THE HONG KONG UNIVERSITY OF SCIENCE & TECHNOLOGY

COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

Computer Organization (COMP 2611)

Mid-term Examination 1 of the Spring Semester, 2013

March 8, 2013

Name: ____________________________ Student ID:________________________

Email:____________________________ Lab Section Number:________________

Instructions:

1. **This examination paper consists of 11 pages in total, including 6 questions within 9 pages, 1 appendix page and 1 draft page. Use the back of the pages as draft paper.**
2. **Please write your name, student ID, email and lab section number on this page.**
3. **Please answer all the questions in the spaces provided on the examination paper.**
4. **Please read each question very carefully, answer clearly and to the point. Make sure that your answers are neatly written.**
5. **Keep all pages stapled together. You can tear off the appendix and draft page only.**
6. **Calculator and electronic devices are not allowed.**
7. **The examination period will last for 2 hours.**
8. **Stop writing immediately when the time is up.**

Question	Points	Scores	Marker
1	15		
2	19		
3	12		
4	16		
5	21		
6	17		
TOTAL	100		

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Problem 1: Multiple Choice Questions (15 points)

Circle all the correct answers, and only those you are sure are correct. A incorrect answer circled will reduce your marks by as many as a correct one would increase them.

a) The 5 basic components of a computer are:

A. Hardware, Operating System, Applications, Compilers, Source code
B. Input, Output, Memory, Datapath, Control
C. Keyboard, CPU, Hard disk, Monitor, Power supply
D. Memory, input devices, output devices, CPU
E. None of the above

b) Which of the following is correct?

A．8 Gigabyte = 8 * 2^{10} bytes
B．1 Megabyte = 2^{20} bytes
C．500 Mega bits per second = 500 * 10^{2} bits per second
D．4 GHz = 4 * 10^{9} s^{-1}
E．None of the above

c) Which of the following is correct?

A. Both hardware and software are organized into hierarchical levels
B. Interaction between levels is through well-defined interfaces
C. Lower-level details are visible to the higher level to offer more information
D. The Instruction Set Architecture is the interface between hardware and software
E. None of the above.

d) Which of the following is correct?

A．The algorithm determines the number of machine instructions executed
B．The high level programming language, compiler, and architecture determine how fast the I/O operations are executed
C．The Processor and the RAM determine how fast each instruction is executed
D．The I/O system determines the number of operations executed in the program
E．None of the above

e) Which of the following is a feature of Random Access Memories (RAM)?
A. Used for permanent storage.
B. Loses data after the power is cut off.
C. CDROM is a kind of RAM.
D. Used by processor to store programs and data.
E. None of the above.

f) Which of the following is correct?

A. Decreasing response time always improves throughput
B. Replacing the processor by a faster one improves both response time and throughput.
C. Adding a processor to a system always improves response time.
D. Execution time and throughput are usually independent of each other.
E. None of the above.

g) Which of the following is correct?

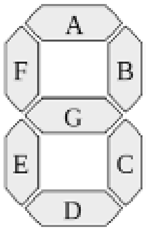
A. Machine X runs a program in 20s while machine Y runs it in 30 sec. In general we can say that, X is 50% faster than Y
B. Everything else the same, increasing the length of the clock cycle could improve the performance
C. The number of CPU clock cycles in a program is equal to the number of instructions in the program
D. The CPI of a program on a given machine is defined as the average number of clock cycles each instruction of the program takes to execute on this machine
E. None of the above

h) Which of the following is correct?

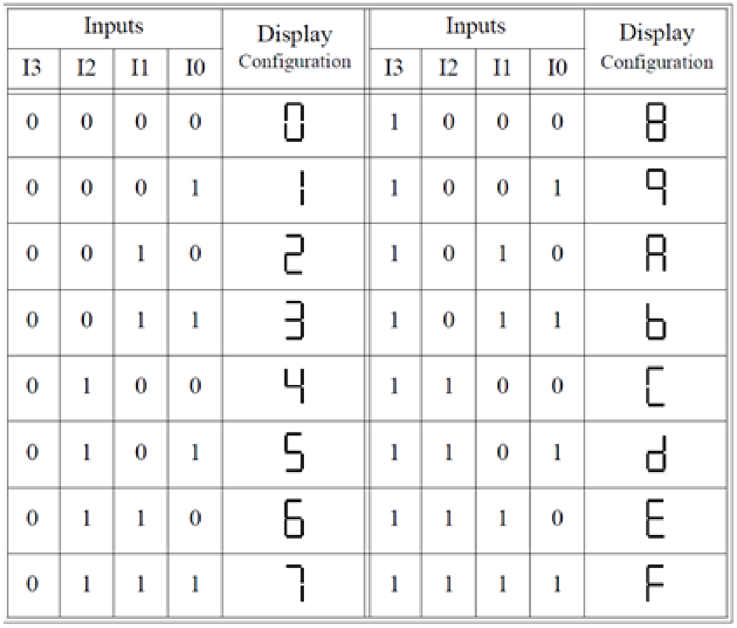
A. Assembly Language is the level of abstraction closer to the problem domain
B. Assembly Language is a symbolic notation used to represent binary instructions
C. Pure assembly language instructions have a one to one mapping to machine language instructions
D. In Assembly language Instructions and data are written as strings of bits
E. None of the above

Problem 2: Boolean Algebra and Combinational Logic (19 points)

Consider a 7-segment digital display used to display a digit in hexadecimal in the following format 0, 1,…, 9, A, b, C, d, E, F). Notice that both b and d use miniscule letters. Each segment below (i.e., A, B, C, D, E, F, G) is represented by a logic function that depends on an input value on 4 bits.



Denote the 4 bit binary number input as I_3, I_2, I_1, $I_{0,}$ with I_3 being the most-significant bit, and I_0 being the least-significant bit. The display configuration for each input is shown in the table below.



Inputs				Display Configuration	Inputs				Display Configuration
I3	I2	I1	I0		I3	I2	I1	I0	
0	0	0	0	0	1	0	0	0	8
0	0	0	1	1	1	0	0	1	9
0	0	1	0	2	1	0	1	0	A
0	0	1	1	3	1	0	1	1	b
0	1	0	0	4	1	1	0	0	C
0	1	0	1	5	1	1	0	1	d
0	1	1	0	6	1	1	1	0	E
0	1	1	1	7	1	1	1	1	F

a) Fill out the following truth table to indicate when segment A in the display is on? (6 points)

Inputs				**Output**
I_3	**I_2**	**I_1**	**I_0**	**A**
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

b) Based on the truth table in (a), what is the logic function in sum-of-product representation for segment A? (6 points)

c) Based on (a) construct a K-Map, and then use it to simplify the equation in (b). Your final logical equation should be as simple as possible (show the grouping on the K-Map). (7 points)

I_1I_0 I_3I_2				

Problem 3: Sequential Logic (12 points)

a) A decade counter is a sequential logic circuit that counts modulo 10, i.e., it starts at 0 and for each push of a button it increments the value stored in the counter by 1 until it reaches 9, then the goes back to 0. If we were to build one, what is the minimum number of flip-flops necessary? Justify your answer. (4 points)

b) If we were to build a register file that contains 32 registers each capable of storing 32 bit numbers. How many flip-flops do we need? (4 points)

c) If we were to implement this register file with two read ports, other than the flip-flops what other combinational logic elements we would need? (4 points)

Problem 4: Data Representation (16 points)

a) Convert the following numbers from base 10 to base 2, base 8, and base 16. (3 points)

$26_{\_10}$ = $_{\_2}$ = $_{\_8}$ = $_{\_16}$

$51_{\_10}$ = $_{\_2}$ = $_{\_8}$ = $_{\_16}$

b) High-level programming language may use 8 bits (`int8_t` in C++), or 16 bits (`short` in C++) or 32 bits (`int` in C++) to store integer values.
`Cast` operation helps to convert `int8_t` or `short` to `int`. For example, given an `int i` and a `short j`, `i = (int)j` has the effect of expanding 16-bit `j` to fit in 32 bits.

Assume `short j = -58` and 2's complement is used for binary number representation.
Show the representation of `j` in binary? (4 points)
After `int i = (int) j`, what is the binary content of `i`? (3 point)
What decimal number does `i` represent? (2 point)

c) Consider the following 32-bit sequence: 0100 0000 0100 1100 0101 0100 0100 0001
What is its hexadecimal representation? (2 points)

What text does it represent if it is a sequence of ASCII characters? ASCII table is attached in the Appendix. (2 points)

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Problem 5: Floating Point Number Representation (21 points)

Recall the IEEE 754 32-bit single precision standard for floating point representation,

Sign	Exponent	Significand
1 bit	8 bits	23 bits

with the implicit leading 1 for the significand, and the biased exponent with bias value of 127.

The recent version of the IEEE754 added a 16-bit half precision (referred to as `binary16`), with the following format:

Sign	Exponent	Significand
1 bit	5 bits	10 bits

It follows the same design philosophy as IEEE 754 single and double precision formats. Answer the following questions:

a) What is the value of bias in `binary16`? (3 points)

b) What real decimal number (or symbols) do you expect each of the following binary patterns to represent if `binary16` is applied? (6 points)

Binary bit pattern	**Decimal Value**
0 00000 0000000000	
1 00000 1000000000	
0 01111 0000000000	
1 10000 0000000000	
1 11111 0000000000	
1 11111 1111111111	

c) What is the largest number (excluding +infinity) that can be represented using `binary16`? Write down its binary form and convert it to decimal. (3 points)

d) What is the smallest positive non-zero number using binary16? Write down its binary form and convert it to decimal. (3 points)

e) Can the decimal value $0.10_{(10)}$ be exactly represented by half precision? Justify your answer. Simple Yes/No without justification receives 0 point. (3 points)

f) Can half precision represent any 16-bit integer exactly? Justify your answer. Simple Yes/No without justification receives 0 point. (3 points)

Problem 6: Performance Evaluation (17 points)

(Topic will not be covered in Fall 15 midterm)

Machine M1 and machine M2 implement the same instruction set architecture (ISA). The instruction set consists of three classes of instructions: class A, class B and class C. The table below shows the instructions mix and the CPI for each class of instructions in a given program for machines M1 and M2 respectively.

Instruction Class	**Percentage of instructions in the program** (Value assumed to be between 0 and 100 %)	**CPI in M1**	**CPI in M2**
A	x	1	2
B	y	1	2
C	z	20	10

Assuming the execution of instructions is carried sequentially without overlap, answer the following;

a) What is the *average proportion of time* machine M1 (respectively machine M2) would spend on executing instructions of class C. Show your answers in terms of *x*, *y* and *z*. (6 points)

b) Assume the clock rate of M1 (respectively of M2) is C_{M1} (respect. C_{M2}). Calculate the performance ratio between M1 and M2 (i.e. Performance_M1/Performance_M2). Show your answers in terms of x,y, *z*, $C_{M1 \text{ and}}$ C_{M2} only. (6 points)

c) Assume the clock rates of M1 and M2 are the same. Given a program, calculate the maximum percentage of Class C instructions in the program such that M1 always executes the program faster than M2. (Hint: the answer should be a numerical value without any of the variables). (5 points)

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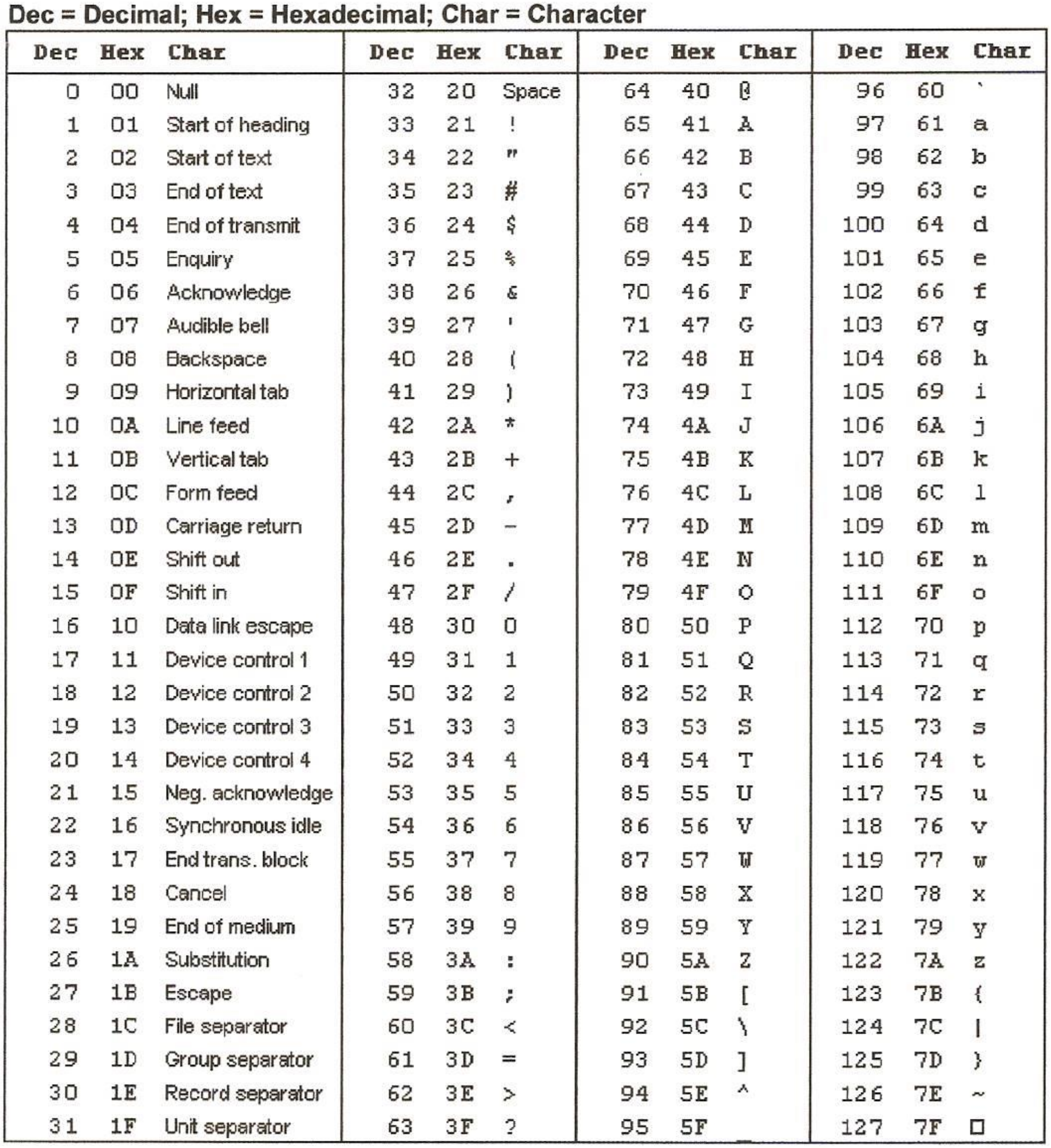
APPENDIX: ASCII Code Table



Dec = Decimal; Hex = Hexadecimal; Char = Character

Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	00	Null	32	20	Space	64	40	@	96	60	`
1	01	Start of heading	33	21	!	65	41	A	97	61	a
2	02	Start of text	34	22	"	66	42	B	98	62	b
3	03	End of text	35	23	#	67	43	C	99	63	c
4	04	End of transmit	36	24	$	68	44	D	100	64	d
5	05	Enquiry	37	25	%	69	45	E	101	65	e
6	06	Acknowledge	38	26	&	70	46	F	102	66	f
7	07	Audible bell	39	27	'	71	47	G	103	67	g
8	08	Backspace	40	28	(	72	48	H	104	68	h
9	09	Horizontal tab	41	29	)	73	49	I	105	69	i
10	0A	Line feed	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage return	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	47	2F	/	79	4F	O	111	6F	o
16	10	Data link escape	48	30	0	80	50	P	112	70	p
17	11	Device control 1	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	50	32	2	82	52	R	114	72	r
19	13	Device control 3	51	33	3	83	53	S	115	73	s
20	14	Device control 4	52	34	4	84	54	T	116	74	t
21	15	Neg. acknowledge	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	54	36	6	86	56	V	118	76	v
23	17	End trans. block	55	37	7	87	57	W	119	77	w
24	18	Cancel	56	38	8	88	58	X	120	78	x
25	19	End of medium	57	39	9	89	59	Y	121	79	y
26	1A	Substitution	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	63	3F	?	95	5F	_	127	7F	□

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