COSC2644
Introduction to Computer Systems

Assignment 1

Completed for: COSC2644 Introduction to Computer Systems SP4 2019

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05/01/2020

Task 1. A) Convert student number to binary.

<table>
<tr>
<td>LSB 1695074
2 3390149
2

13
12

19
18

10
10

01
02

14
14

9
2

R 1</td>
<td>847537
2 1695074
16

9
8

15
14

10
10

7
6

14
14

0</td>
<td>423768
2 847537
8

4
4

7
6

15
14

13
12

17
16

R 1</td>
<td>211884
2 423768
4

2
2

3
2

17
16

16
16

8
8

0</td>
</tr>
<tr>
<td>105942
2 211884
2

1
2

11
10

18
9

8
8

4
4

0</td>
<td>52971
2 105942
10

5
4

19
18

14
14

2
2

0</td>
<td>26485
2 52971
4

12
12

9
8

17
16

11
10

R 1</td>
<td>13242
2 26485
2

6
6

4
4

8
8

5
4

R 1</td>
</tr>
</table>

<table>
<tr>
<td>6621
2 13242
12

12
12

4
4

2
2

0</td>
<td>3310
2 6621
6

6
6

2
2

1
2

R 1</td>
<td>1655
2 3310
2

13
12

11
10

10
10

0</td>
<td>827
2 1655
16

5
4

15
14

R 1</td>
<td>413
2 827
8

2
2

7
6

R 1</td>
</tr>
<tr>
<td>206
2 413
4

1
2

13
12

R 1</td>
<td>103
2 206
2

0
2

6
6

R 0</td>
<td>51
2 103
10

3
2

R 1</td>
<td>25
2 51
4

11
10

R1</td>
<td>12
2 25
2

5
4

R1</td>
</tr>
<tr>
<td>MSB
6
2 12
12

R 0</td>
<td>6/2 = 3 R 0
3/2 = 1 R 1
1/2 = 0 R 1</td>
<td colspan="3">0011 0011 1011 1010 1100 0101

This is the equivalent in binary for the student decimal number 3390149.</td>
</tr>
</table>

Task 1. B) Convert binary string to octal.

Octal split result into groups of 3, each set goes from 0 to 7.

001 100 111 011 101 011 000 101

Set ↓ *Position →* *Result ↓*

	2^2	**1^1**	**0^0**	
1	0	0	1	1
2	1	0	0	4
3	1	1	1	7
4	0	1	1	3
5	1	0	1	5
6	0	1	1	3
7	0	0	0	0
8	1	0	1	5

Task 1. B) Convert binary string to Hexadecimal.

Hexadecimal result is split into groups of 4 with possible values of 0-15 = 0 – F.

0011 0011 1011 1010 1100 0101

Set ↓ *Position →* *Result ↓*

	2^3	**2^2**	**2^1**	**2^0**	
1	0	0	1	1	3
2	0	0	1	1	3
3	1	0	1	1	B
4	1	0	1	0	A
5	1	1	0	0	C
6	0	1	0	1	5

Task 1. C + D) Convert student number to base 12, Add 24 to the result

Base 12 conversion

3390149/12 = Subtracting original number by the position values and how many times it will fit into the initial or remaining value.

1 1	7	5	A	8	5	
12^6	12^5	12^4	12^3	12^12	12^1	12^0
2985984	248832	20736	1728	144	12	1

This method calculates 12 powers and for this method the greatest value that can go into the number to be divided is less than the value to be divided. For each of the values is subtracted and the amount of times the value can go into the original value is recorded.

Is the same as….

		Multiply rounded value of second column by 12 to get remainder by subtracting with column 1		
1st column divisible by 12			Remainder	
3390149	282512	3390144	5	
282512	23542	282504	8	
23542	1961	23532	10	A
1961	163	1956	5	
163	13	156	7	
13	1	12	1	
1	0	0	1	
Adding 24			Remainder	
3390173	282514	3390168	5	
282514	23542	282504	10	A
23542	1961	23532	10	A
1961	163	1956	5	
163	13	156	7	
13	1	12	1	
1	0	0	1	

Adding 24 can be divided by twelve 2 times because being the Base 12 number system and will therefore add 2 onto the 1 position to effectively make the new value 1175AA5. The reason this is easy to calculate is the number is divisible by 12 and therefore the result can be placed into its position based on its value without doing any in-depth calculations.

Task 1. E) Convert student number to base 26 letters instead of numbers,

Name in Base 26 format				
First Name Ben first letter less than 2 (2 letters)	EE			
Last Name first 3 letters	TOM			
	E = 4			
	T = 19			
	O = 14			
	M = 12			
Convert the two sets to Base 10				
Position for Base 26	**2**	**1**	**0**	
	26 * 26	26 * 1	1	
Value	676	26	1	
Position for set 1		**4**	**4**	
		26 * 4	4 * 1	
Value		104	4	108
Position for set 2	**19**	**14**	**12**	
	19 * 676	14 * 26	12 * 1	
Value	12844	364	12	13220
Total in Base 10				**13328**
Base 26	**T**	**S**	**Q**	
Take remainders list from right to left Until number is an integer or find values of positions and subtract from each until 0	19	18	16	
	19 * 676	18 * 26	16 * 1	
	12844	468	16	13328

		Remainder
13328 / 26	512	**16**
512 / 26	494	**18**
494 / 26	**19**	0

Finding value by dividing by 26 and obtaining remainder until value of the remainder reaches 0.

Task 2 - Binary Addition

A + B). Last 3 numbers for student number: 149 converting each digit to binary and adding result.

		Base 10 to Base 2					
		Number 149					
		1	**0001**				
		4	**0100**				
		9	**1001**				
	Overflow	**Summing the values in binary for validation to 4-bit arithmetic**					
Position		3	2	1	0		
Carry				1			
		0	**0**	**0**	**1**		
		0	**1**	**0**	**0**		
		1	**0**	**0**	**1**		
Binary		1	1	1	0		
Value		8	4	2	0		
Total		**14**					

C). Binary result to Base 4

Number 14	Binary to Base 4	
Position	1	0
Value	4	1
	3 * 4 = 14 / 4 = 3 R 2	2 * 1 = 2/1 = 2
Result	3	2
	Position 1 and 0	Position 1 only
Base 2	11	10
Base 4	3	2

Task 3. A) Truth tables

The following identities /A .(B +/C) = (/A+B).(/A+/C) are FALSE.

A	B	C		/C	(B + / C)	/A	/A.(B+/C)
0	0	0		1	1	1	1
0	0	1		0	0	1	0
0	1	0		1	1	1	1
0	1	1		0	1	1	1
1	0	0		1	1	0	0
1	0	1		0	0	0	0
1	1	0		1	1	0	0
1	1	1		0	1	0	0

A	B	C		/A	(/A+B)	/C	(/A + /C)	(/A+B) . (/A + /C)
0	0	0		1	1	1	1	1
0	0	1		1	1	0	1	1
0	1	0		1	1	1	1	1
0	1	1		1	1	0	1	1
1	0	0		0	0	1	1	0
1	0	1		0	0	0	0	0
1	1	0		0	1	1	1	1
1	1	1		0	1	0	0	0

B) The following /(A.B.C) = /A . /B . /C identities are also FALSE

A	B	C		(A.B.C)	/(A.B.C)
0	0	0		0	1
0	0	1		0	1
0	1	0		0	1
0	1	1		0	1
1	0	0		0	1
1	0	1		0	1
1	1	0		0	1
1	1	1		1	0

A	B	C		/A	/B	/C	/A./B./C
0	0	0		1	1	1	1
0	0	1		1	1	0	0
0	1	0		1	0	1	0
0	1	1		1	0	0	0
1	0	0		0	1	1	0
1	0	1		0	1	0	0
1	1	0		0	0	1	0
1	1	1		0	0	0	0

Task 4. – Bitwise Operations

Byte A	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M(Mask)	0	0	1	0	0	0	0	0
A OR M	x	x	1	x	x	x	x	x
Byte B	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M1(Mask)	1	1	1	1	1	1	1	1
B OR M1	x	x	x	x	x	x	x	x
Byte B	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M2(Mask)	0	1	1	1	1	1	1	1
B AND M2	0	1	1	1	1	1	1	1
Byte C	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M(Mask)	0	1	0	0	0	0	1	0
C OR M	x	1	x	x	x	x	1	x
Byte D	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M(Mask)	0	0	0	0	0	0	0	0
D AND M	0	0	0	0	0	0	0	0
Byte D	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M2(Mask)	0	0	0	0	1	0	0	0
D OR M2	x	x	1	x	1	x	x	0
Byte E	x	x	x	x	x	x	x	x
Bit Position	7	6	5	4	3	2	1	0
M(Mask)	1	1	1	0	0	1	1	1
E XOR M	1	1	1	x	x	1	1	1

Task 5. Logic circuits and truth tables

Circuit A							
((B.C)NOR/A).B.A)							
Circuit B							
A.B./C							
	A	B	C	B.C	/A	D = (B.C) NOR /A	**Final Output O = D.A.B**
	0	0	0	0	1	0	**0**
	0	0	1	0	1	0	**0**
	0	1	0	0	1	0	**0**
	0	1	1	1	1	0	**0**
	1	0	0	0	0	1	**0**
	1	0	1	0	0	1	**0**
	1	1	0	0	0	1	**1**
	1	1	1	1	0	0	**0**
	A	B	C	/C	**Final Output O = A.B./C**		
	0	0	0	1	**0**		
	0	0	1	0	**0**		
	0	1	0	1	**0**		
	0	1	1	0	**0**		
	1	0	0	1	**0**		
	1	0	1	0	**0**		
	1	1	0	1	**1**		
	1	1	1	0	**0**		

Both circuits are equivalent as demonstrated in the truth tables.

Task 6. Pipelining

The total time it takes is effectively adding the time it takes to prepare the meal and multiplying by each person. The time for a pipelined process is largest time in each cycle.

Task 6						
Pipelined	**Cycle -->**					
Robin	7	10	15			
bryan		7	10	15		
finchie			7	10	15	
dan				7	10	15
			Time	**60 minutes**		
Total cycles 6	**1**	**2**	**3**	**4**	**5**	**6**
Non pipelined (sequential)	**Cycle -->**			Sub-totals		
Robin	7	10	15	32		
bryan	7	10	15	32		
finchie	7	10	15	32		
dan	7	10	15	32		
			Total Time	**128 minutes**		
Total cycles 16	**1,5,9,13**	**2,6,10,14**	**3,7,11,15**	**4,8,12,16**		

Sequentially the resources are not being used while the meal recipe is being read, prepared and cooked. However, pipelining allows the use of resources while another task is being executed effectively improving efficiency and throughput.

Because of the constraint of one recipe the other resources are not used as each cycle each person is at a different stage of execution. Therefore, the extra resources are idle as one instance of each is being used during each stage of the pipeline.

Task 7 CPU Architecture

Multithreading and multiprocessing

Multiprocessing in terms of hardware has more than one physical processing core to execute multiple processes. They can either be structured in a symmetric way or asymmetric, however asymmetric is based on a different architecture (Tech Differences, 2019). Symmetric multi-processing uses multiple cores (with their own cache), that share a pool of memory through a bus and communicate between each other as they complete processes in the operating system (Tech Differences, 2019; Tutorialspoint.com, 2019). Asymmetric has a master core and slave cores where instructions are delegated from the master core that executes a process in the operating system and controls memory access of each core (Tech Differences, 2019).

Multithreading, however, takes advantage of a pipeline of a processor as one thread is executing another is created while functional units of the processor are idle. This happens with every clock cycle and each thread is executing a different stage per cycle. Multithreading allows a greater throughput efficiently sharing resources and executing multiple threads in a shorter time. A thread is contained in a process (single threaded process), but there can exist multiple threads in a single process (multi-threaded). As an example, a user can therefore have processors (multiprocessing) in the background such as a phone call on loudspeaker while using another application. While in the application the user for instance can be running a word processor on a phone while typing and displaying text at the same time, these are executed using threads (Programmer and Software Interview Questions and Answers, 2019).

Circumstances where simultaneous multi-threading can degrade performance

The architecture of the processor may slow down performance due to bottlenecking in some circumstances of an application being executed (En.wikipedia.org, 2019). Bad multithreading can also lead to issues such as deadlocks, starvation, race conditions and Live lock (Kitowska, 2019). These errors are an occurrence due to sharing of resources and data as a result of poor multithreading leading to bottlenecking.

Task 8. Memory

On the table which represents memory, not virtual memory, there is a page occupying the space where process A is referencing next by the CPU. Therefore, the process B page 3 will need to be swapped to secondary memory so the process A page can be moved from virtual memory into the frame in memory. The CPU would check if there is an entry in the page table and check if it's in memory, perform a swap with the file from disk and update the table with the new entry (En.wikipedia.org, 2020).

Process A referencing the end of page 7 which is not in memory and therefore will generate a page fault (interrupt). This occurs because the page is not in memory and will need to be fetched from virtual memory and mapped to memory. The MMU looks at the table for A processes address space and translates the logical address from virtual memory to the corresponding physical memory. The page is read and transferred from disk storage(GitHub, 2020).

Organising pages close together does not affect RAM speed and information access, but bus size, processor, RAM timings (CAS, RAS to CAS, tRAS, RAS pre-charge) and latencies do. Moreover, RAM is random access and process pages may not execute in an order as other pages may need to be accessed first. Through logical assignment of pages in memory, fragmentation is minimised, however if they were to be located close together, it would increase fragmentation, decrease available memory in page memory management as the frames are a set size in paging.

If Page 7 needs to be brought in from virtual memory, page 3 may or may not get swapped. Algorithms in the operating systems kernel determine what happens to pages in memory, when they get swapped, therefore, because of this page 7 may not replace page 3. Page frames are dynamically allocated to minimise fragmentation and increase compaction, so page 7 will be brought into the appropriate frame for its size. However, due to the algorithm and the use of the page occupying the space will determine if it is replaced (GeeksforGeeks, 2020).

Task 9 – Hamming and SECDED code

The total amount of bits that can be covered by a 4-bit hamming code is 8-bits as

(22 => m + p +1) example of a 3-bit binary string (22 => 3 + 3 + 1) does fulfill the condition but for (24 => m + p +1) which 8 is equal to (8 => 3 + 4 + 1 = 7) as an extra bit in the code can be allocated to the SECDED code.

B) Hexadecimal CC916 is equal to 12 12 9 which is equivalent to 1100 1100 1001 in binary. There was no error in the transmission because the parity for P0 needs to be even in which a 1 is added to the total amount of bits with the value of 1. This amounted to an even parity of 1 value, all other parity bits were even, indicating no error.

There was no error in the transmission of the message as the parity 0 was assumed to be even and there are no errors on the other parity bits as the results came up as even, so there is no reason to correct.

Original Binary value $1100\ 1100\ 1001_2$ from Hexadecimal $CC9_{16}$																					
Position		17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
		1	?	1	0	0	1	1	0	0	?	1	0	0	?	1	?	?	?		
p0																				?	
p1		1		1				1				1				1				1	Odd
p2		1		1				1				1				1				1	Odd
p4				1			1					1								1	Odd
p8				1			1	1												1	Odd
p16		1																		1	Odd
Inserted parity bits																					
Position		17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Parity bits	
		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1		
p0		1	1	1			1	1			1	1			1	1	1	1	1	0	Even
p1		1		1				1				1				1		1		0	Even
p2		1		1				1				1				1	1			0	Even
p4				1			1					1			1					0	Even
p8				1			1	1			1									0	Even
p16		1	1																	0	Even

Advanced question 1

Intel optane memory

Intel Optane is an architecture of memory developed by intel as 3D grid (3D x-point) coupled with controllers. It is an architecture designed as separate modules or integrated with storage for use in data centres, cloud, analytics and content delivery (Intel, 2020). The memory is non-volatile even when power is cut compared to DRAM, due to the architecture it is a transistor less technology (Intel, 2020). The memory is implemented and integrated in various form factors such as M.2 NVME, with Solid state drives and in Dual inline memory modules. This will only work with a primary drive and not secondary drive where no OS is installed when used with storage as a cache drive.

Designed for data centres with high density 512GB, 256GB and 128GB DIMM modules intel claim are fast, however, they are not as fast as DDR4 RAM (Alcorn, 2020). Power consumption is also greater due to the technology and increased capacity due to higher densities (Alcorn, 2020). Intel also claim it is also faster and more enduring than NAND flash memory to be fast in all workloads and increase speeds of systems using HDD by using the Optane drive as a cache (Alcorn, 2020). However, not all workloads benefit from optane memory and has limited compatibility (Alcorn, 2020).

Advanced question 2

Using the last two decimal digits of the student number and converting to a floating-point number in base 2. The system is a 16-bit system with a 1-bit sign, 6-bit exponent and 9-bit mantissa. IEEE standard is a 1-bit sign, 5-bit exponent and 9-bit mantissa.

The bits to the left of the decimal point are in positive base 2 place values and to the right are fractional going from ½ and the denominator increasing powers of 2, effectively dividing further.

Floating point in binary is accomplished by scientific notation, the sign bit represents if the number is a positive (0) or a negative (1) number. The exponent of the binary string is how far the decimal place in the mantissa moves. The exponent total value is represented by a binary string with a range of a negative to positive value unless it is biased in which the exponent represents 0 to a positive integer. This is calculated by dividing the number by two and taking the integer value.

The mantissa is the integer and fractional values converted from a decimal number to the binary string. Powers of two to the left and negative two powers to the right of the decimal point. A mantissa is normalised by applying the exponent to a de-normalised mantissa, effectively performing scientific notation in binary.

If the number were to be negative twos complement would be used to represent it in binary, however the numbers in the student number are positive, therefore no example is given.

Student number S3390149

A = 4 X (4.9)
B = 9 Y (9.4)

← example

4 = 2×2 + 0
2 = 1×1 + 0
1 = 0×0 + 1

100

.9 × 2 = 1.8
.8 × 2 = 1.6
.6 × 2 = 1.2
.2 × 2 = 0.4
.4 × 2 = 0.8

← Repeats

1110011100

Sign Exponent = Bias(31) + 2 = 31

positive 0 100001 100.111001100

Mantissa

9 = 4×4 + 1
4 = 2×2 + 0
2 = 1×1 + 0
1 = 0×0 + 1

1001

.4 × 2 = 0.8
.8 × 2 = 1.6
.6 × 2 = 1.2
.2 × 2 = 0.4

0110

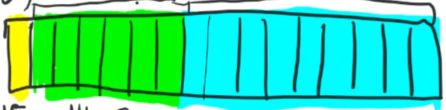
Sign exponent Mantissa

0 100010 1001.011001

3 + Bias(31)

34

Sign Exponent Mantissa



15 14-9 8-0

1 Bit Sign

6 Bit exponent

9 Bit Mantissa

Bias for exponent

15 total values / 2 to get bias. Exponent $6_2 = 63$

Bias 0 - 31

Non bias -32 - 31

$8\ 4\ 2\ 1 . \frac{1}{2}\ \frac{1}{4}\ \frac{1}{8}\ \frac{1}{16}$

floating point in binary

10

10 = 5×2 + 0
5 = 2×2 + 1
2 = 1×1 + 0
1 = 0×0 + 1

0 × 2 = 0

Sign exponent Mantissa

0 100010 1010.00000

34 = 3 + Bias(34)

1

1 = 0×0 + 1

1

0 × 2 = 0

0

Sign exponent Mantissa

0 011111 1.000000000

31

1/3 0 = 0 × 0 + 0 .3333 × 2 0.6666 Repeating

0 .6666 × 2 1.33332

01

Sign exponent Mantissa

0 011111 $0.\overline{01}$

31

Here is an example and from this a solution to add x and y from the previous question has been implemented below. Depending on the precision of the floating point, calculate which string has the greatest exponent and carry the decimal to be in line and the string with the largest exponent and add 0 placeholders (padding). Disregard the point and add from right to left following binary addition (LSB → MSB) and include any carry overs from repeated bits not shown to the string and place decimal in the result.

X has a smaller exponent so a 0 is added to the MSB resulting in the decimal place moving towards the right

	x	0 100001 100.1110011 Exponent bias 31 + 2^2												
	y	0 100010 1001.011001 Exponent bias 31 + 2^3												
Carry				1	1	1	1			1	1			
		0	1	0	0	1	1	1	0	0	1			
		1	0	0	1	0	1	1	0	0	1			
		1	**1**	**1**	**0.**	**0**	**1**	**0**	**0**	**1**	**1**			
		8	**4**	**2**	**1**	**½**	**¼**	**1/8**	**1/16**	**1/32**				
	Octal	16.23												

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