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

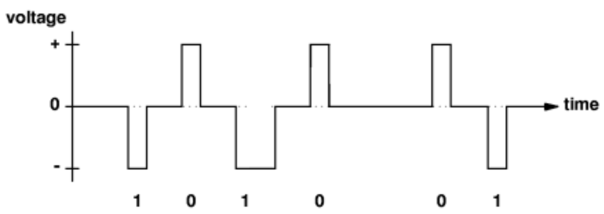
Data can be sent synchronously or asynchronously.

- 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.

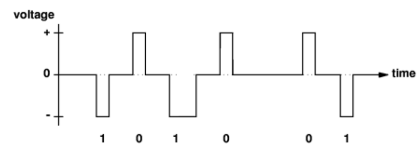
Consider sending different voltages on a wire.

- 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.

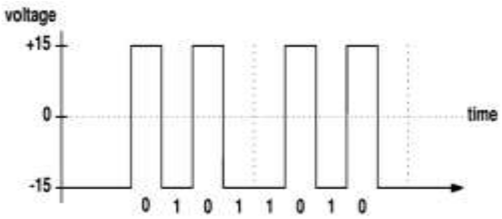
RS-232-C standard

- 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

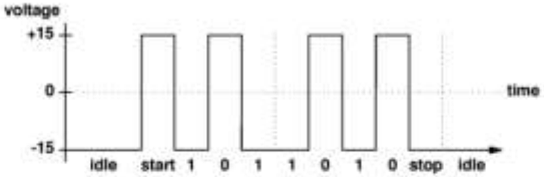
- Bit wise synchronous but byte wise asynchronous
- A 1 bit is sent as -15 volts (MARK)
- A 0 bit is sent as +15 volts (SPACE).
- When there is nothing to send, the line is kept at the -15 volt state.
- If the voltage stays at zero, the line is broken.

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 Examples

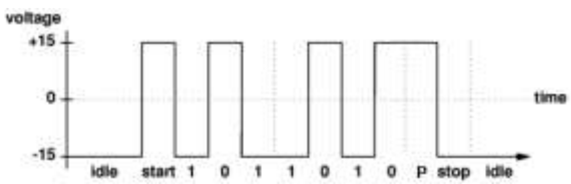
- XOR can be calculated as addition without carry.
- Even parity adds a bit to make the number of one bits an even number.

Data	Parity
01100100	1
01101100	0
01101110	1

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%.

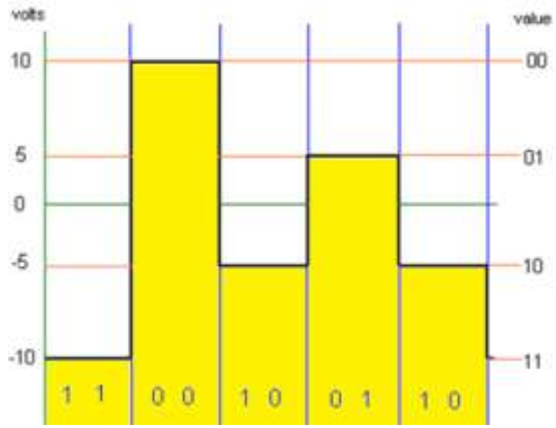
Improving Performance

- 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



Buad 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 Buad rate.
- Systems may have a Buad 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

  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).

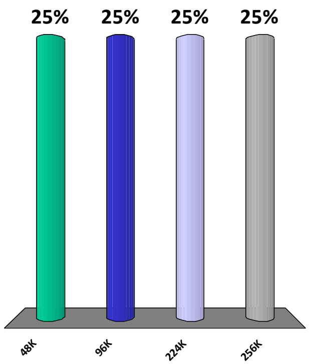
Max rate = 2 * 3000 * $\log_2 2$

Max rate = 6000 bits/second

What is the maximum transmission rate in bits/second?

A system has 16KHz bandwidth and uses 8 different values

1. 48K
2. 96K
3. 224K
4. 256K



Nyquist Formula Example

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

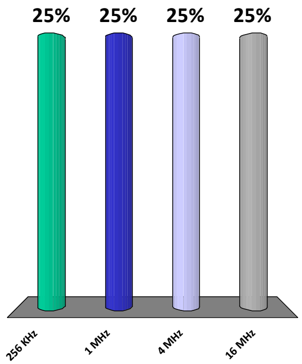
$$B = \frac{transrate}{2 * \log_2 V}$$

B = 16KHz

What bandwidth is required?

You want to transmit 4M bits/sec using 16 different signals

1. 256 KHz
2. 1 MHz
3. 4 MHz
4. 16 MHz



Nyquist Formula Example

If a telephone modem can transmit 56K bits/sec over a modern phone system, how many different states must it be able to send?

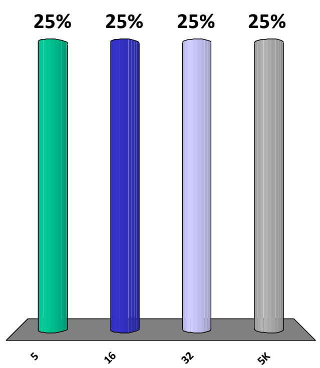
$$V = 2^{\frac{transrate}{2B}}$$

V = 128 states

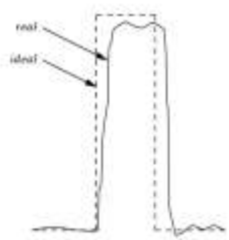
How many different values must you use?

You need to send 80K bits/sec over a 16 KHz bandwidth channel

1. 5
2. 16
3. 32
4. 5K



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 noise 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.

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)

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

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

- 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

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

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

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

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

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

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

maxrate = $B * dB / 3.0103$ 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?

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

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.

What is the maximum transmission rate?

Assume a radio channel with 100KHz bandwidth and 17dB of noise

1. 564 bits/sec
2. 5.6 K bits/sec
3. 565K bits/sec
4. 5.6 M bits/sec