

# CSCI 516 - Fundamental Concepts in Computing and Machine Organization

## Homework Assignment 6

### Questions

Given the following assembly instructions, answer the questions.

loop:

```
LDUR X9, [X0, #0]
LSL X9, X9, #2
STUR X9, [X0, #0]
ADD X10, X10, #8
CMP X1, X10
B.GT loop
```

X0 stores the base address of an array, X1 indicate the number of iterations for this loop.

1. Assume there is no forwarding or branch prediction. How many stalls are in the pipeline in the previous code (one iteration). List all the stalls between the execution of the instructions.

If there is no data forwarding, there is 10 stalls in total.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LDUR X9, [X0, #0]	IF	ID	EX	MEM	WB													
LSL X9, X9, #2		IF	(S)	(S)	ID	EX	MEM	WB										
STUR X9, [X0, #0]					IF	(S)	(S)	ID	EX	MEM	WB							
ADD X10, X10, #8								IF	ID	EX	MEM	WB						
CMP X1, X10									IF	(S)	(S)	ID	EX	MEM	WB			
B.GT loop												IF	(S)	(S)	ID	EX	MEM	WB
Outside															IF	(S)	(S)	
LDUR X9, [X0, #0]																		IF

- LDUR X9, [X0, #0] writes back the value to X9 in the fifth stage (WB), then send to the third stage of LSL X9, X9, #2 for execution. (2 stalls)
- LSL X9, X9, #2 writes back the value to X9 in the fifth stage (WB), then send to the third stage of STUR X9, [X0, #0] for execution. (2 stalls)
- ADD X10, X10, #8 writes back the value to X10 in the fifth stage, then send to the third stage of CMP X1, X10. (2 stalls)
- CMP X1, X10 do the comparison at the fourth stage and get the result in the fifth stage, then send the the third stage of B.GT loop (2 stalls).
- B.GT control hazard with 2 stalls.

2. Assume there is forwarding, no branch prediction.

a. (8 points) Unroll the loop two times.

b. (8 points) Reorder the code and see how many cycles are needed to complete the unrolled code.

a. Unroll the loop two times.

loop:

```
LDUR X9, [X0, #0]
LSL X9, X9, #2
STUR X9, [X0, #0]
LDUR X11, [X0, #8]
LSL X11, X11, #2
STUR X11, [X0, #8]
ADD X10, X10, #16
CMP X1, X10
B.GT loop
```

b. Reorder the code loop:

```
LDUR X9, [X0, #0]
LDUR X11, [X0, #8]
LSL X9, X9, #2
LSL X11, X11, #2
STUR X9, [X0, #0]
STUR X11, [X0, #8]
ADD X10, X10, #16
CMP X1, X10
B.GT loop
```

On average, 9 cycles are needed after unrolling and reordering the code.