**Computer Organization and Architecture CE-207T**

**Section D**

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**Universal Serial Bus**

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**Universal Serial Bus**

USB, or universal serial bus, is a mechanism used to connect peripheral devices to computers. It allows easy, high-speed connections of peripherals to PCs that, once plugged in, configure automatically.

* **Why a serial bus in a parallel computer!**

When it comes to computers, using serial buses like USB alongside parallel systems is a big deal. It helps make things connect better and work more efficiently.

1. **Simplicity and Cost**:
   * Fewer wires reduce complexity and manufacturing costs.
   * Easier maintenance and troubleshooting due to fewer points of failure.
2. **Scalability**:
   * Supports longer distances between host and device without significant signal degradation.
   * Differential signaling allows for longer cable lengths.
3. **Bandwidth Efficiency**:
   * Offers higher bandwidth efficiency compared to parallel buses.
   * Modern USB versions provide high data transfer rates (up to 40 Gbps with USB4).
4. **Power Delivery**:
   * Supplies power to connected devices, eliminating the need for separate power cables.
   * Beneficial for mobile devices and peripherals.

* **Historical background**

The evolution of USB technology has been a journey of continuous improvement and innovation, starting from its inception in the mid-1990s to the latest advancements in USB4.

* **1995:** Seven companies, including Intel, Microsoft, and IBM, started developing USB technology.
* **1996:** USB 1.0 launched, offering data rates of 1.5 Mbps or 12 Mbps, but not widely adopted commercially.
* **1998:** USB 1.1 introduced, widely adopted, improving compatibility and performance.
* **2000:** USB 2.0 launched with faster data transfer rates of 480 Mbps, introduced Mini-A and Mini-B connectors, and support for battery charging.
* **2007:** Micro-A, Micro-AB, and Micro-B connectors replaced Mini connectors. USB On-The-Go technology enabled direct device-to-device communication.
* **2008:** USB 3.0 introduced SuperSpeed mode with 5 Gbps data transfer rate, managed by USB Implementers Forum (USB-IF).
* **2013:** USB 3.1 launched with Gen 1 supporting SuperSpeed and Gen 2 supporting SuperSpeed+ mode of 10 Gbps.
* **2014:** Introduction of USB-C connector with higher data and power transfer rates.
* **2017:** USB 3.2 launched with 10 Gbps and 20 Gbps modes via USB-C connector.
* **2019:** USB4 released, based on Thunderbolt 3, offering compatibility with Thunderbolt 3 and data transfer speeds up to 40 Gbps.
* **2022:** USB4 2.0 introduced with speeds up to 80 Gbps over USB-C.
* **USB mechanism (working)**

A USB works like a manager (host) directing a meeting (data transfer) between different devices (like a computer and a printer). The manager sets the pace by signaling the start of each round (frame), ensuring everyone knows when to start and stop. During each round, the manager talks to each device, asking for or giving information. This happens through special spots (endpoints) on each device where data can be stored temporarily. These spots come in pairs, with one for sending data out (like a message going from the computer to the printer) and one for receiving data in (like a response from the printer back to the computer). For example, a spot called "Endpoint 1" has two parts: "EP1IN" for receiving data and "EP1OUT" for sending data. The size of these spots can be different for different devices, depending on how much data they can handle at once. Overall, USB makes sure devices can talk to each other smoothly, making it easy for them to share information and work together.

* **Comparison between different specifications / versions (1.0 till now)**

Below is a concise comparison of various USB specifications/versions, detailing their release year, data transfer speed, and key features.

| **USB Version** | **Release Year** | **Data Transfer Speed** | **Features** |
| --- | --- | --- | --- |
| USB 1.0 | 1996 | Low-speed (1.5 Mbps) and Full-speed (12 Mbps) | Basic data transfer, limited power delivery |
| USB 2.0 | 2000 | High-speed (480 Mbps) | Faster data transfer, support for battery charging |
| USB 3.0 | 2008 | SuperSpeed (5 Gbps) | Significant speed improvement, backward compatibility with USB 2.0 |
| USB 3.1 | 2013 | Gen 1 (SuperSpeed, 5 Gbps) and Gen 2 (SuperSpeed+, 10 Gbps) | Introduction of Gen 2 with faster data transfer rates |
| USB 3.2 | 2017 | Various modes including 10 Gbps and 20 Gbps | Enhanced speed and efficiency with USB-C connector |
| USB4 | 2019 | Up to 40 Gbps | Integration of Thunderbolt 3 technology, increased data transfer speeds, backward compatibility with Thunderbolt 3, USB 3.2, and USB 2.0 |

* **Predicting data transfer rate in different versions**

Below are the key data transfer rates for various USB specifications/versions, showcasing the evolution of USB technology from its inception to the latest advancements in USB4.

1. **USB 1.0:**

Data transfer rates: Low-speed (1.5 Mbps) and Full-speed (12 Mbps).

1. **USB 2.0:**

Data transfer rate: High-speed (480 Mbps).

1. **USB 3.0:**

Data transfer rate: SuperSpeed (5 Gbps).

1. **USB 3.1:**

Data transfer rates: Gen 1 (SuperSpeed, 5 Gbps) and Gen 2 (SuperSpeed+, 10 Gbps).

1. **USB 3.2:**

Data transfer rates: Various modes including 10 Gbps and 20 Gbps.

1. **USB4:**

Data transfer rate: Up to 40 Gbps.

* **Comparison of serial and parallel bus protocols (in terms of hardware, software, responsiveness etc.)**

Here is a comparative analysis of serial and parallel bus protocols, outlining their differences in hardware, software, responsiveness, and other key aspects.

| **Aspect** | **Serial Bus** | **Parallel Bus** |
| --- | --- | --- |
| Hardware Complexity | - Fewer wires, simpler hardware design. | - More wires, complex hardware configurations. |
| Software Complexity | - Generally simpler software protocols. | - More intricate software protocols. |
| Responsiveness | - Lower responsiveness due to sequential data transmission. | - Higher responsiveness with simultaneous data transmission. |
| Data Transfer Speed | - Initially lower speeds but increased with advancements. | - Historically higher speeds, but limited scalability. |
| Signal Integrity | - Better signal integrity due to reduced crosstalk. | - More susceptible to signal degradation. |
| Scalability | - Greater scalability for long-distance communication. | - Limited scalability due to signal integrity challenges. |

* **At least three unique applications of USB (not found in parallel buses)**

USB has revolutionized the way we connect devices to computers and other systems. Unlike traditional parallel buses, USB offers a range of versatile functionalities.

1. **Universal Connectivity Hub:** USB acts as a versatile link, connecting many devices to computers. It links keyboards, mice, printers, and more, making it easy to use different devices together. Unlike parallel buses, USB offers compatibility with a wide range of devices, simplifying connections.
2. **Power and Charging:** USB doesn't just transfer data; it also charges devices. It powers smartphones, tablets, speakers, and headphones. With USB Power Delivery, it can even charge laptops. USB provides both data transfer and power delivery, which parallel buses don't typically offer.
3. **Data Transfer:** USB helps move files between devices. You can transfer photos, videos, and music between computers, phones, and storage drives. USB cables are reliable for tasks like backing up data and sharing files. It's a simple and convenient way to manage digital content across devices, something that's not as easy with parallel buses.