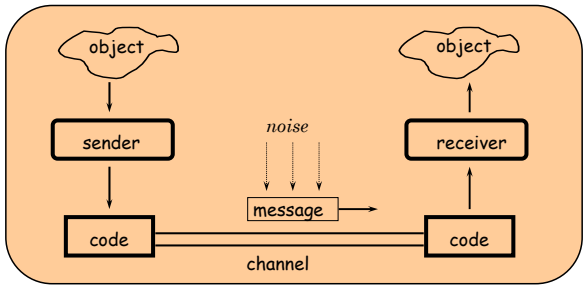
Communication

Digital Information Exchange in Mechatronic systems



Outline:

- Basic concepts about communication
- The OSI-model
- Communication application in mechatronics
- Circuit board communication
- Physical layer – Standards and examples
- Data link layer functions

Some terms

- Bandwidth, W (3 dB attenuation)
- Information, $I=\log_2 N$ (bits). (N:number of symbols)
- Capacity (bits/s) - [Baud (symbols/s)]
- Max. Cap. = $W \log_2(1+S/N)$ (theoretical)

e.g. Your home PC

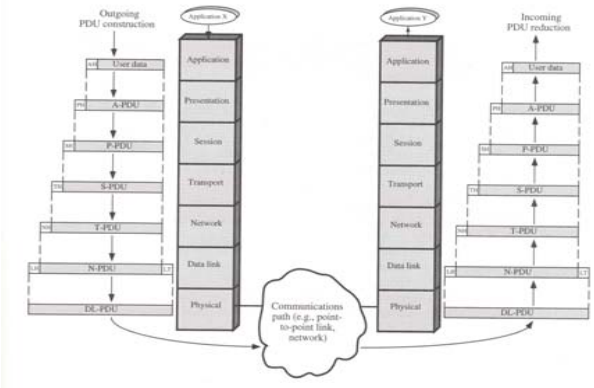
Consider your own PC at home. Try to figure out, how many different types of digital communication channels it contains. Include both those for external connection and those internal ones you know of.

The OSI model

(Open System Interconnection)

- ISO 7498 (1984)
- A model, a framework – not a standard for communication
- Layer-based
- 7 layers

OSI - the layer structure



Picture from:
Data & Computer Communications
William Stallings

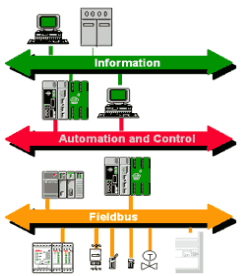
The 7 OSI Layers

1) Physical
   Electrical and physical interface
2) Data link
   Error detection/correction
   Data link protocols e.g. HDLC
3) Network
   Complete path between nodes
4) Transport
   In sequence, error free, no losses or duplicates
5) Session
   Remote login. Dialogue discipline (full/half duplex)
6) Presentation
   Data formats e.g. JPEG, TIFF
7) Application
   File transfer. Database queries.

Fundamental OSI principles

- Only physical connection at layer 1
- Attention only to adjacent layers
- Only necessary layers used
- Peer-to-peer : Virtual horizontal communication in the model

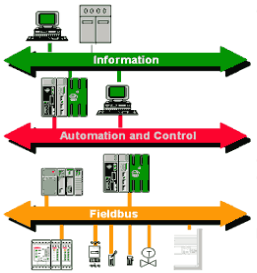
What's relevant for Mechatronics? - 1



Application	Network size	Amount of data	Reaction time	Costs
LAN,WAN	high	Very high	1 s	high
Control + Automation	medium	high	100 ms	low
intelligent decentralized I/O	small	medium	10 ms	low

Picture from:
HMS Industrial Networks

What's relevant for Mechatronics? - 2



Open Industrial networks

Ethernet, Ethernet IDA, Ethernet/IP

Ethernet, Profinet, Ethernet/IP, IDA, Profibus-FMS, Profibus-DPV1, ControlNet, Modbus, Canopen, Pnet, Foundation Fieldbus HSE, CC-Link, FL-Net, JPCN-1

Profibus.DP, AS-Interface, DeviceNet, Interbus, FIPIO, Sercos, CAN, Profibus-PA, Foundation Fieldbus H1, Lonworks, EIB, SDS

Picture from:
HMS Industrial Networks

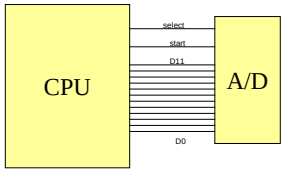
What's relevant for Mechatronics - 3


Ny "bladare" bygger på I²C

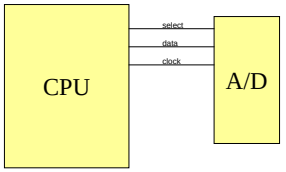
- 5(!) microcontrollers in one camera
- They have to cooperate!
- Communication ?

Circuit Board communication

Classic design



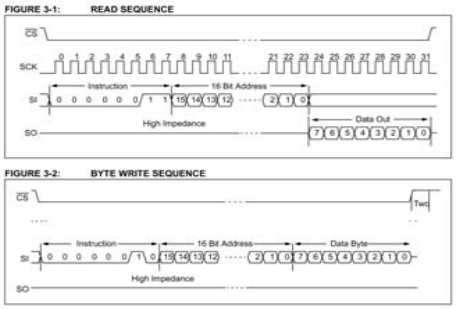
Serial bus design



Serial Buses - Advantages - Products

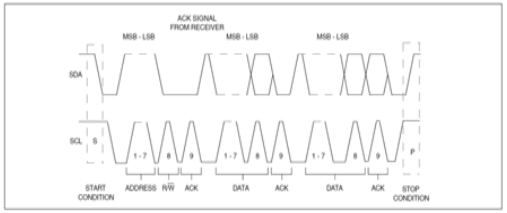
- Bi-directional command & data
- Few wires
- Small circuits
  e.g. a 12 bit A/D in an SO-8
- Inter-CPU communication
- High speed (~1Mbit/s)
- Also applicable to memories and other devices
- I2C (Philips)
- SPI (Motorola)
- Microwire (National Semiconductor)

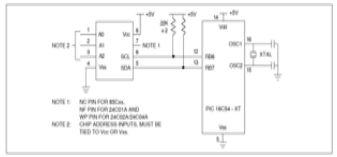
SPI Product Example



64k SPI EEPROM

I2C Product Example



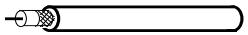


Physical Layer - Media

Optical fiber

Twisted pair (TP)

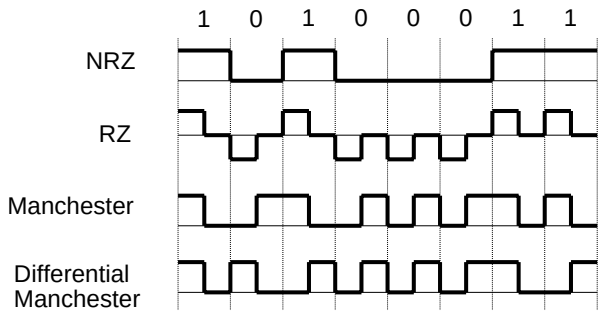
Coaxial cable



Physical Layer - Signals

- Voltage
- Current
- Light
- Bit encoding can also be more complex…

Bit Coding Principles



Data Link Layer Principles

- Parity (even or odd)
- Checksum
- CRC - Cyclic Redundancy Check (binary polynom used for error detection)
- Error correction can be implemented

Data Link Layer - HDLC

High-level Data Link Control

Field #	length, bits	value	description
1	8	01111110 (7E hex)	start flag
2	8		address
3	8		control field
4	any length ≥0		data
5	16		checksum
6	8	01111110 (7E hex)	end flag

How can we be sure that the data don't contain the "end flag"?

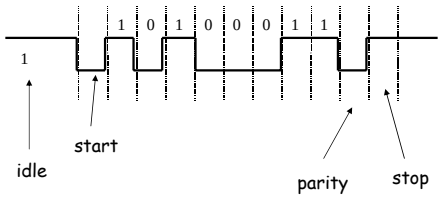
HDLC solves this with "bit-stuffing"!

Some Physical Layer Examples...

EIA232 (RS232)

- Simple point to point connection
- Serial data communication
- Signal levels:
  - +3 to +25 V means 0
  - -3 to -25 V means 1
- Low speed (<150kbit/s)
- EIA562 (allow low level), EIA574 (9-pole) in PC

EIA232 continued



Logical levels indicated

Due to coding this will appear inverted on an oscilloscope

USB - Universal Serial Bus

- Bus topology
- Hotswap
- Low cost
- 4-wire twisted pair (supply included)
- 12 Mbit/s (USB 1.1) 480 Mbit/s (USB 2.0)
  5 Gbit/s (USB 3.0)
- www.usb.org

Designing With USB Made Easy

- USB to serial
- Driver for OS (Win) included
- Appears as a serial port (COMx)
- http://www.ftdichip.com/

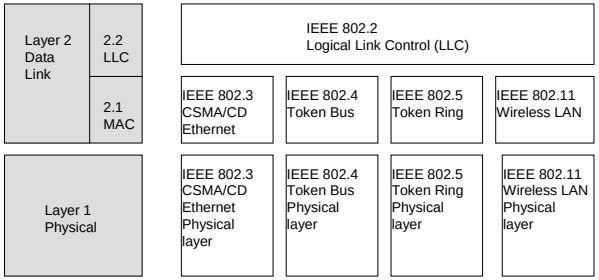
FireWire IEEE1394

- Bus topology
- Hotswap
- 400 Mbit/s, (800 Mbit/s) (peer to peer)
- Applications: video cameras, VCR, scanner, CD, DVD, hard disk
- www.firewire.org (Apple)

Communication
part 2

- LAN - Ethernet
- TCP/IP
- Control loop via network – a real time problem
- Fieldbuses

LAN - Local Area Network IEEE-standards

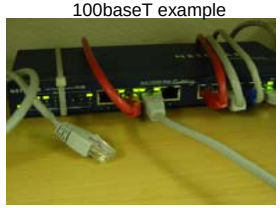


Ethernet - physical layer

- Various media
  - Thick ethernet (10base5)
  - Thin ethernet, cheapernet (10base2)
  - TP, RJ45 (10baseT), kat5 (100baseT), kat5E (1000baseT), kat6a (10Gbase-T)
- Manchester coding

10base2 example

100baseT example



Wireless LAN

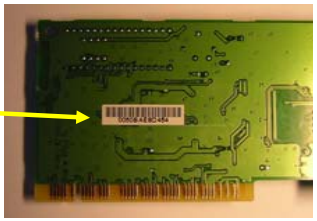
- IEEE 802.11b (1, 2, 5.5, 11Mbps)
- IEEE 802.11g (54 Mbps)

- IEEE 802.15 Bluetooth
  - Piconet / Scatternet
  - 64kbps SCO, 721kbps ACL

Ethernet - data link

- CSMA/CD
  - Carrier-Sensing Multiple Access/Collision Detection
- MAC-address
  - Medium Access Control
  - 48 bit hardcode unique number

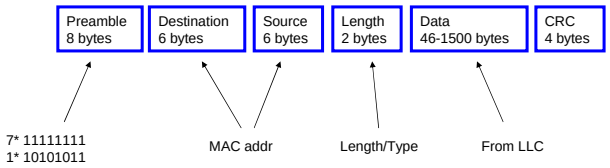
MAC address



CSMA/CD

- Carrier-Sensing (check that the line is free)
- Multiple Access (begin a new transmission)
- Collision Detection (detect if the information is garbled)
- Some 50 μs travel time = time slot
- No real time guarantee!

The Ethernet Packet

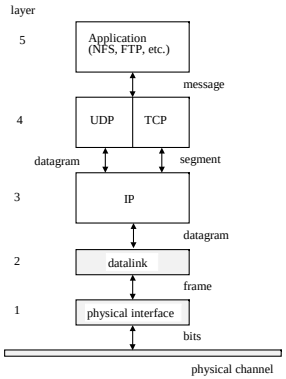


TCP/IP

Transmission Control Protocol/Internet Protocol

- IPS (Internet Protocol Suite) is the full name. TCP and IP are just included protocols
- 5 layer structure
- Defined and revised by the users
- Layers 1 & 2 not covered. Assumed to exist
- Layers 3 & 4 similar to OSI 3 & 4 def.
- Layer 5 (application) not comparable to OSI

IPS (TCP/IP)



IP layer

- Responsible for moving datagrams from one point to another
- unique, multicast or broadcast
- IP address 32 bits, Four 8-bit blocks, 0-255 (134.34.6.222)
- IPv4 today - IPv6 is defined

IP Datagram (IPv4)

Version 4 bits	Internet Header Length 4 bits	Type of Service 8 bits	Tot Length 16 bits
Identification 16 bits	Flags 3 bits	Fragment Offset 13 bits	
Time to Live 8 bits	Protocol 8 bits	Header Checksum 16 bits	
Source Address 32 bits			
Destination Address 32 bits			
Options & Padding 32 bits			
Data (variable length)			

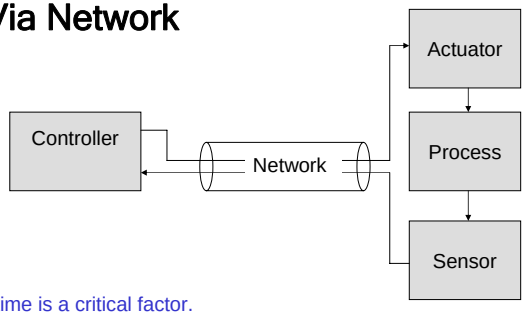
TCP

- Single source – single destination
- Establish connection, transfer data, close connection
- Acknowledgement, retransmission
- Provide services for FTP,SMTP, TELNET
- TCP header

UDP

- Connectionless - unreliable
- Multicast and broadcast
- Applications
  - Data collection
  - Data presentation
  - Real time applications (audio)
- UDP header – less complex

Feedback and Control Via Network



In mechatronics time is a critical factor.
Will this structure work?

Mechatronic system

Fieldbus

- Replace analog signals (cables) with a network
- Advantages
  - Easy installation
  - Simple maintenance
  - Less connection errors
  - Easy debugging
  - Simple reconfiguration
- Requires a new competence

Fieldbus Requirements

- Noise immunity
- Fast
- Real time performance (deterministic)

Fieldbus Features

- "The industrial automation LAN"
- About 100! different buses aiming at different applications (cars, discrete manufacturing, continuous production).
- "Smart" nodes
- Not only sensor and actuator signals

Some Fieldbuses

- ASI
- PROFIBUS
- CAN
- DeviceNet
- ControlNet
- Interbus-S
- FIP
- Fieldbus Foundation

Overview information links:

http://www.weighing-systems.com/TechnologyCentre/fieldbus1.html

http://www.pacontrol.com/download/fieldbuscomp.pdf

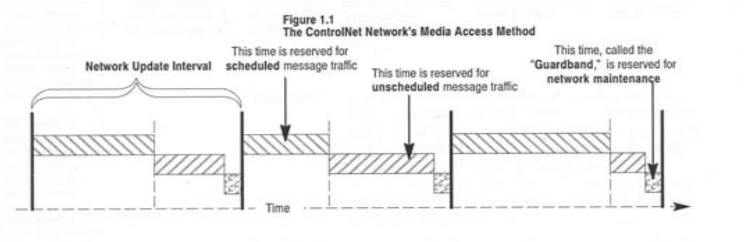
PROFIBUS

- DP, PA, FMS (Decentr. Periph. ; Proc. Aut.)
- Token bus with master/slave
- 500k-12Mbit/s
- RS485
- Max 127 nodes (PA 256)
- http://www.profibus.com

Most Fieldbuses are not deterministic by design!

- The fieldbus definitions include no tool for direct timing control.
- Token passing principles together with maximum data block size provides the real time performance.

ControlNet Timing



Deterministic Fieldbus Examples

- ControlNet http://www.controlnet.org
- TTP http://www.tttech.com, http://ttpforum.org
- Foundation Fieldbus http://www.fieldbus.org

Ethernet TCP/IP a fieldbus?

- Not by design!
- Today it is starting to be (mis-)used
- High performance – Low cost
- Speed and limited load compensates for real time performance and determinism
- Development of "Lean TCP/IP stacks"

Ethernet Encapsuled Fieldbus

- E.g. Ethernet/IP – (DeviceNet oriented but in Ethernet data frames http://www.odva.org/)
- Full use of the standard and available equipment
- Not strictly real time but high performance and segmentation (switching) give real time performance.

Ethernet Slightly Redefined Fieldbus

- E.g. EtherCAT (http://www.ethercat.org/) Beckhoff
  - CSMA/CD replaced (master/slave)
- E.g. ThrottleNet (http://www.lucas.lth.se/)
  - Bandwidth limitations to ensure real time traffic
- Ethernet standard is used as far as possible without affecting real time performance.