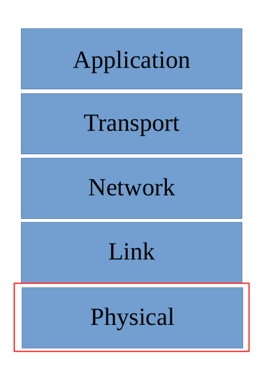
Systems and Devices 2 (Network)
Lec 6: Physical Layer

Before we get started ...

- We have finished looking at network protocols from the software side.
  - No more protocols :)
- The final step down our protocol stack is to the physical layer.
  - Layer 1, the physical cables, hardware.
  - Need to consider how raw data bits are encoded across the communications channel i.e. how electrons move, physics stuff etc.

Internet protocol stack

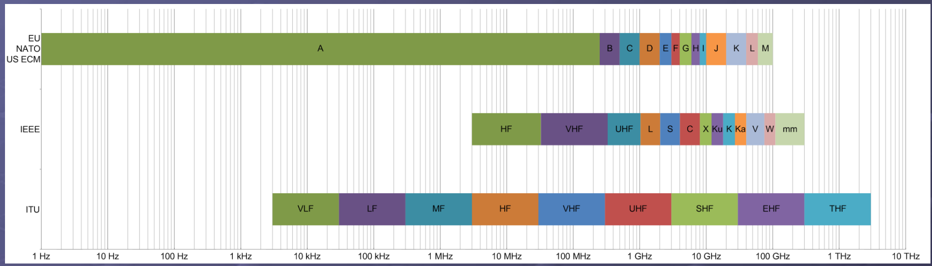


- Application
- Transport
- Network
- Link
- Physical (layer 1)
  - Defines how **bits** within a frame are transferred, link dependant e.g. twisted-pair copper wire or fibre optic cable. Specifies link hardware requirements i.e. distances, voltages, connectors …
    - Category 5 cable (Cat 5) : twisted pair copper cable with RJ45 connectors

Physical layer

- Q : how are our Ethernet frames actually transmitted across our network cables?
  - What bit encoding, connectors, cable, voltages etc are used to transfer our 1s and 0s?
  - What types of problems do we face when transmitting 10,000,000,000 bits per second (10Gbps).

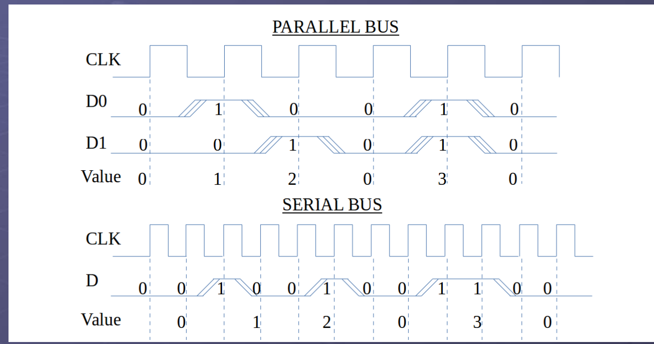
Pause to consider



Cellphone, Microwave links, Radio stuff

- Q: 10,000,000,000 bits per second (10Gbps), does this mean that data is changing on the wire 10,000,000,000 times a second?

Back to basics ...



- Synchronous parallel or serial buses
  - Clock + one or more data lines
- Asynchronous bus = no clock signal
  - Therefore, need a protocol to synchronise TX and RX hosts.

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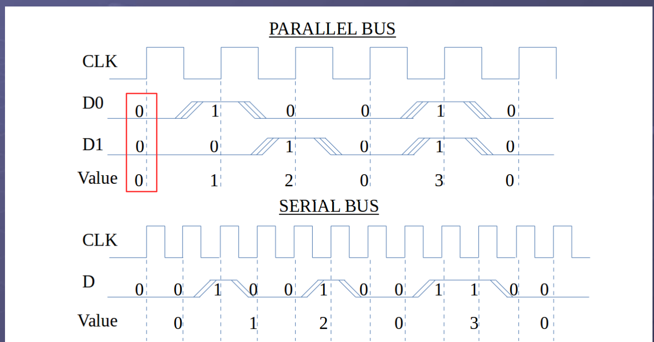

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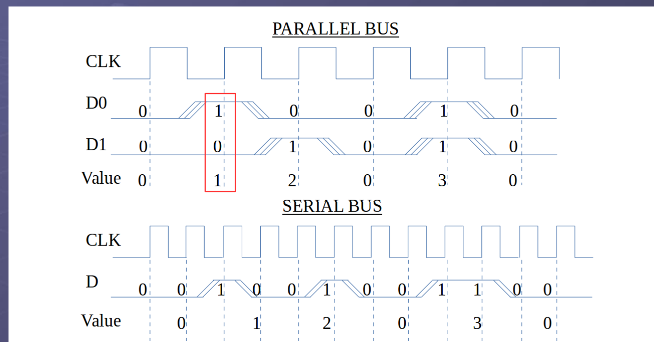

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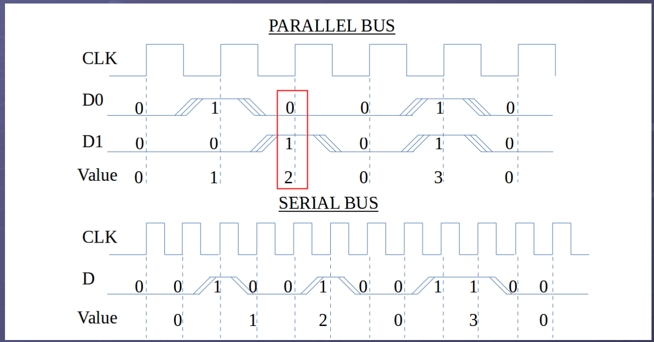

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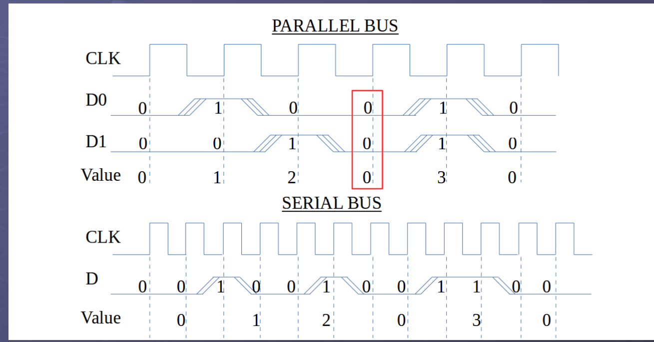

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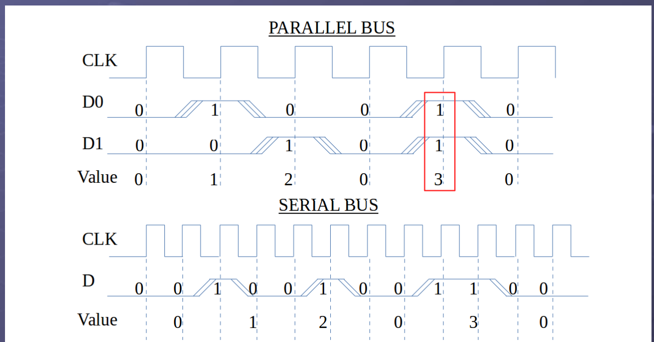

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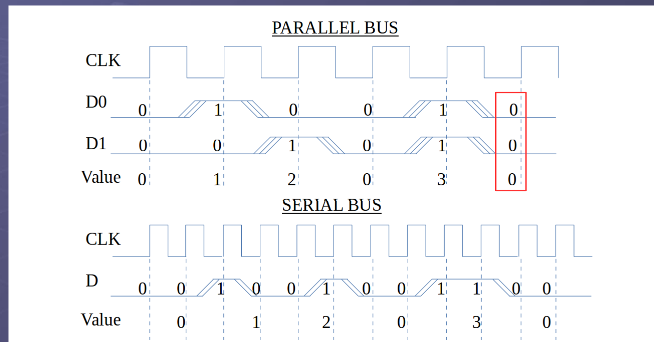

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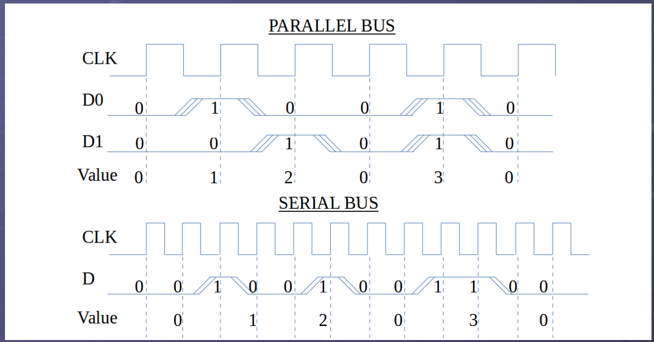

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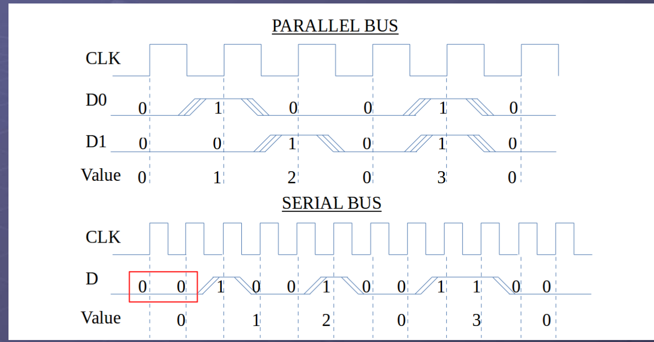

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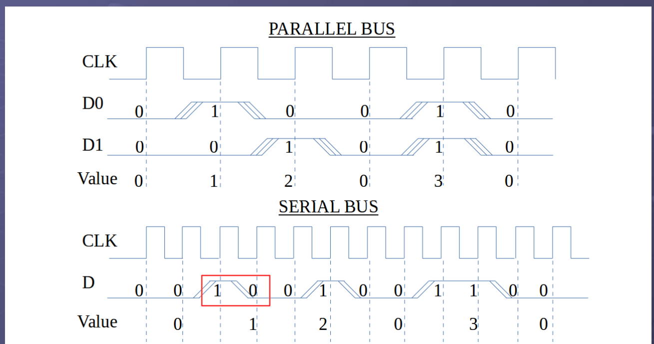

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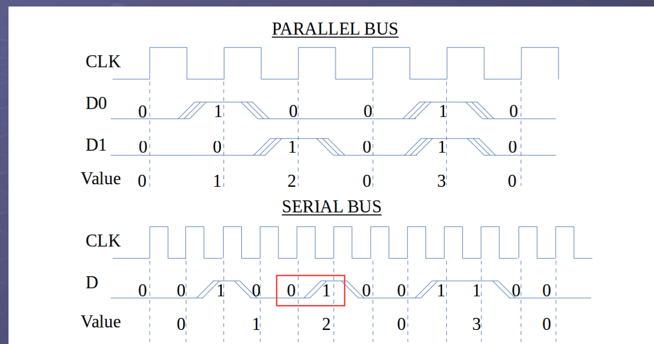

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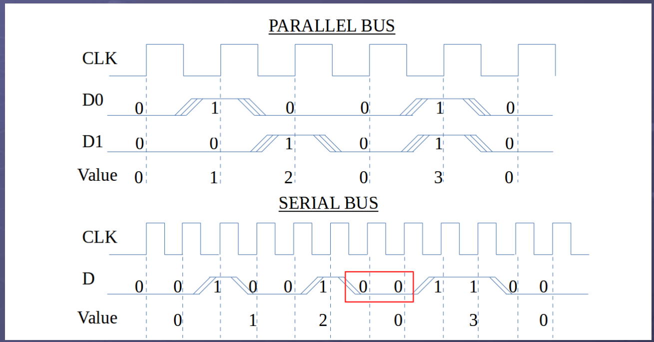

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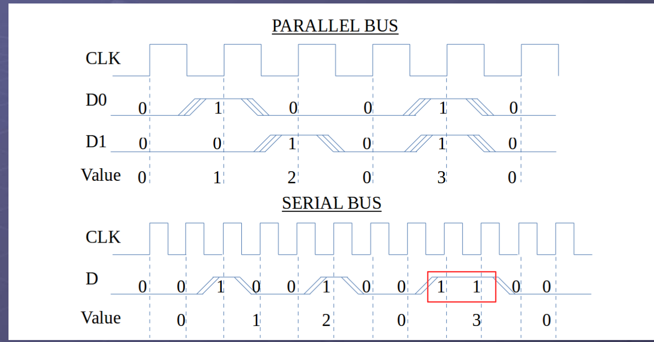

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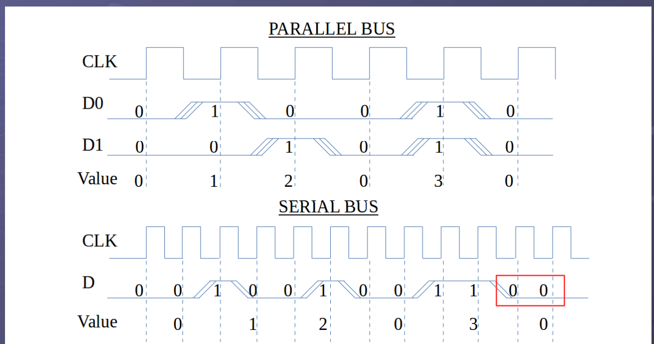

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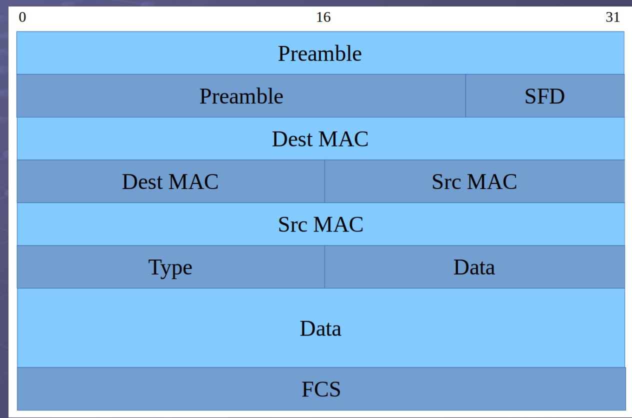
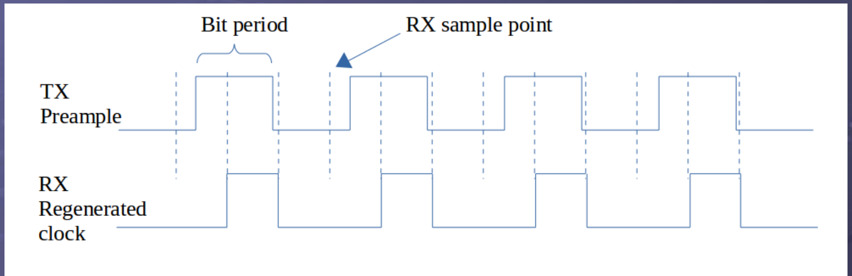
Ethernet frame



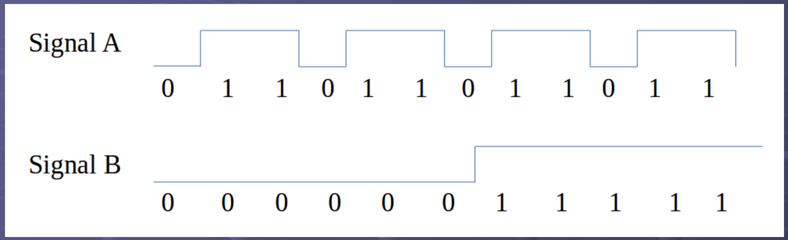
- Preamble : 56 bits (7 bytes) of alternating 1' and 0's

Clock synchronisation



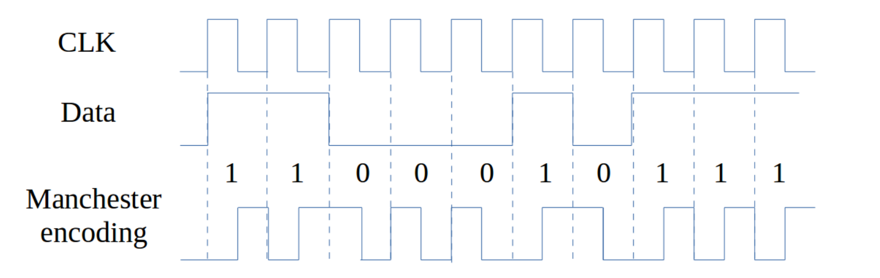
- At the beginning of a transmission TX host outputs an alternating pattern of 1s and 0s. The RX host samples this signal to determine the TX clock speed
  - End of pre-amble is signalled by the Start of Frame Delimiter (SFD) : 10101011

Problems ...



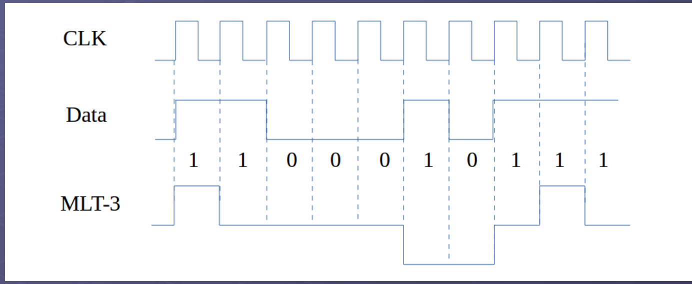
- RX host loosing synchronisation
  - Not too bad for signal A i.e. regular transitions allowing RX host to resynchronise However, signal B has long strings of 0s and 1s, no synchronisation points.
- Where do data bits start and end?
  - Non Return to Zero (NRZ) encoding.

Solution?



- Manchester encoding (self clocking encoding)
  - Phase encoding : logic 1 represented by a 0 to 1 transition, logic 0 represented by a 1 to 0 transition.
  - Used in older 10BaseT networks. Disadvantage for long strings of 1s or 0s increased cable signal frequency.

Solution?



- Multi Level Transmit (MLT-3)
  - Rather than using just 0V and +V to encode data bits we can use 0V, +V and -V. Helps prevent DC bias.
  - Logic 1 encoded by a repeating sequence : -V, 0V, +V, 0V. Logic 0 encoded by maintaining the same state. Disadvantage, no change for long strings of 0s.

Solution?

- 4B5B encoding
  - To help reduce the occurrence of long strings of 0s encode each nibble using a five bit key (string).
  - Worst case is now three 0s
  - Used in 100Base-TX

Data (Hex)	Data (Binary)	4B5B code	Data (Hex)	Data (Binary)	4B5B code
0	0000	11110	8	1000	10010
1	0001	01001	9	1001	10011
2	0010	10100	A	1010	10110
3	0011	10101	B	1011	10111
4	0100	01010	C	1100	11010
5	0101	01011	D	1101	11011
6	0110	01110	E	1110	11100
7	0111	01111	F	1111	11101

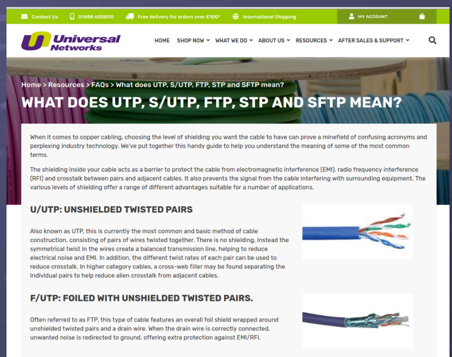
Ethernet cables

Name	IEEE Standard	Speed	Cable
10BASE-T	802.3i	10Mb/s	Cat 3
100BASE-TX	802.3u	100Mb/s	Cat 5
1000BASE-SX	802.3z	1Gb/s	Multi-Mode Fibre (MMF)
1000BASE-T	802.3ab	1Gb/s	Cat 5e
10GBASE-SR	802.3.ae	10Gb/s	Multi-Mode Fibre (MMF)
10GBASE-T	802.3an	10Gb/s	Cat 6A / Cat 7
40GBASE-T	802.3bq	40Gb/s	Cat 8
100GBASE-SR4	802.3bm	100Gb/s	Laser MMF

- Different Ethernet standards
  - Q : what allows different cables to work at different speeds?

Ethernet cables

- A : the faster the cable the more shielding needed to reduce noise e.g. cross talk.
- Standardised around an eight wire cable i.e. four twisted pairs
- When looking at cables what do these acronyms mean: UTP, FTP, STP, SFTP, UFTP, FFTP, SFTP, SFFTP, arrrr can you name them all :)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Home > Resources > FAQs > What does UTP, S/UTP, FTP, STP and SFTP mean?

WHAT DOES UTP, S/UTP, FTP, STP AND SFTP MEAN?

When it comes to copper cabling, choosing the level of shielding you want the cable to have can prove a minefield of confusing acronyms and perplexing industry technology. We've put together this handy guide to help you understand the meaning of some of the most common terms.

The shielding inside your cable acts as a barrier to protect the cable from electromagnetic interference (EMI), radio frequency interference (RFI) and crosstalk between pairs and adjacent cables. It also prevents the signal from the cable interfering with surrounding equipment. The various levels of shielding offer a range of different advantages suitable for a number of applications.

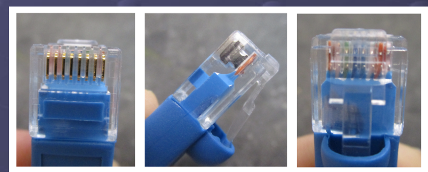
U/UTP: UNSHIELDED TWISTED PAIRS

Also known as UTP, this is currently the most common and basic method of cable construction, consisting of pairs of wires twisted together. There is no shielding, instead the symmetrical twist in the wires create a balanced transmission line, helping to reduce electrical noise and EMI. In addition, the different twist rates of each pair can be used to reduce crosstalk. In higher category cables, a cross-web filler may be found separating the individual pairs to help reduce alien crosstalk from adjacent cables.

F/UTP: FOILED WITH UNSHIELDED TWISTED PAIRS.

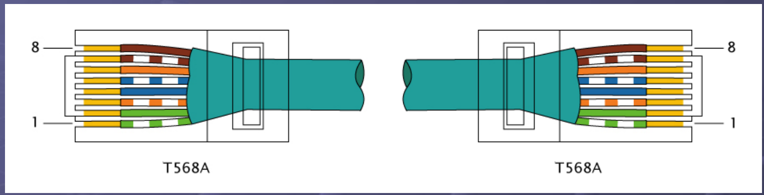
Often referred to as FTP, this type of cable features an overall foil shield wrapped around unshielded twisted pairs and a drain wire. When the drain wire is correctly connected, unwanted noise is redirected to ground, offering extra protection against EMI/RFI.

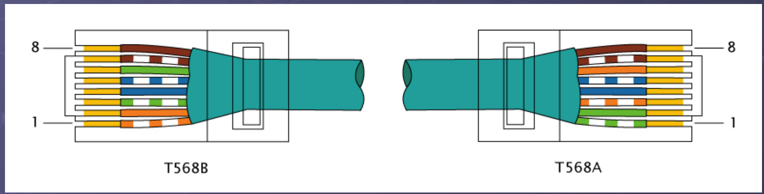
Ethernet cables



- RJ45 connector
  - Registered jack, 8 pin, 8 contact (8P8C)
  - Crimps onto the eight wires within the cable

Cable types



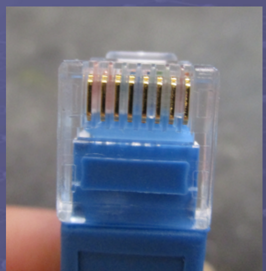


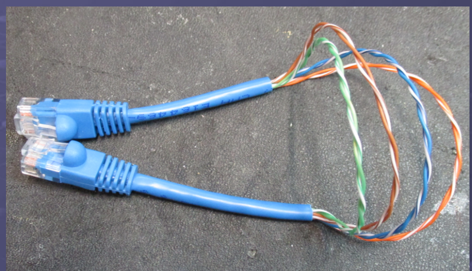
- Straight-through (patch) and crossover
  - Two common wiring schemes : T568A or T568B

Cable types

- In the old days, when connecting two 100Base-TX NICs together using a direct network cable i.e. not via a switch/router you needed to use a crossover cable.
  - Connect TX on one host to the RX on the other.
- With the introduction of 1000Base-T, auto-negotiation is now normally used i.e. pins are bi-directional, connected hardware detected using Link Integrity Tests (LIT)
  - To detect when a cable is plugged in, Normal Link Pulse (NLP) are transmitted down the cable, allowing hosts to transfer code words to identify what 802.3 standards its supports i.e. cable is always "busy".

Ethernet cables

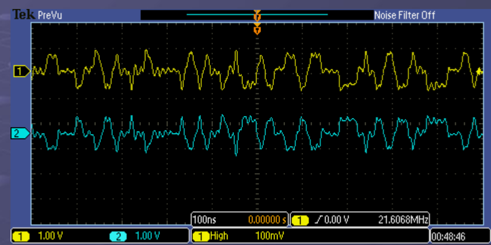


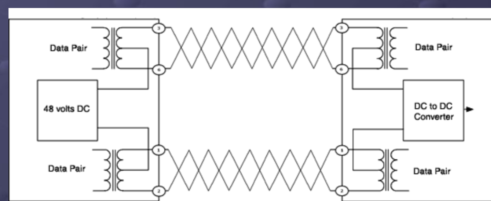


- Q : why do we typically use Cat5 Unshielded Twisted Pair (UTP) cables?
- Q : the 100Mb/s network in the lab uses 100Base-TX using MLT-3 4B5B encoding, but how are these "bits" transmitted down the cable?

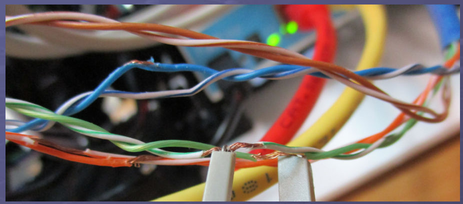
Problems ...

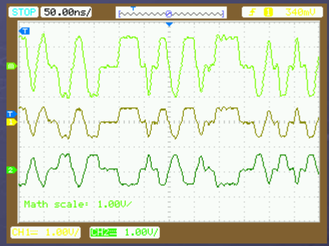
- Noise
  - Cross-talk, interference from other cables
    - Full duplex so can transmit and receive at the same time
  - External electromagnetic interference can cause Single Event Upsets (SEU) i.e. bit flips





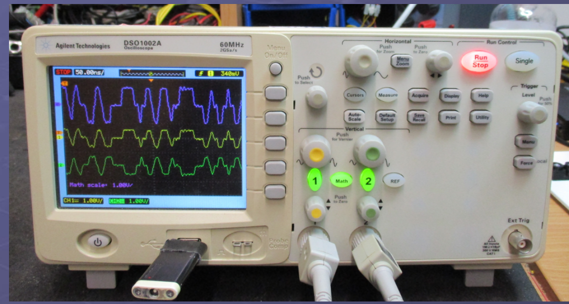
Solution?





- Differential signalling
  - Transmit the data and its complement down a twisted pair e.g. TX+ and TX-. Electromagnet fields “cancel” out.
  - External noise will be picked up on both cables, therefore subtracting these two signals will remove noise and reinforce the data signal.
    - A - -A = 2A

Demo



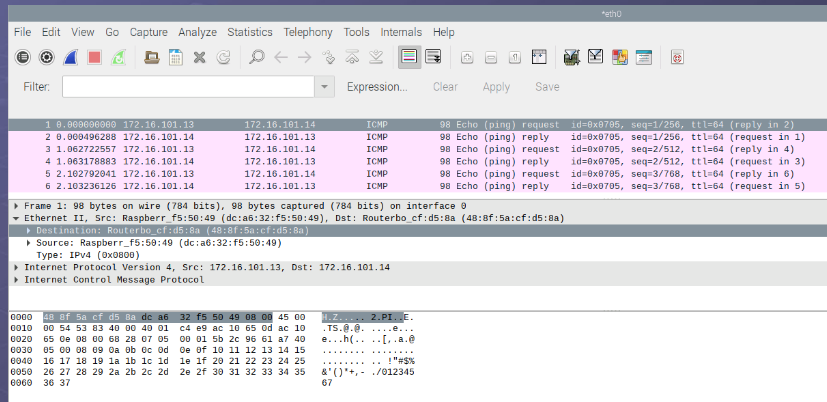
Pin	Description	100Base-T	1000Base-T4
1	Transmit Data+ or BiDirectional	TX+	BI_DA+
2	Transmit Data- or BiDirectional	TX-	BI_DA-
3	Receive Data+ or BiDirectional	RX+	BI_DB+
4	Not connected or BiDirectional	n/c	BI_DC+
5	Not connected or BiDirectional	n/c	BI_DC-
6	Receive Data- or BiDirectional	RX-	BI_DB-
7	Not connected or BiDirectional	n/c	BI_DD+
8	Not connected or BiDirectional	n/c	BI_DD-

- 100Base-TX (Fast Ethernet) only uses two twisted pairs (4 wires) i.e. one pair for transmit, one for receive. Pins 1,2,3 and 6. (all four twisted pairs used for Gbps)
  - Problem : encoding used is hard to read off scope :(

Demo

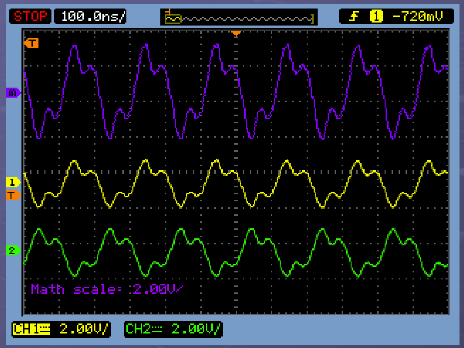
- Solution, convert 100Base-TX to 10Base-T by passing the connection through an old 10Base-T hub :)
  - This uses “simple” Manchester encoding.
  - Also removes line integrity test signals.
- To see what network standard an interface is using, you can run the command line tool:
  - `ethtool <NIC>`

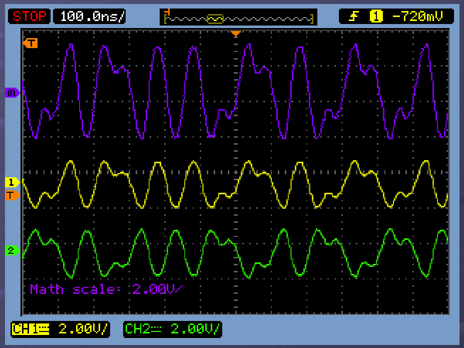
Demo



- Test data : Ping
  - We should see this data on the scope, maybe :)

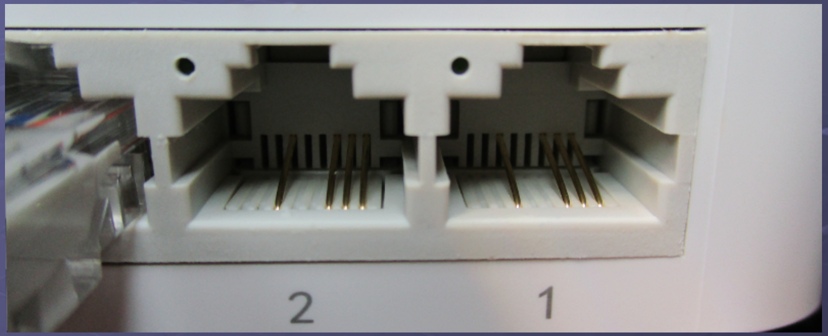
Demo





- Can you see the matrix?
  - -V → +V = 1
  - +V → -V = 0

Final Quick Quizzz



- What Ethernet standards does this switch <u>not</u> support?

Summary

```
 _______________________________________
/ Our journey down the Internet protocol \
\ stack is now “complete”                /
 ---------------------------------------
        \   ^__^
         \  (oo)\_______
            (__)\       )\/\
                ||----w |
                ||     ||
```

- SYS2(NET) is only an introduction to networking, there are a lot more protocols and hardware out their …