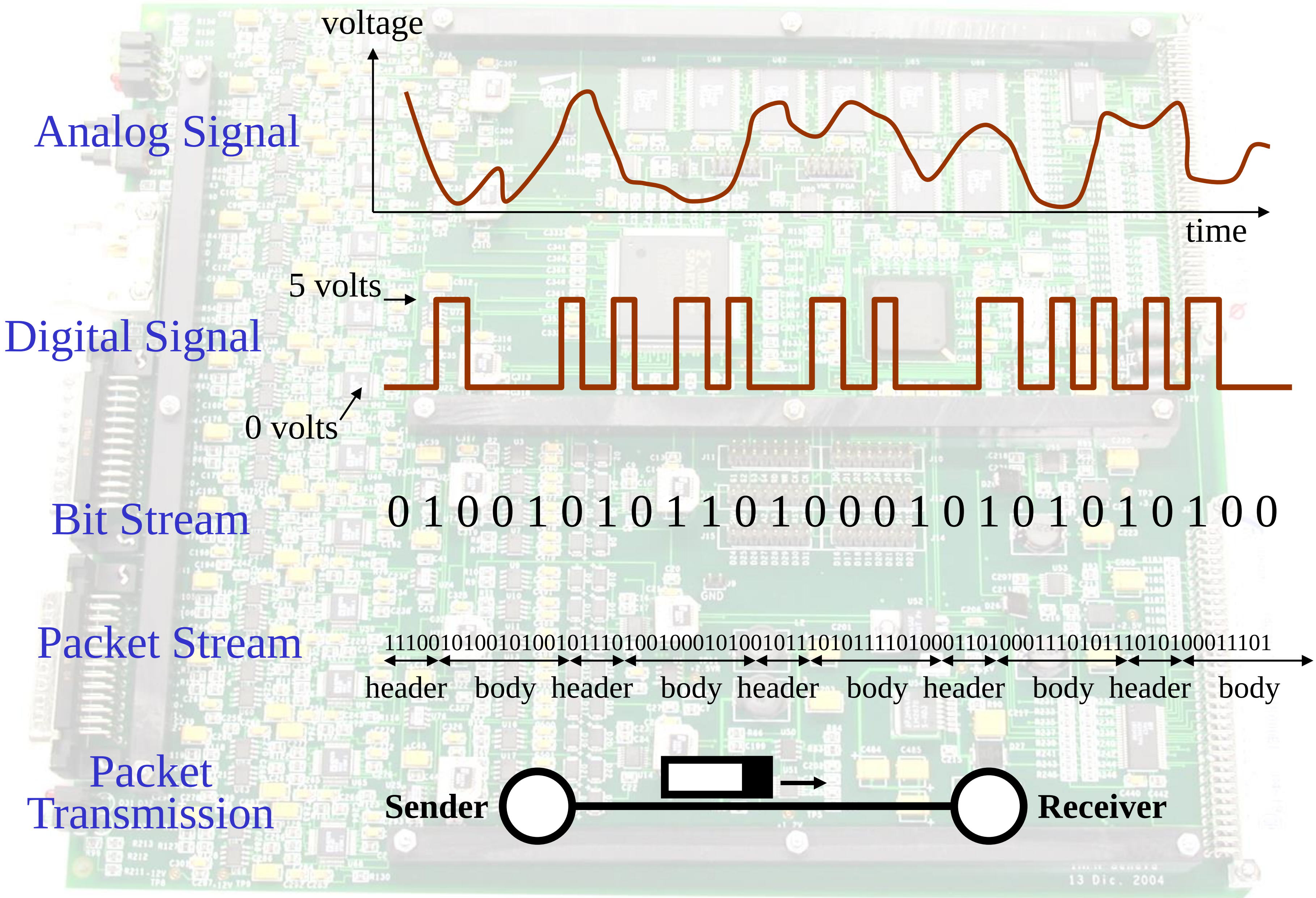
Digital vs Analog

- **Analog -** continuously changing signal, like a voltage
- **Digital** - discrete set of values, set of 1’s and 0’s
- most sensing elements work in analog
- most data display and data recording systems need digital
- therefore signal conditioning / conversion parts of the system must achieve this conversion

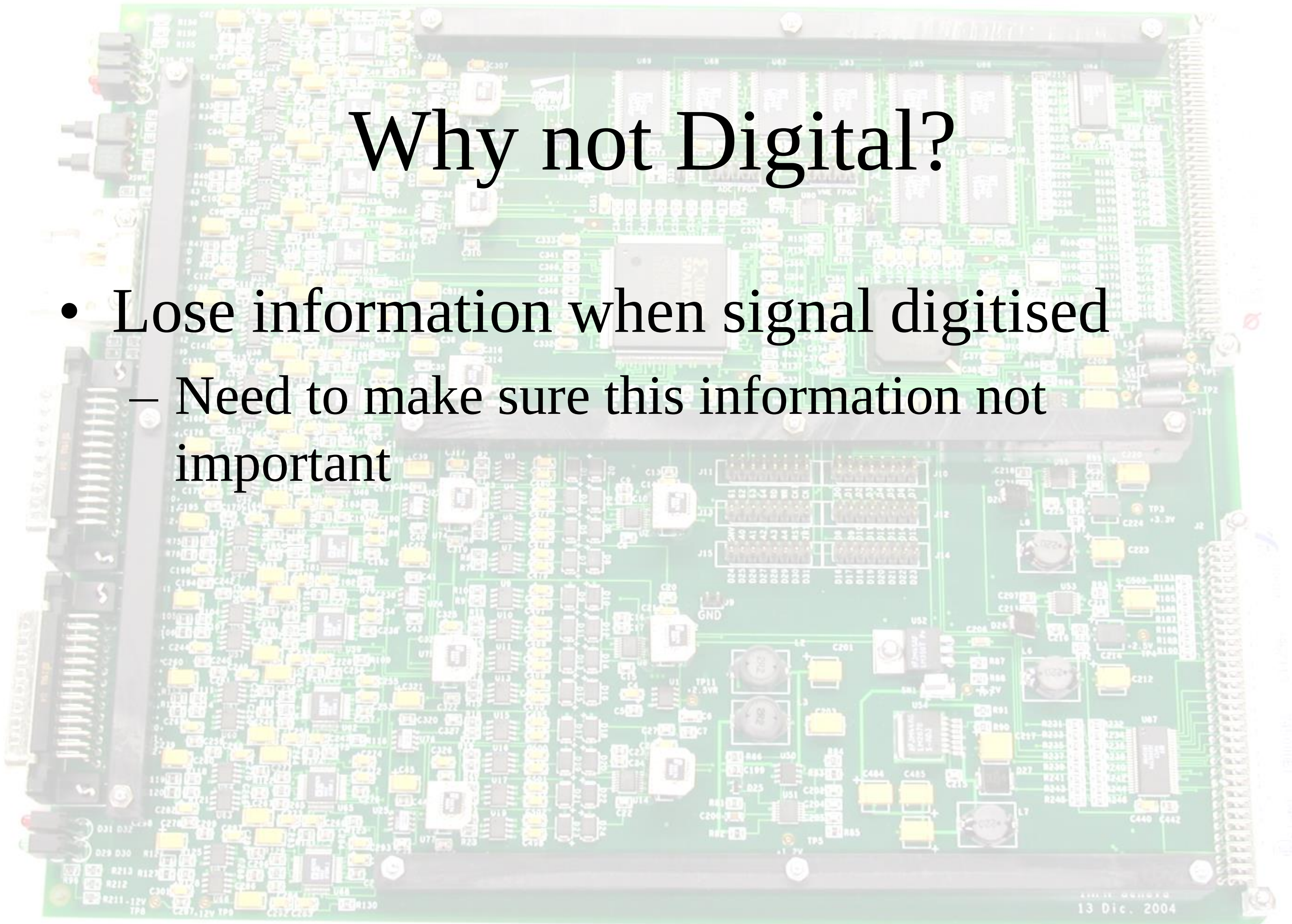


Analog Signal
voltage
time
Digital Signal
5 volts
0 volts
Bit Stream
0 1 0 0 1 0 1 0 1 1 0 1 0 0 0 1 0 1 0 1 0 1 0 1 0 0
Packet Stream
111001010010100101110100100010100101110101111010001101000111010111010100011101
header body header body header body header body header body
Packet Transmission
Sender
Receiver

Why Digital?

- Greater fidelity
  - Can make perfect copies
  - Can ensure signal transmitted correctly
  - Less prone to noise (easy to remove noise)
- Can use computer systems / software
  - Storage
  - Display
  - Analysis
- Better use of resources
  - Compression for storage / transmission
  - Multiplexing on transmission lines (send several signals at once)
- Security
  - Can encrypt

Why not Digital?



- Lose information when signal digitised
  - Need to make sure this information not important

Bits and Bytes

- Digital consists of 1’s and 0’s (or on’s and off’s, high’s and low’s, +0V or +5V)
- Each individual 1 or 0 is called a bit
- Bits are lumped together into batches of 8, called a Byte
- One Byte is enough to represent a character (‘A’ = 01000001 for example)
- File sizes given in multiples of Bytes
  - Kilo Byte = kB = 1000 Bytes
  - MegaByte = MB = 1 million Bytes
  - GigaByte = GB = 1 billion Bytes
- Transmission rates given in
  - Bytes per second; kBps, MBps, GBps
  - Bits per second; bps, Mbps, Gbps
  - Bits per second also called Baud; 1kbps = 1kBaud
- 8Mbps = 1MBps

Analog to Digital Conversion

- Abbreviated ADC
- Carried out by DAQ's (digital acquisition boards)
- Two stage process
  - Sampling
  - Quantisation
- These stages can be done in either order
  - We'll consider sampling first as this is usually the order

Sampling

- want to sample at twice the highest frequency we're interested in. This is Nyquist Theorem

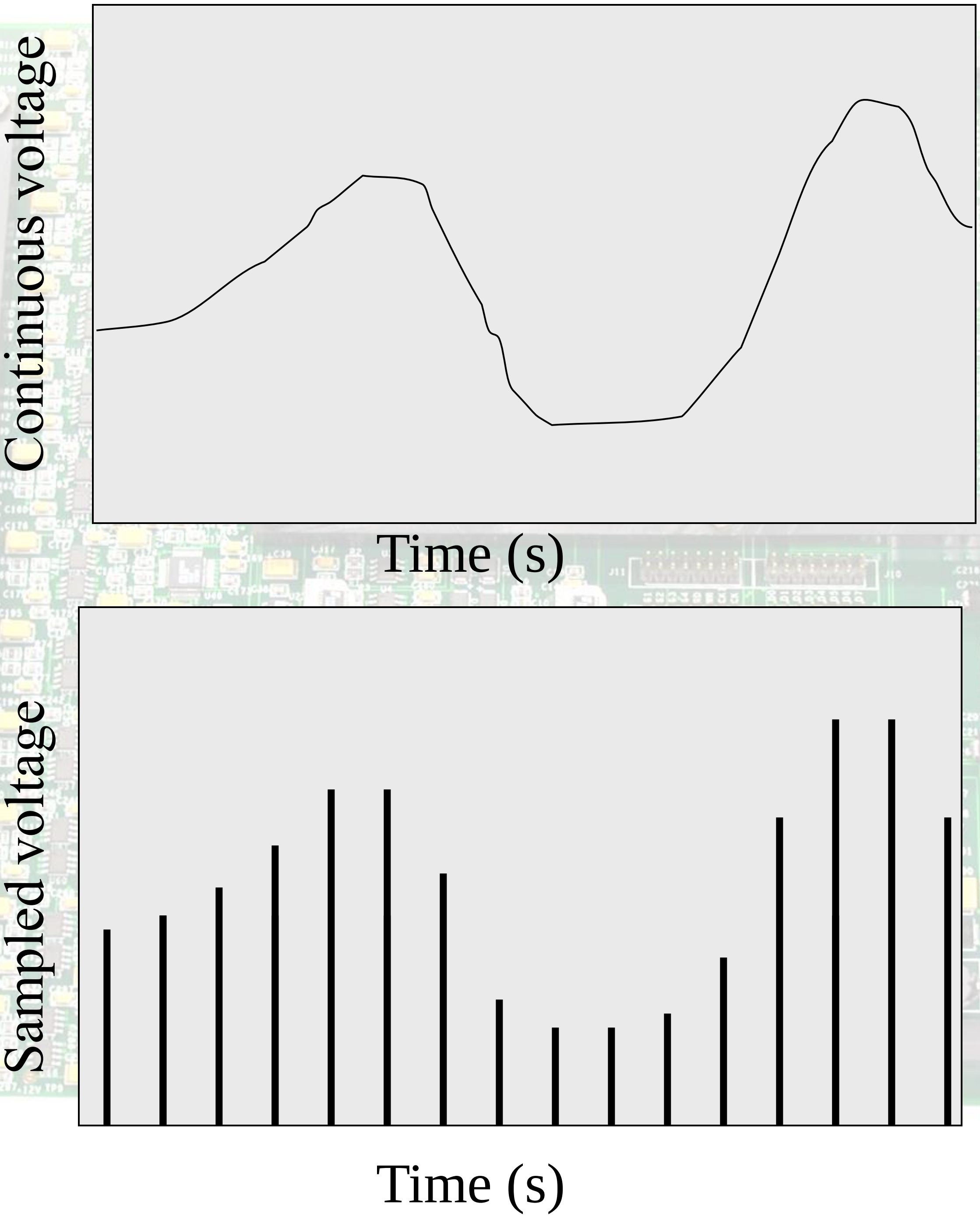
$$\textit{sampling rate} = 2 \; x \; \textit{highest frequency}$$

$$\textit{highest frequency} = \frac{\textit{sampling rate}}{2}$$

- the higher the sampling rate the larger the final file will be

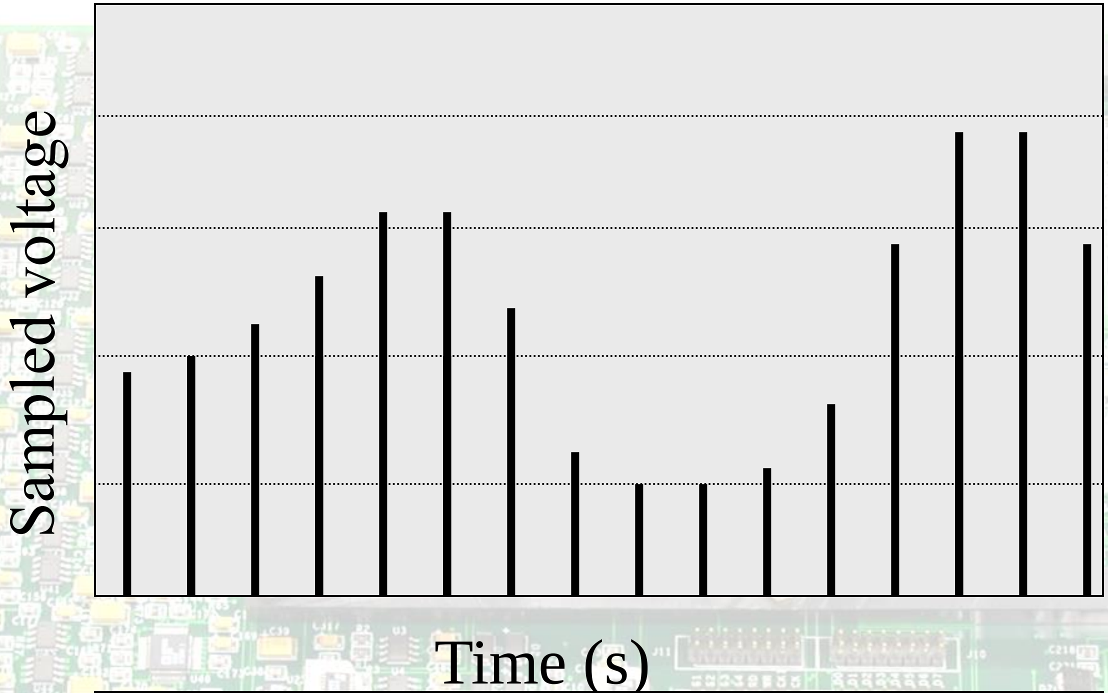
Pre-Filtering

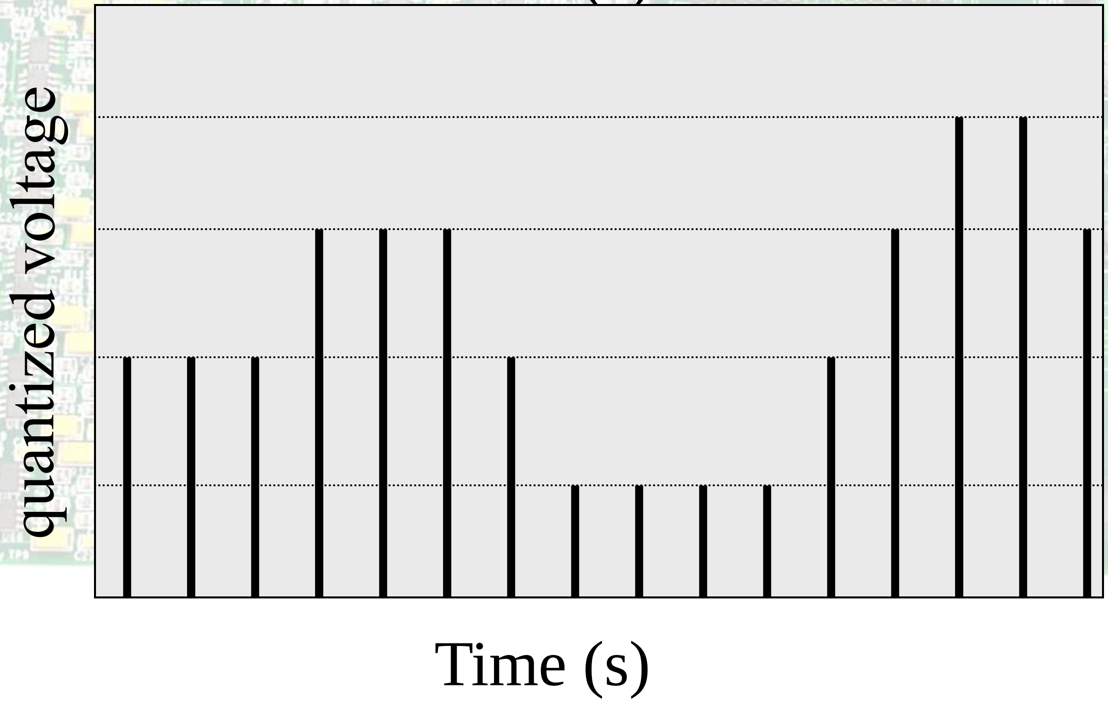
- once you decide on the sample rate you need then you need to get of any higher frequencies in the original signal
- this is pre-filtering
- if these higher frequencies were left in they would lead to unwanted artifacts in the sampled signal
- these artifacts come in the form of signals at spurious frequencies and are called “aliases”
- for example: if a signal is sampled at 50Hz but contained a signal at 30Hz, this would appear in the final sampled waveform as a 30 - 50/2 = 5Hz signal
- no filter is perfect, so we sample at a rate slightly greater than needed (e.g. 44kHz rather than 40kHz for audio)


Continuous voltage
Time (s)
Sampled voltage
Time (s)

Quantizing

- the computer can’t store an exact value for each sample voltage
- has a discrete number of levels (256 for 8-bit)
- puts sampled voltage into best corresponding match from the 256 levels
- quantisation inherently introduces some high frequency noise into the signal
- if input voltage too high, exceeding the highest of the 256 levels get ***clipping***
- for low signal levels quantisation noise is no longer random - introduce ***dither*** to get rid of these artifacts


Sampled voltage
Time (s)


quantized voltage
Time (s)

Problems

- A voltage signal varies between 0V and 5V. It is digitised into an 8 bit (256 level) format. What is the smallest variation in voltage that can be detected?
  - each level is 5V / 256 volts apart
  - = 0.0195V
- 25 seconds of audio is sampled at 44kHz and digitised to 12 bits. What is the final size of the uncompressed audio file?
  - 25 seconds at 44kHz => 1.1×10^6 samples
  - each sample takes 12 bits = 1.5 bytes => 1.65MB

Problems

- A voltage signal contains a wide range of frequencies, the ones of interest are up to 500Hz. What is the minimum sampling rate that can be used? Before the signal can be sampled it must be pre-filtered. What does this achieve? Why is it necessary? In practice, what sampling rate would you recommend?
- A voltage signal contains a range of frequencies, one of which is 350Hz. It is sampled at 500Hz. What happens to the signal at 350Hz?

Problems

- A 16 bit ADC has a range of 0V to 5V and samples at 220kHz. It is preceded by an ideal filter at a frequency determined by the Nyquist criterion.
  - What is the resolution of the ADC? **[76μV]**
  - What is the sensitivity of the ADC? **[13107 V^{-1}**]
  - What is the dynamic range of the ADC in dB? **[48dB]**
  - Draw a curve of the frequency response of the ADC.

Data Communications

- have talked about elements of computer measurement system
- now need to talk about ways in which these are connected together
- main standards:
  - RS232
  - GPIB
  - USB
  - Ethernet
  - wireless

Brief Comparison

Standard	# of devices	Parallel/serial	Speed	Applications
RS-232	2	Serial	<500kbps	Mice,keyboard modems
GPIB	15	Parallel	1Mbps	Scientific instruments
USB	127	Serial	5Gbps	Cameras, printers, flash memory
ethernet	Infinite	Serial	100Gbps	The Internet
wireless	infinite	Serial	54Mbps	The Internet

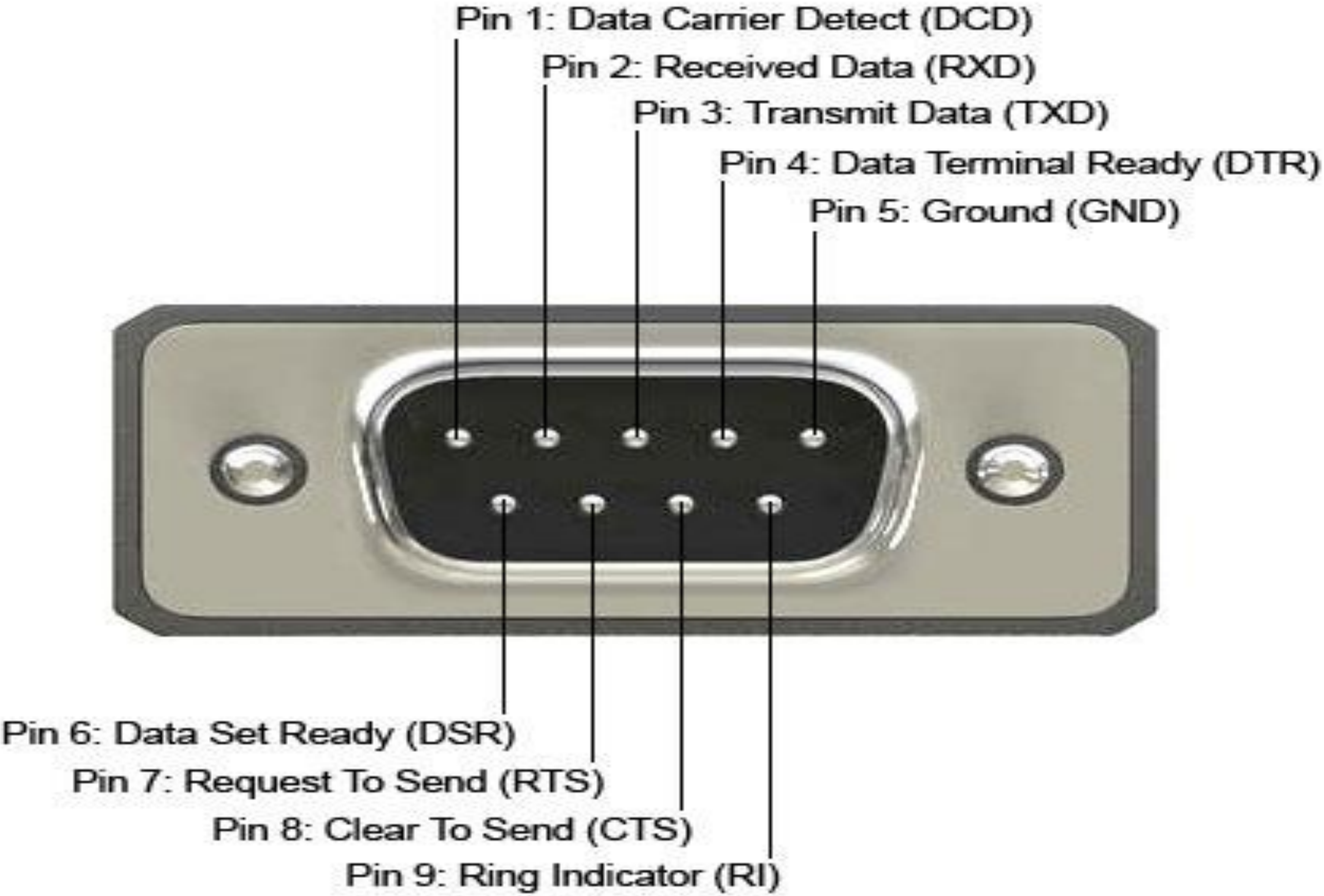
Brief Comparison

- Serial – one data line, each bit follows after the other
- Parallel – several data lines, byte at a time say
- bps = bit per second (=baud)

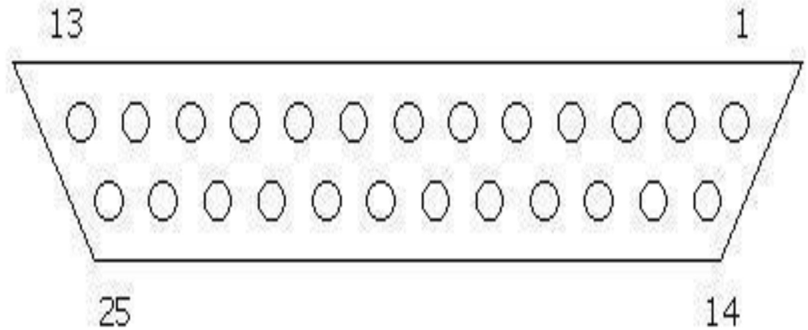
RS-232

- looks like mouse cable
- specifications state minimum of 25 or of 9 wires
- most used for control, for data communication only three important:
  - send
  - receive
  - ground
- devices at either end called DTE and DCE

RS232 Pinout



DB-25 connector:



1. Protective Ground
2. Transmit Data (TD)
3. Receive Data (RD)
4. Request to send (RTS)
5. Clear To Send (CTS)
6. Data Set Ready (DSR)
7. Signal Ground
8. Data Carrier Detect (CD)
9. Reserved
10. Reserved
11. Unassigned
12. Secondary CD
13. Secondary CTS
14. Secondary TD
15. Transmit clock
16. Secondary RD
17. Receiver clock
18. Local Loop back
19. Secondary RTS
20. Data Terminal Ready (DTR)
21. Remote loop back
22. Ring Indicate
23. Data rate detect
24. Transmit clock
25. Test mode

(Fig 2. a)

RS-232 Interface

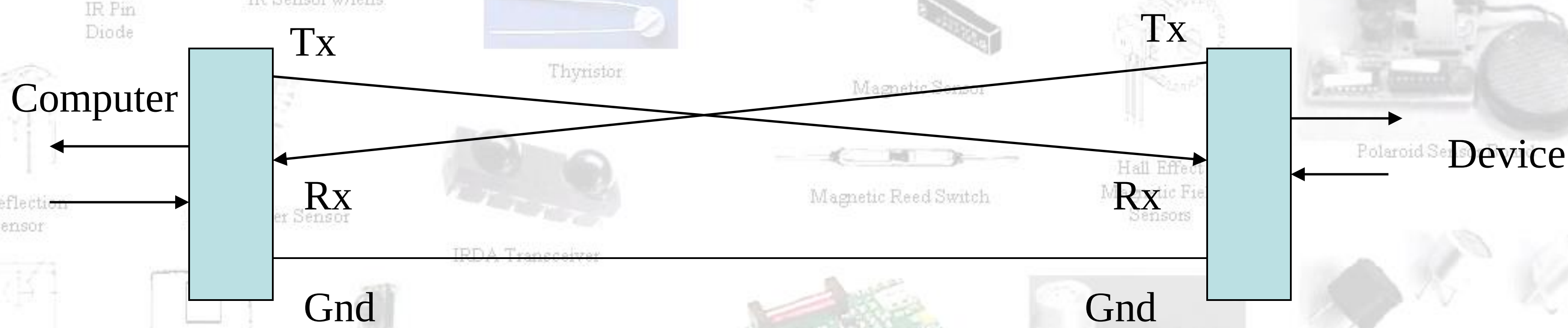
RS-232 is the Serial interface on the PC

Three major wires for the Serial interface:

- Transmit - *Pin 2*
- Receive - *Pin 3*
- Ground - *Pin 7 (25 pin connector)*
  - Pin 5 (9 pin connector)

Note: SR510 switches pins 2,3 internally

HP-Func. Gn. Requires a null-modem cable



Transmit connects to Receive

RS-232 Settings

Computer and device must have the same settings for

- Baud Rate
- Parity
- Stop bits

Baud Rate - data transmitted in bits/second

Parity - Check against faulty data transfer. If used, 8 (typically) data bits sent plus parity bit. Responsibility of device to check parity

Stop Bits - denotes end a data string. Use 2 stop bits with SR510. (Recommended)

RS232 - Data format (SR510)

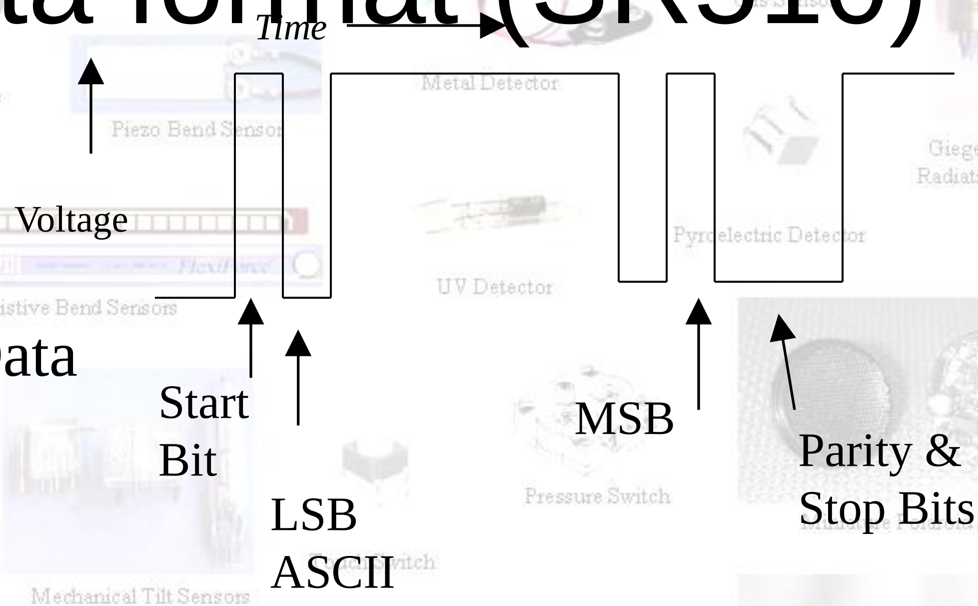
Data Format:

Bit 0: Start bit

Bit 1-8: ASCII code of Data

Bit 9 : Parity Bit

Bit 10-11 : Stop bits



Data is sent LSB first (eg. ASCII A=01000001)

Logic of Data is inverted. Control lines use positive logic

Each ASCII character requires about 12 bits to be transmitted or about 833μs for character.

A string of “G 22<cr>” would require about 4.2msec to be sent.

GPIB

- defined by a standard IEEE-488
- originally HP-IB, now GPIB
- almost universally acceptable, need driver for instrument
- up to 15 devices connected to line, each with unique address 0-30
- listeners / talkers / controllers on line
- data wires / interface management wires / handshake wires

GPIB Configuration

For high data transfer rate, need to limit capacitance in bus system.

- A maximum separatio of four meters between any two devices.
- Any average separation of two meters for entire bus.
- Maximum total cable length of 20m
- Maximum of 15 devices connected to each bus, with at least 2/3 powered on.

For high-speed :

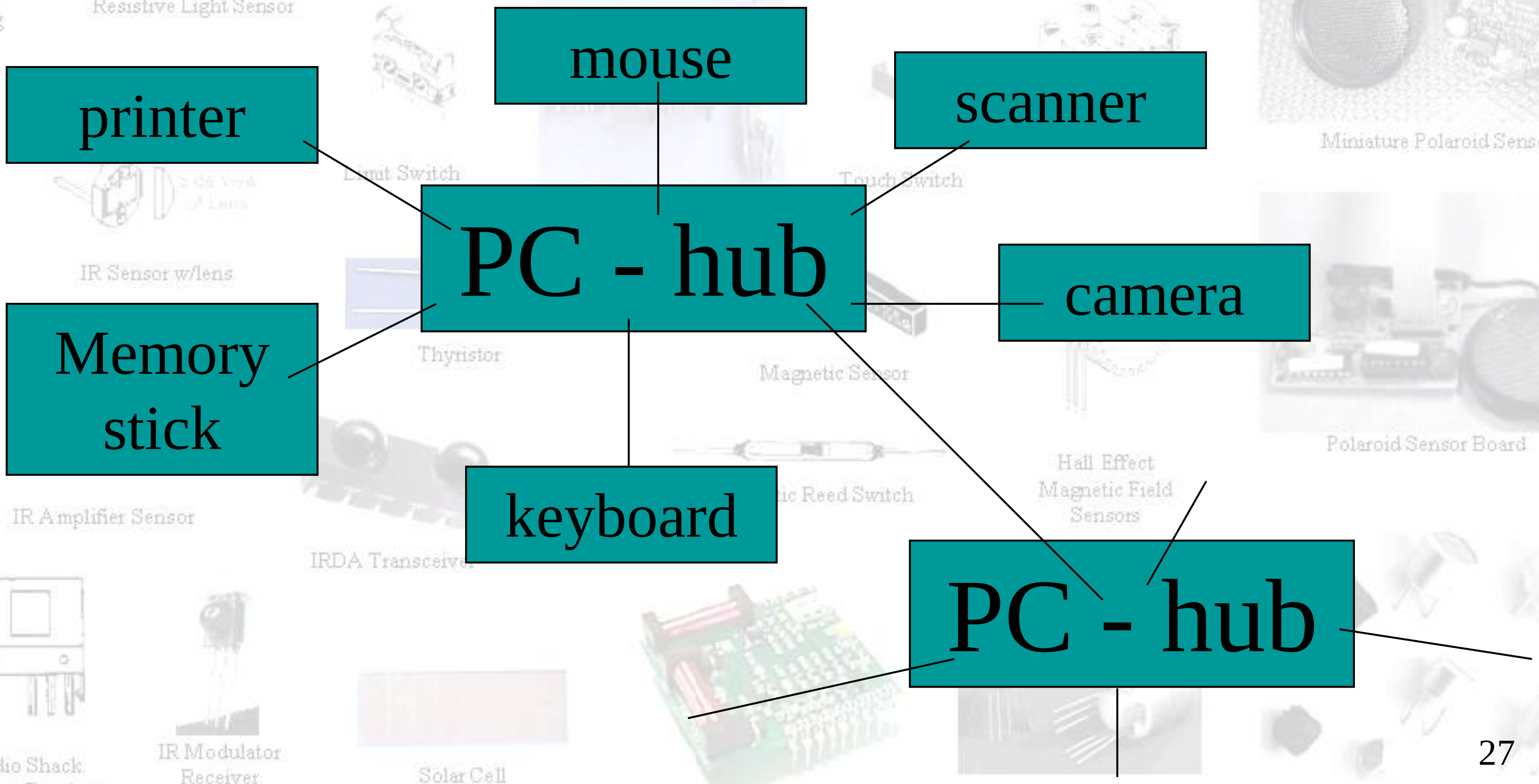
- All devices powered on.
- Cable lengths short as possible (<15m total)
- 1 device per meter of cable (on average).

USB

- Taking over in benchtop lab equipment
- Extension of computer PCI bus
- Old version – USB 1.1 – 1.5Mbps (low and full speed)
- Next version – USB 2 – 480Mbps – backward compatible (High Speed)
- New version – USB 3.0 – 5Gbps (superspeed)
- Four wires
  - 5V and ground, can supply up to 500mA to sensor
  - Twisted pair for signal
- Two types of connector, A and B
- Different sized connectors available (mini, micro, etc)
- Hot swoppable – don't have to reboot machine
- Distances – 4m per cable, total of 25m with multiple hubs
- Doesn't do **Direct Memory Access**, ties up processor (but DMA has security issues)

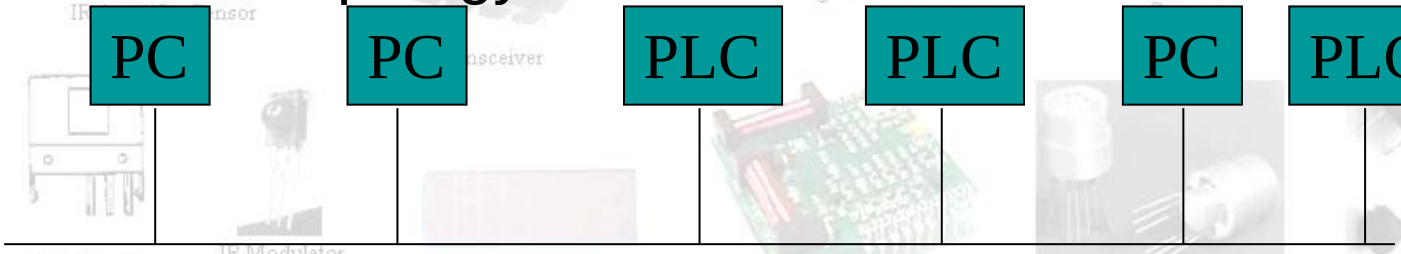
USB continued

- Star topology between hubs



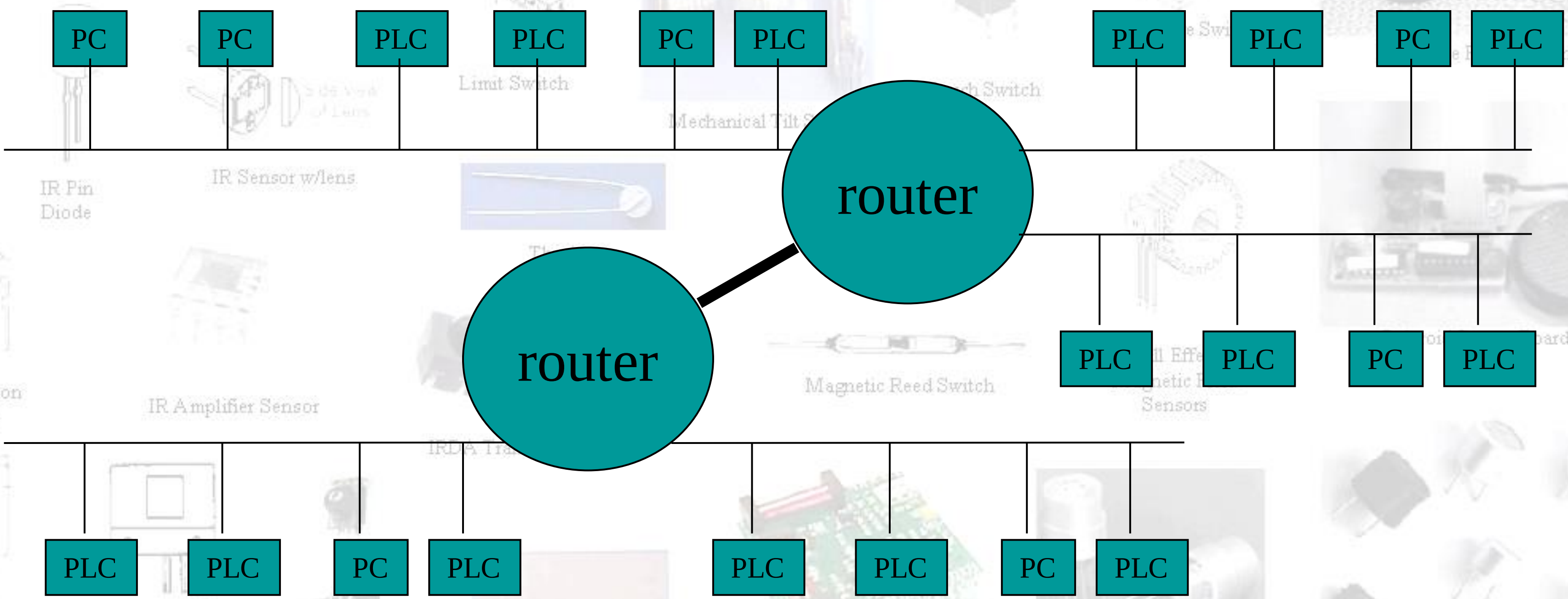
Ethernet

- Typical configuration for computer networks
- Have common backbone wire that all machines talk on
- Every device needs an address – know which information is for each one
- Each ethernet segment can be ~100m’s long
- Each device needs a network card (MAC address and ethernet address)
- These addresses are ~unique to each computer
- IP addresses – something like 193.1.203.157
- All machines on same segment will have related IP addresses
- Backbone topology



Ethernet Continued

- Connect each segment via bridges/routers to get global span
- Routers are the post offices of the internet – determine whether message is local or should be forwarded.



Wireless

- Great technology – no wires to install
- Wireless networks span about 80m
  - 802.11b (WiFi)
    - Frequency: 2.4 - 2.4835 Ghz
    - Rates: 1, 2, 5.5, 11 Mbps
  - 802.11a
    - 5Ghz
    - Faster
    - Up to 54Mbps
  - 802.11g
    - 2.4Ghz
    - Faster
    - up to 54Mbps

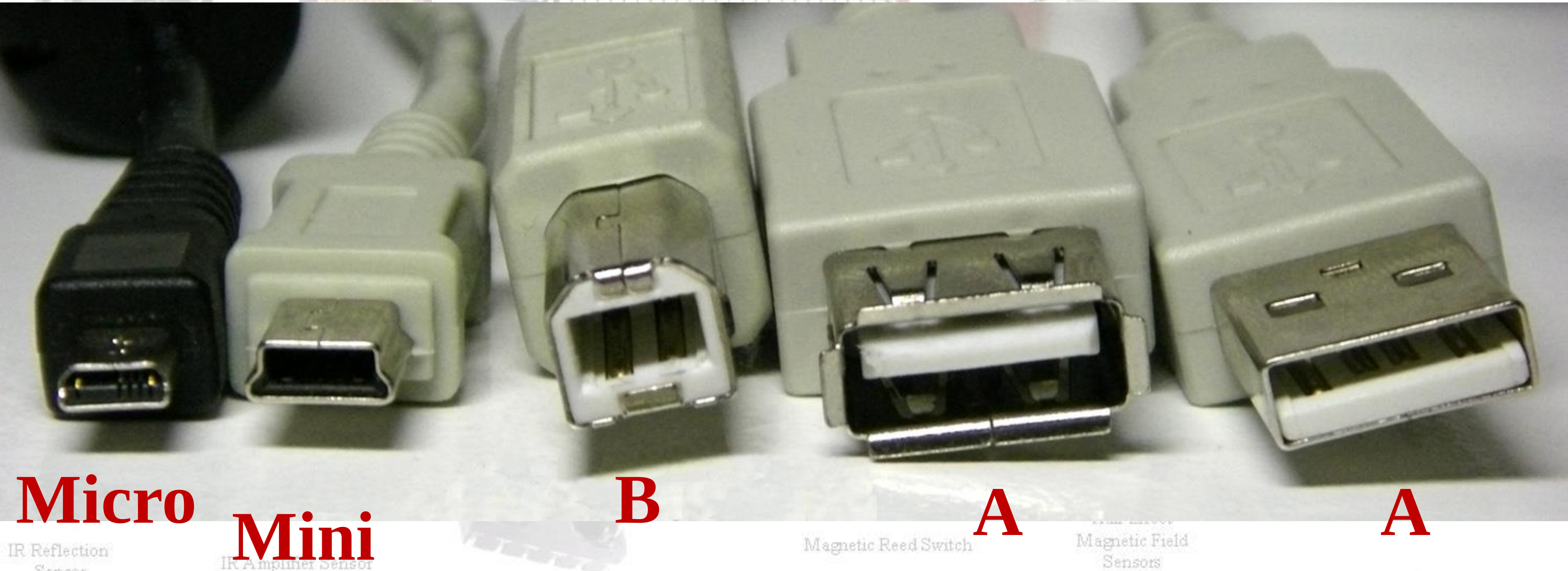
Other Technologies

- Thunderbolt
  - used lots in MAC's
  - Up to 20Gbps
  - Does DMA
  - Based on miniDisplayPort
  - Cables of several metres
  - 20 pin connectors
- FireWire
  - Sony and MAC
  - Supplies power (more than USB)
  - 50Mbps
  - Cables of several metres
  - 4 pin or 6 pin (supplies power) connectors

RS232

GPIB

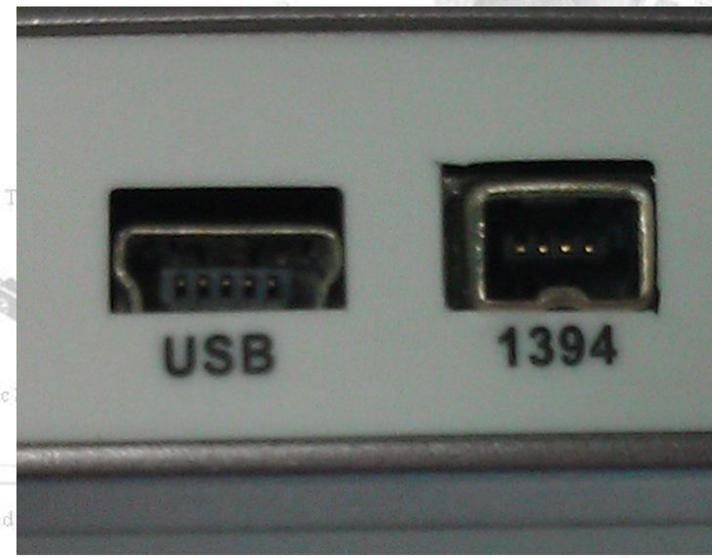
USB



Ethernet

Thunderbolt

FireWire



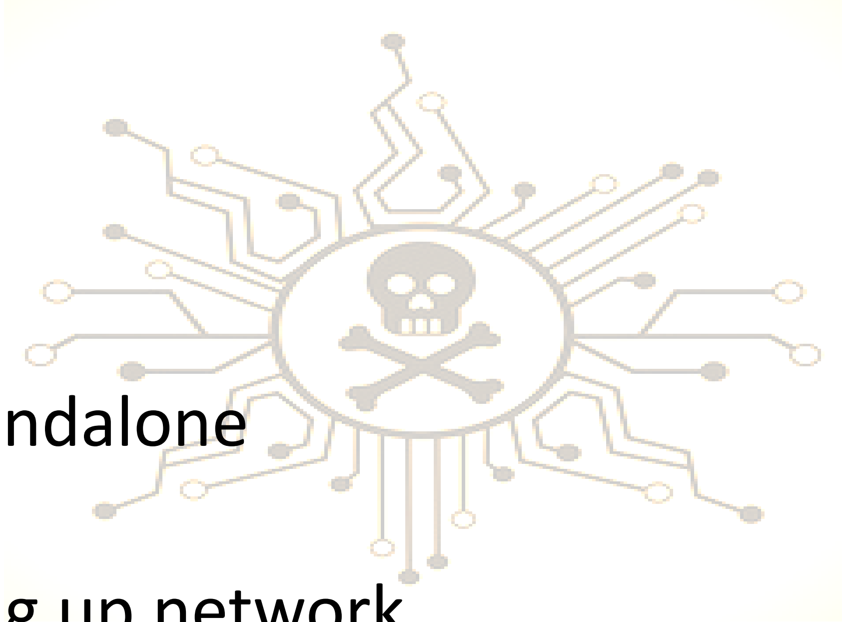
Computer Viruses

- Really called Malware
  - Implies malicious intent
- Comes in different forms
  - Viruses: insert into host programme then replicate themselves
  - Trojan: bona fide programme that contains malicious code
  - Worm: standalone programme that replicates

Computer Virus

- Composed of different bits of code
  - Code to search for vulnerable targets
  - Trigger to activate virus
  - Payload, part of code that does damage like filling storage space, slowing down systems
- Tend to effect computers rather than damaging the actual network
- Types of Virus:
  - Operating system
  - Macros
  - Boot sector
  - emails

Worms

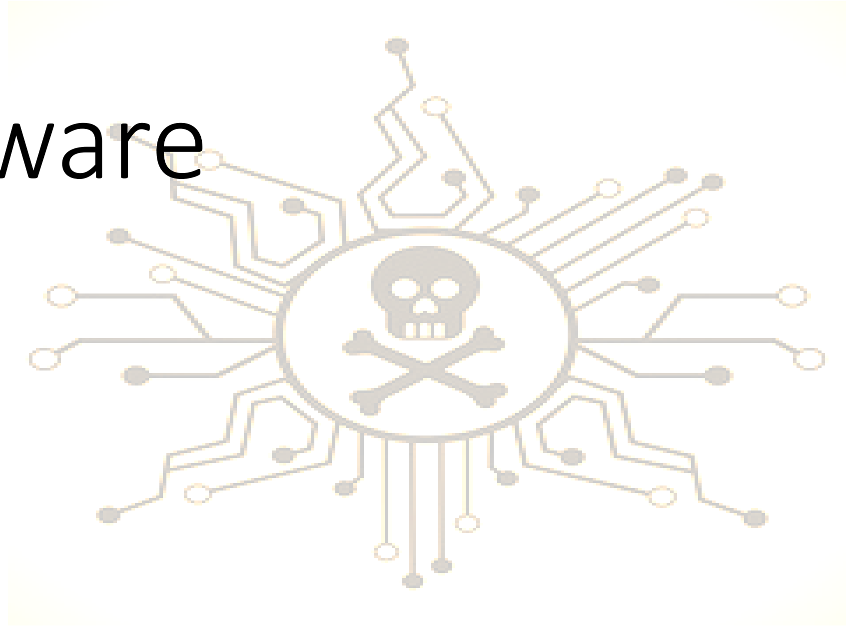


- Unlike viruses, worms are standalone programmes
- Can cripple a network by tying up network connection
  - Denial of service attacks
- Can act as a backdoor, hand over control of computer

Trojans

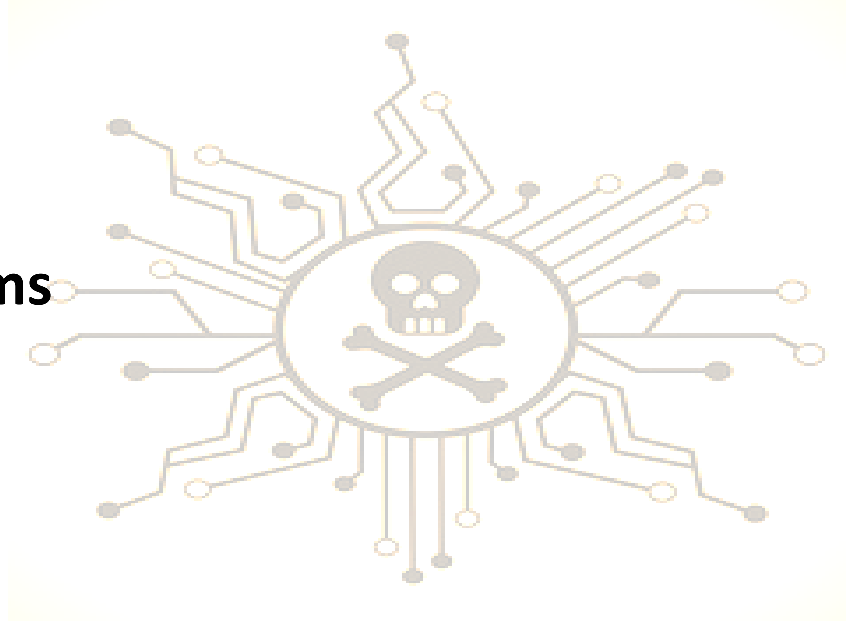
- Innocent looking programme contains a hidden package
- Most common type of malware
- Can access stored passwords and account details
- Ransomware usually takes the form of a Trojan
- Don’t “infect” the computer, spread and copy, in the same ways viruses or worms do

Other Types of Malware



- Ransomware
- Rootkits
- Spyware
- keyloggers

Anti-Virus Software



- **Looks to protect computer systems**
- **Examples:**
  - **Norton from Symantec**
  - **McAfee**
  - **AVG**
- **Methods of detection:**
  - **Look for patterns in computer code**
  - **Let programmes operate in sandbox and search for aberrent behaviour**
- **Won't find everything**
- **Cloud based multi-scanner systems becoming popular**
- **Firewalls aim to limit threats by limiting computer access**

Virus Protection and Recovery

- Keep back-ups
- Careful with unsolicited emails
- Use a firewall
- Use virus scanner but don’t over rely on it
- Careful with internet addresses
  - Can look authentic, but link is to someplace different
- Don’t be fooled by phishing
- Be clever with passwords
- If selling a PC, need to wipe the hard drive, formatting isn’t enough