MODULE 4: Computer Organization and MARIE

Lecture 4.1
Computer Organization Fundamentals

Prepared By:
- Scott F. Midkiff, PhD
- Luiz A. DaSilva, PhD
- Kendall E. Giles, PhD

Electrical and Computer Engineering
Virginia Tech

Lecture 4.1 Objectives

- Identify and describe the major hardware components of a computer architecture
- Describe the functions of a system bus, memory, and central processing unit (CPU)
- Describe the function of the system clock and convert between clock frequency and clock cycle time
- Explain what interrupts are used for

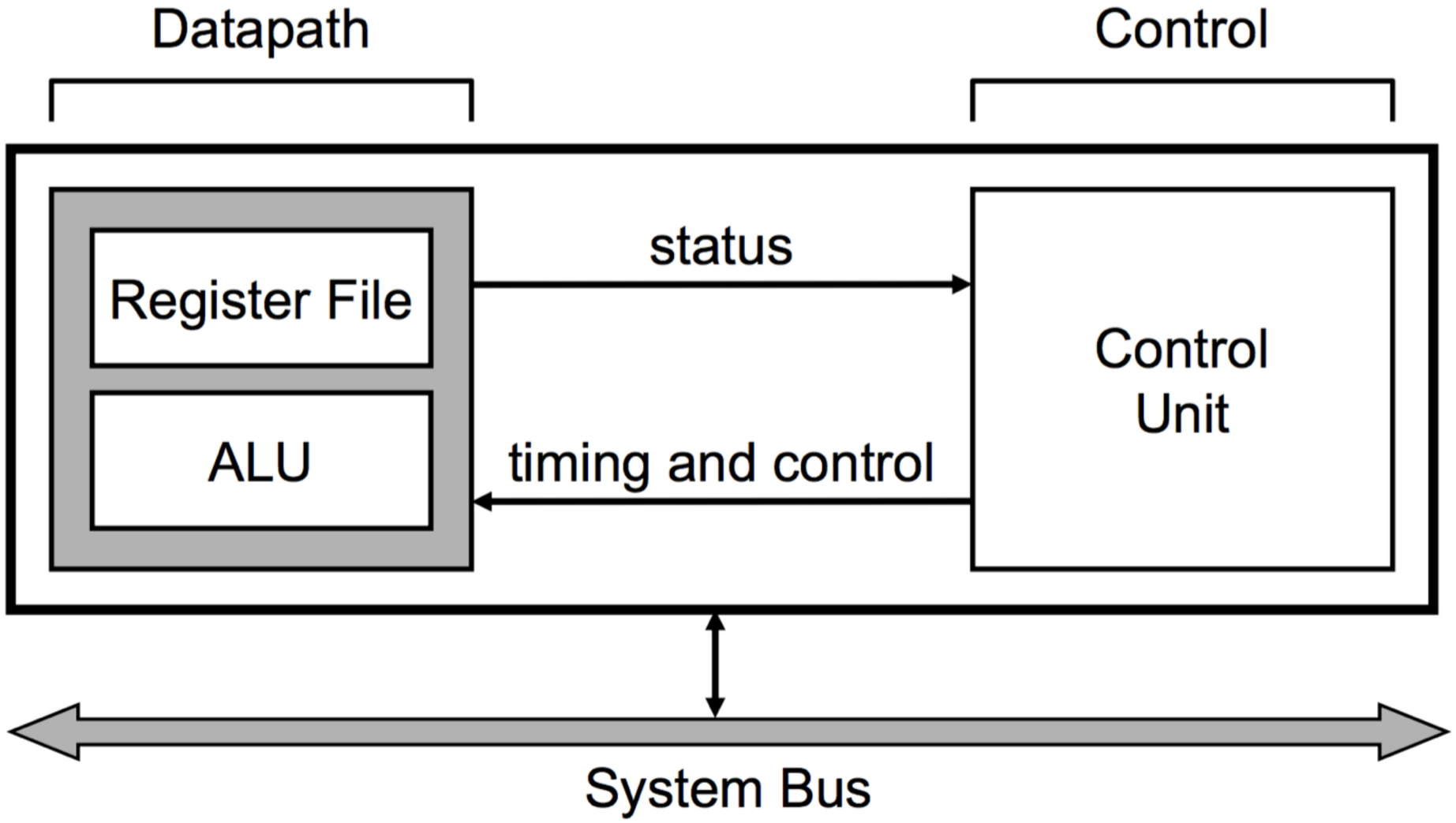
Central Processing Unit (CPU)

- CPU executes instructions stored in memory
  - Fetches instructions, decodes them, executes the indicated operations on the appropriate data
- Special registers
  - Program counter (PC) that specifies the memory address of the instruction to fetch and execute
  - Instruction register (IR) that receives the instruction

Fetch-execute Cycle

- Fetch-execute cycle: the steps for instruction execution
  - Fetch the next instruction located at address in PC and store in IR
  - Decode opcode (operation code)
  - Read operand(s), if any, from memory
  - Execute operation
  - Write results, if any, to memory
  - Repeat for next instruction as specified by PC

CPU Components (1)



CPU Components (2)

- Register file
  - Special memory for storing intermediate results
  - Register file is within the CPU and, therefore, much faster than memory locations
- Arithmetic and logic unit (ALU)
  - Performs arithmetic operations, such as addition and subtraction
  - Performs logic operation, such as bitwise AND and bitwise complement
- Register file and ALU are collectively referred to as the datapath

CPU Components (3)

- Control unit
  - Responsible for coordinating units via timing and control signals
  - Status signals from data path to allow control to depend on datapath results, for example, for conditional branch instructions

CHECK POINT

As a checkpoint of your understanding, please pause the video and make sure you can do the following:

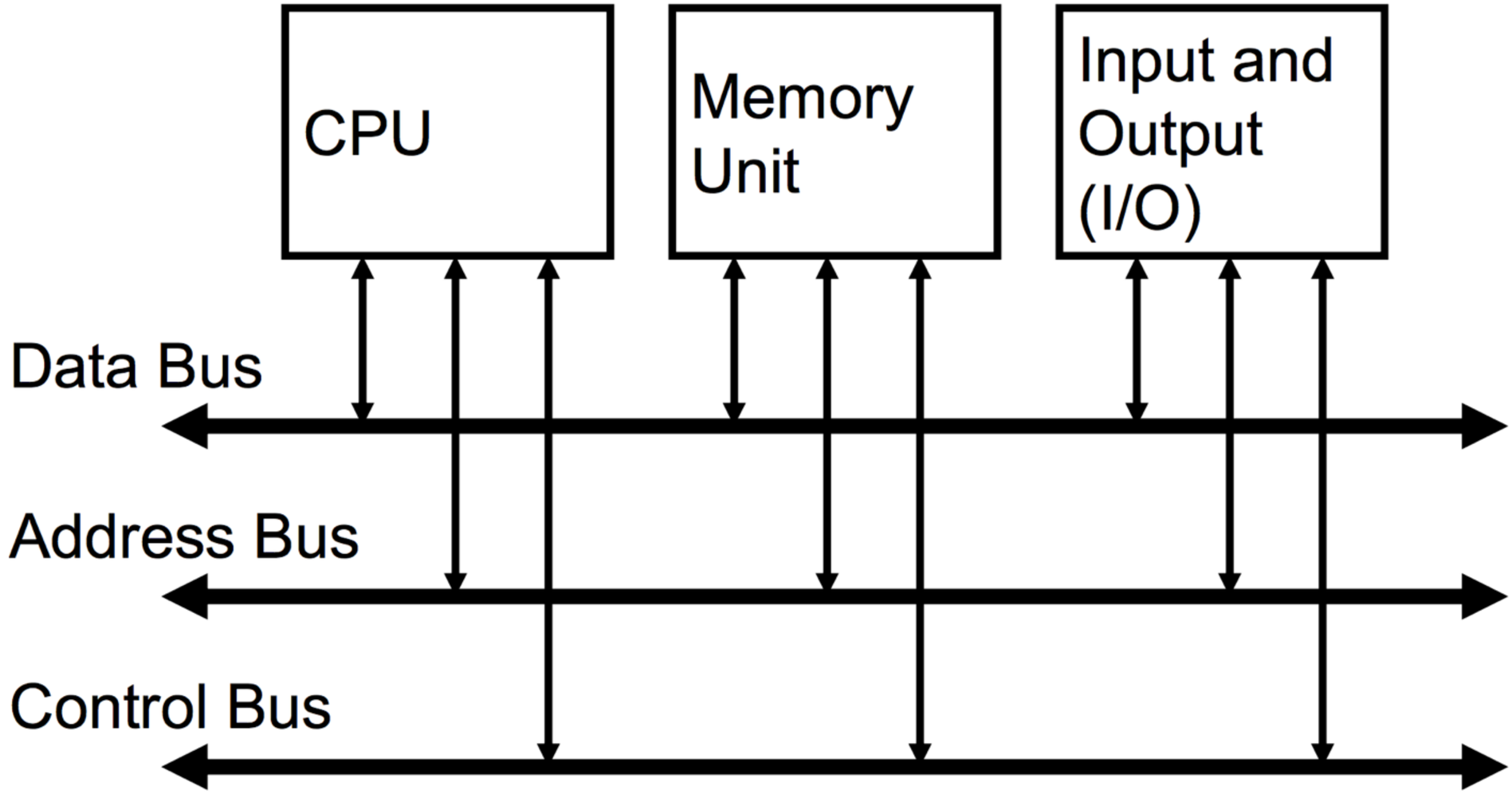
- Describe the main components of a computer's CPU

If you have any difficulties, please review the lecture video before continuing.

System Bus (1)

- The system bus connects the CPU and other subsystems in a way that reduces the number of interconnections
- Multiple devices share a single bus, so rules or a protocol are needed for the bus to operate correctly
    - Bus arbitration

System Bus (2)



Operation of a Simple Bus

- CPU sets address bus to indicate the memory location or input/output (I/O) register to be accessed
- CPU sets control bus values to determine operation (read or write) and timing
- If a write, CPU puts data on the data bus and the memory or I/O device stores the data from the data bus
- If a read, the selected memory or I/O device puts data on the data bus and the CPU stores the data from the data bus

Clock

- System clock synchronizes all the system components
    - Regulates how quickly instructions can be executed
- Certain buses may have their clocks (slower than the system clock)
- Clock frequency measured in Hz
- Clock cycle time measured in seconds

$$Frequency = \frac{1}{cycle\_time}$$

CHECK POINT

As a checkpoint of your understanding, please pause the video and make sure you can do the following:

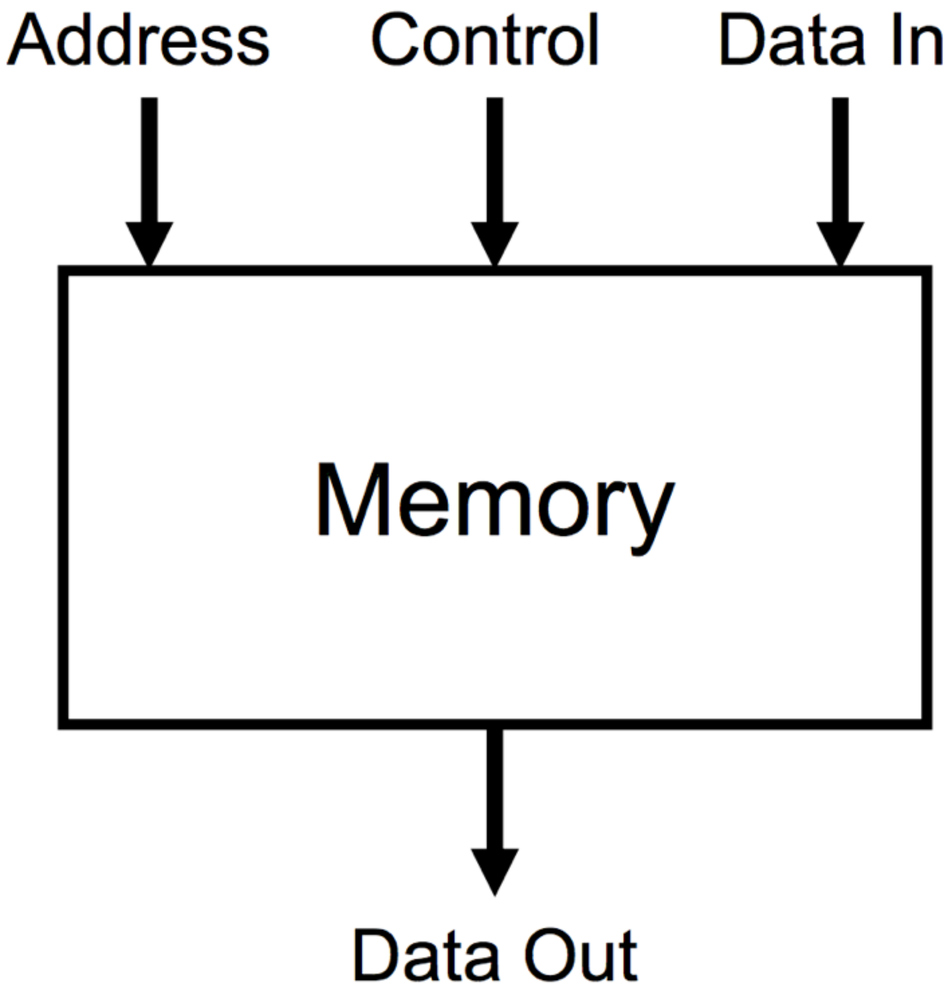
- Describe the operation of a computer's system bus
- Write the formula to convert between clock frequency and clock cycle time

If you have any difficulties, please review the lecture video before continuing.

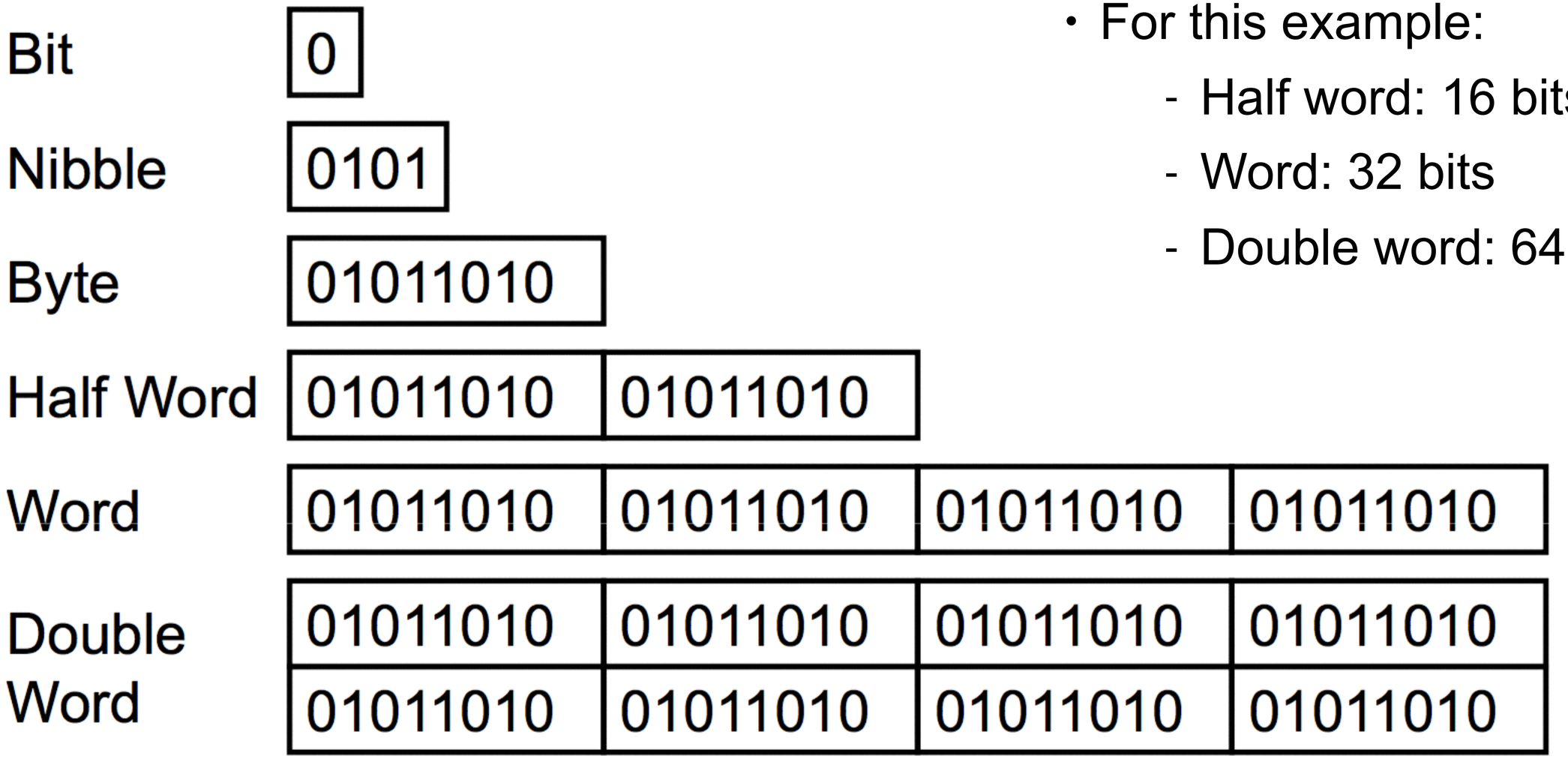
Memory

- Memory (and registers within the CPU) store data
- Support two basic operations
  - Read: access the stored data
  - Write (or load): store data
- A processor normally operates on one “word” of data
  - A word is some number of bits stored together
  - The word length depends on the processor
  - The word length is often used to categorize the processor, i.e., a processor may be said to be 64-bit processor if its word length is 64 bits
- Different data lengths may be used and some common terms are defined

Memory Block Diagram



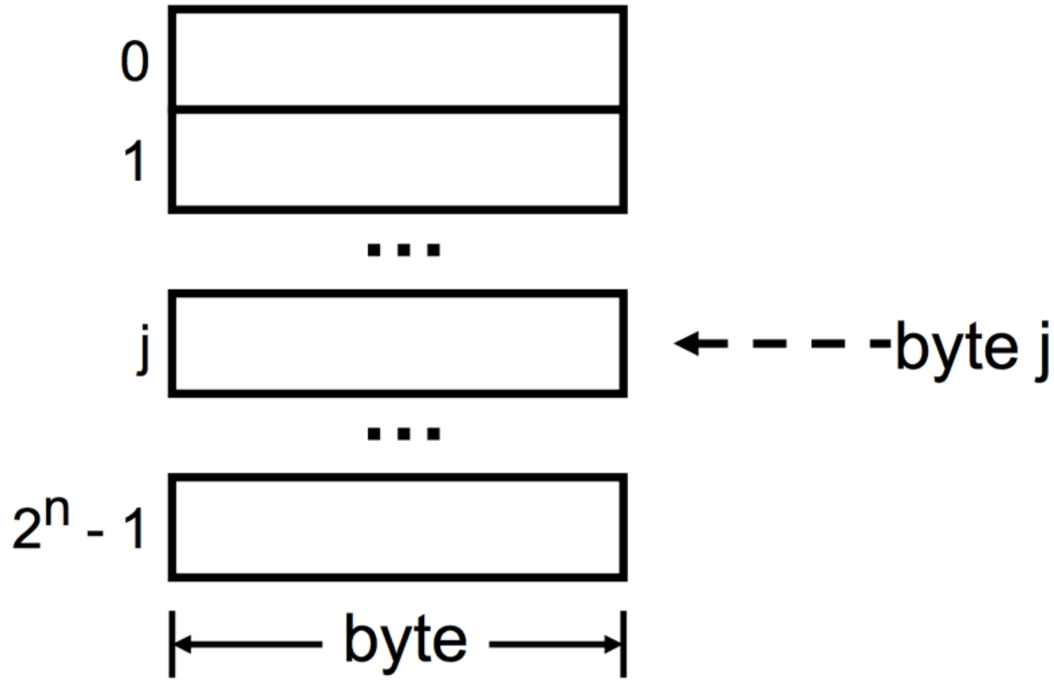
Data Lengths



- For this example:
  - Half word: 16 bits
  - Word: 32 bits
  - Double word: 64 bits

Memory Addresses

- Most machines use byte addressable memory
  - A unique address is associated with each byte of storage
  - n-bit address allows access to 2^n bytes of memory



Interrupts

- A software procedure that is automatically invoked by the processor hardware due to some hardware exception
  - Caused by hardware, perhaps external, hence it is asynchronous with the processor's operation
  - Example is an external hardware interrupt from an input/output device, like a keyboard or disk controller, that is requesting service
- Interrupts allow the processor to respond quickly to exceptional events without requiring software to constantly check for the events
  - Often a more efficient means of input/output control than polling

CHECK POINT

As a checkpoint of your understanding, please pause the video and make sure you can do the following:

- Describe the operation of a computer's memory
- Explain the purpose of computer interrupts

If you have any difficulties, please review the lecture video before continuing.

Summary

- The CPU executes instructions stored in memory, by following a fetch-execute cycle
  - The CPU is composed of the register file, the ALU, and the control unit
  - The system clock controls how quickly instructions are executed
- The system bus interconnects the CPU, the memory unit and the I/O subsystems
- Interrupts allow the processor to respond quickly to exceptional events

MODULE 4: Computer Organization and MARIE

Lecture 4.1
Computer Organization Fundamentals

Prepared By:
- Scott F. Midkiff, PhD
- Luiz A. DaSilva, PhD
- Kendall E. Giles, PhD

Electrical and Computer Engineering
Virginia Tech