

Started on	Monday, 24 February 2020, 5:36 PM
State	Finished
Completed on	Monday, 24 February 2020, 5:51 PM
Time taken	15 mins 21 secs
Marks	9.00/12.00
Grade	7.50 out of 10.00 (75%)

Question **1**  
Correct  
Mark 2.00 out of 2.00

Assume you have the following code

```
/* Accumulate in temporary */
void inner4(vec_ptr u, vec_ptr v, data_t *dest)
{
    long int i;
    int length = vec_length(u);
    data_t *udata = get_vec_start(u);
    data_t *vdata = get_vec_start(v);
    data_t sum = (data_t) 0;
    for (i = 0; i < length; i++) {
        sum = sum + udata[i] * vdata[i];
    }
    *dest = sum;
}
```

and you modify the code to use 4-way loop unrolling and four parallel accumulators. Measurements for this function with the x86-64 architecture shows it achieves a CPE of 2.0 for all types of data.

Assuming the model of the Intel i7 architecture shown in class (one branch unit, two arithmetic units, one load and one store unit), the performance of this loop with any arithmetic operation can not get below 2.0 CPE because of  ✓ .

When the same 4x4 code is compiled for the IA32 architecture, it achieves a CPE of 2.75, worse than the CPE of 2.25 achieved with just four-way unrolling. The mostly likely reason this occurs is because of  ✓ .

Question **2**

Correct

Mark 1.00 out of 1.00

Assume you have the following code

```
/* Accumulate in temporary */
void inner4(vec_ptr u, vec_ptr v, data_t *dest)
{
    long int i;
    int length = vec_length(u);
    data_t *udata = get_vec_start(u);
    data_t *vdata = get_vec_start(v);
    data_t sum = (data_t) 0;
    for (i=0; i < length; i++) {
        sum = sum + udata[i] * vdata[i];
    }
    *dest = sum;
}
```

and you modify the code to the form below.

```
/* Accumulate in temporary */
void inner4(vec_ptr u, vec_ptr v, data_t *dest)
{
    long int i;
    int length = vec_length(u);
    data_t *udata = get_vec_start(u);
    data_t *vdata = get_vec_start(v);
    data_t sum = (data_t) 0;
    data_t sum2 = (data_t) 0;
    for (i = 0; i < length-1; i += 2) {
        sum = sum + udata[i] * vdata[i];
        sum2 = sum2 + udata[i+1] * vdata[i+1];
    }
    for (; i < length; i++) {
        sum = sum + udata[i] * vdata[i];
    }
    *dest = sum + sum2;
}
```

What type of optimizations is being applied?

Pick all optimizations the programmer performed that play a significant role in performance.

Select one or more:

- ☐ a. Inlining
- ☐ b. Instruction pipelining
- ☐ c. Common subexpression elimination
- ☒ d. Loop unrolling
- ☒ Correct!
- ☐ e. Machine independent optimization
- ☒ f. Parallel accumulators
- ☒
- ☐ g. Strength reduction

Your answer is correct.

This is an example of loop unrolling and multiple accumulators.

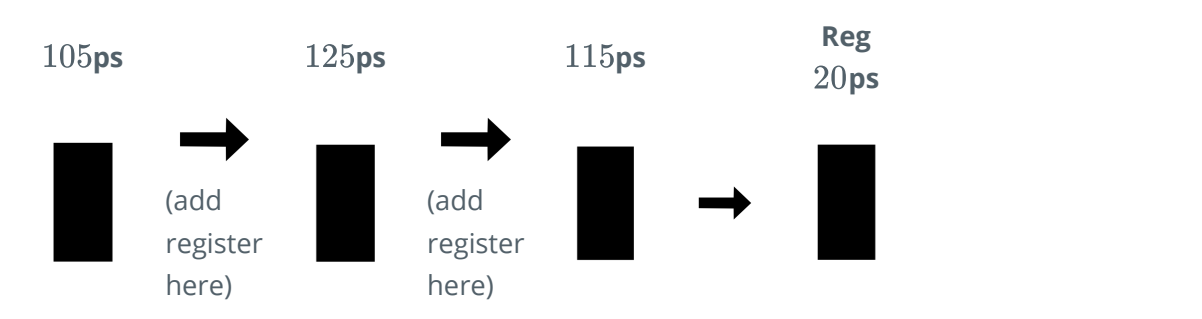
The correct answers are: Loop unrolling, Parallel accumulators

Question 3

Correct

Mark 2.00 out of 2.00

We have a combinatorial logic function that can be decomposed into three steps each with the indicated delay with a resulting clock speed of 2.74 GHz.



Assume we further pipeline this logic by adding two additional registers. What would be the resulting clock speed in GHz?

6.8966

You can use an expression if you like.

Your last answer was interpreted as follows: 6.8966

Correct answer, well done.  
The cycle time of the fully pipelined design would depend on the largest stage delay ( 125 ) and one register delay. This results in a total cycle time of 145 with a resulting clock speed of 6.89655172414 GHz.

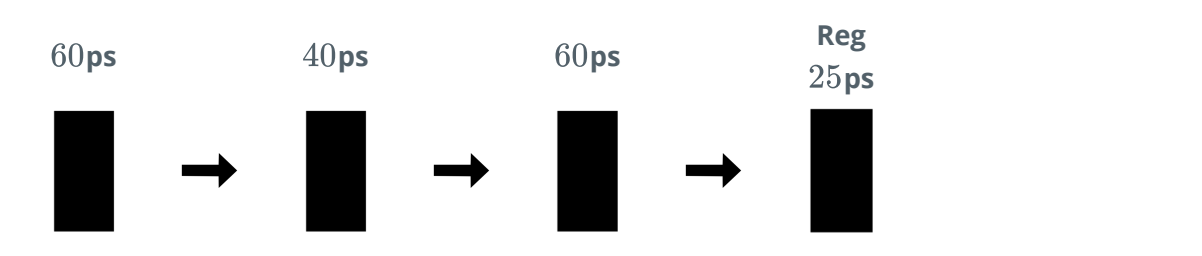
A correct answer is  $\frac{200}{29}$ , which can be typed in as follows: 200/29

Question 4

Incorrect

Mark 0.00 out of 1.00

We have a combinatorial logic function that can be decomposed into three steps each with the indicated delay with a resulting clock speed of 5.41 GHz.



Assume we further pipeline this logic by adding just one additional register between the first two or last two stages of combinational logic. What would be the highest resulting clock speed we could achieve in GHz?

11.76

You can use an expression if you like.

Your last answer was interpreted as follows: 11.76

Incorrect answer.  
Your answer 11.76 is not close enough to the correct answer.  
If we add the additional register between the first two logic blocks, the delays would be 60 and 100. If we put the register between the 2nd and 3rd block, the delays would be 100 and 60. The best overall delay is thus 100, and the total pipeline delay is 100+25. This results in a clock speed of 8.0 GHz.

A correct answer is 8.0, which can be typed in as follows: 8.0


Question **5**

Correct

Mark 1.00 out of 1.00

The following code fragments each compute the same results. Which would incur the least delay due to pipelining on a computer with a single functional unit? You can assume all memory loads take the same time.

Select one:

- ☐ a. `leaq 8(%rbx), %rdi`  
`leaq (%rdi), %rsi`  
`sar $4,%rsi`  
`movq 16(%ebc), %rbi`  
`movq (%rbi),%rax`  
`sal $2,%rax`  
`addq %rsi,%rax`
- ☒ b. `leaq 8(%rbx), %rdi`  
`leaq 16(%ebc), %rbi`  
`movq (%rdi), %rsi`  
`movq (%rbi),%rax`  
`sar $4,%rsi`  
`sal $2,%rax`  
`addq %rsi,%rax`
-  ☐ c. `leaq 8(%rbx), %rdi`  
`leaq 16(%ebc), %rbi`  
`movq (%rdi), %rsi`  
`sar $4,%rsi`  
`movq (%rbi),%rax`  
`sal $2,%rax`  
`addq %rsi,%rax`

Your answer is correct.

If two instructions of the same type are executed one immediately after another, for a single functional unit, they will be pipelined faster.

The correct answer is: `leaq 8(%rbx), %rdi`  
`leaq 16(%ebc), %rbi`  
`movq (%rdi), %rsi`  
`movq (%rbi),%rax`  
`sar $4,%rsi`  
`sal $2,%rax`  
`addq %rsi,%rax`

Question 6

Partially correct

Mark 3.00 out of 5.00

The following graphs illustrate different data flow graphs for the equations shown below. Drag the appropriate equation to the matching data flow graph that illustrates the order of evaluation.

$r = ((r * x) * y) * z$

$r = r * ((x * y) * z)$

$r = (r * (x * y)) * z$

$r = r * (x * (y * z))$

$r = (r * x) * (y * z)$

✓

✗

✗

✓

✓

r

x

y

z

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r

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x

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r

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r

r

x

y

z

\*

\*

\*

r

Your answer is partially correct.

You have correctly selected 3.

For each of the figure it is very clear from the dependency.

Ex: [1]  $r * x$  should be computed first as the result is required to compute  $(r * x) * y$  and this is dependent on computing the next result  $((r * x) * y) * z$

Hence  $r$  should be  $r = ((r * x) * y) * z$

Similar explanation holds for rest of expressions given.

The correct answer is:

The following graphs illustrate different data flow graphs for the equations shown below. Drag the appropriate equation to the matching data flow graph that illustrates the order of evaluation.

$[r = ((r * x) * y) * z]$

$[r = (r * (x * y)) * z]$

$[r = r * ((x * y) * z)]$

$[r = r * (x * (y * z))]$

$[r = (r * x) * (y * z)]$

r

x

y

z

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r

r

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https://moodle.cs.colorado.edu/mod/quiz/review.php?attempt=570464&cmid=42806

5/5