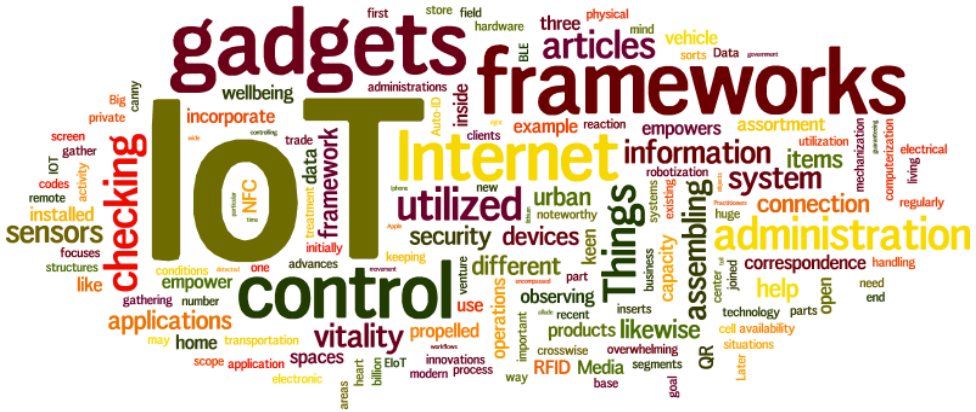
Internet of Things

UART

Serial Communication

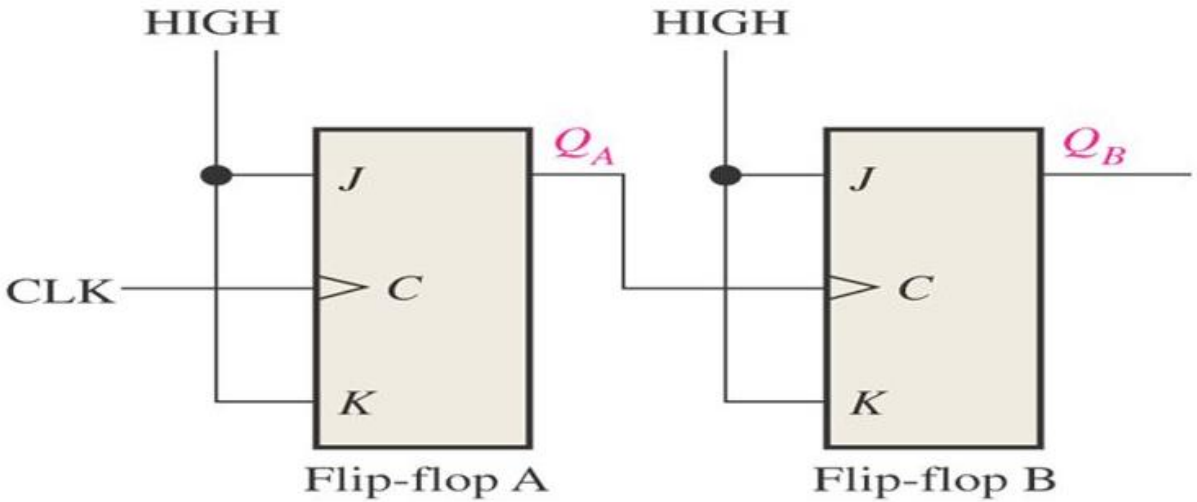


Thanks to Dr. Manas Khatua

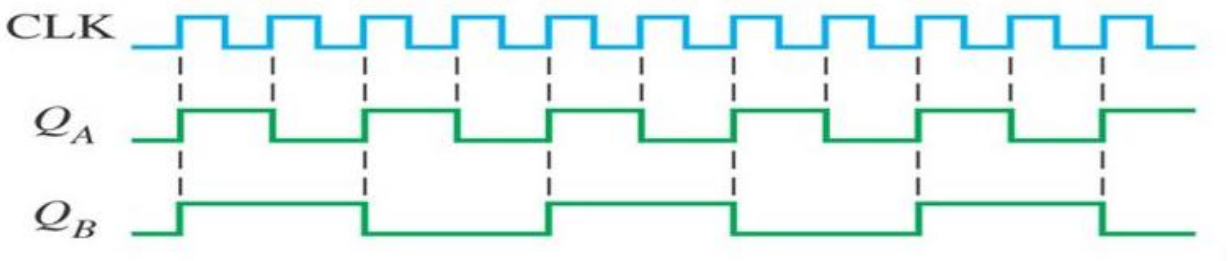
UART

- UART stands for Universal Asynchronous Receiver Transmitter
  - one of the earliest modes of communication applied to computers
  - its origin goes back at least as far as the 1960s
  - called 'universal' because
    - its parameters - speed, data size and so on - are not fixed, and can be configured, however, both side should agree
  - It is used for asynchronous serial communication
    - **Serial communication** stands for the process of sending data one bit at a time sequentially
    - **Asynchronous** means there is no clock signalling line to synchronize, and transmitter and receiver might turn on at different time instant
      - Two devices do not necessarily share a common clock.
      - Both systems might for example agree on some fixed Baud rate.
        - Baud rate is a measure of the speed of data transfer, expressed as symbol per sec.
          - Also represented by bit per second (bps).
          - Bit Rate = Baud rate x the number of bit per baud
          - Common baud rates: 9600, 4800, 19200, 38400, etc.

Clock based Synchronization



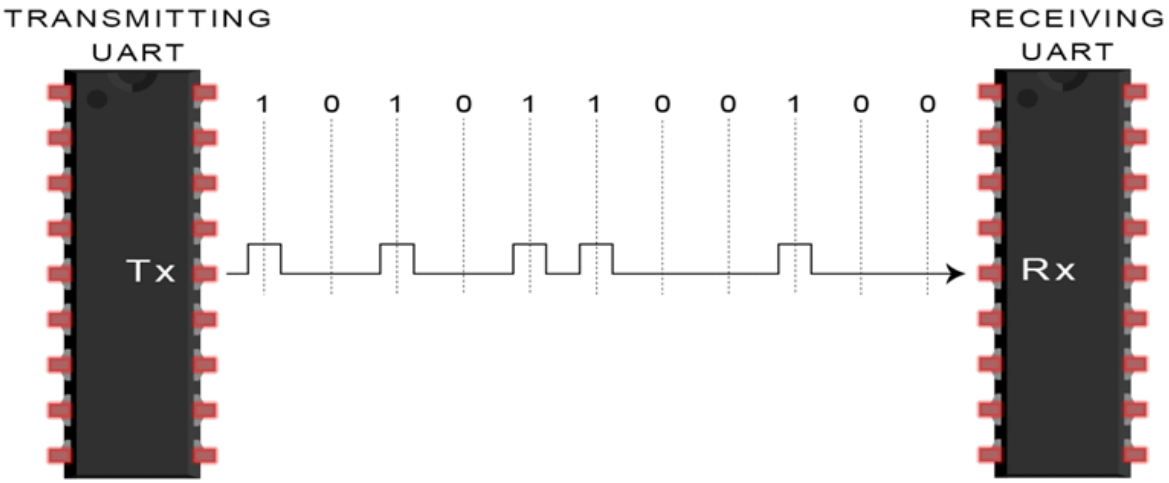
Clock	J	K	Q_{n+1}	State
0	x	x	Q_n	
1	0	0	Q_n	Hold
1	0	1	0	Reset
1	1	1	1	Set
1	1	1	$\overline{Q}_n$	Toggle



Source: Google Image

Synchronization in UART

- This synchronisation is done in the form of a high to low (or low to high) transition on the data line.
  - The line will ideally high in idle
  - then drop low when transmission starts.
    - This transition acts to synchronise the timing between both devices.
    - The receiver then knows to clock in enough cycles of data based on its baud clock.



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- However, there are two problems with this scheme:
  - The single high to low transition is not enough to synchronise timing over a long period of time.
    - So, they need periodic re-synchronisation.
  - If the first bit of data it wants to send is also represented by a high level, then there are no transition, and vice-versa.
    - So, they need some way to distinguish the first bit.

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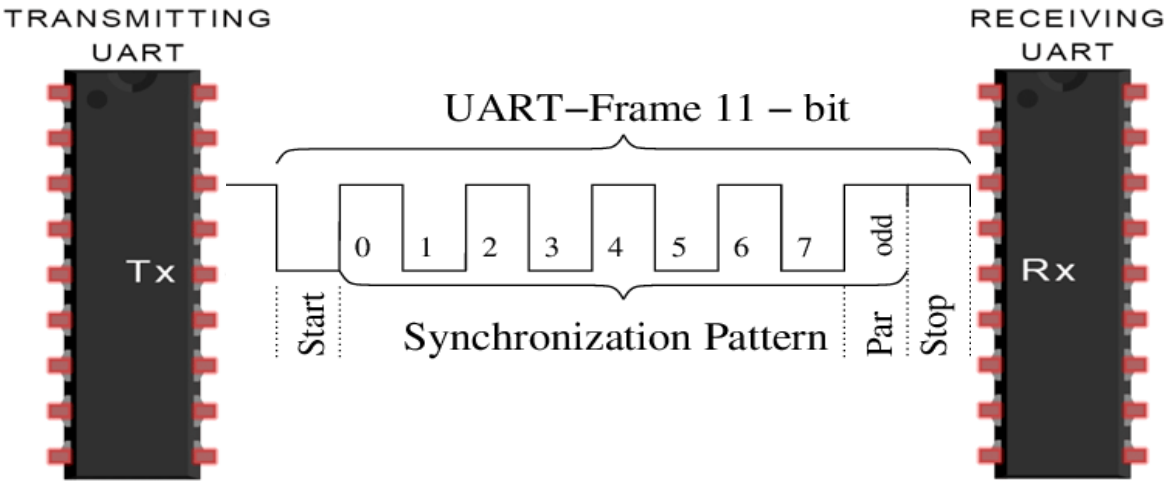
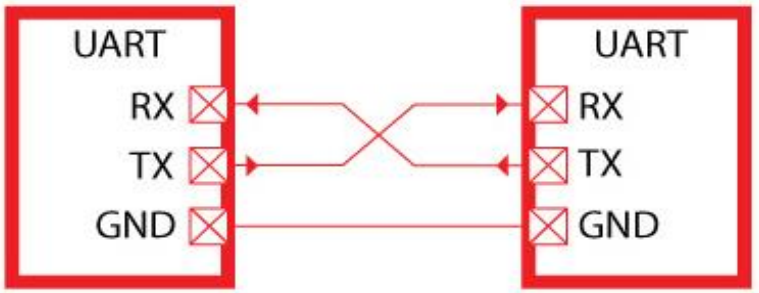
Both of these problems are solved in UART by using **start** and **stop bits**.

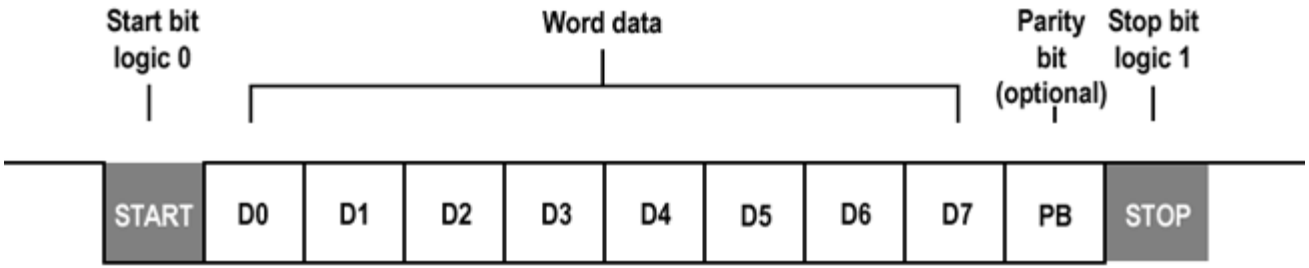


UART Communication

- UART Communication
  - Communication may be simplex, full duplex, or half duplex
    - Simplex: One direction only, transmitter to receiver
    - Half Duplex: Devices take turns transmitting and receiving
    - Full Duplex: Devices can send and receive at the same time
  - Data format and transmission speed are configurable
  - Communication goes through the two independent lines/wires
    - TX (transmission)
    - RX (reception).



Data Framing



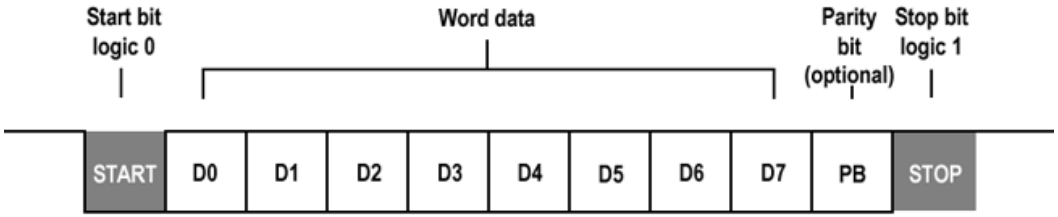
Start Bit:

- The UART transmission line is normally held at a high voltage level when idle i.e. it is not transmitting data
- It start bit is set to logic low as it is used to signal the receiver that a new framing is coming.

Data Frame:

- If one parity bit is used, then next 5-8 bits carry the "data bits" (information). Otherwise, data bits can be 5-9 bits.
- Certainly, the standard data size is 8-bit, but other sizes have their uses.
- A 7-bit data chunk can be more efficient than 8, especially if you're just transferring 7-bit ASCII characters.

Cont…



Parity:

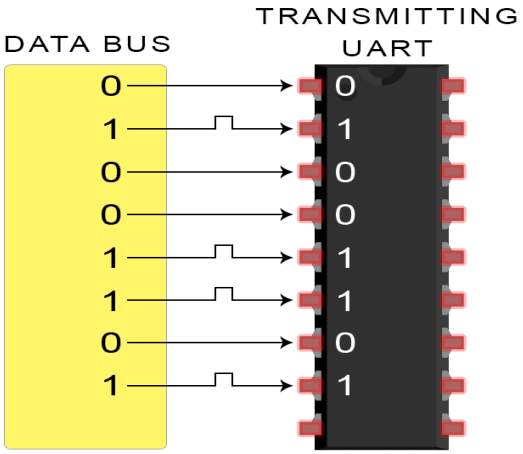
- It is an optional bit.
- It is used to detect the wrong data packets, i.e. error during transmission
- Two type of parity bit used: even parity, odd parity.
  - Even parity:
    - If the count of bits with value 1 is odd, the parity bit value is set to 1, making the total count of occurrences of 1s in the whole set (including the parity bit) an even number.
    - If the count of 1s in a given set of bits is already even, the parity bit's value is 0.
  - Odd parity:
    - the coding is reverse of even parity.

Stop Bits:

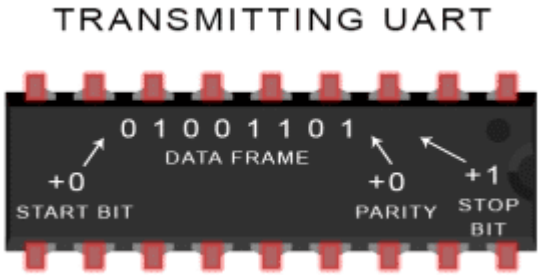
- To signal the end of the data packet, the sending UART drives the data transmission line from a low voltage to a high voltage.

Steps of UART Communication

1. The transmitting UART receives data in parallel from the data bus:



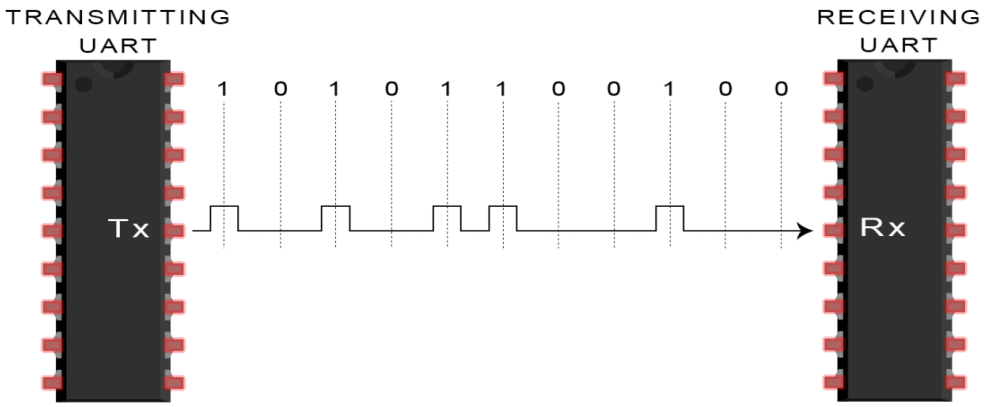
2. The transmitting UART adds the start bit, (even) parity bit, and stop bit(s) to the data frame:



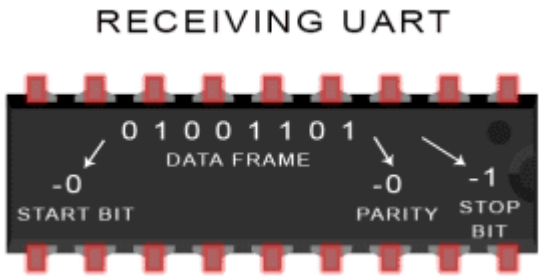
Cont…

3. The entire packet is sent serially from the transmitting UART to the receiving UART. In most cases, the data is sent with the least significant bit first.

The receiving UART samples the data line at the pre-configured baud rate:

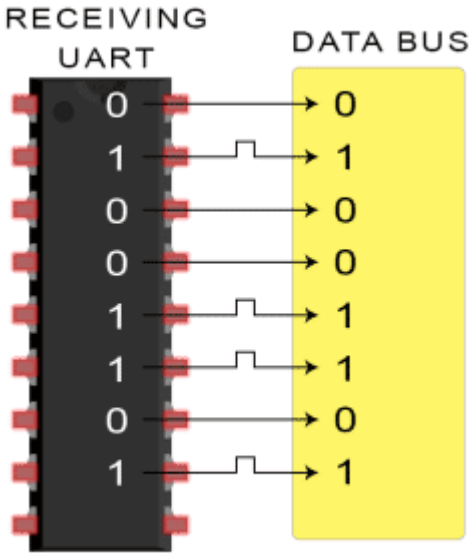


4. The receiving UART discards the start bit, parity bit, and stop bit from the data frame:



Cont…

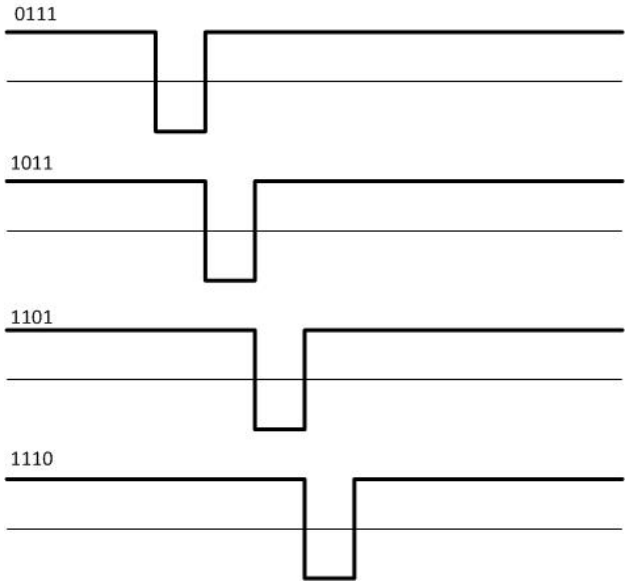
5. The receiving UART converts the serial data back into parallel and transfers it to the data bus on the receiving end:



Note:

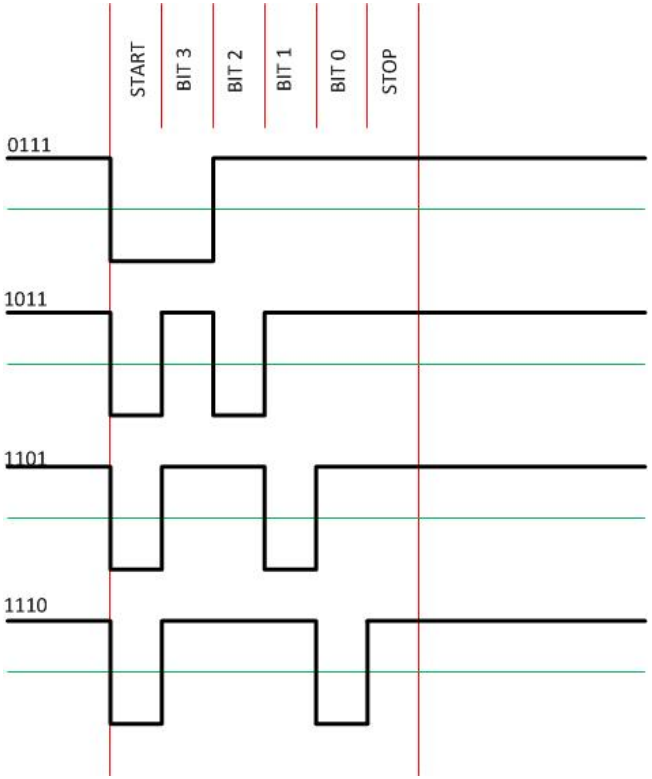
- For communication between the devices, both of them have to have same baud rate
  - The baud rate between the transmitting and receiving UARTs can only differ by max 10%.

Use of Start bit



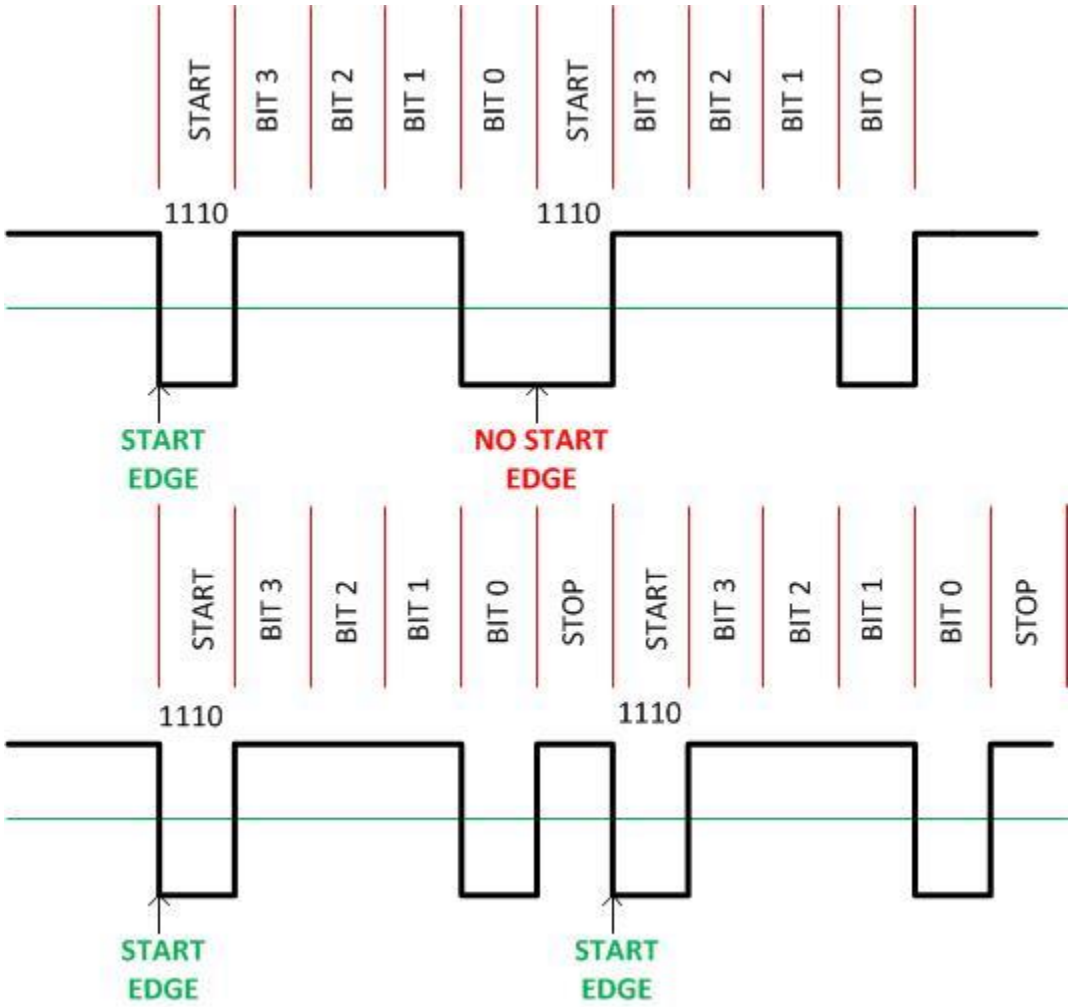
Without any time reference, they all look alike as a voltage signal.

As time matters with asynchronous signals, it is needed to send a "LISTEN UP" signal in the form of start bit.



Source: https://electronics.stackexchange.com/questions/335695/why-the-start-bit-and-the-stop-bits-are-necessary

Use of Stop bits



- In the first figure, no transition for start bit !
- So, the stop bit ensures the line goes back to the idle state at the end of the transmission.
- It also gives the receiver a time window to handle the bytes just received, reset, and get ready to listen for the next start bit.
- **Note:** Start & Stop bits are used for synchronization, but not to define the data length

Source: https://electronics.stackexchange.com/questions/335695/why-the-start-bit-and-the-stop-bits-are-necessary

9600 8N1 (an example)

- **9600 8N1** – 9600 baud, 8 data bits, no parity, and 1 stop bit - is one of the more commonly used serial protocols.

- A device transmitting the ASCII characters 'O' and 'K' would have to create two packets of data.
- The ASCII value of O (that's uppercase) is 79, which breaks down into an 8-bit binary value of 01001111, while K's binary value is 01001011

- Since we're transferring at 9600 bps, the time spent holding each of those bits high or low is 1/(9600 bps) or 104 µs per bit.
- For every byte of data transmitted, there are actually 10 bits being sent: a start bit, 8 data bits, and a stop bit.
- So, at 9600 bps, we're actually sending 9600 bits per second or 960 (9600/10) bytes per second.

Advantages and Disadvantages

Advantages:

1) Well documented and widely used method.

2) Only uses two wires

3) No clock signal is necessary

4) Has a parity bit to allow for error checking

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

Disadvantages:

1) The size of the dataframe is limited to max 9 bits.

2) Doesn't support multiple master-slave systems

3) The baud rate of each UART must be with 10% of each other.

Applications and Standards

- UART is normally used in microcontrollers for exact requirements

- Today, UART is being used in many applications like
  - GPS Receivers,
  - Bluetooth Modules,
  - GSM and GPRS Modems,
  - Wireless Communication Systems,
  - RFID based applications
  - etc.

- The first of the serial data transmission standards was RS232, or more correctly RS-232 or COM-port. This was developed in 1962.

- There are more recent standards which allow high speed data transmission along with multiple transmitters and receivers

  - e.g. USB, DP, HDMI, DDR, Ethernet, PCI Express, SAS/SATA, Thunderbolt, etc.

Lessons Learned

- ✓ What is serial communication
- ✓ What is asynchronous communication
- ✓ UART communication mechanism
- ✓ Pros and Cons of UART communication
- ✓ Applications of UART communication

Thanks!