

Computer Organization and Architecture

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Lecture 09



Revision

Digital Circuits Cont.

- **Multiplexer**
- **Demultiplexer**

Multiplexer / Demultiplexer

- The basic function of the Multiplexer (MUX).
- The typical application of a MUX.
- A 4-to-1 MUX designed with Small Scale Integration (SSI).
- A 4-to-1, 8-to-1, & 16-to-1 Medium Scale Integration (MSI) MUX.
- The basic function of the Demultiplexer (DEMUX).
- The typical application of a DEMUX.
- A 1-to-4 DEMUX design with Small Scale Integration (SSI).

Multiplexer (MUX)

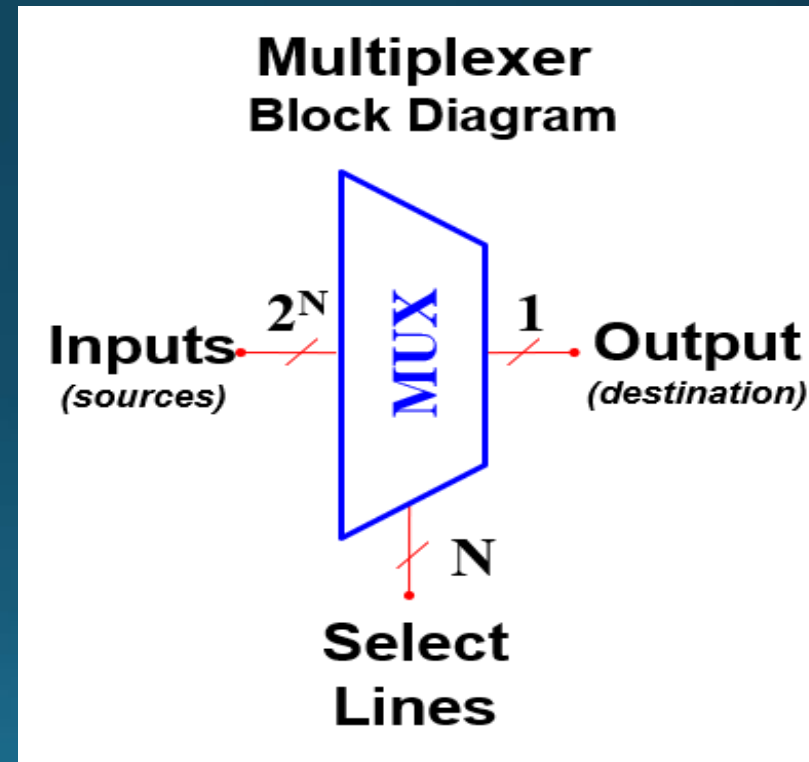
What is a Multiplexer (MUX)?

A MUX is a digital switch that has multiple inputs (sources) and a single output (destination).

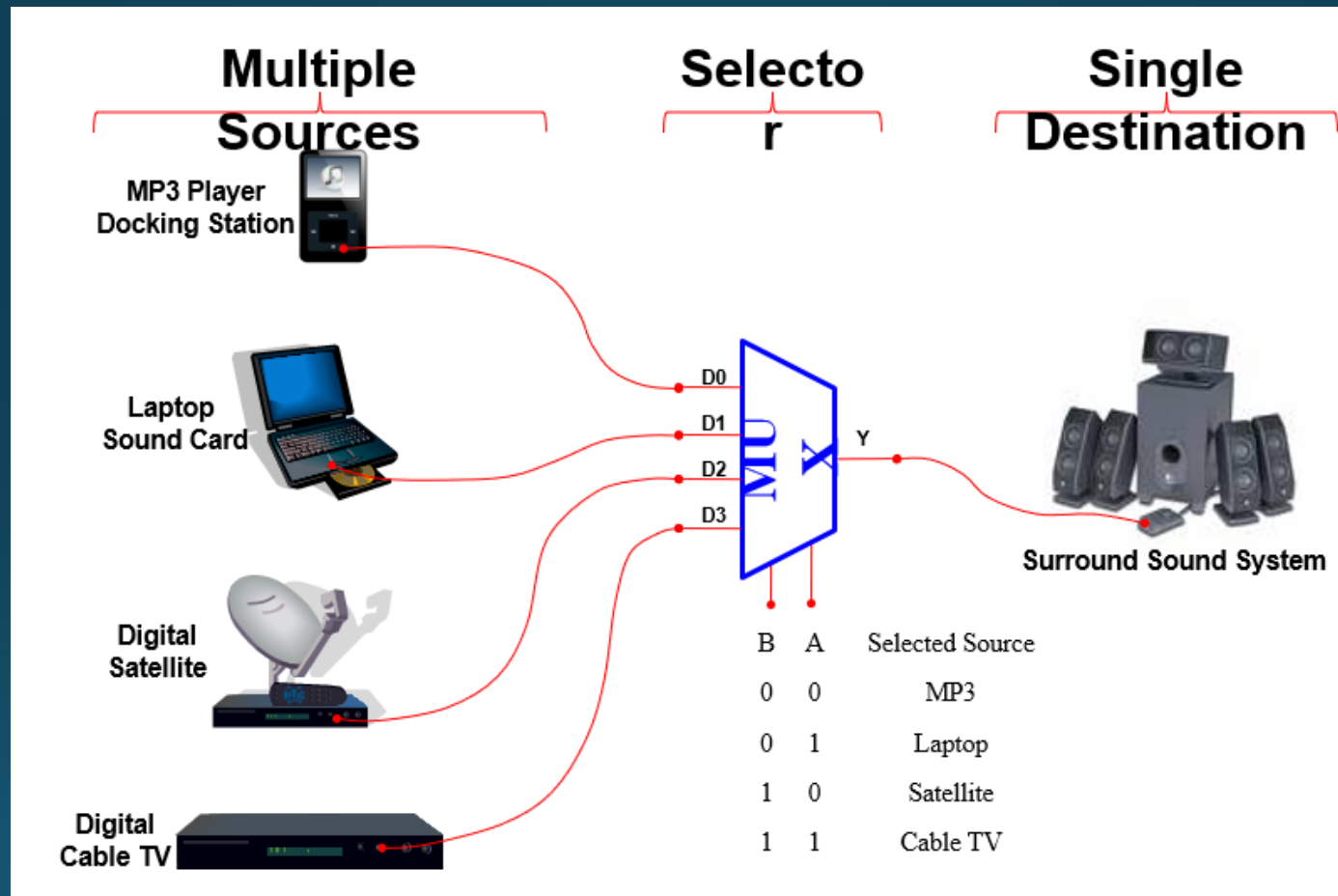
The select lines determine which input is connected to the output.

MUX Types

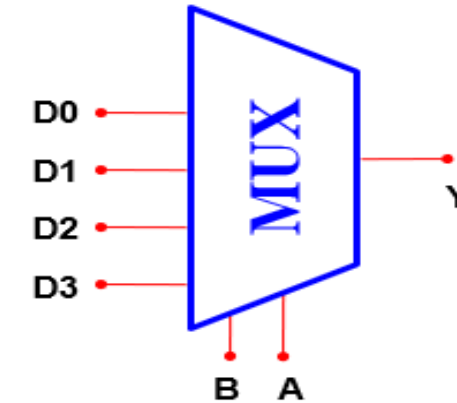
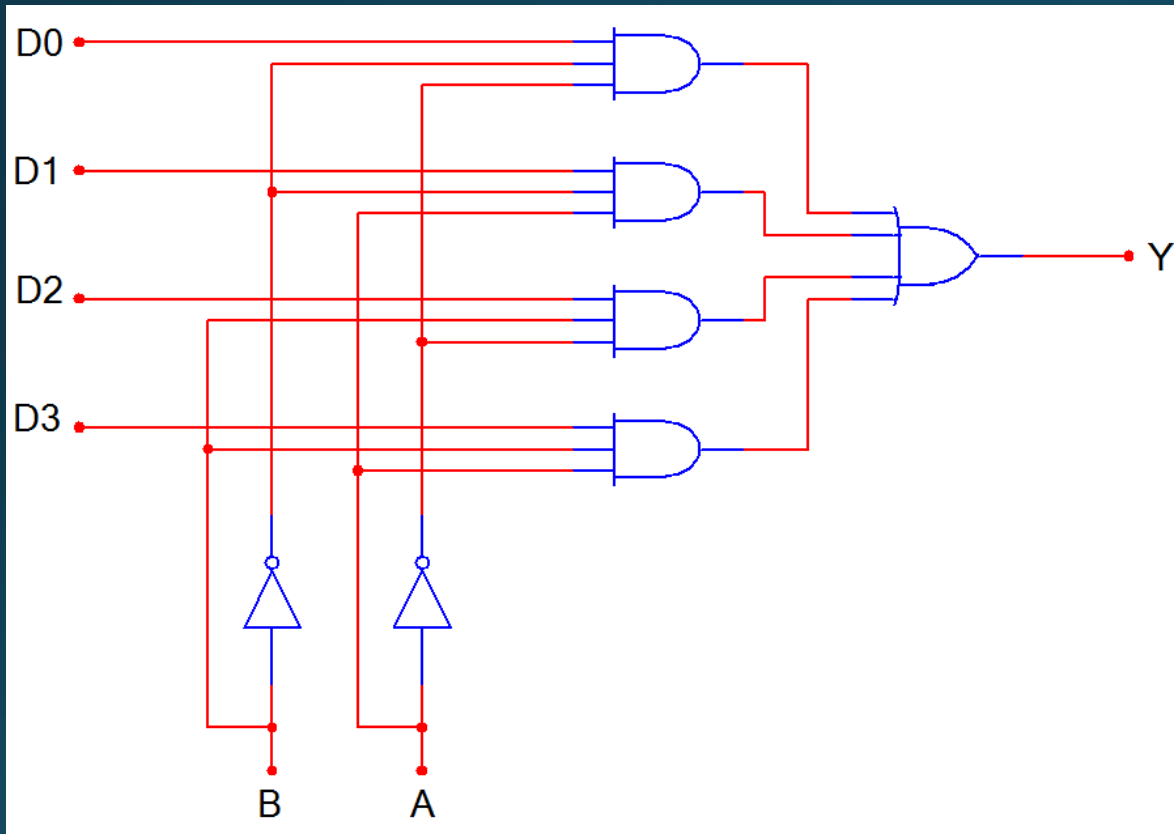
- 2-to-1 (1 select line)
- 4-to-1 (2 select lines)
- 8-to-1 (3 select lines)
- 16-to-1 (4 select lines)



Typical Application of a MUX



4-to-1 Multiplexer (MUX)



B	A	Y
0	0	D0
0	1	D1
1	0	D2
1	1	D3

DeMultiplexer (DEMUX)

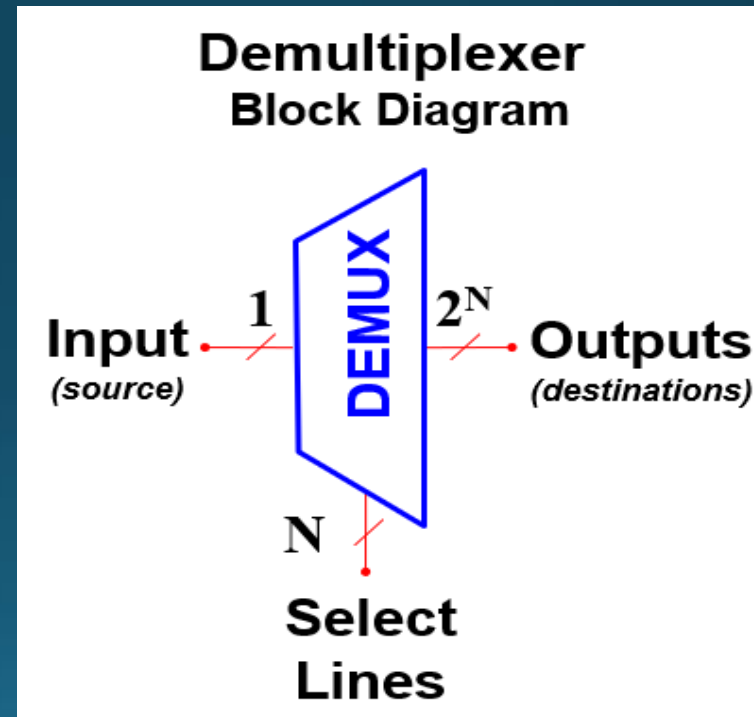
What is a Demultiplexer (DEMUX)?

A DEMUX is a digital switch with a single input (source) and a multiple outputs (destinations).

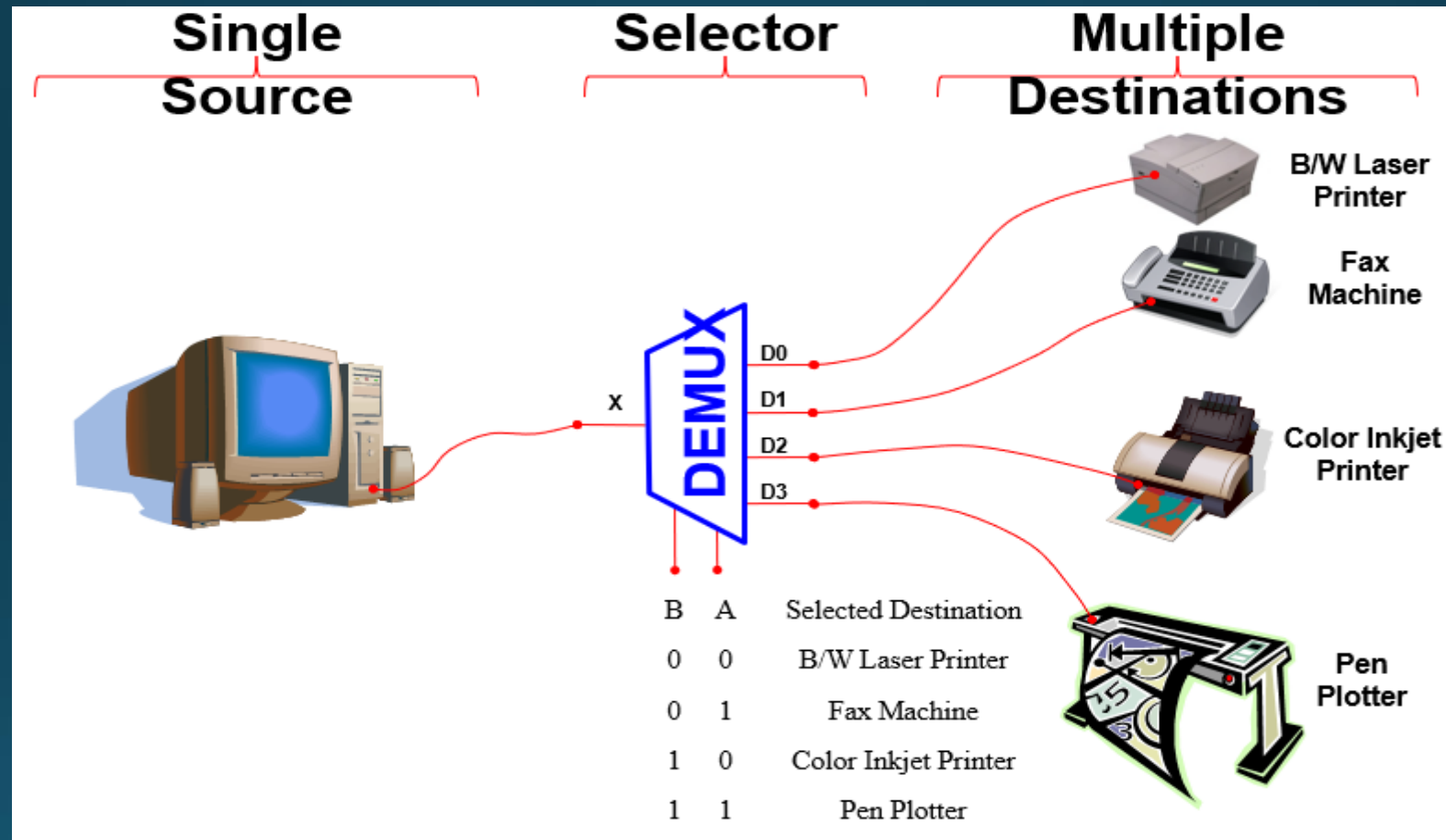
The select lines determine which output the input is connected to.

DEMUX Types

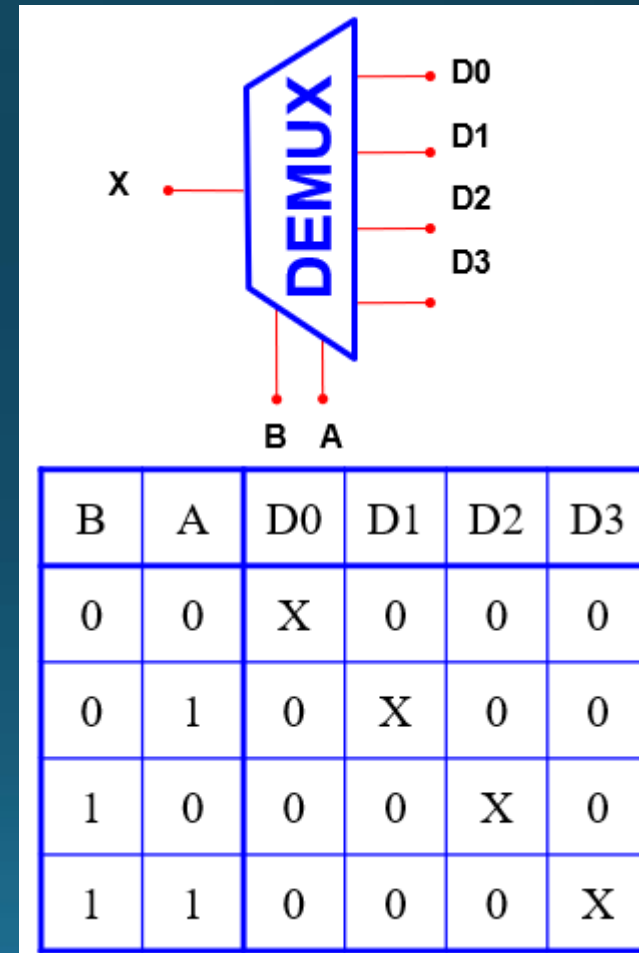
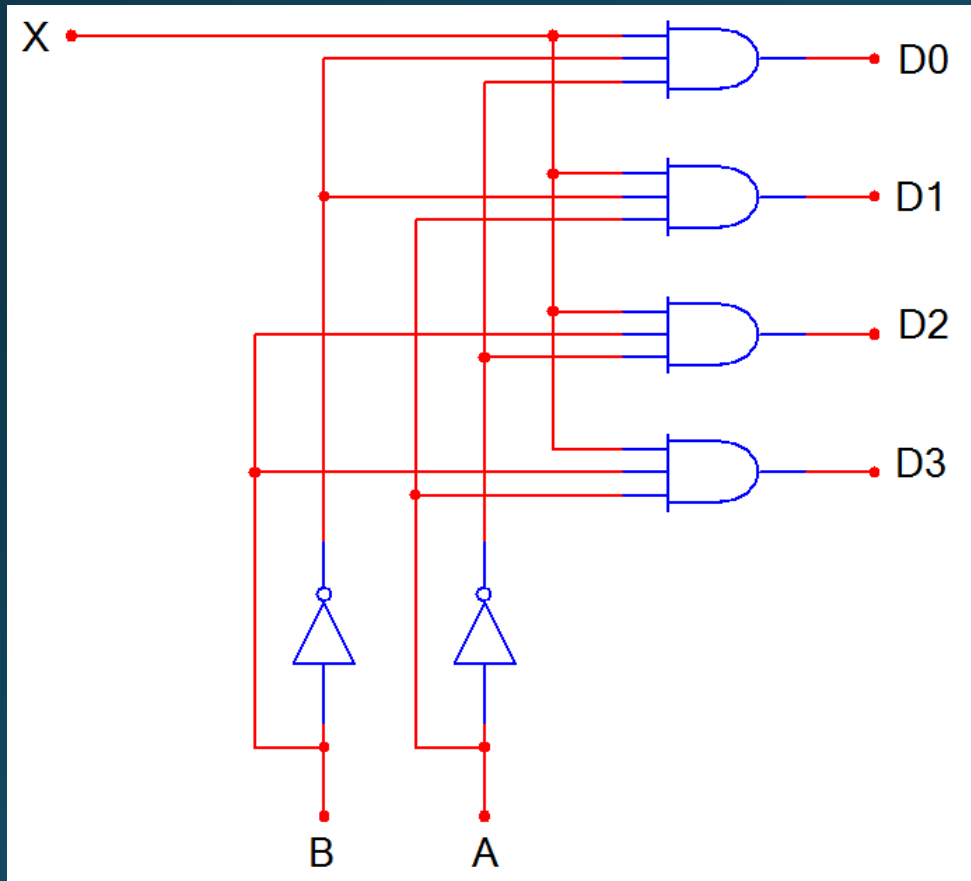
- 1-to-2 (1 select line)
- 1-to-4 (2 select lines)
- 1-to-8 (3 select lines)
- 1-to-16 (4 select lines)



Typical Application of a DEMUX



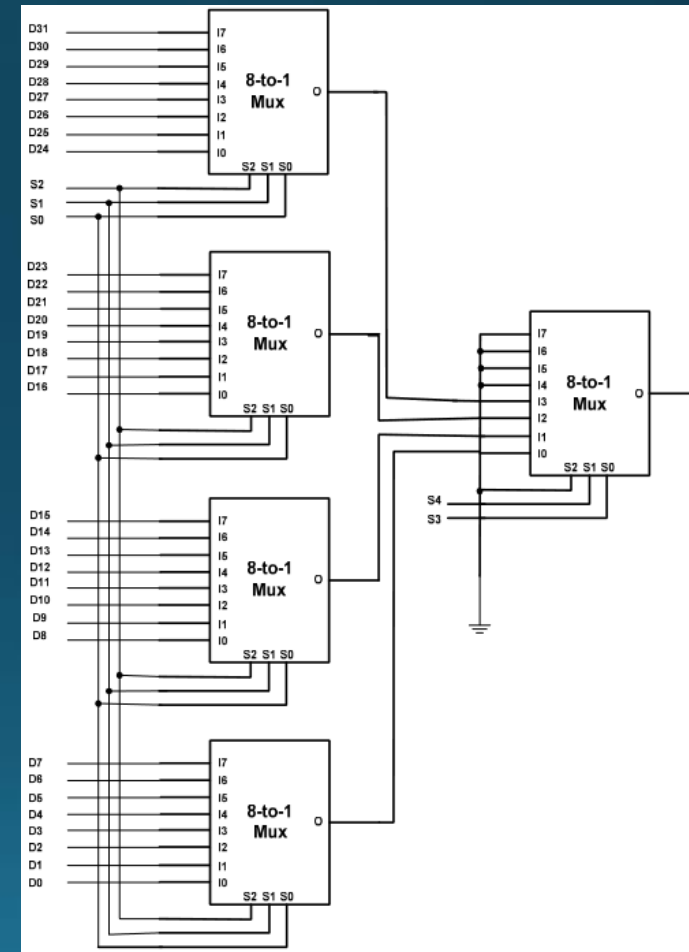
1-to-4 De-Multiplexer (DEMUX)



Example of expansion Multiplexer

Design a 32-to-1 multiplexer using only 8-to-1 multiplexer

We use four 8-to-1 in the first stage and another one to select between the output of the others:



MUX vs DeMUX

Difference between Multiplexer and Demultiplexer

Both multiplexer and demultiplexer are types of combinational digital circuit that are used in several large-scale digital systems. However, there are many differences between a multiplexer and a demultiplexer, which are highlighted in the following table

Difference between Multiplexer and Demultiplexer

Basis of Difference	Multiplexer	Demultiplexer
Definition	A multiplexer is a combinational digital circuit that takes multiple data inputs and provides only single output.	A demultiplexer is a combinational digital circuit that takes single input and provides multiple outputs.
Abbreviated name	The abbreviation used to represent the multiplexer is MUX.	The abbreviation used to represent the demultiplexer is DEMUX.
Input and output lines	Multiplexer has 2^n input lines and 1 output line. Where, n is the number of select lines.	Demultiplexer has 1 input line and 2^n output lines. Where, n is the number of select lines.
Also known as	Multiplexer is also known as a "data selector".	Demultiplexer is also known as "data distributor".

Difference between Multiplexer and Demultiplexer

Basis of Difference	Multiplexer	Demultiplexer
Operating principle	The operating principle of the multiplexer is "many to one".	The operating principle of a demultiplexer is "one to many".
Acts as	Multiplexer acts as a digital multi-position switch.	Demultiplexer acts as a digital circuit.
Conversion technique	A multiplexer performs parallel to serial conversion.	A demultiplexer performs serial to parallel conversion.
Function of control signal	In case of multiplexer, the function of control signal is to select a specific input that has to be transmitted at the output.	In demultiplexer, the function of control signal is to deliver the single input signal over the multiple output lines.

Difference between Multiplexer and Demultiplexer

Basis of Difference	Multiplexer	Demultiplexer
Examples	• Examples of some common multiplexers are – • 8:1 Multiplexer • 16:1 Multiplexer • 32:1 Multiplexer	• Some common demultiplexers are – • 1:2 Demultiplexer • 1:4 Demultiplexer • 1:8 Demultiplexer • 1:16 Demultiplexer
Practical importance	In practice, the multiplexer increases the efficiency of the communication system by enabling the data transmission using a single line.	In practice, the demultiplexer takes the output of a multiplexer and convert in its original form at the receiver end.

Difference between Multiplexer and Demultiplexer

Basis of Difference	Multiplexer	Demultiplexer
Usage in time-division multiplexing	A multiplexer is used at the transmitter end in the time-division multiplexing (TDM).	The demultiplexer is used at the receiver end in the time-division multiplexing.
Applications	The multiplexers are commonly used in communication systems, telephone networks, computer memories, etc.	The demultiplexers are used in communication systems, reconstruction of parallel data, ALU, etc.

Internal Memory

Computer memories

Computer memories are categorized into:

1. Internal memories
 2. External Memories
- **Internal memories:** directly attached to main board and directly accessible by the processor.
 - Main memories (RAM and ROM)
 - Cache Memory
 - Registers
 - **External memories:** secondary storage devices that are accessible by the processor via an I/O module.
 - Disks (Hard Disk or Floppy Disk or optical Disks)
 - Tape

Characteristics of memory systems

The most important characteristics of computer memories are:

- Location
- Capacity
- Unit of transfer
- Access method
- Performance
- Physical type
- Physical characteristics
- Organization

Location

The term *location* refers to whether the memory is internal or external to the computer.

- CPU (registers)
- Internal (main memory and caches)
- External (secondary storages)

Capacity

- Capacity is the size of memory.
- For internal memory, capacity is expressed in terms of **bytes or words** with:
 - **Word size:** Common word lengths are 8, 16, and 32 bits
 - Number of words
- For external memory, capacity is expressed in terms of bytes.

Unit of Transfer

- **For internal memory**, unit of data transfer is the number of bits read out of or written into memory at a time.
 - The unit of transfer need not equal a word or an *addressable unit*. It is Usually governed by data bus width.
- **For External memory**, unit of data transfer is the blocks.
 - a block is Usually much larger than a word.
- **Addressable unit:**
Smallest location which can be uniquely addressed
 - Word level or byte level in internal memory
 - Cluster on M\$ disks

Access Methods (1)

Access Method is the way the processor can write or retrieve data to or from a memory.

- **Sequential Access:** Access is made in a linear sequence.
 - Start at the beginning and read through locations in order
 - Access time depends on the location of data and previous location
 - e.g. tape
- **Direct Access:**
 - Individual blocks have unique address based on its location
 - Access is done by jumping (direct access) to a general part, then additional sequential search in this part to reach the final location.
 - Access time depends on location and previous location
 - e.g. disk

Access Methods (2)

- **Random Access:**

- Each location in memory has individual/unique address.
- **Access time** is independent on the location or the previous access and **is then constant**
- e.g. RAM

- **Associative Access:**

- Data is located by a comparison with contents of a portion of the store
- Access time is independent of location or previous access
- e.g. cache

Performance

Three *performance* parameters are used:

- **Access time (Latency)**
 - the time required to perform a read or write operation, that is, the time between presenting the address and getting the valid data.
- **Memory Cycle time**
 - Cycle time is the *access time* + *recovery time*
 - The *recovery time* is the additional time required before a next access can commence. (required time for transients of signals on system bus)
- **Transfer Rate**
 - Rate at which data can be moved or transferred into or out of memory unit.

Physical Types

The most common physical types are:

- **Semiconductor memory**
 - RAM
 - ROM
- **Magnetic surface memory**
 - used for Disks & Tape
- **Optical**
 - used for CD & DVD
- **magneto-optical**

Physical Characteristics

The physical characteristics of data storage are: **volatile** and **nonvolatile** memory .

- **volatile memory:** information decays naturally or is lost when electrical power is switched off.
- **nonvolatile memory:** information once recorded remains without change until deliberately changed.
- **Examples:**
 - Magnetic-surface memories are **nonvolatile**.
 - Semiconductor memory may be either **volatile** or **nonvolatile**.
 - *Nonerasable* memory cannot be altered, except by destroying the storage unit, hence, a nonerasable memory must also be nonvolatile. Semiconductor memory of this type is known as read-only memory (ROM).

Organization

The *organization* is meant the following:

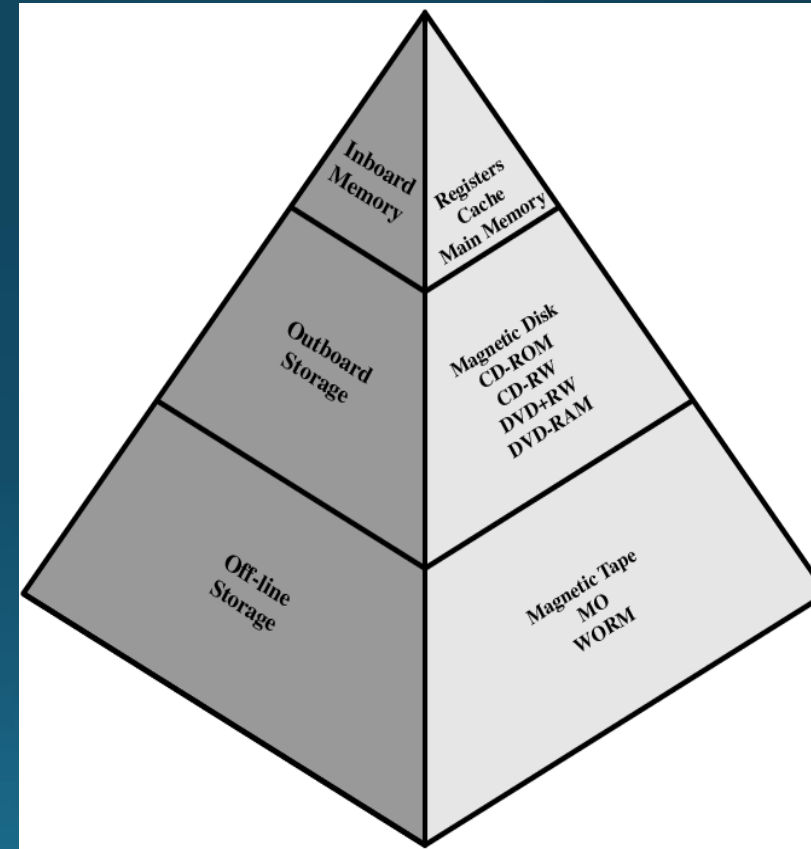
- The Physical arrangement of bits to form words. The obvious arrangement is not always used, as will be explained presently.
- The Physical arrangement of words to form a memory device.

Memory Hierarchy

- **Computer memory is organized into a hierarchy:**
 - **Registers**
 - In CPU
 - **Cache memory**
 - May include one or more levels of cache
 - **Main memory**
 - “RAM” and ROM
 - **External memory**
 - secondary storage

Memory Hierarchy Diagram and List

- Registers
- L1 Cache
- L2 Cache
- Main memory
- Disk cache
- Disk
- Optical
- Tape



Three key Questions

- How much?
 - Capacity
- How fast?
 - Access Time
- How expensive?
 - Cost or money
- **There is a trade-off among the three key characteristics of memory: cost, capacity, and access time:**
 - Faster access time, greater cost per bit
 - Greater capacity, smaller cost per bit
 - Greater capacity, slower access time

So you want fast?

- It is possible to build a computer which uses only static RAM (see later)
- This would be very fast
- This would need no cache
 - How can you cache cache?
- This would cost a very large amount

The Bottom Line

As one goes down the hierarchy, the following occur:

- Decreasing cost per bit
- Increasing capacity
- Increasing access time
- Decreasing frequency of access of the memory by the processor

Semiconductor Memory

- Today, the main memories chips are constructed from semiconductor.
- Types of semiconductor memories:
 - RAM
 - SRAM
 - DRAM
 - ROM
 - Mask ROM,
 - PROM,
 - EPROM,
 - EEPROM,
 - flash Memory
- The main difference between a RAM and a ROM is that a RAM is written under normal operation, while a ROM is programmed outside the computer and is only normally read.

Semiconductor Memory Types

- Types of semiconductor memories and properties:

Memory Type	Category	Erasure	Write Mechanism	Volatility
Random-access memory (RAM)	Read-write memory	Electrically, byte-level	Electrically	Volatile
Read-only memory (ROM)	Read-only memory	Not possible	Masks	Nonvolatile
Programmable ROM (PROM)				
Erasable PROM (EPROM)	Read-mostly memory	UV light, chip-level	Electrically	
Electrically Erasable PROM (EEPROM)		Electrically, byte-level		
Flash memory		Electrically, block-level		

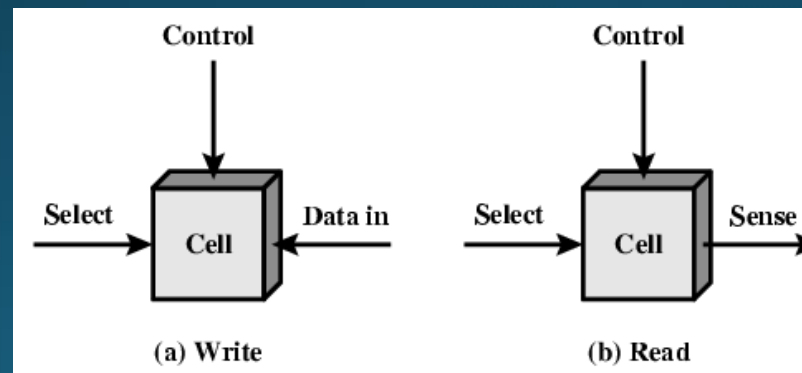
Semiconductor Memory cell

- The basic element of a semiconductor memory is the memory cell.
- All semiconductor memory cells share certain **properties**:
 - They **exhibit two stable states**, which can be used to represent binary 1 and 0.
 - They are **capable of being written into** (at least once), to set the state.
 - They are **capable of being read** to sense the state.

Memory Cell Operation

The memory cell has three terminals capable of carrying an electrical signal.

- **Select terminal**, selects a memory cell for a read or write operation (through address Bus).
- **Control terminal** indicates read or write (control Bus).
- **Data in, for writing**, provides an electrical signal that sets the state of the cell to 1 or 0 (Data Bus).
- **Sense, for reading**, that terminal is used for output of the cell's state (Data Bus).



Random Access Memory (RAM)

- **Characteristics of RAM:**

- Random Access: individual words of memory are directly accessed through wired-in addressing logic.
- Read/Write data from/to memory.
- Volatile: data are lost when the power turned OFF
- RAM is used only as Temporary data storage
- Access time is constant for any location.

- **Types of RAM:**

- SRAM (Static RAM)
- DRAM (Dynamic RAM)

Static RAM

- A static RAM (SRAM) is a digital device, using the same logic elements used in the processor.
- Binary values are stored using traditional flip-flop logic-gate configurations.
- Reading or Writing binary bits are based on two on/off switches.
- A static RAM will hold its data as long as the power is supplied to it.
- Because no special action (except power) is required to retain stored data, these devices are called **static** memory. In other words, a binary bit is temporary stored as a result of the operation of two inverters connected back to back.

Dynamic RAM

- A dynamic RAM (DRAM) is an analog device that made with cells store data as charge on capacitors.
- The presence or absence of charge on a capacitor is interpreted as a binary 1 or 0.
- Because capacitors have a natural tendency to discharge, a DRAM requires periodic charge refreshing to maintain data storage, even when powered.
- Because refresh circuit is required to retain stored data, these devices are called **dynamic** memory.

SRAM versus DRAM

- **Both SRAM and DRAM are Volatile**
 - Power is needed to preserve data

DRAM

- Essentially analogue
 - Level of charge determines the binary value
- DRAM more dense
- Less expensive
- Dynamic cell
 - Simpler to build
 - smaller per bit
 - Bits are stored as charge
 - Need refresh circuit
- Less expensive
- Slower
- Used in Main memory

SRAM

- Essentially Digital
 - the bin values are stored as a static volt level high or low.
- SRAM less dense
- More expensive
- SRAM Cell
 - More complex construction
 - Larger per bit
 - Bits are stored in flip-flop.
 - No refreshing needed when powered
- more expensive
- Faster
- Used in Cache



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