Communication Techniques between Microcontrollers

1. **Parallel**
    a. In parallel, all bits are transmitted at the same time using separate communication lines.
    b. Used for shorter distance.
    c. In order to transmit, we use wires and lines.
    d. More costly, faster and less time-consuming than serial.
    e. Example: Printers and hard disk.
2. **Serial**
    a. Data bits are transmitted serially one by one i.e. bit by bit on single communication line.
    b. Requires only one communication line rather than n number of lines to transmit data from sender to receiver.
    c. Bits of data are transmitted on single lines in serial fashion.
    d. Less costly and allows long distance transmission.

    Two Methods:

    - **Asynchronous**
        - In synchronous communication, data is transmission and receiving is a continuous stream at a constant rate. Synchronous communication requires the clock of transmitting device and receiving device synchronized.
        - Examples: Universal Asynchronous Receiver Transmitter (UART), CAN
    - **Synchronous**
        - Synchronous and asynchronous communication protocols are well-defined standards and can be implemented in either hardware or software.
        - Examples: I2C, SPI

UART:

In UART communication, two UARTs communicate directly with each other. The transmitting UART converts parallel data from a controlling device like a CPU into serial form, transmits it in serial to the receiving UART, which then converts the serial data back into parallel data for the receiving device. Only two wires are needed to transmit data between two UARTs. Data flows from the Tx pin of the transmitting UART to the Rx pin of the receiving UART

Advantages:

• Only uses two wires

• No clock signal is necessary

• Has a parity bit to allow for error checking

• The structure of the data packet can be changed as long as both sides are set up for it

• Well documented and widely used method

Disadvantages:

• The size of the data frame is limited to a maximum of 9 bits

• Doesn't support multiple slave or multiple master systems

• The baud rates of each UART must be within 10% of each other

SPI COMMUNICATION PROTOCOL

SPI is a common communication protocol used by many different devices. For example, SD card modules, RFID card reader modules, and 2.4 GHz wireless transmitter/receivers all use SPI to communicate with microcontrollers.

ADVANTAGES

• No start and stop bits, so the data can be streamed continuously without interruption

• No complicated slave addressing system like 12C

• Higher data transfer rate than 12C (almost twice as fast)

• Separate MISO and MOSI lines, so data can be sent and received at the same time

DISADVANTAGES

• Uses four wires (12C and UARTs use two)

• No acknowledgement that the data has been successfully received (12C has this)

• No form of error checking like the parity bit in UART

• Only allows for a single master

I2C Communication Protocol

It employs two wires, SDA (Serial Data) and SCL (Serial Clock), to connect multiple devices to a single bus. This allows for efficient communication between microcontrollers, sensors, and other peripherals. I2C's multi-master capability and low power consumption make it ideal for various applications, from simple sensor networks to complex IoT devices.

I2C Advantages:

- Requires only two wires for communication.
- Supports multiple masters and multiple slaves on the same bus.
- Uses ACK/NACK bits to confirm successful data transfer.
- Simpler hardware implementation compared to UARTs.
- Widely used and well-established protocol.

I2C Disadvantages:

- Lower data transfer rate compared to SPI.
- Limited data frame size to 8 bits.
- More complex hardware implementation compared to SPI.

Universal Serial Bus (USB)

USB is a versatile interface standard that allows computers to communicate with a wide range of devices. USB offers plug-and-play functionality, supports high-speed data transfer, and can provide power to connected devices. It's widely used for peripherals like keyboards, mice, printers, and external storage drives.

Advantages of USB:

- Easy to connect and disconnect devices without restarting the computer.
- Devices can be swapped while the computer is running.
- USB can provide power to connected devices, eliminating the need for separate power adapters.
- USB supports various data transfer speeds, from low-speed to high-speed and SuperSpeed USB.
- USB devices can be configured to serve different functions.

Disadvantages of USB:

- USB cables have limited length, which can restrict the placement of devices.
- USB cables can be susceptible to electromagnetic interference, which may cause data corruption or connection issues.
- While USB can provide power to devices, it may not be sufficient for high-power devices.
- The USB standard has evolved over time, leading to multiple versions and compatibility issues.

CAN Bus

The CAN (Controller Area Network) bus is a serial communication protocol used to connect multiple electronic devices in a system. Every device receives all messages, but smart filters allow them to focus on relevant information (like muting notifications in a group chat). CAN bus detects and corrects data errors, ensuring clear communication. It is perfect for applications needing quick responses.

Advantages of CAN Bus:

- CAN bus is robust and can operate in harsh environments.
- It has built-in mechanisms for error detection and correction.
- Short message formats optimize data transmission.

Disadvantages of CAN Bus:

- All nodes receive all messages, which can increase network traffic.
- Data transmission is restricted by message size limitations.