Digital Design and Computer Architecture
60-265

Dr. Robert D. Kent
LT 5100
519-253-3000 Ext. 2993

rkent@uwindsor.ca

Lecture 1
Introduction

Preliminary Remark

- Review Course Outline (posted on website)

Course Syllabus

- This course presents a variety of topics on the design and use of modern digital computers, including:
  - Digital representations, Digital (Boolean) Logic
  - Modular design concepts in digital circuits
    - Combinational circuits
    - Sequential circuits.
  - Instruction architecture, cycle, timing logic
  - Memory, CPU and Bus Organization.
  - Assemblers, assembly language
- The detailed schedule and topics covered may be adjusted at the discretion of the instructor
  - Students will be advised in advance of lecture topics and assigned reading.

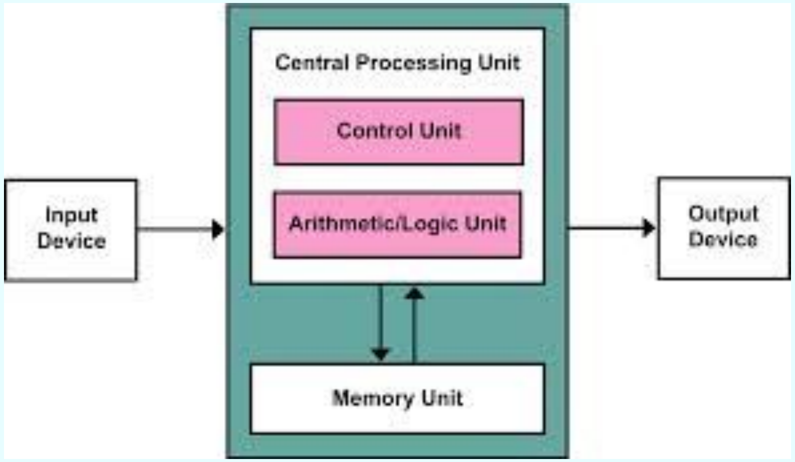
Digital Design and Computer Architecture

- Von Neumann Architecture
  - The 5 component design model
- The Instruction Cycle
  - Basic
  - Exceptions
- Instruction architecture
  - software design
  - hardware circuits

Digital Design & Computer Architecture

Computer Science – Grade 11

Von Neuman Architecture



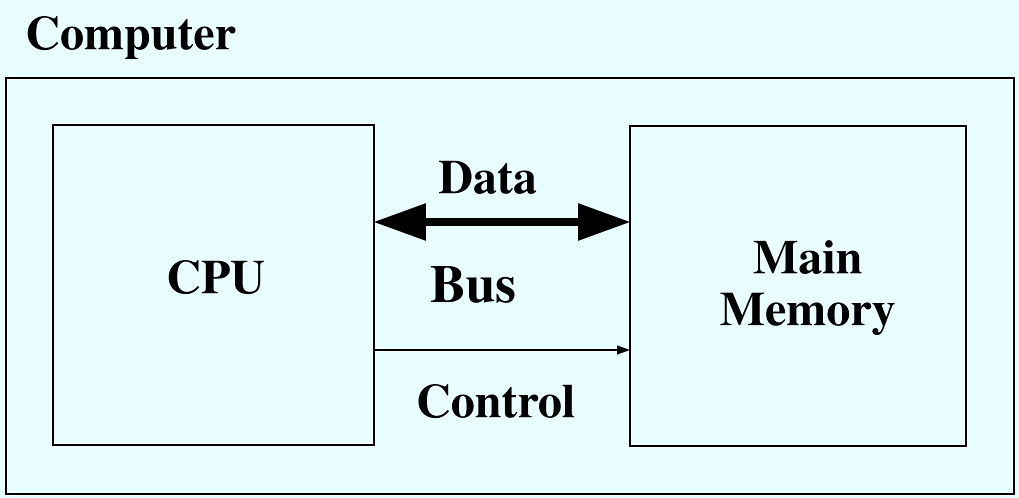
Objectives

- Von Neumann Architecture
  - 5 component design of the *stored program digital computer*
  - the *instruction cycle*
    - Basic
    - Exceptions
  - instruction architecture
    - software design
    - hardware circuits

- Digital Design
  - Boolean logic and gates
  - Basic Combinational Circuits
  - Karnaugh maps
  - Advanced Combinational Circuits
  - Sequential Circuits

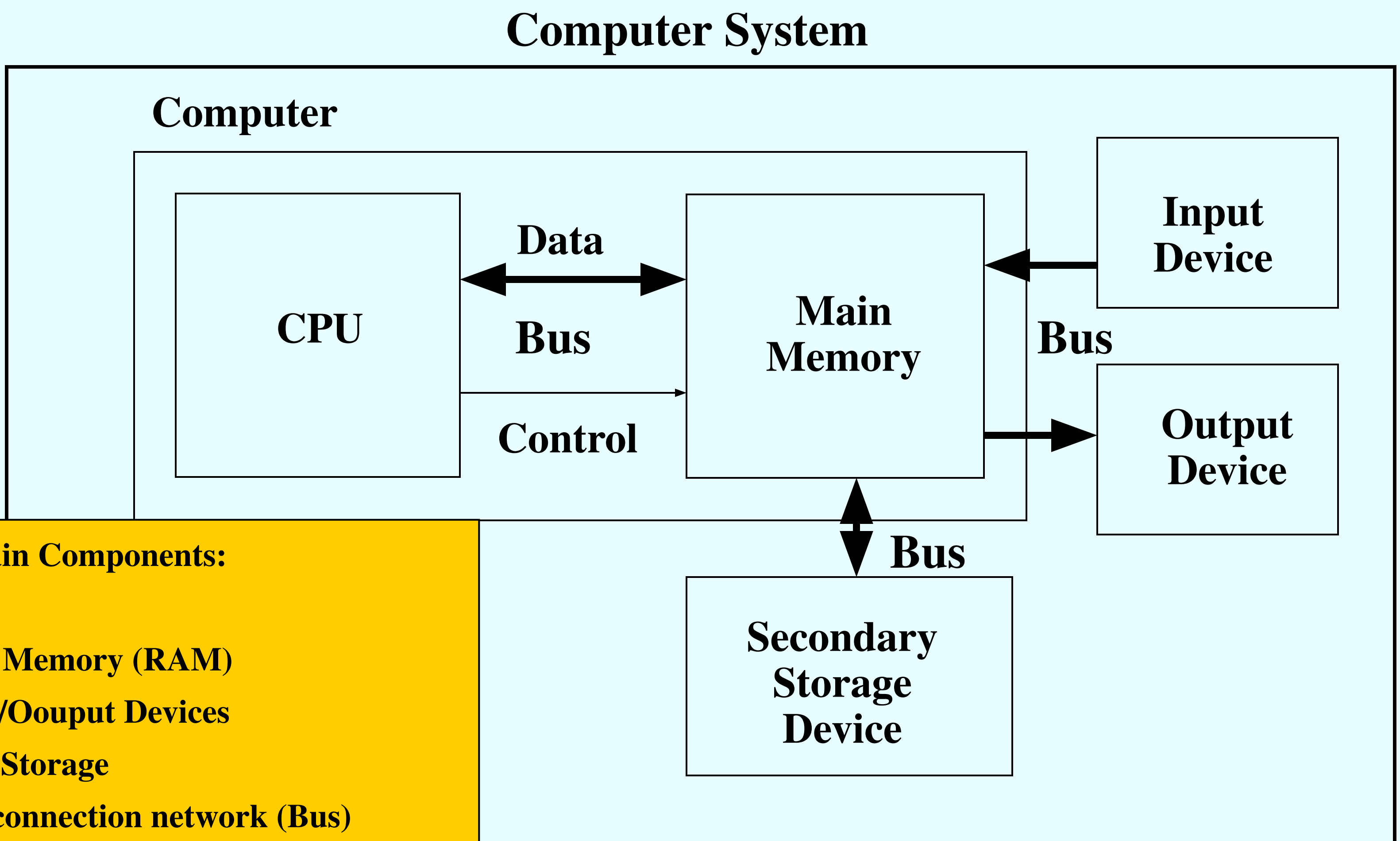
von Neumann Architecture

- Principles
  - Data and instructions are both stored in the main memory(stored program concept)
  - The content of the memory is addressable by location (without regard to what is stored in that location)
  - Instructions are executed sequentially unless the order is explicitly modified
  - The basic architecture of the computer consists of:



von Neumann Architecture

- A more complete view of the computer *system* architecture that integrates interaction (human or otherwise) consists of:



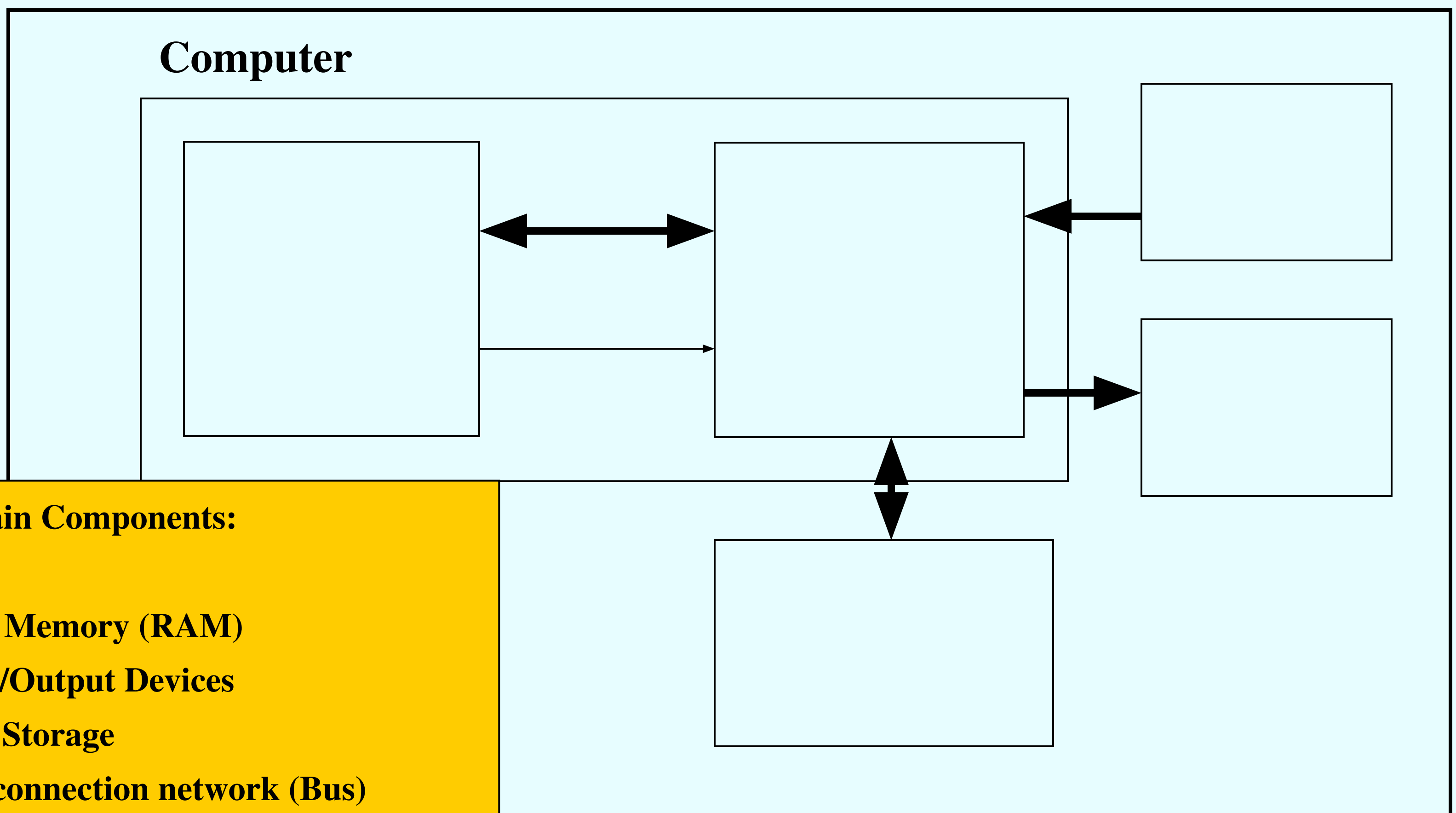
Five Main Components:

1. CPU
2. Main Memory (RAM)
3. Input/Oouput Devices
4. Mass Storage
5. Interconnection network (Bus)

von Neumann Architecture

- A more complete view of the computer *system* architecture that integrates interaction (human or otherwise) consists of:

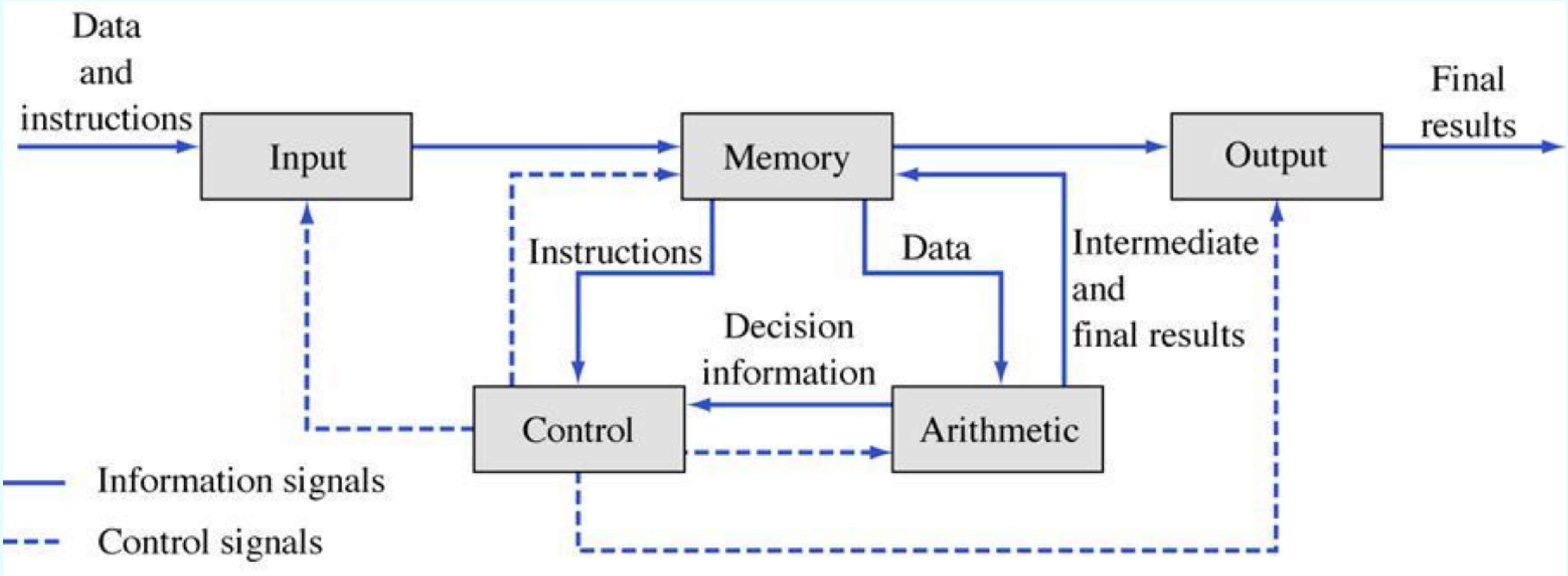
Computer System



Five Main Components:

1. CPU
2. Main Memory (RAM)
3. Input/Output Devices
4. Mass Storage
5. Interconnection network (Bus)

Another view of a digital computer

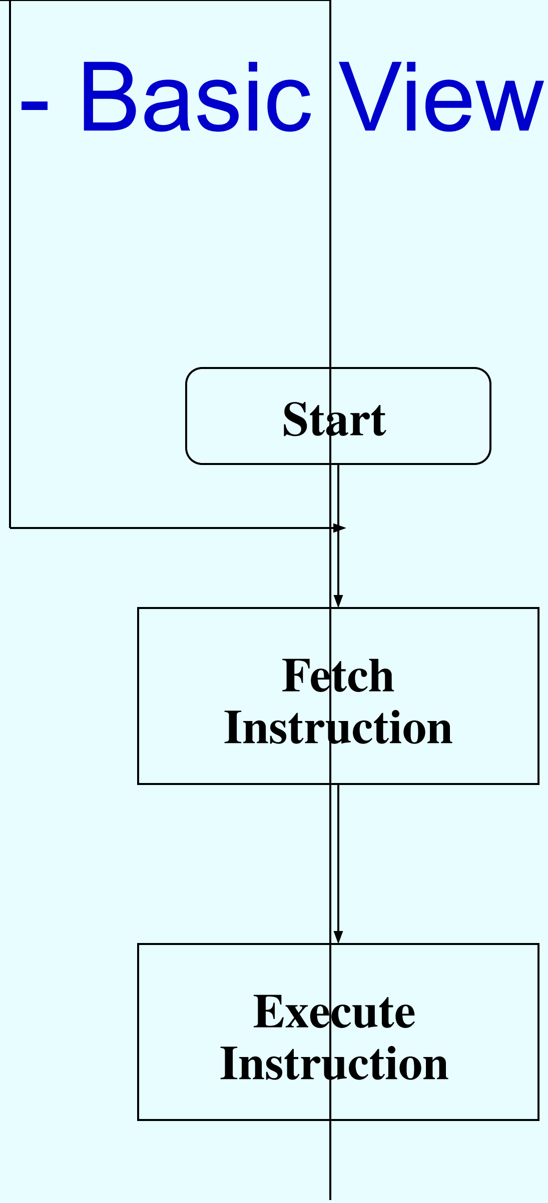


The Instruction Cycle

- The Instruction Cycle
  - Basic
  - Intermediate
  - Exceptions

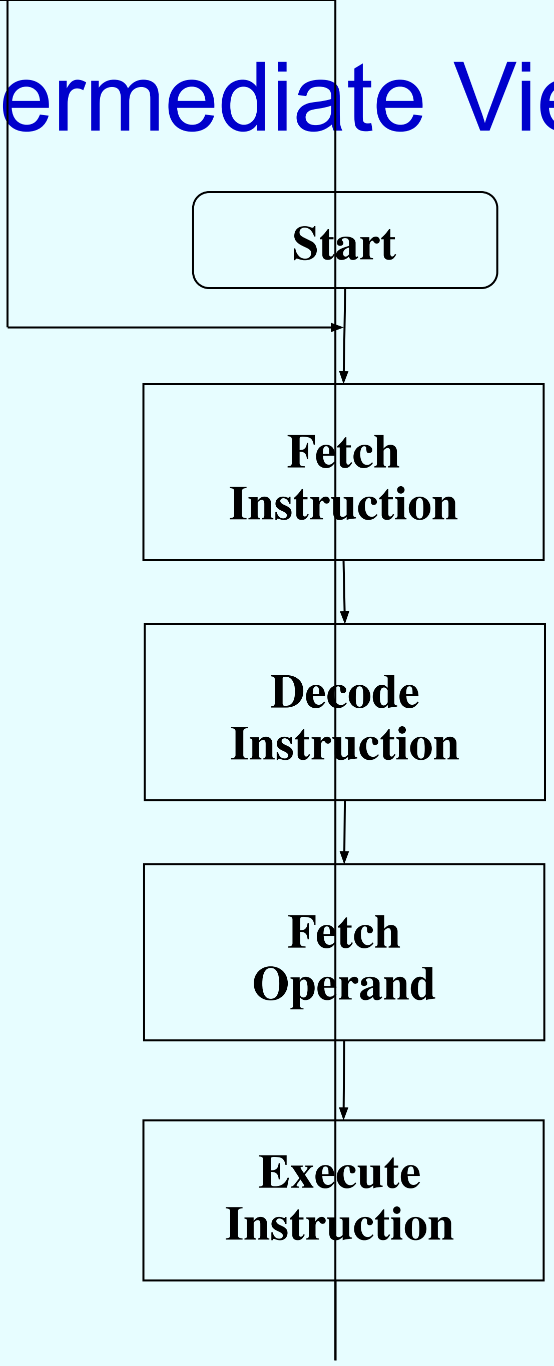
The Instruction Cycle - Basic View

- Once the computer has been started (bootstrapped) it continually executes instructions (until the computer is stopped)
- Different instructions take different amounts of time to execute (typically)
- All instructions and data are contained in main memory



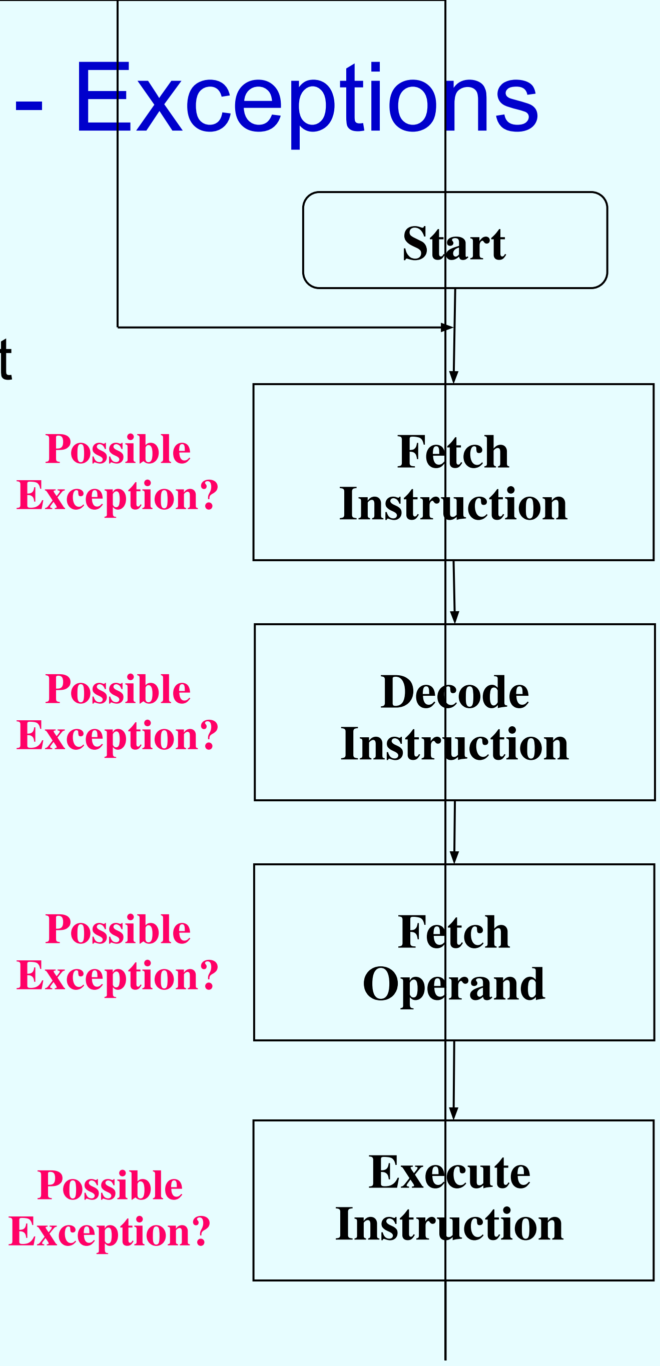
The Instruction Cycle - Intermediate View

- A complete instruction consists of
  - operation code
  - addressing mode
  - zero or more operands
    - immediately available data (embedded within the instruction)
    - the address where the data can be found in main memory



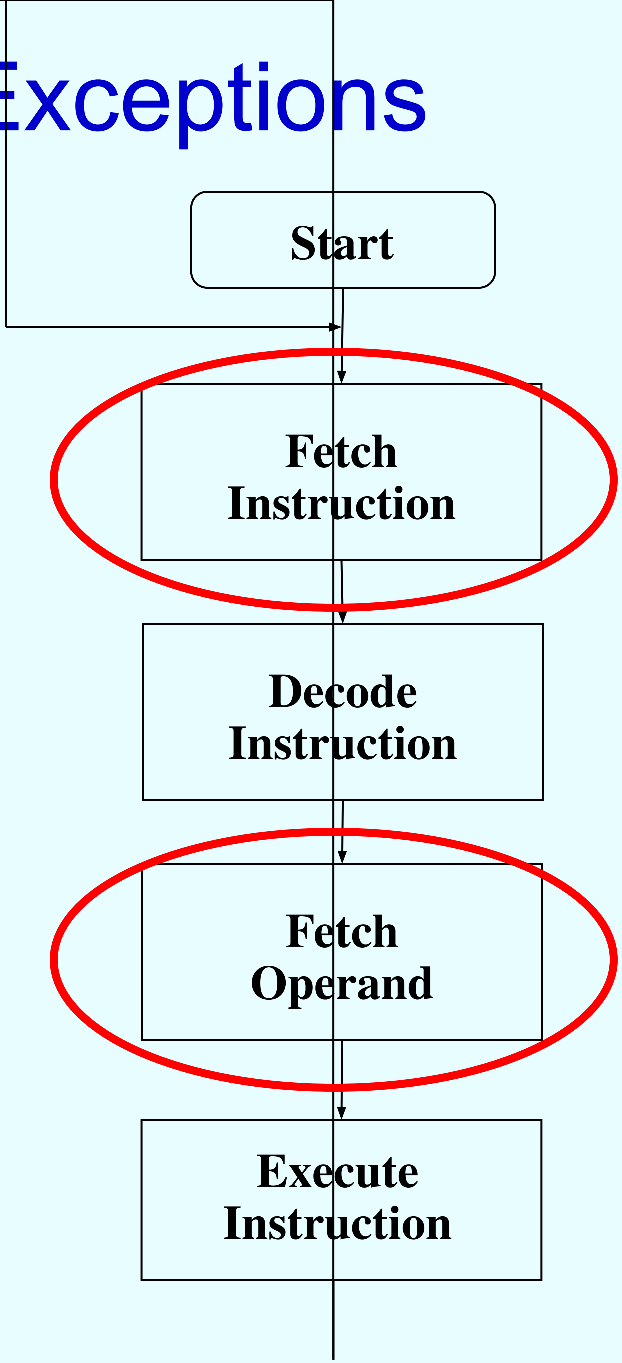
The Instruction Cycle - Exceptions

- Exceptions, or errors, may occur at various points in the instruction cycle, for example:



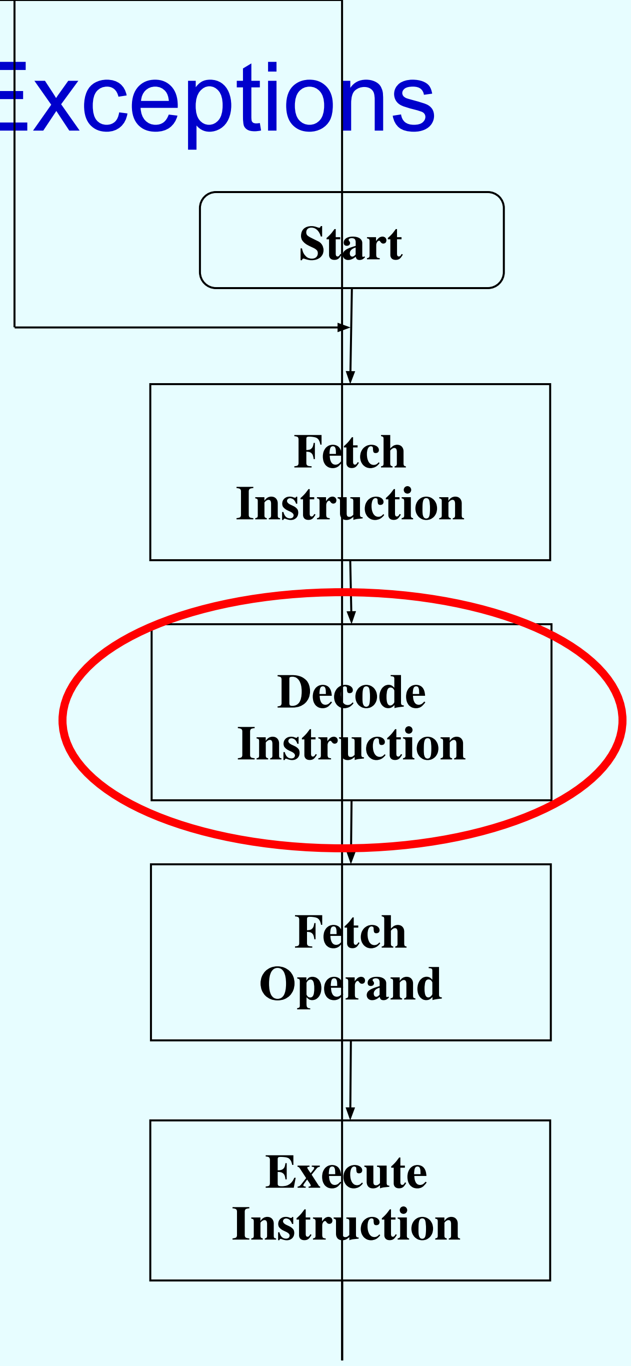
The Instruction Cycle - Exceptions

- Exceptions, or errors, may occur at various points in the instruction cycle, for example:
  - Addressing - the memory does not exist or is inaccessible



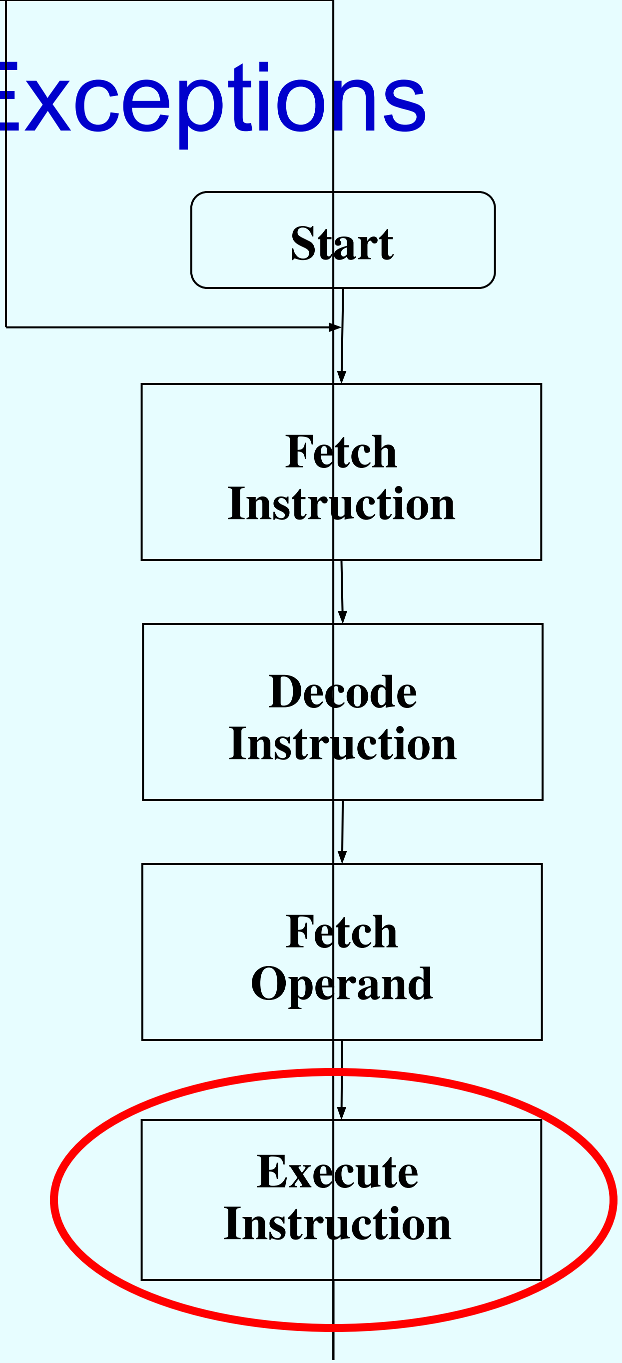
The Instruction Cycle - Exceptions

- Exceptions, or errors, may occur at various points in the instruction cycle, for example:
  - Operation - the operation code does not denote a valid operation



The Instruction Cycle - Exceptions

- Exceptions, or errors, may occur at various points in the instruction cycle, for example:
  - Execution - the instruction logic fails, typically due to the input data
    - divide by zero
    - integer addition/subtraction overflow
    - floating point underflow/overflow



Instruction Architecture

- Software design
- Hardware circuits

Instruction Architecture - Software Design

- Each computer CPU must be designed to accommodate and understand instructions according to specific formats.
- Examples:
  - All instructions must have an operation code specified
  - NOP   no operation
  - TSTST   test and set

OpCode

Instruction Architecture - Software Design

- Each computer CPU must be designed to accommodate and understand instructions according to specific formats.
- Examples:
  - Most instructions will require one, or more, operands
  - These may be (immediate) data to be used directly
  - or, addresses of memory locations where data will be found (including the address of yet another location)

OpCode	**Operand (Address)**

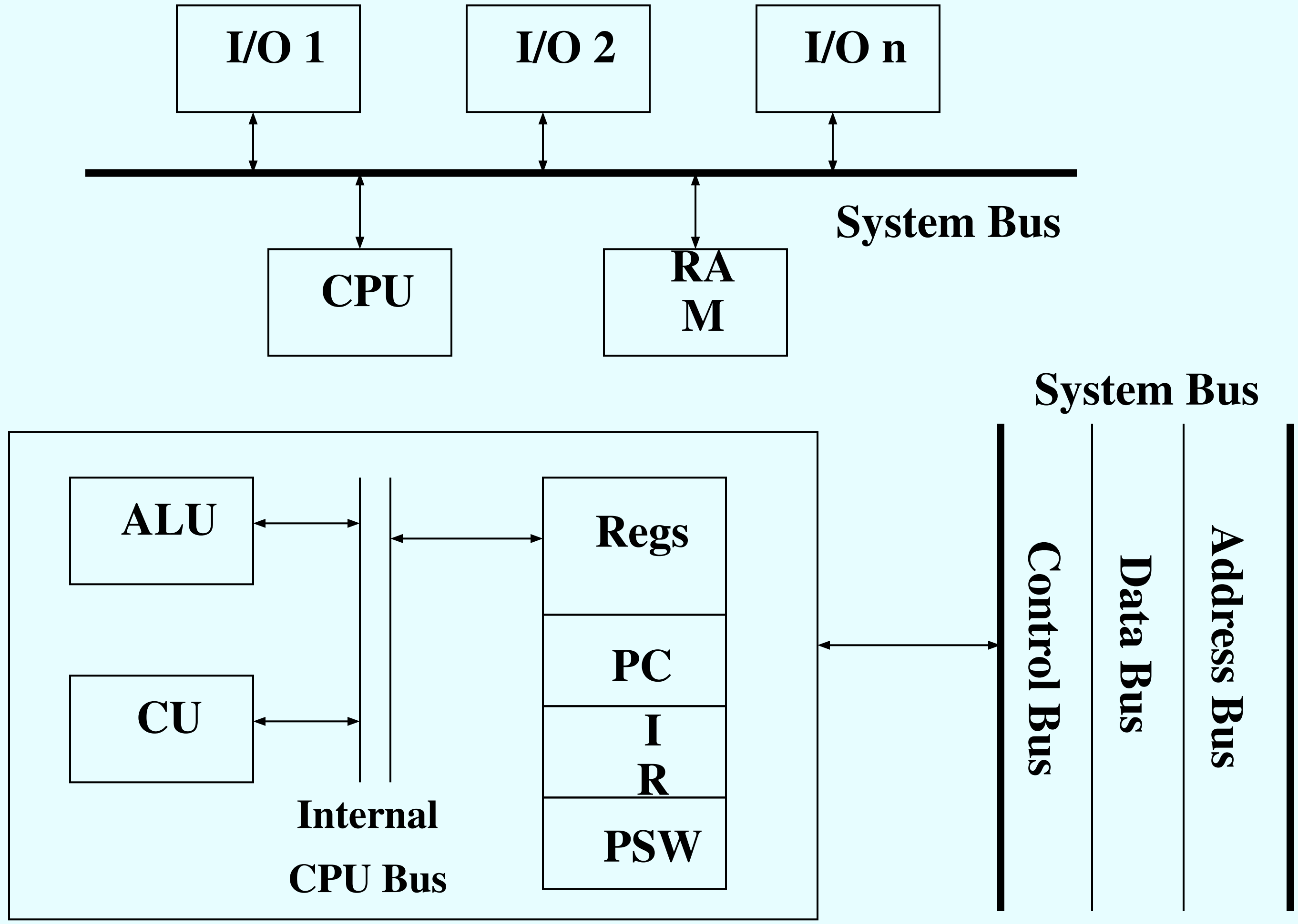
Instruction Architecture - Software Design

- Sometimes the instruction format requires a code, called the Mode, that specifies a particular addressing format to be distinguished from other possible formats
  - direct addressing
  - indirect addressing
  - indexed addressing
  - relative addressing
  - doubly indirect addressing
  - etc.

OpCode	**Mode**	**Op. (Addr.)**	**Mode**	**Op. (Addr.)**

Instruction Architecture - CPU

- The CPU must be designed to accommodate the instructions and data to be processed



Instruction Architecture - Hardware Circuits

- Everything that the computer can do is the result of designing and building devices to carry out each function – no magic!
- At the most elementary level the devices are called logic gates.
  - There are many possible gate types, each perform a specific Boolean operation (e.g. AND, OR, NOT, NAND, NOR, XOR, XNOR)
- ALL circuits, hence all functions, are defined in terms of the basic gates.
- We apply Boolean Algebra and Boolean Calculus in order to design circuits and then optimize our designs.

Instruction Architecture - Hardware Circuits

- Data is represented by various types of “signals”, including electrical, magnetic, optical and so on. Data “moves” through the computer along wires that form the various bus networks (address, data, control) and which interconnect the gates.
- Combinations of gates are called integrated circuits (IC).
- All computer functions are defined and controlled by IC’s of varying complexity in design. The manufacture of these may be scaled according to size/complexity:
  - LSI large scale integration
  - VLSI very large scale integration
  - ULSI ultra large scale integration

Instruction Architecture - CU

- The control unit must decode instructions, set up for communication with RAM addresses and manage the data stored in register and accumulator storages.
- Each such operation requires separate circuitry to perform the specialized tasks.
- It is also necessary for computer experts to have knowledge of the various data representations to be used on the machine in order to design components that have the desired behaviours.

Instruction Architecture - ALU

- All instructions together are called the instruction set
  - CISC complex instruction set
  - RISC reduced instruction set

- Each ALU instruction requires a separate circuit, although some instructions may incorporate the circuit logic of other instructions

Our Goal – Design Circuits!

- After all the conceptualization we must now get down to the most fundamental business – learning how to design circuits that can implement the logic we intend to impose and use
- Circuit design arises out of a study of Boolean Set Theory and Boolean Algebra
  - We need to study and learn some new mathematics
- We will need to understand *design optimization*
  - How to make the design as lean and efficient as possible
- We will work towards higher level abstraction of device components, but start at an elementary level of concrete behaviours with predefined units called ***gates***.

Assignment

- Why is Boolean important for understanding computer architecture?
- Draw the symbols for and, nand, or, nor, not, XOR and write the truth table for each.
- Explain, CMOS, NMOS, PMOS, NFET, PFET and draw a symbol for each.
- What is an “adder”? Draw circuit for “Adder”.
- What is a “FLIP-FLOP”? Draw the circuit and explain.
- Who was Von Neuman?
- Explain “Von Neuman’s” theory.