THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY - LEVEL 5
ECX5236 – COMPUTER ARCHITECTURE
FINAL EXAMINATION 2006

DURATION : THREE HOURS

088

DATE : 18th April 2007 **TIME : 0930 - 1230 HOURS**

Answer any ***five*** questions. All questions carry equal marks.

1.

(i) When instructions flow smoothly through a pipeline without delays the CPI of the pipelined processor will be equal to 1. Prove this statement.

(ii) What will be the value of the CPI in the worst-case scenario?

(iii) What are the sources that cause delays or stalls in a pipeline?

(iv) Describe pipeline hazards and show how they can be prevented.

2.

(i) Draw typical virtual machine schematics for different styles of Instruction Set Architecture (ISA) i.e. Accumulator, Memory-Memory, Stack, Load-Store.

(ii) Briefly describe the addressing modes: Direct, Indirect, Immediate and Register.

(iii) Consider $n \times m$ matrix. The matrix is stored in the memory. When a program needs an element (i,j) it has to use a suitable addressing mode to find the Effective Address of the element.

(a) Propose an addressing mode for indexing a matrix. Describe it.

(b) Show how it can be used for finding the Effective Address of an element of the matrix.

3.

(i) Write policies are needed for data caches when an instruction writes data to the cache. Briefly describe the Write Back and Write Through policies.

(ii) A hierarchical Cache – Main Storage memory subsystem has following specifications: cache access time of 50ns, main storage access time of 500ns, 80% of memory request are for read, hit ratio of 0.9 for read access and the Write Through policy is employed. Estimate the following.

(a) Average access time of the system considering only the memory read cycle.

(b) Average access time of the system both for read and write requests.

(c) The hit ratio taking into consideration the write cycle.

4.

(i) Distinguish between paging and segmentation of the memory.

(ii) Virtual address format for the paged memory system is given below.

Virtual Page Number	Offset

Here the field ***Offset*** is n bits wide and the field ***Virtual Page Number*** is m bits wide.

(a) The physical address space of the system is 2^k, where $m+n>k>n$. With the help of the values k, m and n show that the pure paged memory system could be inefficient in some cases. (Assume the value n is a constant.)

(b) Design a *memory management unit* (MMU), which converts virtual addresses to physical addresses. Give your design in block diagram form and describe how the MMU functions.

5. A design of an instruction execution path has L logic delays. So it will take L time to execute an instruction in one-stage pipeline. However the logic path can be divided into a number of stages. In the multistage pipeline it is assumed that logic delay L is equally subdivided. Accordingly in each stage the minimum clock period is calculated as $T_{clock} = t_{\max} + \tau$; where tmax is approximated to the largest delay of a stage and τ is the sum of setup time of a latch and clock skew. Let k as the length of the instruction sequence and s as the number of stages.

(i) What is the clock period T_{clock} in terms of L, s and τ?

(ii) What is the execution time of the k number of instructions?

(iii) Derive an equation to calculate the optimum number of stages in the pipeline.

(iv) Prove that minimum execution time of k number of instructions is $\left(\sqrt{L} + \sqrt{\tau(k-1)}\right)^2$

6. You are to connect an external device to a computer through the parallel port or through the ISA bus. The device accepts a data byte when its *Accept data* pin receives a rising edge of a signal. Immediately the device will set its *data valid* pin to low. As soon as the data byte is written to its memory the *data valid* pin will set to high. The device accepts data only when the *data valid* pin is high.

(i) Draw a block diagram to show the connectivity of the device with the computer through the parallel port (Appendix A) or ISA bus (Appendix B). Indicate which pins of the parallel port or the ISA bus you are going to connect with the pins of the device.

(ii) Draw a typical timing diagram for data transferring from the computer to the device.

(iii) Give an algorithm for sending a byte to the device from the computer. You must show all values used for configuring the ISA bus (values for address bus and the data bus) or the parallel port (addresses and values of the relevant ports) each time when they are used.

(iv) Expand your algorithm to send a file to the device.

7.

(i) Briefly describe the tasks of an I/O system of a computer.

(ii) Briefly describe the following I/O control systems: Programmed I/O, Interrupt I/O, and Coprocessor I/O.

(iii) A system has the following specifications: 500 ns memory cycle time for read/ write, average of 2μs for execution of an instruction. Determine the peak data transfer rate for

(a) Interrupt Driven IO, assuming interrupt service routine to be 7 instructions;

(b) Programmed IO, assuming each byte transfer requires 4 instructions.

8.

(i) Derive the Amdahl's law in terms of f (fraction of the computation time in the old system that can be improved), S_e (achievable speedup only if the enhanced part of the system is used) and S_{new} (overall speedup).

(ii) Implementations of floating-point (FP) square root vary significantly in performance. Suppose FP square root is responsible for 20% of the execution time of a critical benchmark on a machine. One proposal is to add FP square root hardware that will speed up this operation by a factor of 10. The other alternative is just to try to make all FP instructions run faster; FP instructions are responsible for a total of 50% of the execution time. The design team believes that they can make all FP instructions run two times faster with the same effort as required for the fast square root.

(a) Compare these two design alternatives giving all calculations.

(b) What percentage of the FP instructions' execution time would make the hardware solution better?

Appendix A

Parallel port connector description

Pin: D-sub	Signal	Function	Source	Register		Inverted at con-nector?	Pin: Centro-ics
				Name	Bit #		
1	nStrobe	Strobe D0-D7	PC[1]	Control	0	Y	1
2	D0	Data Bit 0	PC[2]	Data	0	N	2
3	D1	Data Bit 1	PC[2]	Data	1	N	3
4	D2	Data Bit 2	PC[2]	Data	2	N	4
5	D3	Data Bit 3	PC[2]	Data	3	N	5
6	D4	Data Bit 4	PC[2]	Data	4	N	6
7	D5	Data Bit 5	PC[2]	Data	5	N	7
8	D6	Data Bit 6	PC[2]	Data	6	N	8
9	D7	Data Bit 7	PC[2]	Data	7	N	9
10	nAck	Acknowledge (may trigger interrupt)	Printer	Status	6	N	10
11	Busy	Printer busy	Printer	Status	7	Y	11
12	PaperEnd	Paper end, empty (out of paper)	Printer	Status	5	N	12
13	Select	Printer selected (on line)	Printer	Status	4	N	13
14	nAutoLF	Generate automatic line feeds after carriage returns	PC[1]	Control	1	Y	14
15	nError (nFault)	Error	Printer	Status	3	N	32
16	nInit	Initialize printer (Reset)	PC[1]	Control	2	N	31
17	nSelectIn	Select printer (Place on line)	PC[1]	Control	3	Y	36
18	Gnd	Ground return for nStrobe, D0					19,20
19	Gnd	Ground return for D1, D2					21,22
20	Gnd	Ground return for D3, D4					23,24
21	Gnd	Ground return for D5, D6					25,26
22	Gnd	Ground return for D7, nAck					27,28
23	Gnd	Ground return for nSelectIn					33
24	Gnd	Ground return for Busy					29
25	Gnd	Ground return for nInit					30
	Chassis	Chassis ground					17
	NC	No connection					15,18,34
	NC	Signal ground					16
	NC	+5V	Printer				35

[1]Setting this bit high allows it to be used as an input (SPP only)

[2]Some Data ports are bidirectional

Parallel port register definitions

Base address: 0378h

Data Register (Base Address)					
Bit	***Pin: D-sub***	**Signal Name**	**Source**	**Inverted at connector?**	**Pin: Centronics**
0	2	Data bit 0	PC	no	2
1	3	Data bit 1	PC	no	3
2	4	Data bit 2	PC	no	4
3	5	Data bit 3	PC	no	5
4	6	Data bit 4	PC	no	6
5	7	Data bit 5	PC	no	7
6	8	Data bit 6	PC	no	8
7	9	Data bit 7	PC	no	9
Some Data ports are bidirectional. (See Control register, bit 5 below.)					
Status Register (Base Address +1)					
Bit	***Pin: D-sub***	**Signal Name**	**Source**	**Inverted at connector?**	**Pin: Centronics**
3	15	nError (nFault)	Peripheral	no	32
4	13	Select	Peripheral	no	13
5	12	PaperEnd	Peripheral	no	12
6	10	nAck	Peripheral	no	10
7	11	Busy	Peripheral	yes	11
Additional bits not available at the connector: 0: may indicate timeout (1=timeout). 1, 2: unused					
Control Register (Base Address +2)					
Bit	***Pin: D-sub***	**Signal Name**	**Source**	**Inverted at connector?**	**Pin: Centronics**
0	1	nStrobe	PC[1]	yes	1
1	14	nAutoLF	PC[1]	yes	14
2	16	nInit	PC[1]	no	31
3	17	nSelectIn	PC[1]	yes	36
[1]When high, PC can read external input (SPP only). Additional bits not available at the connector: 4: Interrupt enable. 1=IRQs pass from *nAck* to system's interrupt controller. 0=IRQs do not pass to interrupt controller. 5: Direction control for bidirectional Data ports. 0=outputs enabled. 1=outputs disabled; Data port can read external logic voltages. 6,7: unused					

Appendix B

ISA (Industry Standard Architecture) Bus

Pins layout

D	Description	Name	Pin	Pin	Name	Description	D
/	Ground	GND	B1	A1	IO CHK	I/O Channel Check	-I
O	Reset	RESET	B2	A2	SD7	System Data bit 7	I/O
/	Power +5V	+5V	B3	A3	SD6	System Data bit 6	I/O
I	Interrupt Request 9	IRQ9	B4	A4	SD5	System Data bit 5	I/O
/	Power -5V	-5V	B5	A5	SD4	System Data bit 4	I/O
I	DMA Request 2	DRQ2	B6	A6	SD3	System Data bit 3	I/O
/	Power -12V	-12V	B7	A7	SD2	System Data bit 2	I/O
/	Zero Wait State	0WS	B8	A8	SD1	System Data bit 1	I/O
/	Power +12V	+12V	B9	A9	SD0	System Data bit 0	I/O
/	Ground	GND	B10	A10	IO RDY	I/0 Channel Ready	-I
O	System Memory Write	SMEMW	B11	A11	AEN	Address Enable	O
O	System Memory Read	SMEMR	B12	A12	SA19	System Address bit 19	O
I/O	I/O Write	IOW	B13	A13	SA18	System Address bit 18	O
I/O	I/O Read	IOR	B14	A14	SA17	System Address bit 17	O
O	DMA Request Acknowledge 3	DACK3	B15	A15	SA16	System Address bit 16	O
I	DMA Request 3	DRQ3	B16	A16	SA15	System Address bit 15	O
O	DMA Request Acknowledge 1	DACK1	B17	A17	SA14	System Address bit 14	O
I	DMA Request 1	DRQ1	B18	A18	SA13	System Address bit 13	O
I/O	Refresh cycle in progress	REFRESH	B19	A19	SA12	System Address bit 12	O
O	System Clock	CLOCK	B20	A20	SA11	System Address bit 11	O
I	Interrupt Request 7	IRQ7	B21	A21	SA10	System Address bit 10	O
I	Interrupt Request 6	IRQ6	B22	A22	SA9	System Address bit 9	O
I	Interrupt Request 5	IRQ5	B23	A23	SA8	System Address bit 8	O
I	Interrupt Request 4	IRQ4	B24	A24	SA7	System Address bit 7	O
I	Interrupt Request 3	IRQ3	B25	A25	SA6	System Address bit 6	O
O	DMA Request Acknowledge 2	DACK2	B26	A26	SA5	System Address bit 5	O
O	T/C	TC	B27	A27	SA4	System Address bit 4	O
?	Buffered Address Latch Enable	BALE	B28	A28	SA3	System Address bit 3	O
/	Power +5V	+5V	B29	A29	SA2	System Address bit 2	O
O	Oscillator	OSC	B30	A30	SA1	System Address bit 1	O
/	Ground	GND	B31	A31	SA0	System Address bit 0	O

Signal Description

CLOCK (*System Drive*) output

The system clock is a synchronous microprocessor cycle clock.

RESET (*Reset Drive*) output

This signal goes high at power-up, hardware reset, or when low line-voltage occurs.

SA0 to SA19 (*System Addresses*) input/output

The system address lines run from bit 0 through 19. They are latched onto the falling edge of BALE.

SD0 to SD7 (*System Data bits*) Input/Output

System data bits 0 to 7.

BALE (*Buffered Address Latch Enable*) input
The buffered address latch enable is used in latch SA0 to SA19 on the falling edge of BALE. During DMA cycles, BALE is forced high.

IO CHK (*I/O Channel Check*) active low input
I/O channel check is active low signal which indicate that a parity error exists in the I/O board.

IO RDY (*I/O Channel Ready*) input
This signal lengthens I/O or memory cycles and should be held low with valid addresses. It can be held low for a maximum of 2.5 microseconds.

IRQ 3 to 7, 9 (*Interrupt Requests*) input
These interrupt request signals indicate I/O service request attention. They are prioritized in the following sequences: highest IRQ 9 and lowest IRQ 3, 4, 5,6,7,8.

IOR (*I/O Read*) active low input/output
Instructs an I/O device to drive its data onto the data bus.

IOW (*I/O Write*) active low output
Instructs an I/O device to read the data off the data bus.

SMEMR (*System Memory Read*) output
The system memory read signal is low while the low first megabyte memory is being read.

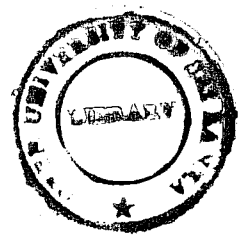
SMEMW (*System Memory Write*) output
The system memory write signal is low while the low first megabyte memory is being written.

DRQ 0 to 3 (*DMA Requests*) active high input
DMA Request channels 0 to 3 are for 8-bit data transfers. DRQ4 is used on the system board. Hold a DRQ line high until its DMA Request Acknowledge (DACK) goes active. Their priority is in the following sequences: highest DRQ 0,1,2, and 3.

DACK 1 to 3 (*DMA Request Acknowledges*) output
These signals are used to acknowledge the corresponding signals for DRQ 0 to 3.

AEN (*Address Enable*) output
The address enable is high when the DMA controller drives the address bus and is low when the CPU drives the address bus.

REFRESH (*Refresh cycle in progress*) active low input/output
This signal indicates a refresh cycle is in progress.



TC (*T/C*) output

OSC (*Oscillator*) output
The oscillator signal is used for the color graphic card.
High-speed clock (70 ns, 14.31818 MHz), 50%duty cycle

0WS (*Zero Wait State*) input
The zero wait state indicates to the microprocessor that the present bus cycle can be completed without inserting any additional wait cycles.