

4DM4 Assignment 2

Advanced Static Pipelining

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Part (a): DAXPY Loop, No Unrolling, with No Scheduling

4DM4 Assignment 2(a), DAXPY Loop, No Unrolling, No Scheduling

ASSUMPTIONS:

IF = 2-stage pipeline (F1, F2)
 MEM = 2-stage Pipeline (M1, M2)
 FP-ADD = 3-stage Pipeline
 FP-MULT = 6-stage Pipeline

Instruction	Clock Cycle																				
loop: L.D F2, 0(R1)	F1	F2	ID	EX	M1	M2	WB														
MULT.D F4, F2, F0		F1	F2	ID	STL	STL	M1	M2	M3	M4	M5	M6	WB								
L.D F6, 0(R2)			F1	F2	STL	STL	ID	EX	M1	M2	WB										
ADD.D F6, F4, F6				F1	STL	STL	F2	ID	STL	STL	STL	STL	A1	A2	A3	WB					
S.D 0(R2), F6							F1	F2	STL	STL	STL	STL	ID	EX	STL	M1	M2	WB			
DADDUI R1, R1, #8								F1	STL	STL	STL	STL	F2	ID	STL	EX	M1	M2	WB		
DADDUI R2, R2, #8													F1	F2	STL	ID	EX	M1	M2	WB	
DSGTUI R3, R1, done														F1	STL	F2	ID	EX	M1	M2	WB
BEQZ R3, loop																F1	F2	ID			
No-op (how many no-ops?)																	F1	F2	ID		

Each iteration of this loop takes 23 clock cycles. The given clock speed is 3 GHz. The following equation can be used to calculate the MFLOP rating for this process.

$$\text{MFLOP Rating} = (3\text{GHz}) * \frac{1 \text{ FLOP}}{21 \text{ clock cycles}} = 142.9 \text{ MFLOP/s} \quad (1)$$

Part (b): DAXPY Loop, No Unrolling, with Scheduling

4DM4 Assignment #2(b), Compressed Timing Table, No Unrolling with Scheduling

Instruction Slot #1	IF (F1,F2)	ID	EX (Int, FP)	MEM (M1,M2)	WB	Comment/Hazard
loop: L.D F2, 0(R1)	1,2	3	4	5,6	7	
L.D F6, 0(R2)	2,3	4	5	6,7	8	
MULT.D F4, F2, F0	3,4	5	6-11	12,13	14	F4 OK (No data hazard at cc 5)
DADDUI R2, R2, #8	4,5	6	7	8,9	10	
DADDUI R1, R1, #8	5,6	7	8	9,10	11	
ADD.D F6, F4, F6	6,7	8-11	12-14	15,16	17	F6 stalls from cc 9-11 F4 forwarded from EX to EX
S.D 0(R2), F6	7-11	12	13	14,15	16	F6 Forwarded from EX to M2
DSGTUI R3, R1, done	8-12	13	14	14,15	16	
BEQZ R3, loop	12,13	14	-	-	-	
loop: start next iteration						

Each iteration of this loop takes 16 clock cycles. The given clock speed is 3 GHz. The following equation can be used to calculate the MFLOP rating for this process.

$$\text{MFLOP Rating} = (3\text{GHz}) * \frac{1 \text{ FLOP}}{16 \text{ clock cycles}} = 187.5 \text{ MFLOP/s} \quad (2)$$

Part (c): DAXPY Loop, with Unrolling, with No Scheduling

4DM4 Assignment #2(c), Compressed Timing Table, Unrolled with no Scheduling

Instruction Slot #1	IF (F1,F2)	ID	EX (Int, FP)	MEM (M1,M2)	WB	Comment/Hazard
loop: L.D F2, 0(R1)	1-2, 14-16, 28-30, 42-44	3, 17, 31, 45	4, 18, 32, 46	5-6, 19-20, 33-34, 47-48	7, 21, 35, 49	F2 stalled for cc 15, 29, 43
MULT.D F4, F2, F0	2-3, 16-17, 30-31, 44-45	4, 18, 32, 46	7-12, 21-26, 35-40, 49-54	-	13, 27, 41, 55	F4 stalled for cc 5-6 Bypasses M1, M2
L.D F6, 0(R2)	3-4, 17-18, 31-32, 45-46	7, 21, 35, 49	8, 22, 26, 50	9-10, 23-24, 37-38, 51-52	11, 25, 39, 53	Stalled at F2 for cc 5,6
ADD.D F6, F4, F6	4-7, 18-21, 32,35, 46-49	8, 22, 36, 50	13-15, 27-29, 41-43, 55-57	-	16, 30, 44, 58	F6 stalled for cc 5,6 and cc 9-12 F4 forwarded from WB to EX Bypasses M1, M2
S.D 0(R2), F6	7-8, 21-22, 35-36, 49-50	13, 28, 42, 55	14, 28, 42, 56	16-17, 30-31, 44-45, 58-59	18, 32, 46, 60	Stalled at F1 for cc 9-12, and cc 15 F6 forwarded from EX to M2
DADDUI R1, R1, #8	8-13, 22-27, 36-41, 50-55	14, 28, 42, 56	16, 30, 44, 58	17-18, 31-32, 45-46, 59-60	19, 33, 47, 61	R1 stalled for cc 9-12 and 15
DADDUI R2, R2, #8	13-14, 27-28, 41-42, 55-56	16, 30, 44, 58	17, 31, 45, 59	18-19, 32-33, 46-47, 60-61	20, 34, 48, 62	R2 stalled for cc 15
DSGTUI R3, R1, done	56-58	59	60	61-62	63	
BEQZ R3, loop	58-59	60	-	-	-	Branch slot R3
No-Op (how many ?)	59-60	61	-	-	-	
loop: start next iteration						

Each iteration of this loop (unrolled 4 times) takes 64 clock cycles. The given clock speed is 3 GHz. The following equation can be used to calculate the MFLOP rating for this process.

$$\text{MFLOP Rating} = (3\text{Ghz}) * \frac{1 \text{ FLOP}}{63 \text{ clock cycles}} = 47.6 \text{ MFLOP/s} \quad (3)$$

Part (d): DAXPY Loop, with Unrolling, with Scheduling

4DM4 Assignment #2(d), Compressed Timing Table, DAXPY Loop, With Unrolling, and with Scheduling

Instruction Slot #1	IF (F1,F2)	ID	EX (Int, FP)	MEM (M1,M2)	WB	Comment/Hazard
loop: L.D F2, 0(R1)	1-2, 8-9, 15-16, 23-24	3, 10, 17, 25	4, 11, 18, 26	5-6, 12-13, 19-20, 27-28	7, 14, 21, 29	
L.D F6, 0(R2)	2-3, 9-10, 16-17, 24-25	4, 11, 18, 26	5, 12, 19, 27	6-7, 13-14, 20-21, 28-29	8, 15, 22, 30	
MULT.D F4, F2, F0	3-4, 10-11, 17-18, 25-26	5, 12, 19, 27	6-12, 13-19, 20-26, 28-34	7-8, 14-15, 21-22, 29-30	9, 16, 23, 31	F4 OK (No hazards)
DADDUI R2, R2, #8	4-5, 11-12, 18-19, 26-27	6, 13, 20, 28	7, 14, 21, 29	8-9, 15-16, 22-23, 30-31	10, 17, 24, 32	
DADDUI R1, R1, #8	5-6, 12-13, 19-20, 27-28	7, 14, 21, 29	8, 15, 22, 30	9-10, 16-17, 23-24, 31-32	11, 18, 25, 33	
ADD.D F6, F4, F6	6-7, 13-14, 20-21, 28-29	8-11, 15-18, 22-25, 30-33	12-14, 19-21, 26-28, 34-36	15-16, 22-23, 29-30, 37-38	17, 24, 31, 39	F6 stalled at D for 3 extra cc F4 forwarded from EX to EX
S.D 0(R2), F6	7-11, 14-18, 21-25, 29-33	12, 19, 26, 34	13, 18, 27, 34	14-15, 19-20, 28-29, 35-36	16, 21, 30, 37	F6 forwarded from EX to M2
DSGTUI R3, R1, done	34-38	39	40	41-42	43	
BEQZ R3, loop	38-39	40	-	-	-	Branch slot R3
loop: start next iteration						

Each iteration of this loop (unrolled 4 times) takes 43 clock cycles. The given clock speed is 3 GHz. The following equation can be used to calculate the MFLOP rating for this process.

$$\text{MFLOP Rating} = (3\text{Ghz}) * \frac{1 \text{ FLOP}}{43 \text{ clock cycles}} = 69.7 \text{ MFLOP/s} \quad (4)$$

Part (e): DAXPY Loop, with Unrolling, with Scheduling. On Dual-Issue Machine

4DM4 Assignment #2(e), Compressed Timing Table, DAXPY Loop, With Unrolling and Scheduling. On Dual-Issue Machine

					slot # 1			slot # 2				
Instruction Slot # 1		Instruction Slot #2		IF	ID	EX1	MEM1	WB1	EX2	MEM2	WB2	Comment/Hazard
loop:	L.D F2, 0(R1)	L.D F6, 0(R2)	1,2	3	4	5,6	7	4	5,6	7		
	L.D F3, 8(R1)	L.D F7, 8(R2)	2,3	4	5	6,7	8	5	6,7	8		
	L.D F4, 16(R1)	L.D F8, 16(R2)	3,4	5	6	7,8	9	6	7,8	9		
	L.D F5, 24(R1)	L.D F9, 24(R2)	4,5	6	7	8,9	10	7	8,9	10		
DADDUI	R2, R2, #8	MULT.D F12, F2, F0	5,6	7	8	9,10	11	7-12	13,14	15		F12 OK (No hazards)
DADDUI	R1, R1, #8	MULT.D F13, F3, F0	6,7	8	9	10,11	12	8-13	14,15	16		F13 OK (No hazards)
DADDUI	8(R2), 8(R2), #8	MULT.D F14, F4, F0	7,8	9	10	11,12	13	9-14	15,16	17		F14 OK (No hazards)
DADDUI	8(R1), 8(R1), #8	MULT.D F15, F5, F0	8,9	10	11	12,13	14	11-16	16,17	18		F15 OK (No hazards)
DADDUI	16(R2), 16(R2), #8	ADD.D F16, F12, F6	9,10	11	12	13,14	15	12-14	15,16	17		F12 forwarded from M2 to EX
DADDUI	16(R1), 16(R1), #8	ADD.D F17, F13, F7	10,11	12	13	14,15	16	13-15	16,17	18		F12 forwarded from M2 to EX
DADDUI	24(R2), 24(R2), #8	ADD.D F18, F14, F8	11,12	13	14	15,16	17	14-16	17,18	19		F14 forwarded from M2 to EX
DADDUI	24(R1), 24(R1), #8	ADD.D F19, F15, F9	12,13	14	15	16,17	18	15-17	18,19	20		F15 forwarded from M2 to EX
DSGTUI	R3, R1, done	noop										
BEQZ	R3, loop	noop										Branch slot R3
	S.D 0(R2), F16	S.D 8(R2), F18	15,16	17	18	19,20	21	18	19,20	21		
	S.D 16(R2), F18	S.D 24(R2), F19	16,17	18	19	20,21	22	19	20,21	22		
loop: start next iteration												

Each iteration of this loop (unrolled 4 times) is ran using 2 seperate slots, allowing for 2 instructions to run simultaneously. The whole iteration takes 22 clock cycles. The given

clock speed is 3 GHz. The following equation can be used to calculate the MFLOP rating for this process.

$$\text{MFLOP Rating} = (3\text{GHz}) * \frac{1 \text{ FLOP}}{22 \text{ clock cycles}} = 136.3 \text{ MFLOP/s} \quad (5)$$