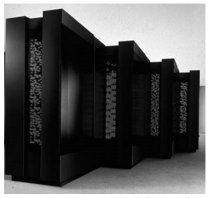
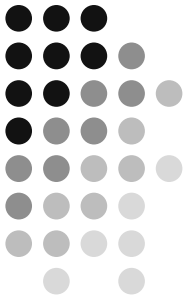
COMP25111
Operating Systems
Lectures 14
Controlling Input and Output 1

Dr Richard Neville
r.neville@manchester.ac.uk
Room: G12 Kilburn Building, Bottom floor



Week 9



NOTE: The **up-to-date** version of this lecture is kept on the associated web site – available [on-line] @ Blackboard select: COMP15111 Introduction to Computer Systems **www.manchester.ac.uk/portal**

https://stream.manchester.ac.uk/Play.aspx?VideoId=9176

Where to find this Lecture 14 of the COMP25111 course?

First Go to Blackboard 9; then select: COMP25111 Operating Systems

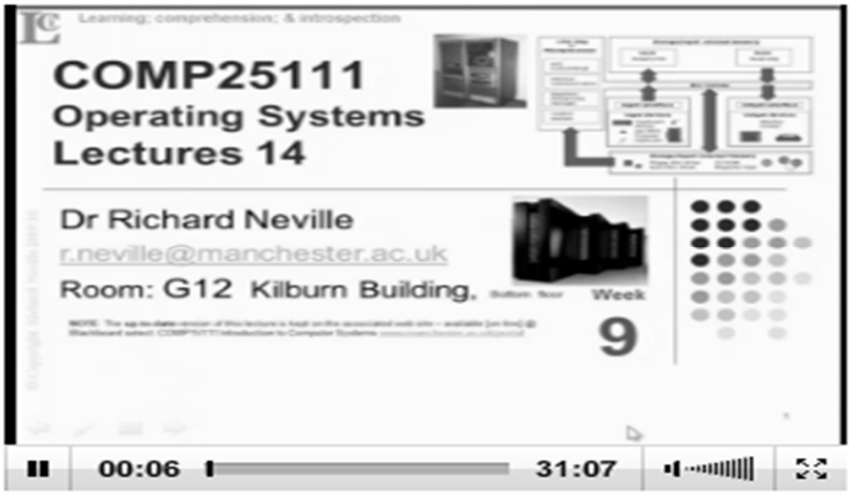
Then select: **Week 9**

This topic provides...
14: Controlling Input and Output 1 by RN;
15: Controlling Input and Output 2 by RN.

Then select: **Lecture 14 Information**

Then select: **Real Time VIDEO Lecture14**

Then select:



1. Question

Name three page replacement policies?

ANSWER(S):

1) Answer(s):

2)

3)

NOTE: In the exam approximately 2 question are taken from the topics (and program examples) coved in each lecture.

COMP25111

Systems Architecture 1

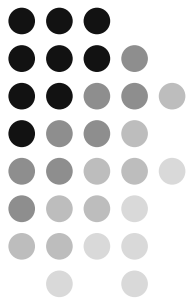
Lectures 14

Controlling Input and Output 1

Quotation

"... an Operating System also controls all the computer's I/O devices."

Ref. A.S. Tanenbaum: Modern Operating systems, Chapter 'INPUT/OUTPUT'.



Learning Outcomes

D-words

C-words

You should be able to

1) Explain in simple terms how a processor interacts with an I/O device; and

2) State what is meant by programmed I/O.

Programmed [implies in the computer science sense]: *Quotation*

"a sequence of instructions that a computer can interpret and execute"

Ref. Quote form: Dictionary net, available on-line from [URL]: http://www.dictionary.net/programmed, (last visited [accessed]: 25-11-2010).

Footnote

1: Explain: aligned to describe; discuss; give examples.
2: State: aligned to define, identify.

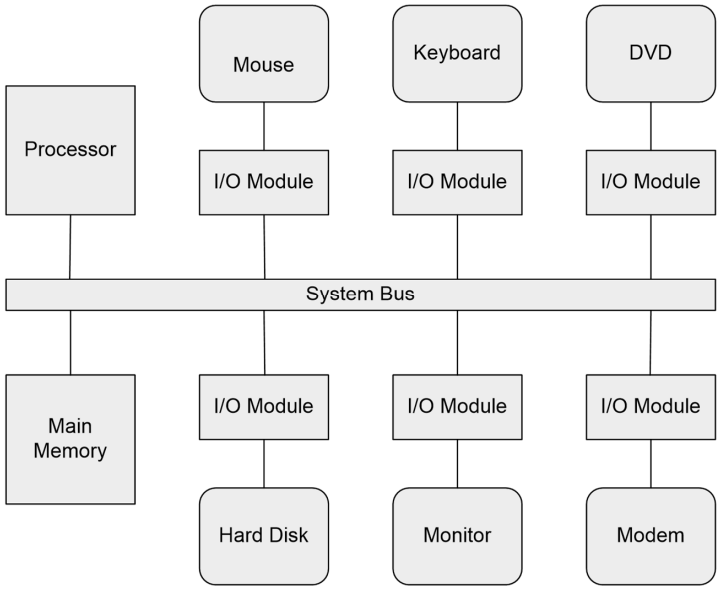
Reference: Bloom, B.S., *Taxonomy of Educational Objectives.* Handbook I: The Cognitive Domain. 1956: New York: David McKay Co Inc.

FOOTNOTE2: D-words: direction words. C-Words: content words.
Ref.: Michael J. Wallace (1980, 2004)
Study Skills in English, ISBN 9780521537520.
D-Words also aligned to; Ref.: Taxonomy of Educational Objectives: The Classification of Educational Goals; pp. 201–207; B. S. Bloom (Ed.) Susan Fauer Company, Inc. 1956.

Input/Output

- A computer system will connect to a wide variety of input and output devices.
- These will include the mass storage, but also devices such as:
  1) Human interface devices (keyboard, monitor, mouse)
  2) Communication devices (network cards, modems, etc)

I/O Connection



Each I/O module has an interface to the system and controls one or more I/O devices.

An I/O module contains special-purpose hardware for performing transfers

between the device and the processor or main memory.

Controlling I/O

A few additions to notes are required.

- The processor controls the I/O devices by writing to special purpose registers provided by the device's I/O module.
- A register is very much like a memory location. Nominally the are **two** different types:

1) One is capable of holding one or more bytes of data; &

2)

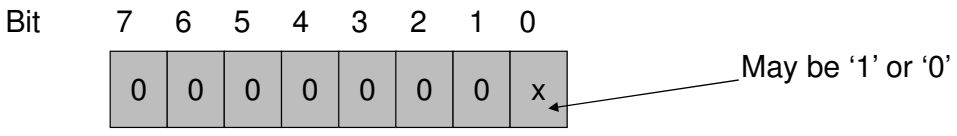
Both are normally placed within the computer system memory; so that it has a unique address.

Simple I/O Device

- Suppose we have a simple I/O device.
  - Let's suppose it is a keyboard that sends characters into the computer system.
  - In terms of the speed of a processor people type slowly;
    - So the processor can do a lot of work whilst it is waiting for characters.

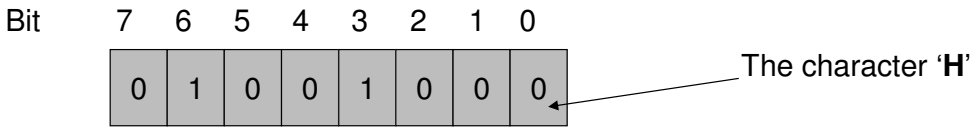
Simple I/O device

- Two registers (status and data registers).
  - Status register
    - Indicates the status of the I/O device.
    - In our simple example, we will assume that only one bit in the status register is used (bit 0) and the other 7 bits have the value 0. Bit 0 has two states:
      1) If bit 0 is set to '**1**', a character has been typed and its value is in the data register; and
      2) If bit 0 is cleared to '**0**', no character has arrived since the last time the processor read from the data register.



Simple I/O device

- **Data** Register
  - This holds the 'value' of the character typed at the keyboard.
  - Characters are encoded using numeric schemes, an 8-bit scheme is called ASCII, each of the 256 possible ASCII characters has an 8-bit code.
    - ASCII is gradually being superseded by the 16-bit Unicode standard [1] – used in Java.
  - So the word "**H**ello" would be encoded as the sequence (decimal) **72**-101-108-108-111.



Reference:

[1] R. S. King. (2012) Will unicode soon be the universal code? [The Data] Spectrum, IEEE, IEEE Journals & Magazines 1. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6221090 and http://spectrum.ieee.org/telecom/standards/will-unicode-soon-be-the-universal-code

ASCII

Decimal	Octal	Hex	Binary	Value	
65		101	41	1000001	A
66		102	42	1000010	B
67		103	43	1000011	C
68		104	44	1000100	D
69		105	45	1000101	E
70		106	46	1000110	F
71		107	47	1000111	G
72		110	48	1001000	H
73		111	49	1001001	I
74		112	04A	1001010	J
75		113	04B	1001011	K
76		114	04C	1001100	L
77		115	04D	1001101	M
78		116	04E	1001110	N
79		117	04F	1001111	O
80		120	50	1010000	P
81		121	51	1010001	Q
82		122	52	1010010	R

Ref. **ASCII Table: 7-bit,** from: http://www.neurophys.wisc.edu/comp/docs/ascii/ , (last visited [accessed]: 25-11-2010).

Mapping

- The registers will be located at a particular **address** within the computer system.
  - Let's assume, the two registers are memory mapped to the following [memory addresses]:
    1) Status Register at address 0xFFFF0000; &
    2) Data Register at address 0xFFFF0004.

Memory mapped [implies in the computer science sense]: ***Quotation***

"The I/O devices are addressed at certain reserved address ranges on the main memory bus. These addresses cannot therefore be used for ram."

Ref. Quote available on-line from [URL]: http://www.hyperdictionary.com/computing/memory+mapped+i/o, (last visited [accessed]: 25-11-2010).

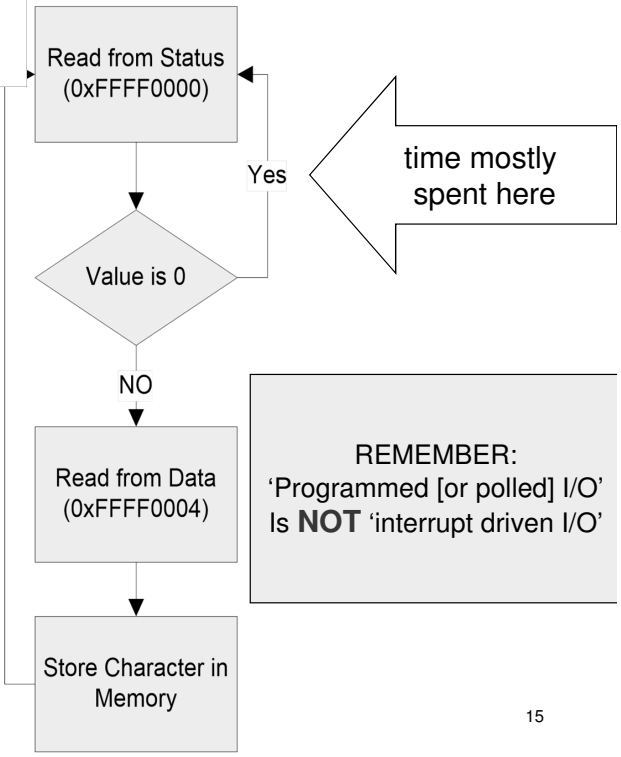
Procedure for Reading a Character (software)

- Processor reads from address 0xFFFF0000 (status register), and has two possible consequences:
  1) If, status bit cleared, bit 0 is **0**, there is no character to read.
  2) If value is **1**, there is a character to read, then:
     - 2.1) Read character from address 0xFFFF0004 (**data** register) and store in main memory;
     - 2.2) The I/O module will now clear the status register's bit 0 to 0, it will remain at this value until another character is typed.

Flowchart for Programmed I/O

The processor periodically polls the status of the I/O device checking on whether a data transfer should be made.

- Assuming that the computer has nothing else to do, it will spend all its time getting data from the keyboard.
- It spends the vast majority of its time waiting for the status to change from 0 to 1:
  - This type of approach is called **polling**.

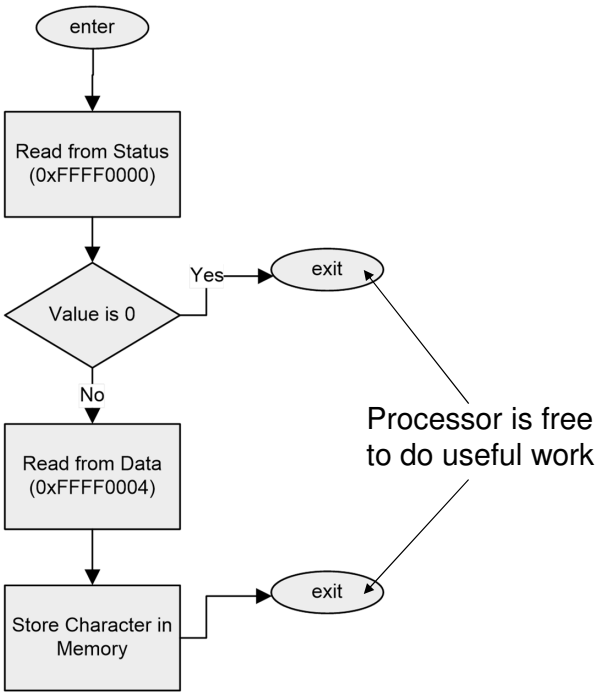


Other operations

- In practice, a computer system will have work to do other than wait for the user to type at the keyboard.
  - Most modern operating systems (e.g. Windows) are multitasking – several processes running at the same time.
- It doesn't make sense for the computer to spend all its time waiting for keyboard entry.
- Moreover, in the flowchart on the preceding slide, the processor doesn't actually do anything useful with the character it reads, it just puts it into memory.

Flowchart for Programmed I/O (redrawn)

- In this case, the code corresponding to the flowchart is periodically called by the controlling program.
- If a character has been typed, it is read and placed in memory.
- If character has not been typed, the flowchart exits and the processor can get on with useful work.



Programmed (Polled) I/O

- The code to read from the keyboard must be called on a regular basis.
  - The **more frequently** the code is called, the more time is wasted executing code when no character is present.
  - The **less frequently** the code is called the longer it takes from the key being pressed until a corresponding action occurs.
    - If the keyboard does not have a buffer (i.e. does not have a queue of characters), the probability of losing a character increases.
  - Solution presented – next page.

Interrupts

A few additions to notes are required.

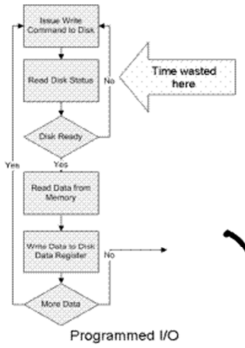
- So far we have viewed a program as being a linear sequence of instructions:
  - The processor executes each instruction in memory in sequential order;
    - Except for the skip and jump instructions.
- It would be useful if we could stop the processor executing a program, execute another piece of code, and then return to what it was doing as if nothing had happened.
-

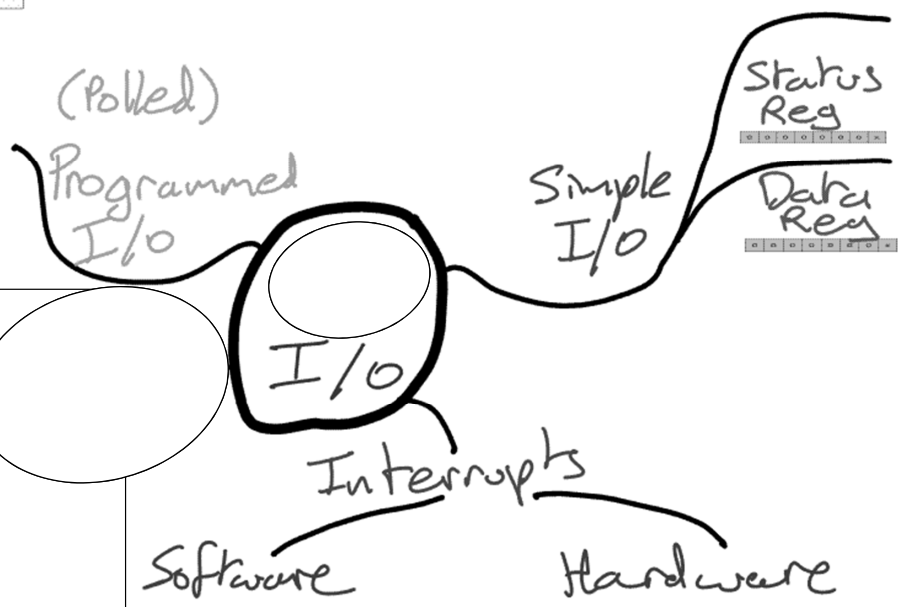
Interrupts

- There are two types of interrupt:
  1. Software Interrupt (or Exception)
     - These occur when the processor meets a special interrupt instruction or when an error has occurred.
       - For example, executing a program that leads to an **overflow** in arithmetic calculation will lead to an **overflow exception** which will then cause some code to run – generally to inform the user of the overflow (a software interrupt is used).
  2. Hardware Interrupt
     - The processor has a number of external connections called interrupt lines, these can be connected to external devices that can signal (by changing the logic level from, say, '0' to '1') that the external device wants to interrupt the processor.
- Next lecture we investigate interrupts …

END

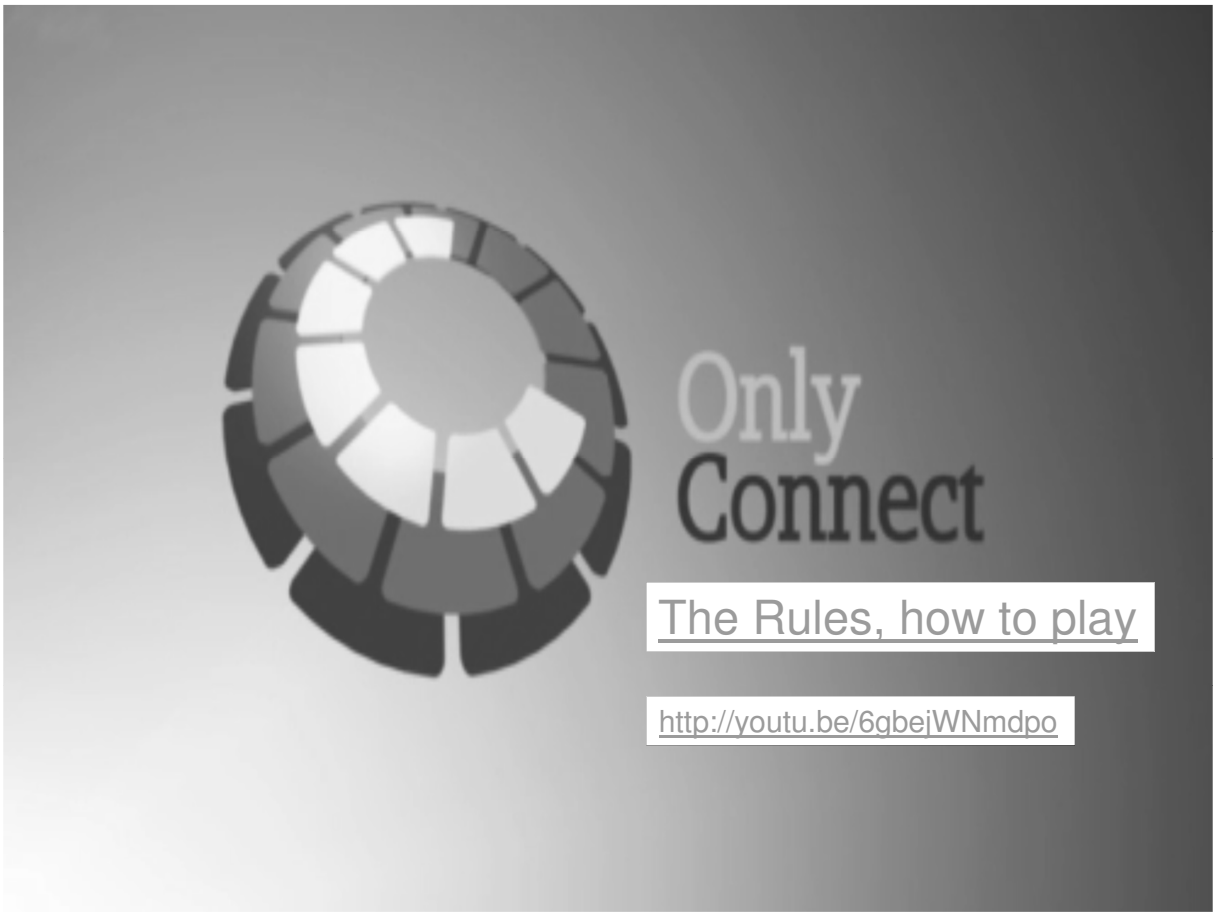
Summary



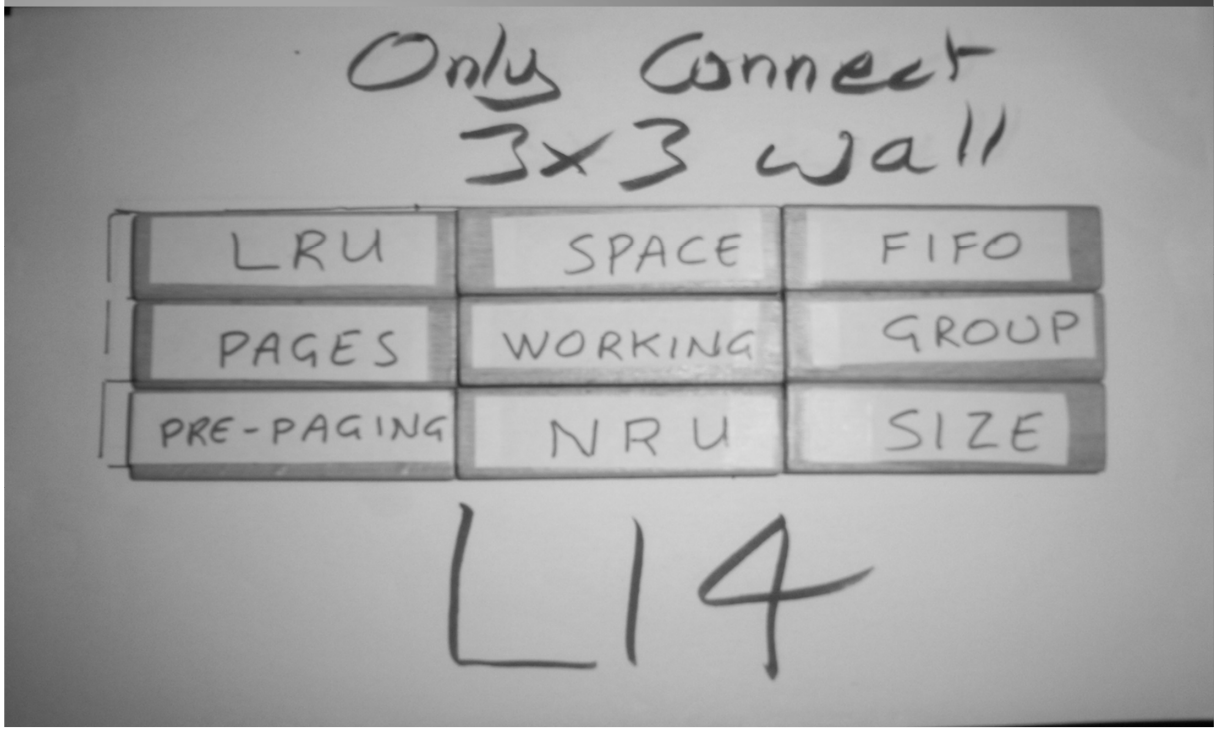


Mind Maps: Topology of Information;
Morphing Information – to associate it.


Only
Connect
Quiz


Only
Connect
The Rules, how to play
http://youtu.be/6gbejWNmdpo

Quiz



List of Questions to ask lecturer

- Before the 9a.m. start lecture the lecturer will be half an hour early and you can ask [any and all] questions in that half hour; before the lecture:

1.

2.

3.

4.

5.

Getting ready for next week
Do next week's Q3's NOW

- Once you have re-read the lecture notes; and listened to the audio recording [while stepping through the PPT] of the lecture again:
- Please have a think about next week's Q3's
  - on the next page
- If you try to answer the Q3's now you will be in a much better position to recall the information.
- Once you have done this, transfer your answers to next weeks "Student [OWN answers] version" at the start of next weeks lecture.
  - YES this implies bringing the last weeks lecture notes to the next lecture …

THIS week's Short Exam Questions Q3

1. Question

   Name three page replacement policies?

   Answer(s):

2. Question

   What is meant by the term 'working set;' with respect to process memory pages?

   Answer(s):

3. Question

   What methodology can minimising page faults by the use of sophisticated replacement algorithms?

   Answer(s):

- NOTE: In the exam approximately 2 question are taken from the topics (and program examples) coved in each lecture

Next Lecture [week's]

Short Exam Questions **Q3**

1. Question
   List a number of devices that connect to the system bus, via I/O modules.

Answer(s):

2. Question
   Name the two different types of information I/O registers store?

Answer(s):

3. Question
   Name the two different types of interrupts.

Answer(s):

- NOTE: In the exam approximately 2 question are taken from the topics (and program examples) coved in each lecture

GLOSSARY

Using the on-line resources and any other resources compile a glossary of the terms below :

- Interface device →
- Communication device →
- Register →
- Unique address →
- Status →
- Data →
- Data register →
- Status register →

GLOSSARY

- Polling →
- Programmed →
- Programmed I/O →
- Periodically →
- Interrupt →
- Software Interrupt →
- Hardware Interrupt →
- Exception →
- Overflow →
- External devices →

Learning Resources 1

- **Descriptions [Theory] (in text books)**
- Remember the key issues, highlighted in GREEN, are the concepts to look for in any book:
  - Section on Input devices, Output devices, Interface, Register, Status register [flag], Data register [flag], Polling, Programmed I/O, Interrupt, Hardware Interrupt, Exception, Overflow [flag], in a number of chapters in: Chalk BS, Carter AT, Hind RW (2004) Computer Organisation and Architecture: An introduction 2nd Edition, Palgrave, ISBN 1-4039-0164-3 .
  - Section on Input Output I/O, Interface [types of & control pins], Register[s], Data register[s], Programmed I/O, Interrupt [various] – in a number of chapters in: Computer Organization and Architecture, Fifth Edition by William Stallings.
  - Section on Input / Output, Communication [methods], Register, Programmed I/O, Interrupt, Overflow [error] – in a number of chapters in: Structured Computer Organization, 5/E, Andrew S. Tanenbaum, Vrije University, Amsterdam, The Netherlands, ISBN-10: 0131485210, ISBN-13: 9780131485211, Publisher: Prentice.
- **Web resources:**
  - **Input and Output Devices**; available [on-line] @ http://www.unm.edu/~tbeach/terms/inputoutput.html
  - **Basics of computer hardware;** available [on-line] @ http://www.osdata.com/system/physical/basics.htm
  - MOS Free e-book [Low resolution (Not high quality graphics or printing – but readable)]: Modern Operating Systems (MOS) 2nd Edition Andrew Tanenbaum, Available [on-line] @: http://www.freebookzone.com/fetch.php?bkcls=os_thry&bkidx=35

Questions

Introduction to Questions:

The set of questions are based on lecture 16.

Answer Sheet will be given later in year and will contain the answers to these questions.

- Remember to find detailed and comprehensive answer you should [also] reference associated text books in the library.
- A reasonable starting place for associated book titles are:

1) This units 'module guide'; given to you in RN's first lecture – or on the web [Blackboard];
2) Those books mentioned in 'Background Reading;'
3) Those books [and web resources] mentioned in Learning Resources.

Questions

1. Question

Input and output devices connect to a wide variety of different devices. These include two main categories.

Name the two main categories; and give examples of each.

Answer(s):

2. Question

- Name and briefly describe the steps taken to service (undertake) a basic means of reading a character from an I/O device using polling.

- **Answer**

2. Answer

The steps necessary to service a keyboard, using polling, are:

1) Answer(s):

2)

3)

4)

5)

6)

7)

3. Question

- Re-write the list of steps, undertaken in Q2, to enable the processor to do other operations (other than just polling the status register). Note: The list should enable the 'programmed polling' I/O to enable processor to be freed up to do [other] useful work.

- **Answer**

3. Answer

The steps necessary to service a keyboard, using programmed polling I/O with exits, are:

1)
2)
3)
4)
5)
6)
7)

Answer(s):

Questions

4. Question

What is meant by memory mapped I/O?

Answer(s):

Revision Exercises

- Scan read Lecture 16's Questions.
  - Answer Lecture 16's Questions
    - Particularly those questions you had difficulties with when you first tried them.

Background Reading

[1] Computer Organisation and Architecture: An introduction 2nd Edition, Palgrave, ISBN 1-4039-0164-3 in a number of chapters in: Chalk BS, Carter AT, Hind RW (2004):

- Section on Input devices, Output devices, Interface, Register, Status register [flag], Data register [flag], Polling, Programmed I/O, Interrupt, Hardware Interrupt, Exception, Overflow [flag].

[2] Computer Organization and Architecture, Fifth Edition by William Stallings:

- Section on Input Output I/O, Interface [types of & control pins], Register[s], Data register[s], Programmed I/O, Interrupt [various].

[3] Structured Computer Organization, 5/E, Andrew S. Tanenbaum, Vrije University, Amsterdam, The Netherlands, ISBN-10: 0131485210, ISBN-13: 9780131485211, Publisher: Prentice:

- Section on Input / Output, Communication [methods], Register, Programmed I/O, Interrupt, Overflow [error].