

# COMP467

## Local Asynchronous Communication

### Goals

- Understand the RS-232 transmission format
- Be able to compute the parity of a byte
- Understand the difference between baud and bits per second
- Be able to calculate the maximum possible transmission rate
- Be able to calculate the maximum transmission rate in the presence of noise

The purpose of a network is to send a stream of bits from one node to another

- The transmitted bits can be text, data, digitized voice or graphics.
- We will only consider the transmission of binary digital data at this time
- 8 bit groups are called “octets”.

Data is usually sent over a single channel one bit at a time.

- A single wire transmits the bits one after another.
- Some short communication systems, such as printer cables, send multiple bits at a time over multiple parallel wires.
- Over long distances multiple bits can get out of synch.
- A single wire is cheaper than multiple wires

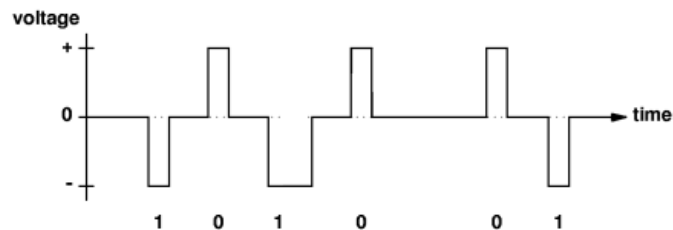
## Data can be sent synchronously or asynchronously.

- With asynchronous transmission there is no time relationship between transmission.
- Once a synchronous transmission starts, another bit is sent at a regular interval. Sender and receiver have to have synchronized clocks.
- Some systems are bit wise synchronous but asynchronous by byte.

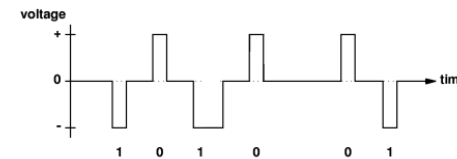
## Consider sending different voltages on a wire.

- Bits could be sent by varying the voltage on the line.
- Positive voltage could represent a 0 bit and negative voltage a 1 bit.
- In a totally asynchronous system, each bit is sent by an arbitrary length pulse of voltage.

## Example of a Totally Asynchronous Network



*Note that very few existing systems actually use this method.*



- It is easy for the receiving side to determine when the next bit arrives and when the signal for that bit is complete
- There is no fixed transmission speed.
- Bits are sent as quickly or as slowly as the sending side chooses.

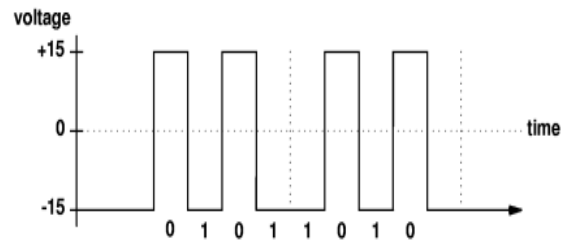
## RS-232-C standard

- An Electronic Industry Association standard for transmitting data over short distances.
- Also known as ITU V.24
- Standards are extremely important in the networking industry.

## RS-232-C

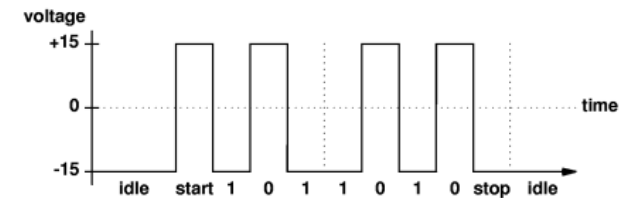
- Bit wise synchronous but byte wise asynchronous
- A 1 bit is sent as -15 volts (MARK)
- A 0 bit is sent as +15 volts (SPACE).
- When there is nothing to send, the line is kept at the -15 volt state.

## Almost RS-232-C



What problems can arise in recognizing bits?

## RS-232 Format



- Each byte starts with a special 0 bit called a start bit. This is not a data bit.
- Each byte ends with a non-data 1 bit called the stop bit.
- There may be 1, 1.5 or 2 stop bits.

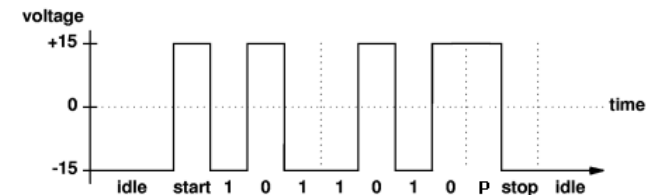
## Error Detection

- Frequently another bit is sent every byte to help detect errors.
- A parity bit is sent that is the XOR of all data bits.
- When the receiver gets a byte, it computes the parity and compares it to the received parity. An error has occurred if the results are different.
- Parity can be even, odd, mark, space or none.

## Parity Example

- The “even” parity for the 7 bit ASCII letter “Z” is:

$$1 \oplus 0 \oplus 1 \oplus 1 \oplus 0 \oplus 1 \oplus 0 = 0$$



## Overhead

- Bits sent that are not part of the actual data are overhead.
- RS-232 has 3 overhead bits, start, stop and parity, for every 8 bits of data. The overhead is 3/11 or 27%.

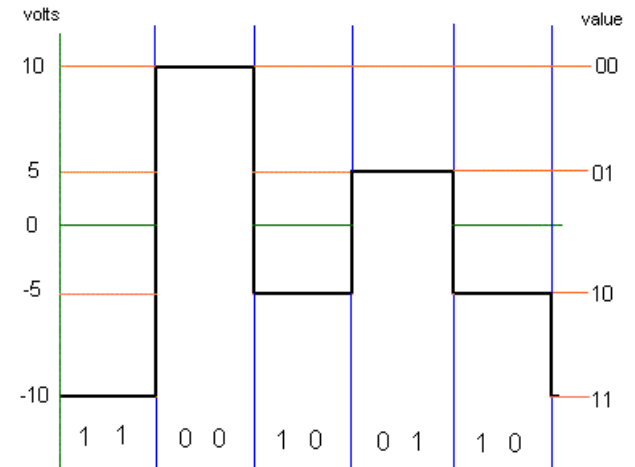
## Improving Performance

- The length of time used to send all bits, including start and stop bits, in RS-232 is the same.
- If each bit period is 1.0 millisecond, then we can send 1000 bits/second.
- If the bit period is reduced, more bits can be sent per second.
- How fast can bits be sent?

## Improving Performance

- The RS-232 standard sends only one of two values, +15 volts and -15 volts.
- If the receiver can detect a wider range of values, say +10v, +5v, -5v and -10v, then more data could be sent in each signal.
- If there are  $V$  possible values, then each signal can represent  $\log_2 V$  bits.
- Each transmission of one of 4 values would send 2 bits.

## Four Possible Transmission States



## Baud and Bits/second

- The Baud rate is the number of states or signals sent every second.
- If  $V$  is greater than 2, then the bit rate is greater than the Baud rate.
- Systems may have a Baud rate greater or less than the bit/second rate.

## How Many States to Use

- If 4 states improves performance, why not 8, 16 or 1024?
- There is a limit to the number of states that can be detected.
- Noise makes it difficult to differentiate states that are close to each other.

## Bandwidth

- Bandwidth is the range of frequencies that can be sent and received.
- The human ear functions between 50Hz to 20KHz, so it has a bandwidth of about 19,950Hz.
- Filters in the telephone system allow only frequencies between 50Hz and 3050Hz for a bandwidth of 3KHz.

## Nyquist Formula

- In 1924 H. Nyquist derived an equation relating bandwidth and maximum data rate  

$$\text{max data rate (bits/sec)} = 2 * B * \log_2 V$$
- where:
  - B = bandwidth
  - V = number of different values that can be sent.

## Nyquist Formula

- Applies to perfect noiseless channels
- Gives the absolute maximum speed possible
- Networks that advertise greater speed should be given the same consideration as perpetual motion machines.

## Calculator Clue

- Most calculators don't have a base 2 logarithm function.
- You can calculate any log base by:

$$\log_A B = \frac{\log_x B}{\log_x A}$$

- Note that  $\log_{10} 2 = 0.30103$

## Nyquist Formula Example

- Consider a telephone line with 3KHz bandwidth and binary signals ( $v = 2$ ).

$$\text{Max rate} = 2 * 3000 * \log_2 2$$

$$\text{Max rate} = 6000 \text{ bits/second}$$

## Nyquist Formula Example

- If you need to transmit 128K bits/second and can send 16 different states, how much bandwidth is required?

$$B = \frac{\text{transrate}}{2 * \log_2 V}$$

$$B = 16\text{KHz}$$

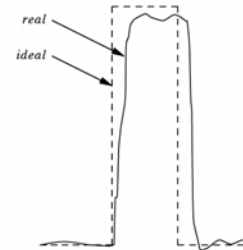
## Nyquist Formula Example

If a telephone modem can transmit 31.2K bits/sec, how many different states must it be able to send?

$$V = 2^{\frac{\text{transrate}}{2B}}$$

$$V = 36.76 \text{ states}$$

## Noise



- In the real world, transmissions are subject to noise and distortion.
- You can hear noise on a weak radio channel.
- Noise makes it difficult to distinguish different states.

## Noise

- Noise is represented as a signal/noise ratio or the ratio of the strength (energy) of the signal to the strength (energy) of the noise.
- If someone whispers (low signal strength) in a noisy room, it is difficult to hear them.
- Noise reduces the rate at which data can be transmitted.

## Shannon Formula

- In 1948 Shannon derived an equation for channels with random thermal noise.

$$\text{max data rate(bits/sec)} = B * \log_2 (S/N+1)$$

- This is a physical law that applies to all communication systems.
- Space probes that transmit very weak signals send only a few bits / second.

## Decibels

- Noise is often measured in decibels (dB)

$$\text{dB} = 10 * \log_{10} S/N$$

$$S/N = 10^{\text{dB}/10}$$

- Note that the decibel scale is exponential.
- A good telephone connection has a noise level of about 34 - 38 dB.

## Shannon Formula with dB

- We can simplify calculations using decibels by combining the equations

$$\text{maxrate} = B * \log_2 (S/N+1)$$

$$\text{maxrate} = B * \log_2 (S/N) \quad \text{ignore +1 if } S/N > 1000$$

$$\text{maxrate} = B * \log_2 (10^{\text{dB}/10}) \quad \text{substitute } S/N = 10^{\text{dB}/10}$$

$$\text{maxrate} = B * \log_{10} (10^{\text{dB}/10}) / \log_{10} 2 \quad \text{change log base}$$

$$\text{maxrate} = B * \log_{10} (10^{\text{dB}}) / (10 * \log_{10} 2) \quad \text{pull out /10}$$

$$\text{maxrate} = B * \text{dB} / (10 * \log_{10} 2) \quad \text{log \& power cancel}$$

$$\text{maxrate} = B * \text{dB} / 3.0103 \quad \text{convert constant}$$



## Shannon Formula with dB

$$\text{maxrate} = \frac{B * dB}{3.01}$$

## Shannon Formula Example

If a telephone line has a signal to noise ratio of 34dB, how fast can it transmit data?

$$\text{max rate} = \frac{B * dB}{3.01} = \frac{3000 * 34}{3.01} = 33.89$$

This is why the fastest telephone modem upload speed is 31.2K bits/second.

56K modems do not really work at 56,000 bits per second and are subject to the Shannon formula limitations.