Computer Organization and Architecture

Memory Unit

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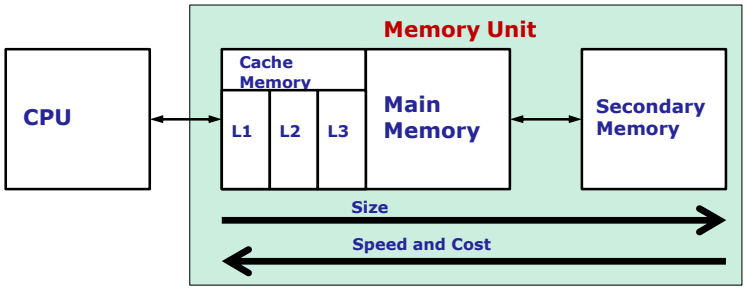
Memory Hierarchy



- Processor processes instructions and data faster than it can be fetched from memory unit
- Memory access time is the bottleneck
- One way to reduce memory access time is to use faster memory
  - A small and faster memory bridge the gap between processor and main memory
- **Virtual memory**

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Read-Only Memories

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Read-Only Memories (ROMs)

- **SRAM and DRAM are volatile** i.e. they loose the stored information if power is turned off
  - Some applications need memory devices that retain the content when the power supply is turned off too
- Disk stores OS—when computer switched on, OS must be loaded onto memory from disk
  - Requires execution of a program that "boots" the operating system
  - Boot program is also very large– stored in disk
- Processor must execute some instructions that load the boot program into memory
- **Memory is volatile**– the processor would have no means of accessing these instructions
- **Provide a small amount of non-volatile memory**
  - **To hold instructions that loads the boot program from the disk**

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Read-Only Memories (ROMs)

- Read-only memories are semiconductor, non-volatile memories
- Their normal operation involve only reading the stored data
- They are extensively used in embedded systems
- Different types of ROMs
  - Read Only Memory (ROM)
  - Programmable ROM (PROM)
    - Allows for loading data by the user, less expensive
  - Erasable, reprogrammable ROM (EPROM)
    - UV light is used for erasing the existing content
  - Electrically erasable reprogrammable ROM (EEPROM)

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Flash Memory

- Approach similar to EEPROM
  - Small difference in how writing to be done on the memory
- Have greater density
  - Higher capacity, lower cost per bit
- Consumes less power
  - Suitable for portable devises
    - Hand-held computers, cell phones, digital cameras, and MP3 music players
- Flash cards
  - flash chips mounted on a small card to have a larger module
- Flash drives
  - Replace hard disk drives
  - Replaced floppy disks, CD ROMs etc

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Virtual Memory

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Virtual Memory

- Ideally, entire memory hierarchy would appear to the processor as a single memory unit
- In modern computer system, the physical main memory is not as large as the address space spanned by the address issued by the processor
- When a program (or process) does not completely fits into the main memory, parts of it will be there in secondary memory
- In modern computers, operating system moves the data automatically between main memory and secondary storage
- Programmer does not need to aware of the limitations imposed by the main memory

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Virtual Memory Technique

- Technique that automatically move program and data blocks into the physical main memory when they are required for execution
- Using virtual program concept, each program may use entire CPU local address space, at least up to secondary storage
- The address issued by the processor either for instruction or data are called virtual address or logical address
- These addresses are translated into physical memory addresses by a combination of hardware and software

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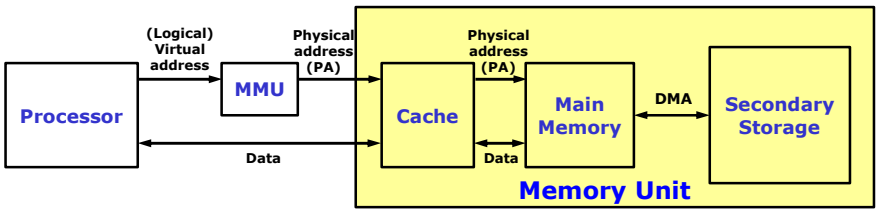
Memory Management Unit (MMU)

- MMU translate the logical address into physical main memory address
- It is a part of the processor



- If the data is not in main memory, MMU causes the operating system to bring data into memory from the disk
- Transfer of data between disk and main memory is performed using direct memory access (DMA) scheme

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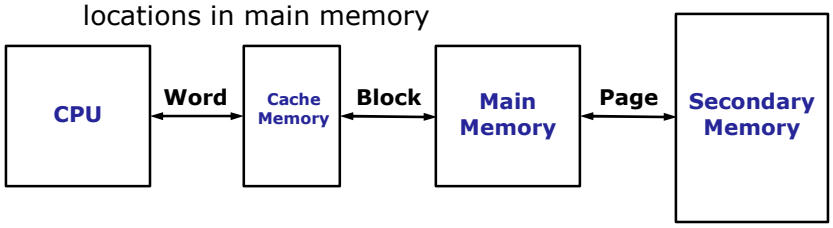
Address Translation

- The virtual memory address translation method is based on the concept of fixed length pages
- The address translations assumes that programs and data are composed of fixed size units called pages
- Unit of transfer between secondary memory and main memory is page
  - A page is a block of words that occupy contiguous locations in main memory



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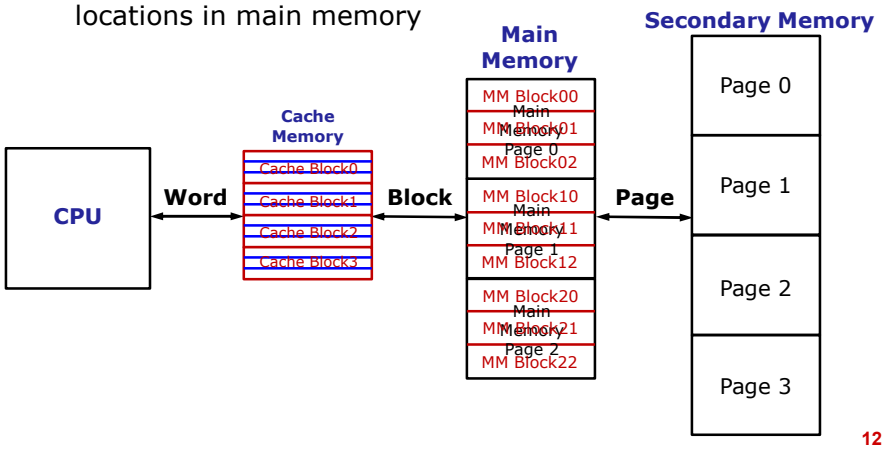

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Page

- The programs or data in the disk are seen by the virtual memory as a collection of pages
- This page is the basic unit of information that is moved between the main memory and the secondary memory
- Each page is of the size 2 KB to 16 KB
- Page should not be too small
  - Disk access time is much longer
  - It take considerable time to locate data in the disk
- Page should not be too large
  - Substantial portion of a page may not be used
- Demand paging: Pages are copied to main memory when requested

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Parallels Between the Concepts of Cache and Virtual Memory

- Cache:
  - Bridges the speed gap between the processor and the main memory
  - It is implemented in hardware
- Virtual memory mechanism:
  - Bridges the size and speed gap between the main memory and secondary storage
  - It is usually implemented in part by software techniques
- Conceptually, cache techniques and main memory techniques are very similar
- They differ mainly in the details of their implementation

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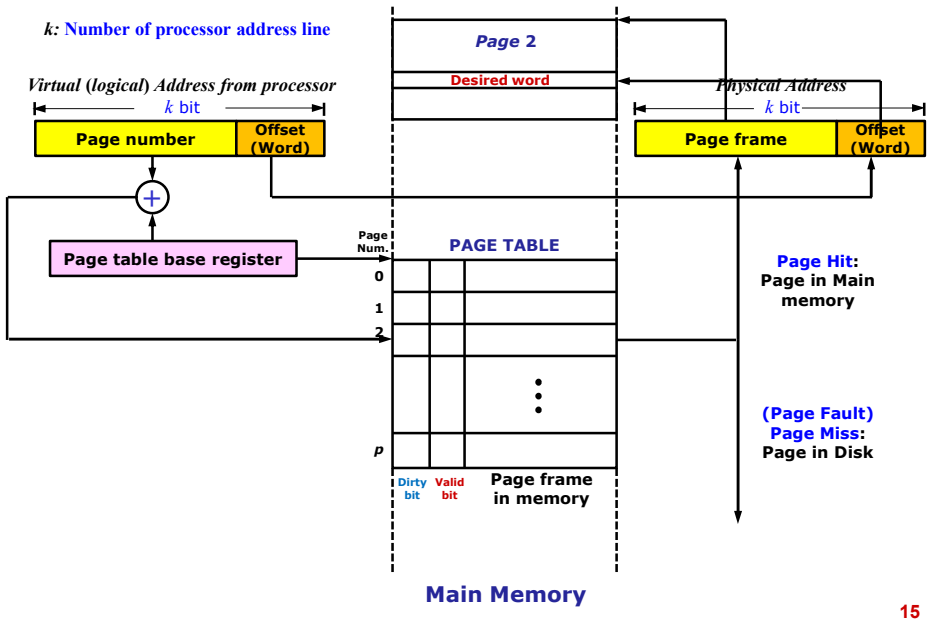
Virtual Memory Address Translation



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Virtual Memory Address Translation

- The virtual address generated by the processor contain page number and offset (word) in the page
- To make sure that required page is in main memory, operating system create **page table for each process**
- This page table is kept in main memory
- Page table base register: Operating system keep the starting address of page table in it
- Page table hold the main memory location for each page
  - The area in main memory that can hold one page is called page frame
- Every entry in page table also include valid bit and dirty bit to describe the status of the page while it is in main memory

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Virtual Memory Address Translation using Translation Lookaside Buffer

- Page table information is used by the MMU for every read and write access
- In order to speed up the address translation procedure, a small cache called Translation Lookaside Buffer (TLB) is incorporated in MMU
- It uses associative/set-associative mapping technique
- It hold a portion of page table corresponding to most recently accessed pages
- TLB holds only the page number and page frame number

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Virtual Memory Address Translation

- Page table information is used by the MMU for every read and write access
- Page fault: Whenever a requested page is not present in the main memory, page fault is said to have occurred
- When a page fault occurs, MMU asks operating system to intervene and raise an exception (interrupt)
  - Process in active get interrupted and control goes to operating system
  - Operating system then copies the requested page from disk to main memory
  - Then returns the control to the interrupted task
- During write operation pages get modified are indicated by dirty bit
- Modified page has to be written back to disk before removed from main memory
- Uses write back policy only

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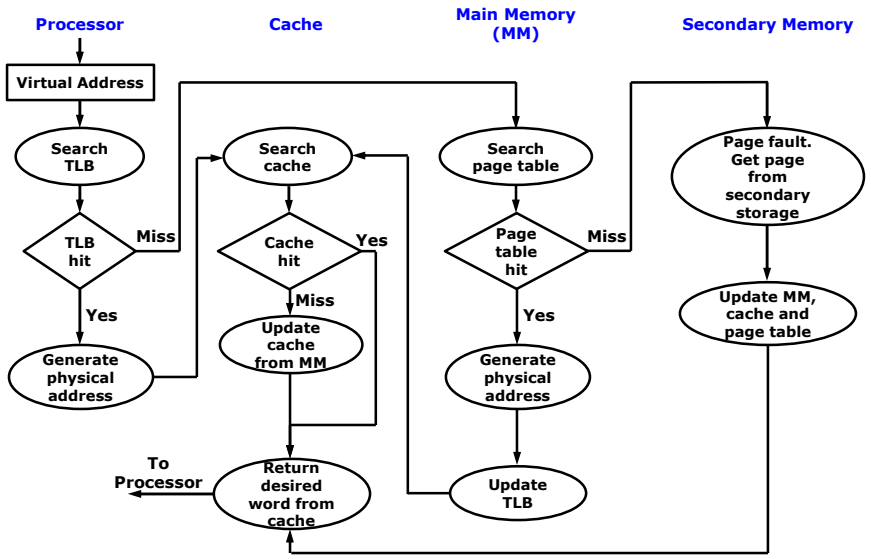
Operation of Memory Hierarchy and Virtual Memory Technique



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