

ADVANCED PROCESSOR  
ARCHITECTURES AND MEMORY  
ORGANISATION –  
Lesson-5: Memory Organisation,  
Types Of Memory

# 1. Memory Organisation

# Random access model

- A memory-, a data byte, or a word, or a double word, or a quad word accessed from or at all addressable locations with a similar process would be used to access from all locations
- Equal access time for a read or for a write
- Independent of a memory address location
- Different from another model, called serial access mode

# Addresses

- Memory (both RAM and ROM) divided into a set of storage locations
- Each location has distinct address
- Hold 1 byte (8 bits) of data.
- The storage locations are numbered
- A number of a storage location (called its *address*) used to tell the memory system which location the processor wants to reference

# Addresses

- Important characteristics of a computer system is the width of the address bus it uses
- Limits the amount of memory that the processor can address
- Most current computers use either 32-bit or 64-bit addresses, allowing them to access either  $2^{32}$  or  $2^{64}$  bytes of memory

# RANDOM ACCESS MODEL OF MEMORY

- Simple model for RAM and ROM
- Both has random-access model of memory
- All memory operations take the same amount of time independent of the address of the byte or word at the memory.

## Example

- Assume that the memory system will support two operations: load (read operation into processor from memory) and store (read operation from processor into memory).
- Load from one set of addresses (2 or 4) will take same time for store from another set of addresses (2 or 4)

# ROM

- Contents of the read-only memory cannot be modified by the computer but may be read.
- A system has ROM unit(s) —for bootstrap program(s), basic input-output system (BIOS) program(s) and for vector addresses for the interrupts
- Used to hold bootstrap program that is executed automatically by the system every time it is turned on or reset. Instructs the system to load its operating system off



# ROM image

- ROM image holds the programs, operating system, and data required by the system.

# Random-access memory (RAM)

- Can be both read and, written,
- Hold the programs, operating system, and data required by the system.
- Generally volatile, meaning that it does not retain the data stored in it when the system 's power is turned off. A
- Data that needs to be stored while the system is off must be written to a permanent storage device, such as a flash memory or hard disk.
- An example is as follows: A mobile phone has 128 kB or 256 kB of RAM to hold the stack and temporary variables of the programs, operating system, and data.

# ALIGNMENT OF MULTIBYTE STORE AND LOAD IN A MEMORY ORGANISATION

- Some memory organisation requires loads and stores to be "aligned. A 4-byte word has been aligned at address 0x000C or 0x1000, which is a multiple of 4. This simplifies the organisation of the memory system.

# LITTLE ENDIAN AND BIG ENDIAN IN A MEMORY ORGANISATION

- Some processor and memory organisation requires *little endian* and other *big endian* aligned multiple bytes when there is store into the memory or load into the processor from memory.
- ARM processor permits programming at the start and enables a programmer to define one of the word-alignments *little endian* or *big endian* at the beginning.

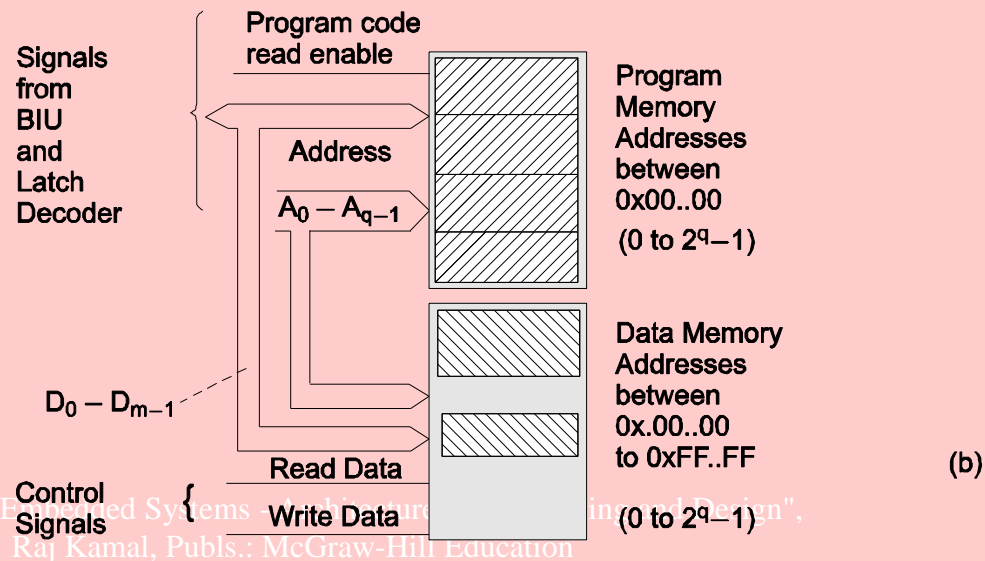
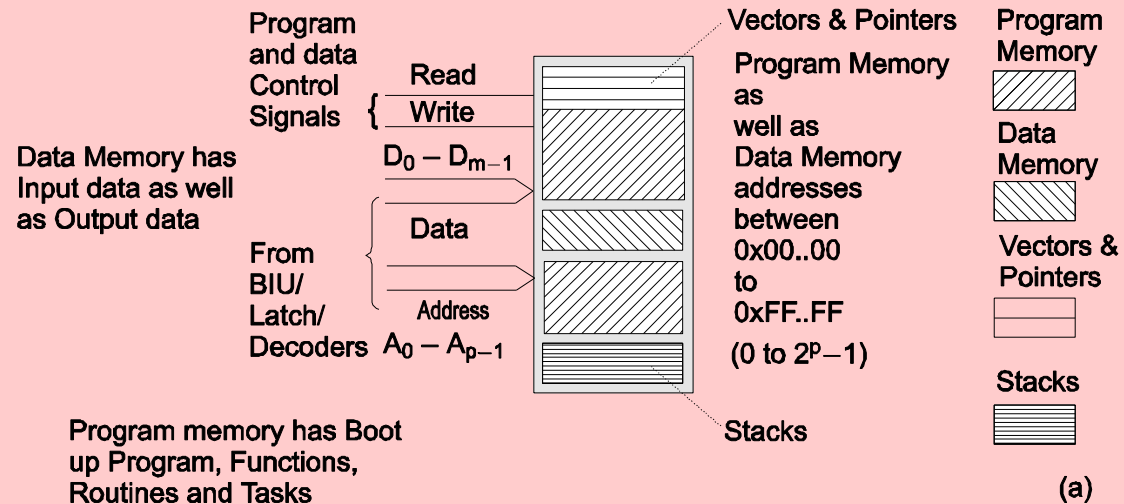
# Princeton Architecture

- 80x86 processors and ARM7 have Princeton architecture for main memory. 8051-family microcontrollers have Harvard architecture.). Vectors and pointers, variables, program segments and memory blocks for data and stacks have different addresses in the program in Princeton memory architecture.

# Harvard architecture

- When the address spaces for the data and for program are distinct
- Handling streams of data that are required to be accessed in cases of single instruction multiple data type instructions and DSP instructions.
- Separate data buses ensure simultaneous accesses for instructions and data.

# Harvard and Princeton Memory Organizations



# Harvard Architecture

- Program segments and memory blocks for data and stacks have separate set of addresses in Harvard architecture.
- Control signals and read-write instructions are also read-write instructions are also separate for accessing the program memory and data memory.



## 2. Types of Memory

# Memory types

- Most systems two types of memory— *read-only memory* (ROM) and *random-access memory* (RAM).
- A computer system has ROM unit(s) for bootstrap program(s), basic input-output system (BIOS) program's) and for vector addresses for the interrupts
- An embedded system has ROM unit(s) for storing ROM image and flash to save non-volatile data and results

# ROM Uses

- Language specific bits for the fonts corresponding to each character to a printer or display unit.
- Images bits for a display.
- Pictogram bytes for the full bit-image corresponding to the pixels for a pictogram. Sequential changes at the inputs of display unit repeatedly generate the full pictogram.
- In a CISC as a control ROM at a micro-programmed unit for implementing instructions

- 1) Masked ROM – Used for large scale manufacturing; mask prepared for foundry
  - A finalised ROM image of system program and data, pictograms, image pixels, pixels for the fonts of a language, combination-circuits implementing a truth-table

2) EPROM – Used in place of masked ROM during development phase; UV Erasable and Electrically programmable by a device programmer

3) E<sup>2</sup>ROM – Used during the program run to save non-volatile data and results (for examples, date and time of a transaction, present port status, port driving history, system malfunctions history); Electrically Erasable by writing a byte or a set of bytes with all 1s and Electrically programmable during a program run one byte write at each write instance.

- 4) Flash – A flash memory functions as the ROM. Electrically Erasable sector of 16 kB to 256 kB at an instance and Electrically programmable one byte at each instance during a program run.

# Flash memory applications

- ROM image and OS,
- Used during the program run to save non-volatile data and results, for examples, a picture in a digital camera, voice mail;
- Storing SMS, MMS messages in a mobile phone. phone book, address book
- Storing voice compressed form in a voice recorder. [Recall of prerecorded message from a telephone exchange.]



5) Boot Block Flash – Flash with a sector reserved for programming once only; that sector can be used for saving ROM image or boot program of the system

**6) Memory Stick** — a removable flash memory card format. [An 8 GB card was unveiled at a 2006 show at Las Vegas]

Exemplary uses: Removable stick in digital camera, Mobile phone, Handheld devices, Handheld compressed voice or video recording in a voice or video recorder

6) PROM (OTP) - Used for small scale manufacturing and for saving once only data; used for saving ROM image or boot program of the system and for storing data like user photo and ID and account type and bank details on a card;

# RAM

- The RAM can be both read and, written, and is used to hold the programs, operating system, and data required by a computer system. In embedded systems, it holds the stack and temporary variables of the programs, operating system, and data

# RAM Characteristics

- RAM is generally volatile,
- does not retain the data stored in it when the system 's power is turned off.
- Any data that needs to be stored while the system is off must be written to a permanent storage device, such as a flash memory or hard disk.

Example :A mobile phone has 128 kB or 256 kB of RAM to hold the stack and temporary variables of the programs, operating system, and data

# RAM Types

- 1) SRAM (static RAM) and DRAM (dynamic RAM) – Used for saving the variables, stacks, process control blocks, input buffer, output buffer, decompressed format of program and data at the ROM image

2) EDO (Extended Data Out) RAM – Used up to 100 MHz clock rate, zero wait state between two fetches, single cycle read or write

3) **SDRAM (Synchronous DRAM)** –  
Synchronised read operation; keeps next word ready while previous one is being fetched; used up to 1 GHz clock cycle



4) RDRAM (Rambus\* DRAM) – Burst accesses of four successive words in single fetch; used for 1 GHz + performance of the system

\* A developer company name

- 5) Parameterised Distributed RAM – when slow bus accesses exist RAM distributed for the specific tasks of the system and devices - for examples for fast IO buffers, fast stacks, ..
- 6) Parameterised Block RAM – Specific block dedicated for specific use, for example, for DCT operations

# Summary

We learnt

- Random access memory model, ROM, RAM
- Addresses
- Data alignment
- Little and big endian
- Flash
- Princeton and Harvard architectures

End of Lesson 5 of Chapter 4  
on  
Memory Organisation and Types of  
Memory