Out-of-Order Execution

Question A

-1	0	3	4
0	4	9	10

r0	f0	f1
r1	f2	r0

Question B

-1	0	3	4
0	4	9	10
5	10	15	16

r0	f0	f1
r1	f2	r0
r0	r1	f0

Question C

-1	0	2	3
0	1	3	4
1	4	7	8
2	8	13	14
4	5	8	15
5	14	19	20

r0	x1	
r1	x1	
r2	r0	r1
r3	f2	r2
r0	x1	
r1	r3	r0

Virtual Memory & Aliasing Problem

Question A

$2048 \times 8/64 = 256$

$32GB/2048Byte = 16777216$

$256^k \geq 16777216 \rightarrow k$

$k \geq 3$

Question B

alias problem：多个虚拟地址映射到了同一个物理地址，当其中一个虚拟地址修改后，若TLB中还有其他映射到同一物理地址的虚拟地址，会产生数据一致性问题。

$L + b \leq k$

映射到同一个PA的VA后k位是相同的，如果以相同的这部分作为index，就可以保证他们映射到同一个地方，因此需要保证上式成立。

为了保证这些VA有相同的tag，所以将VA不同的部分翻译到PA，来保证相同。

Question C

$k = log_2(4096 \times 8) = 15$

$L = log_2(256) = 8$

$b = log_2(64 \times 8) = 9$

因为$L + b \leq k$，所以令$L = 6$

因此设计成为至少4路关联的Cache

Branch Prediction

Question A

	Instruction	Counter	Prediction	Actual
i=0	skip1	01	not taken	taken
	skip2	01	not taken	not taken
	loop	01	not taken	taken
i=1	skip1	10	taken	not taken
	skip2	00	not taken	taken
	loop	10	taken	taken
i=2	skip1	01	not taken	taken
	skip2	01	not taken	not taken
	loop	11	taken	taken
i=3	skip1	10	taken	not taken
	skip2	00	not taken	taken

	skip2 **Instruction** loop	00 **Counter** 11	not taken **Prediction** taken	taken **Actual** not taken

Branch	Accuracy
blt	0%
bge	50%
bnez	50%
overall	33%

Question B

	Instruction	Global History	Counter 0	Counter 1	Prediction	Actual
i=0	skip1	0	01	01	not taken	taken
	skip2	1	01	00	not taken	not taken
	loop	0	10	00	not taken	taken
i=1	skip1	1	10	00	not taken	not taken
	skip2	0	11	00	taken	taken

	Instruction	Global History	Counter 0	Counter 1	Prediction	Actual
	loop	1	11	01	not taken	taken
i=2	skip1	1	11	10	not taken	taken
	skip2	1	11	01	taken	not taken
	loop	0	11	01	taken	taken
i=3	skip1	1	11	00	not taken	not taken
	skip2	0	11	00	taken	taken
	loop	1	11	00	not taken	not taken

Branch	Accuracy
blt	75%
bge	75%
bnez	50%
overall	66%

Question C

bge x2, x5, skip2

因为这一条分支语句很大概率与前一条分支语句的结果相反，而global history相当于将分支依照前一条分支的结果进行分类。在同一类中，bge这条分支语句总是always taken或者always not taken，因此总能预测正确，因此会获得最大的预测收益。

Question D

BHT与BHB互不冲突，且都可以优化分支预测性能。

BHT可以提高分支预测的准确率。

BHB可以缓存分支目标地址，在命中的情况下可以减少计算目标地址的时间。