOOP																		IF	DR	EX	ME	WB		
19 SUB R5, \$02, R5																			IF	DR	EX	ME	WB	
20 DONE LDL \$03(R4), R2																				IF	DR	EX	ME	WB

- b)** Since the given loop requires 3 NOOP operations, the total amount of penalty would be $3n+4$ if the number of iterations was equal to n .
- c)** $CPI = 30/26=1.154$.

Q2)

- a)** 11 correct mispredictions, 19 mispredictions. (Dynamic prediction with 1-bit)
- b)** 18 correct mispredictions, 12 mispredictions. (2-bit predicts among 00, 01, 10, and 11.)
Initially starts with taking the branch (11), then changes between 00 and 01.
- c)** 20 correct mispredictions, 10 mispredictions. Always changes between 00 and 01.