Today’s Topics

• Serial Communication
  • RS-232
  • TTL Serial
• SPI
• I2C
RS-232

• RS-232 is a standard for **asynchronous** serial communication
  • Specifies a protocol and hardware requirements
  • Requires both positive and negative voltages
  • Two data lines Rx and Tx
  • Many other control lines

• TTL Serial Communication
  • Requires three connections
    1. Ground
    2. Rx (Receive)
    3. Tx (Transmit)
  • Operates on 0 and 5V
  • 3.3V and lower voltage versions also common
TTL Serial

- Asyncronous – no clock signal.
  - Transmitter and Receiver must know what the clock (baud) rate is. The baud rate is commonly between 2400-115200 pulses per second
- Data is transmitted in frames.
- Each frame contains a start bit, data bits, an optional parity bit, and one or two stop bits.

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Frame: Start | Data | Parity | Stop
Size (bits): 1 | 5-9 | 0-1 | 1-2
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- The most common protocol is 8-N-1
  - 8 data bits
  - No parity bit
  - 1 stop bit.
TTL Serial

- The endianess of the data must also be specified.
- Which is sent first, the most significant bit (msb) or the least significant bit (lsb)?
- Little endian is more common
TTL Serial Hardware and Wiring

- For communication the Tx of one device needs to be connected to the Rx of the other device.
- Duplex means data can be sent each way.
- Half duplex means data can only travel on one direction at one time.
- Full duplex means data can be sent and received at the same time.
Most commonly serial communication is handled by special hardware called a UART (Universal asynchronous receiver/transmitter). UARTs contain a buffer so the microprocessor does not have to process the data as it arrives.
Serial Peripheral Interface (SPI)

SPI is a synchronous protocol (it has a clock).

Data is read on the rising (or falling) edge of the clock signal.
Serial Peripheral Interface (SPI)

- Clock Generated by ‘Master’
- Data sent from ‘master’ to ‘slave’ on Master Out Slave In (MOSI) date line
- Data sent from ‘slave’ to ‘master’ on Master Out Slave In (MISO) date line
- Master needs to know how much data the slave will return
Serial Peripheral Interface (SPI)

- Slave Select (SS) pin is used to interface with multiple slave devices.
Serial Peripheral Interface (SPI)

- Slave devices can also be daisy chained.
Inter-integrated Circuit (I²C)

Multiple master and multiple slave devices with just two wires.
- SCL is the clock signal generated by the current ‘bus master’
- SDA is the data signal
To transmit data

1. The master first pulls the data line low
2. The master sends an address
3. The master indicates whether it will read or write to the address.
4. The slave device acknowledges that it is being communicated to.
5. The master/slave sends data one or more 8-bit data packets.
6. The receiving device acknowledges that data was received.
7. The master generates a stop condition to indicate the transmission is over
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Inter-integrated Circuit (I²C)

If data is being sent or requested to quickly the slave device can slow things down by holding the clock line low.

ACK/NACK occurs as normal, but we can assume ACK, or no clock stretch would have occurred.

The data frame can be completed as normal, either with a stop condition, another data frame, or a repeated start.

Data transfer is completed as normal, with 8 bits being transferred.

The slave is not ready for more data, so it buys time by holding the clock low. The master will wait for the clock line to be released before proceeding to the next frame.
Inter-integrated Circuit (I²C)

To avoid the situation where device is pulling the clock or data line high and another device is pulling the line low, all devices are “open drain”.
- Devices can only pull the lines low.
- Pull-up resistors are used to bring the lines high.