Local Asynchronous Communication and RS-232

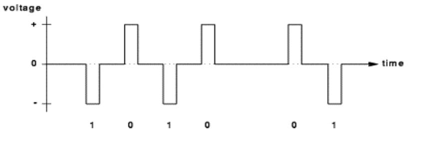
Goals

- Explain how electric current can be used to transmit bits over short distances
- Present a popular mechanism (RS-232) for sending characters this way
- Introduce notions of baud rate and bandwidth
- State the Nyquist Sampling and Shannon's Theorem

Asynchronous communication

- Where the receiver does not know when the sender will transmit
  - transmit when data is ready
  - variable delays between transmissions
  - no sender-receiver coordination beforehand
- E.g., keyboard connected to a computer
- Technically, the electrical signal does not contain information about where individual bits begin and end

Using electric current to send bits



- Use a wire to create a circuit between the sender and receiver
- Negative voltage on the wire could represent a 1 and positive a 0
- Waveform diagram shows variable delay

Communication standards

- Standards ensure that hardware from different vendors can inter-operate
  - what voltages are used?
  - how long should a voltage be held?
  - how rapidly can the voltage change?
- Standards are published by standards organisations - ITU, ISO etc.

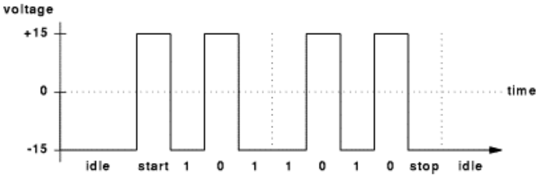
The RS-232 standard

- To connect keyboards, terminals etc. to computers over copper wire
- Is concerned with 7-bit characters
- Details of physical connection (maximum length, plugs and sockets)
- Electrical details (voltages)
- Serial communication
- Asynchronous (for each character)

RS-232 continued

- Never leaves 0 volts on the wire - an idle line is the same as a 1 bit
- Sender and receiver agree how long a bit lasts - receiver uses a local timer
- A 0 start bit signifies the start of a character and is followed by 7 data bits
- A minimum gap of 1 bit between characters (a phantom stop bit of 1)

Example RS-232 waveform



Baud rate

- Transmission hardware is rated in *baud* - the number of signals that are generated per second
- The *baud rate* need not be the same as the *bit rate*, it depends on how many levels of signal are used
- With RS-232 they are the same

Agreeing the Baud rate

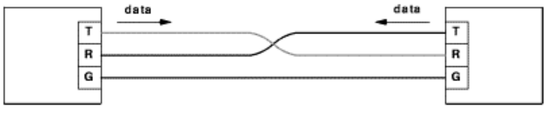
- Sender and receiver agree on length of time each bit is held => maximum number of bits per second (e.g., 300, 9600, 19200)
- RS-232 may often have a configurable baud rate (manually or by software)

Framing errors

- Might occur if the sender and receiver are set to different baud rates
- Receiver samples the signal several times for each bit to check for differences (framing errors)
- Used by the break key to send an abort signal

Full duplex communication

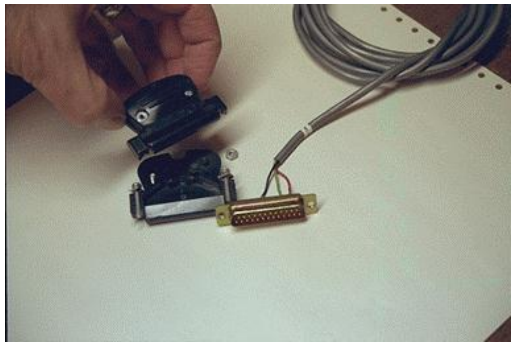
- Two wires required to carry information in one direction (return is a ground)
- Full duplex is two way communication and needs 3 wires - ground is shared



RS-232 connectors and pins

- RS-232 uses a 25 pin connector (extra pins for control functions)
- Computer transmits on pin 2 and receives on 3. Opposite on a modem

A 3 wire RS-232 connection

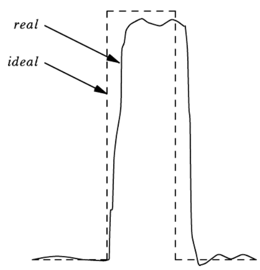


Universal Serial Bus (USB)

- Faster serial data communication standard
- Speeds up to 480 Mbps (USB 2.0)
- 4-wire cable interface
  - • 2 for data, 1 for power,
  - 1 for ground signal
  - Hardware

Limitations of real hardware

- Hardware cannot instantly change voltage and so imperfect signals must be detectable
- RS-232 specifies how much tolerance there should be



Hardware bandwidth

- Hardware cannot change signals instantly => maximum speed at which bits can be sent
- Bandwidth - maximum frequency of signal that a transmission medium can carry
- Measured in cycles per sec = Hertz (Hz)
- Every system (electronic and biological) has a limited bandwidth

Bitrate, Baudrate and Bandwidth

- Bitrate – how many bits per second are being sent
- Baudrate – how many signals per second are used to send those bits
- Bandwidth – the number of signals per second that a medium can accommodate

RS-232 Example

- How long would the transmission last if
  10 000 7-bit characters

were sent across RS-232 operated at 9600 baud?

The Nyquist Sampling Theorem

Theoretical limit on the maximum speed at which data can be sent over an error-free (noiseless) medium:

D = data rate in bit per second (bps)

B = bandwidth in hertz (hz)

For a scheme that uses binary signals (two levels of signal):

Date Rate = D = 2B

For a scheme that uses K levels of signal

$D = 2B\log_2 K$

Shannon's Theorem

- Deals with a noisy medium
- Signal to noise ratio is the strength of the signal compared to the strength of the noise = S/N
- The signal to noise ratio is usually expressed in decibels (db) = $10\log_{10} S/N$
- Maximum data rate on a noisy medium is:

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

Example

- How fast data can be sent across a voice telephone call?
- Telephone system:
  - Bandwidth = 3000 Hz
  - S/N = 30dB
- D =3000 x 10 ~30000bps

The significance of Nyquist's and Shannon's Theorems

- Nyquist's theorem encourages engineers to explore ways to encode bits on a signal.
  - A clever encoding allows more bits to be transmitted per unit time.
- Shannon's theorem informs engineers that no amount of clever encoding can overcome the laws of physics.
  - There is a fundamental limit on the number of bits per second that can be transmitted in a realcommunication system.

Summary

- Local, asynchronous communication
- The RS-232 standard
- Baud rate and bandwidth
- Nyquist's and Shannon's theorems