Fundamentals of Computer Architecture

1. Introducing The Processor

Chapter Overview

- This chapter includes:
  - The key aspects of a computer;
  - A brief history of the computer and its place within our modern society;
  - The typical components within a computer system, focusing on the processor;
  - The simulated processor, *JASPer* - the primary tool with which we are going to study the fundamental concepts of modern computers.

Computers Are Everywhere

- When many people think of a computer they think of the typical desktop PC, or laptop, or even the PDA.
- Within this chapter I'll show you that computers come in more guises than these, and yet they all contain the same fundamental components.

What Is A Computer?

- A hundred years ago a *computer* was a *human being*, either a mathematician or someone who worked for a mathematician.
- A computer was someone who performed calculations to find the answer to a complex mathematical equation.
- They might not have even understood the calculations they were performing (in fact, it was often found that those individuals who *didn't* understand the complex calculations actually performed better. Why? Because they wouldn't be tempted to perform short cuts on their set of operations, which could actually introduce errors into the calculations).
- A good computer simply followed very stringent rules.

What Is A Computer?

- A particular set of rules for one individual computer in the room might have been something like:
  – Take the card from the person on your left;
  – Multiply the last number on the card by three;
  – Write the result on the card;
  – Hand the card to the person on your right;
  – Repeat all operations again.

What Is A Computer?

- It wasn't until the early 1940s that electrical devices were first referred to (most probably by an American called Atanasoff) as computers.
- Over the years the rough definition of a computer has evolved to this:
  – It must take *input* of some sort;
  – It must produce *output* of some sort;
  – It must *process* the information somehow;
  – It must have some sort of *information store*;
  – It must have some way of *controlling* what it does.

What Is A Computer?

- At the heart of any computer you will find a component called a *processor*, more formally described as a *Central Processing Unit*, or *CPU*.
- A processor that is constructed completely as a very large electrical circuit - called an *integrated circuit* - on one single chip of silicon (colloquially called a *computer chip*) is called a *microprocessor*.
- What we term a computer these days is more accurately called a *microprocessor based computer system* or *micro-computer* .

What Is A Computer?

- It is microprocessors used within *embedded systems* (contained in some greater device, like a car or a mobile phone - such that the microprocessor is part of the greater device) that are becoming the largest market within computing.
- Never has there been a better time to gain a fundamental knowledge of how microprocessors work, as this knowledge is increasingly in demand now that microprocessors are truly everywhere.

A Very Brief History Of The Computer

- A few computer firsts:
  - Charles Babbage invented mechanical machines;
  - In 1936 Alan Turing defined the *Turing Machine* - the practical grounding for computing machines;
  - During WWII, Station X was the birthplace of a machine called *Colossus*. Colossus was effectively the first programmable logic calculator;
  - After WWII, the Manchester 'Baby' was the first computer that stored its programs and its data in the same memory - an idea that is used by almost all modern computers today, it's referred to now as a *von Neumann architecture*, named after the famous Hungarian born mathematician John von Neumann.

A Very Brief History Of The Computer

- More computer firsts:
  - 1947 : The invention of the *transistor;*
  - 1958 : The invention of the *integrated circuit;*
  - 1971 : A young company called *Intel* produced the very first microprocessor:
    - *Intel 4004* and contained around 2300 transistors on a single chip;
    - Chip technology is now so advanced that we are close to having one billion transistors on a single chip.
  - 1981 : The first Personal Computer.

Inside A Computer
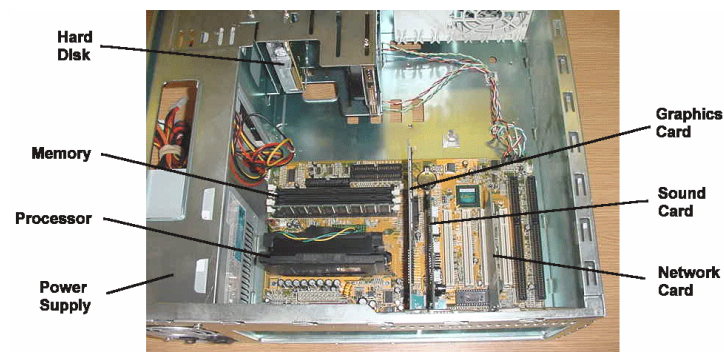
Inside A Computer

- In the figure on the previous slide I've taken the case off a typical PC (many of the internal cables have been removed):
  - The most important component is the processor. It runs a series of instructions (called a *program*), and controls the activity of all other components within the computer;
  - Next we have the *memory* chips. These are used to store our data and instructions;
  - The other labelled components include the hard disk, the graphics card, network card and the power supply. All are used by modern computer systems, but are actually quite minor in the scale of things - we don't need to refer to them to learn how a computer works.

The Minimalist Approach

- What are the smallest number of components we need to build a computer? We need:
  - A processor - to process information, and to control the system;
  - Memory - for data and instruction storage;
  - Some form of input device; we'll use a keyboard to enter data into the system;
  - Some form of output device; we'll use a monitor screen so we can see what our computer is doing.

| Processor	Buses	Memory
		Output
		Input
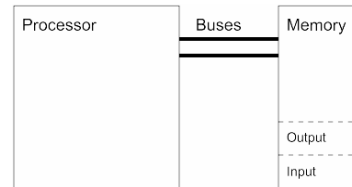
The Minimalist Approach

- To build our simple processor we need the following components:
  - Some *Registers* - a register is a store where we can place one piece of data;
  - An *Arithmetic Logic Unit*, or *ALU* - a very basic calculator for our processor. The ALU will have some registers inside it, as we will see later;
  - A *Control Unit*, or *CU* - to run the processor;
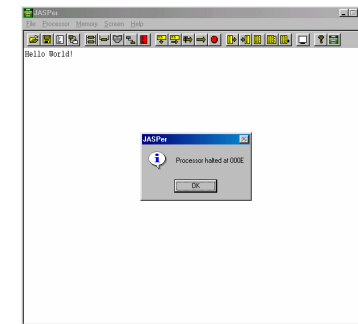 - Some buses - to allow us to move data from one component to another.

Processor — Control Unit — ALU

▬ = Register ▬▬ = Bus
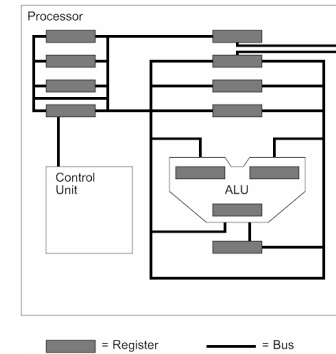
Here's One We Prepared Earlier

- JASPer
  - A Windows program that simulates the JASP processor in a simple system
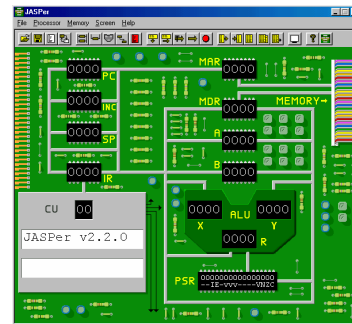
Our First Program - 'Hello World'

- Output after running the Hello World program

Chapter Summary

- **The key aspects of a computer**
  - Any processor based system has five key aspects - it takes input, it produces output, it processes data, it has an information store and it controls what it does;
  - Most modern computers use a von Neumann architecture.
- **A brief history**
  - Hardware developments, notably the invention of the transistor in 1947, and the development of integrated circuits during the 1970s, lead to the introduction of the personal computer. Although other companies produced PCs before IBM, it is IBM that cornered the PC market.

Chapter Summary

- **The typical components within a computer**
  - A rudimentary computer requires a processor and a memory, as well as some simple I/O devices;
  - Modern computers have many I/O devices that we do not need to examine in order to understand the fundamentals of a computer system.
  - A processor consists of registers, an ALU and a CU all connected by buses.
- **The simulated processor, JASPer**
  - JASPer models our simple processor, and can be used to execute programs.