Measurement from tables: $U_V = V * X\% + (2 \text{ or } 3)$ * resolution (if DC / AC)

$P_V = \frac{U_V}{V}$ $P_I \leq \frac{U_I}{I}$ $U_C = \sqrt{P_V^2 + P_I^2}$ $U_R = R * U_C$

Sensors: **Resistive Sensors:** $R = \rho \frac{L}{A}$, $GF = \frac{dR/R_0}{\varepsilon}$

Capacitive: $C = \varepsilon_0 \varepsilon_r \frac{A}{d}$, application: distance (for distance < sensor's diameter), acceleration, & pressure sensor.

Capacitive pressure sensor: Uses a pressure sensitive diaphram as one electrode, whereas the other electrode is fixed.

Inductive sesor: based on Faraday's law of induction; $U(t) = -L * \frac{di}{dt}$, Most important advantage of inductive proximity sensor: Doesn't require physical contant.

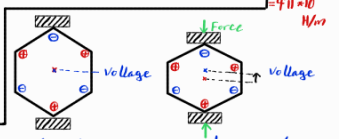
LVDT: An electromechanical sensor used to measure linear displacement. **RVDT:** Same concept as LVDT except that it's rotary.

Main Adv.: LVDT & RVDT doesn't require an electrical contant between the moving part and the coil assembly, making these sensors very reliable.

$L = \mu_0 * \mu_r * N^2 * \frac{A}{L}$, $\mu_0 = 4\pi * 10^{-7}$ H/m

Characteristics	Capacitive Proximity	Inductive Proximity
Range	0.1-60mm	3-60mm
Speed	Up to 5KHz	Up to 50Hz
Diameter	3-40 mm	12-60mm
Sensitive to	Most materials conductive & isolating	Ferrous materials Less-sensitive to non-ferrous metals

Inductive Proximity: An oscillator creates a magnetic field that radiates from the coil at the sensing face. When a ferrous target enters this magnetic field, small independant electrical currents called eddy currents are induced on the metal's surface. This changes the relactance (natural frequency) of the magnetic circuit, which in turn reduces oscillation amplitude.



Piezoelectric sensor: Some substances generate an electrical charge and an associated potential difference when they are subjected to mechanical stress or strain.

Disadvantage: Can't be used for purely static measurements, as a static force results in a fixed amount of charge. $S_q = \frac{\partial q}{\partial F}$ → Force, $S_q = \frac{1}{A} \cdot \frac{\partial q}{\partial P}$ → pressure → in [pC/N]

$S_V = \frac{1}{\varepsilon} \frac{\partial V}{\partial P}$, $\frac{\partial q}{\partial V} = C * \frac{\partial V}{\partial P}$, $C = K * \frac{A}{\varepsilon}$ → $S_q = K * S_V$ → in [mV/N] → Voltage sensitivity

Thermocouple: Consists of 2 different electrical conductors generating a temperature-dependant voltage in the microvolt rang as a result of the thermoelectric effect (seebeck effect). Temp. rang −200 to 2300 °C. **dis advantage:** bad accuracy.

Piezoelectric pressure sensor: Same as capacitive & resistive strain gauge sensors, except that this one can handle much higher pressure range.

Hall effect sensor: Hall effect is the production of a voltage difference (Hall voltage) across the sides of an electrical conductor as a result to an applied magnetic field perpendicular to the current. Compaired to inductive sensors, hall sensor has one major advantage: In inductive sensors we need an alternating magnetic field, where in Hall sensor we can detect static magnetic as well.

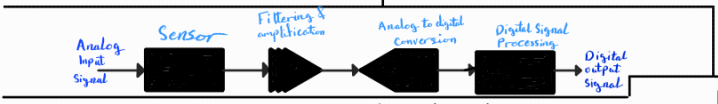
Adv. when used as electronic switches: cheaper, more reliable, and can operate at much higher freq. than a mech. switches. **Photo Diode:** is a semiconductor converting light into an electrical current.

Photo Transistor: Consists of a bipolar transistor encased in a transparent case. **Fiber Bragg Grating (FBG) Sensor:** Can be used as an inline optical filter to block certain wavelengths (used for Wavelength Division Multiplexing), or as a wavelength-specific reflector sensitive to strain and temperature.

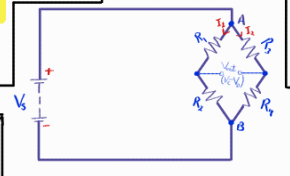
disadv: since FBG is sensitive strain & temp, we have to seperate them for an accurate output.

Bragg wavelength λ_B shifts by $d\lambda$:

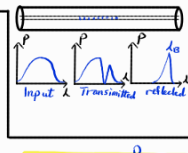
$\frac{d\lambda}{\lambda_B} = C_S * \varepsilon + C_T * dT$ (strain (mech. & temp included), temp. change; C_S: Coeff. Strain, C_T: Coeff. for change of the refractive)



Wheatstone Bridge:



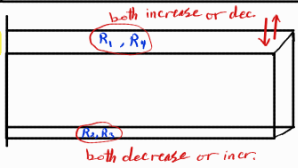
Balanced bridge: $V_{out} = 0$, $\frac{R_1}{R_2} = \frac{R_3}{R_4}$



$V_{out} = V_s * \frac{R_2}{R_1 + R_2} - V_s * \frac{R_4}{R_3 + R_4}$

For typical full bridge: $R_1 = R_2 = R_3 = R_4$

$GF \cdot \varepsilon = \frac{V_{out}}{V_s}$ (Strain ← V_s → V_{out}) ⟸ $\frac{V_{out}}{V_s} = \frac{dR}{R}$



Adv. of Wheatstone bridge:

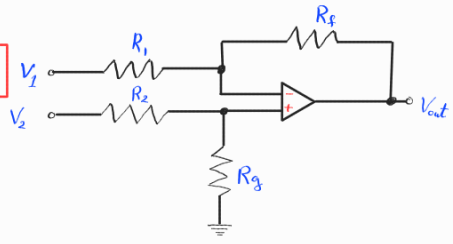
I) For a balanced bridge ($V_{out} = 0$), a high amplification for the output voltage can be used to get a high resolution of the measurement.

II) A symmetrical bridge compensates thermal influences electrically.

III) A symmetrical bridge compensates unwanted mechanical strain orthogonally to the measuring direction electricall.

Differential amplifier: Low differential voltages have to be amplified.

$V_{out} = (V_2 - V_1) * \frac{R_f}{R_1}$, if $R_f/R_1 = R_g/R_2$



Instrumentation Amplifier:

$A = \left(1 + \frac{2R_1}{R_{gain}}\right) \frac{R_3}{R_2}$

Sensitivity of Diff. strain Gauge Bridges:

Full bridge (4 active strain gauges): $\frac{V_{out}}{V_s} = GF \cdot \varepsilon$

Half bridge (2 active strain gauges): $\frac{V_{out}}{V_s} = \frac{1}{2} GF \cdot \varepsilon - \frac{1}{2}$

Quarted bridge (1 active strain gauge): (but no temperature compensation)

Four-Terminal sensing (Kelvin connection): By the use of separate pairs of current-carrying and voltage-sensing cables, a voltage drop in Combined lines because of the line resistance can be avoided. Kelvin connections are typically used to measure the voltage drop at a current sensing (shunt) resistor. As shunt resistors are typically very small (mOhms), an accurate layout is necessary.

More Piezo electric sensors:

dielectric constant (Permittivity) of the crystal

$K = \varepsilon_0 \cdot \varepsilon_r$ → dielectric constant

$\varepsilon_0 = 8.854 * 10^{-12}$ F/m

Capacitive Proximity sensor:

There are two electrodes (at diff. potentials) housed in the sensing head and positioned to operate like an open capacitor. A conductive or non-conductive target increases the capacitance of this capacitor.

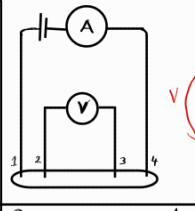
More of Thermocouple: $V = E(T_{sense}) - E(T_{ref})$

Maximum possible error from data sheet: (around ± 1.5°)

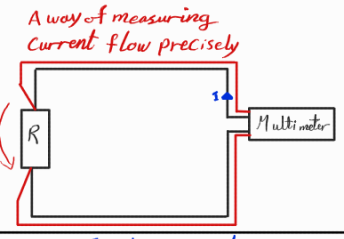
A&B must be from the same material of A&B / material with the same thermoelectric properties.

Interpolation: $E(T_1)$ T_1; $E(T_2)$ T_2; $E(T_3)$ T_3

$\frac{E(T_1) - E(T_3)}{T_1 - T_3} = \frac{E(T_2) - E(T_3)}{T_2 - T_3}$



A way of measuring current flow precisely



Resistive Touch screen: Two transparent conductive layers of indium tin oxide (ITO) are separated by a small air gab and insulating spacer dots. A stylus or finger bends the flexible top cover, creating an electrical contact between the two conductive layes. **4-Wire resistive touch screen:** Uses four conductive bars, two on top side, & two on the bottom. At the touching point, the voltages between the pair of bars is equal (due to the short circuit between the two layers).

Surface Capacitive touch: A glass substrate is covered with ITA coating and a small ac voltage is applied. When the finger touches the screen, a small charge is transferred to the finger. This creates a voltage drop on that part of the screen, and the touch is detected. **Projective Capacitive touch:** A PCT/PCAP consists of a ITO matrix behind a thicker glass/acrylic cover. Capacitance coupling will occur between the finger and the electrodes. The capacitance coupling makes the electrostatic capacitance between the X & Y electrodes change.

	Resistive	Surface capacitive	Projected capacitive
Accuracy	High	Medium	High
Multi-touch	No	Yes	Yes
Durability	Low	Medium	High
Costs	Low	Medium	High
Usable with gloves or Stylus	Yes	Yes (but only thin cotton gloves)	No

Actuators: Can be classified by their type of input energy, e.g. Electrically Powered Actuators:

Electro Magnetic actuator: A solenoid consists of a coil, a plunger and a spring in a common case. If current flows through the coil, the coil acts like an electro magnet, pulling the (steel) plunger. The spring is used for the return path. Solenoids are often used for simple linear actuators and for controlling valves. Solenoid valves are often used in automotive application for example, as fuel injectors or as intake and outtake valves of combustion Chambers.

DC Motor: Consists of an electromagnet as its stator and a coil as its rotor. Current flowing through the coil inside the magnetic field of the stator, a Lorentz force is generated, turning the rotor. For continuous rotation, the direction of the current in the rotor (so called communication) has to be changed periodically. Two types of DC motors: 1- Brushed, 2- Brushless

Brushed DC Motor: The brushes (often made of carbon) in a dc motor have two functions: 1- Carrying the current to the rotating part (rotor). 2- Switching the current flow with the commutator.

Disadvantages: 1) Losses due to brushes friction. 2) Brush material wears down due to friction, creating dust. 3) Resistance of the brushes causes a voltage drop, resulting in a power loss. 4) The repeated switching of current through the rotor coil causes sparks at the commutator contacts, causing electromagnetic noise (called brush fire). Still used for simple low-power applications because of their low costs.

Brushless DC (BLDC): Consists of a permanent magnet rotor and an external, electronically commutated (EC) magnetic field (therefore also called EC motor). As the rotor follows the magnetic field, the motor is a synchronous motor. Hall effect sensors (output signals a,b,c) are used to measure the angle of the rotor and control the commutation of the motor windings (output U, V, W).

Advantages: No wear on brushes (like DC-Motor) + Smaller losses (higher efficiency) + high power density + good for high rpm (unlike servo or stepper).

Servomotors: A rotary or linear actuator allowing the control of the angular or linear position as well as the velocity and acceleration is called a servomotor. The term is independant from the type of motor, but often electrodynamic dc or ac motors are used. Servomotors require a controller, reading in the positioning information, processing it and controlling the output signals for the motor driver.

Piezo Electric actuator: The piezo electric effect can be reversed. A high electric fields results in tiny changes in the width of the crystal. As this width can be changed with better than 1nm Precision, Piezo crystals are the most important tool for positioning objects with extreme accuracy. A typical Piezo actuator needs a driving voltage of 150-200V dc. **Piezo Electric loud speaker/Buzzers:** Can be used in the range from 1 to 100 kHz and often used for signal generation in electronic devices. Ultrasonic piezo electric devices are also used for parking assistance. Due to the reversible piezo electric effect, the piezo membrance can be used as actuator and sensor. **Automotive Piezo electric Valves:** Actual common-rail systems use piezo injectors as they offer fast switching times and a flexible adaptation of the injection pattern. In addition, they can handle high pressure inside the motor.

Magnetostrictive Actuators: During the process of magnetization, ferromagnetic materials change their shape or dimention. The reciprocal effect, the change of the magnetic susceptibility (response to an applied field) of a material when subjected to a mechanical stress, is called the Villari effect.

Examples: Magnetostrictive actuators are used as sound generators (sonars), valves, high force generators and low voltage actuators.

Magnetorheological: A magnetorheological fluid consists of microscopic magnetic particles (0.1 - 10 µm) in a carrier oil. Subjected to a magnetic field, the fluid increases its apparent viscosity up to the point of a viscoelastic solid. Magnetorheological Dampers: x → can be used in shock absorbers or dampers. The fluid viscosity can be continuously controlled with short response times by an applied magnetic field. Due to the costs of such dampers, they're only used in heavy industry or expensive sport cars.

Fluidically Powered Actuators: Examples: Valves, Linear actuators

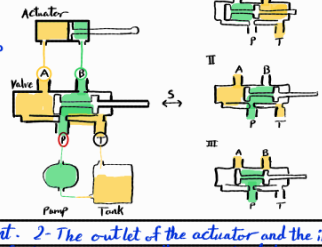
Hydraulic actuators: Pascals law.

Advantages of Hydraulics:
- High torque/mass ratio
- Great flexibility of providing multiple actuators at diff. locations using same power source
- Self-lubricant
- No (high) voltages required
- Efficient heat removal and reduced thermal problems
- Stiffer system

disadvantages (compared to electrically powered)
- Not as Linear (because of valve nonlinearities, fluid friction, compressibility, thermal effect, general nonlinear constitutive relations.
- Leakage can create problems
- Typically noisier than electric motors
- Synchronization of multiple actuators more difficult
- Typically more expensive
- Typically less portable

Port (P): Hydraulic pump
Port (T): Storage tank
Port A/B: Double acting actuator

Four-Ports-three-Ways Valve:



Pneumatic Actuators: Operates similar to hydraulic systems, but with 2 basic differences; 1- Air is the working fluid. Air is far more compressible than hydraulic oils, thus, compressibility has to be taken into account. 2- The outlet of the actuator and the inlet of the pump are open to the atmosphere.

Pneumatic VS Hydraulic System:

Advantages:
- Cheaper
- less weight
- Fewer problems with Leakage

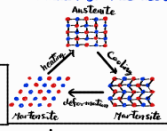
Disadvantages:
- Only suitable for low & medium-duty tasks (Pressure 500KPa to 1 MPa)
- More nonlinear
- Less accurate

Thermal Expansion Actuator: Uses a medium which expands when heated. Often waxes are used (which expand when melted and contract when they solify). Used in thermostates or thermostatic valves.

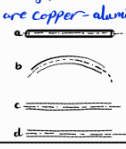
Thermically Powered Actuators: Especially bi-metall & Shape memory alloys are heated by an electric current flowing through them.

Thermo bimetal actuator: Most important thermal actuator. Is composed of two seperate metal joints which expand at different rates when heated. Typical metal combinations are steel & copper or steel & brass. A common app for bimetals are temp dependant switches, used for thermostates. Above a certain temp the bimetal actuator opens or closes an electrical switch.

Shape Memory Alloys: is an alloy that can be deformed when cold but returns to its pre-deformed (remembered) shape when heated. For special apps, they can be a lightweigh, solid-state alternative to hydraulic, Pneumatic, & electromechanical actuators. The most common shape memory alloys are copper-aluminium-nickel (cheap) and nickel titanium (better performance).



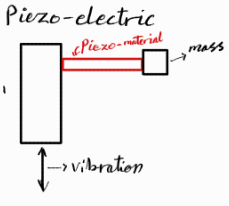
Austenite: high temp. Phase
Martensite: low temp. Phase



Electro-Chemically Powered Actuators:
Working Principle: Gas-proof extensible enclosure with two electrodes. If a dc voltage is applied, dependant on the polarity gas is generated or absorbed. For a higher actuator speed and force, multiple cells are stacked.

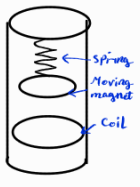
Energy Harvester:

Piezo-electric



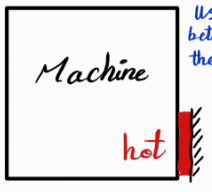
Vibrating machine

Electromagnetic



Generating heat machine:

Thermoelectric generator (TEG, based on Seebeck effect)



Uses the heat difference between the hot machine and the cold environment.

Why hydraulic actuators are used in excavator not electro dynamics?
High forces are needed but usually one for one actuator per time.
So, one central hydraulic pump can be used to power different actuators.

Force calculations

$$P_1 = P_2 \Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = F_2 \cdot \frac{d_1^2}{d_2^2} \Rightarrow F_2 = F_1 \cdot \frac{d_2^2}{d_1^2}$$

$$V_1 = V_2$$

$$A_1 \cdot h_1 = A_2 \cdot h_2$$

$$h_1 = h_2 \cdot \frac{d_2^2}{d_1^2}$$

What kind of actuator would you use for self-expanding stent without any external power supply?
= Shape memory alloy actuator (thermally activated by the warm blood).

Explain the working principle of such a stent?
= The stents are crimped to the artery diameter at low temperatures. When they are inserted into the human body, the blood is heating them up and the stent gets its final (larger) diameter.

Networks:-

To avoid confusion: 1 Kibibyte (KiB) = 2^{10} bytes = 1024 bytes (sometimes also called "large Kilobyte" (KKB)) ⟹ 1024 KiB = mebibyte.

American Standard Code for Information Interchange (ASCII): using 7 bits per character, whereas Extended ASCII uses 8 bits.
The non-printable characters from 0x00 to 0x20 and 0x7F are used as control characters, Therefore ASCII can be used not only to store data, but also to control data transmission for example:
- Start of Text (STX)
- End of Text (ETX)
- ACKnowledge (ACK)
- Negative ACKnowledge (NAK)

Unicode: To avoid problems caused by diff. character encoding.

Code length		Format	The 1st bit(s) indicates the length of the character encoding.
1 byte	7 bits	0x------	
2 bytes	11 //	110x----	10------
3 //	16 //	1110----	10------ 10------
4 //	21 //	11110---	10------ 10------ 10------
5 //	26 //	111110--	-------- -------- -------- --------
6 //	31 //	1111110-	-------- -------- -------- -------- --------

UTF-8: The most popular Unicode coding.

UTF-16: * Variable-length encoding (16 or 32 bits)
* Optimized for Commonly used characters from Basic Multilingual Plane (BMP)
* Used mainly for internal representation of characters in frameworks like .NET, Java, or Tcl.

UTF-32:
* Fixed-length encoding (32 bits)
* Used mainly in APIs.

Data Transmission:

Serial: Data is transmitted over a single line, one bit at a time. Ex. of serial: USB, Ethernet, Serial ATA, CAN

Parallel: Several bits are sent as a whole on the bus. It has not only data lines, but control lines as well.
Ex. of parallel: PCI, Compact Flash.

Synchronous transmission: It always have a clock signal or a way to recover the transmission by the receiver.
Sender & receiver are always synchronized. Ex.: SPI, & I2C buses.

ASynchronous: Communication partners use independent clock sources. If data is transferred, a start bit is set before the data. This signals the receiver that it should start its clock source.
Disadv: Because the clock can (slightly) differ, maximum size of the data that can be transmitted in one piece is limited. Examples: RS-232, RS-485

Simplex: Information is transfered only in one direction (Unidirectional).
Ex.: Radio & TV, GPS, Radio clock signal.

Full-duplex: transmission works in both directions simultaneously (bidirectional)
Ex.: Walkie-Talkie.

Half-duplex: Transmission in both directions (bidirectional), but not simultaneously. Examples of Half-duplex: Ethernet (via twisted pair cables), and Telephone.

Topologies of Computer network: Determines how communication partners are connected / Physical topology: Wirings.

Logical topology: describes the flow of data between the terminal devices.

Ring network: Two nodes are directly connected.
Information to be transmitted is forwarded until destination
An interruption of the ring causes network failure.

Bus Network: Connected via a shared transmission medium.
No active components between the nodes & the medium.
means ⟹ If any node fails, the network doesn't fail.
But an interruption of the bus causes network failure.

Star: All nodes directly connected to a central Hub.
Good expandability & stability. If any node fails neither affect other nodes, nor the network.
disadv: Considerable effort for cabling, and dependence on the the Central hub.

Mesh: If nodes or connections fail, communication still possible via other routes. & High level of reliability.
High cabling effort,
& increased electric power consumption.

Tree: Several star topology networks are hierarchically connected.
Failure of leaf node has no big effect on network's functionality
Expandability is excellent & long distances can be realized.
Suited for search & sort algorithms.
If a node or even the root fails, the entire (sub-)tree behind can no longer be reached.

Cellular: Wireless network use this topology.
Failure of a node doesn't effect the functionality of the network.
Limited range of the base stations, depending on their number & position.

Fourier Series: A square-wave signal (also binary signal) Can be represented by a Fourier series as the sum of a set of oscillating functions. Consists of a fundamental frequency & harmonics.

If you have a certain binary signal with a given max. frequency, the bandwidth of your transmission line must be at least 5 times higher than the base frequency of the transition.
Baud rate: num. of transferred
Bandwidth: Is the range of frequencies which can be transmitted via the medium without interference.
Bit rate: num. of transmitted payload in bits per time ⟹ [b/s]. | Symbol per time ⟹ Symbol rate ⟹ [Symbol/time unit]

TCP/IP Reference Model (DoD): 1- End-to-End principle. 2- Robustness Principle (You should be conservitive in what you do).

Layer Name	Protocols (examples)
Application Layer	HTTP, FTP, SMTP, POP3, DNS, SSH, Telnet
Transport //	TCP, UDP
Internet //	IP (IPv4, IPv6), ICMP, IPsec, IPX
Link //	Ethernet, WLAN, ATM, FDDI, PPP, Token Ring

Starting from application layer, every layer adds additional data to the message before submitting it. The receiver stars reading from link layer (or physical layer).

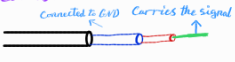
Hybrid Reference Model:

TCP/IP Reference Model → Hybrid Reference Model

Application Layer	Application Layer
Transport Layer	Transport Layer
Internet Layer	Network Layer
Link Layer	Data Link Layer
	Physical Layer

Physical Layer: Responsible for the transfer of ones & zeros. The Physical Connection & the conversion of the data into signals takes place.
Protocoles of this layer define how many bits can be sent per second & whether the transmission can take place simultaneously in both directions.

Ethernet: The most widely used LAN technology. Standards differ in the data rate & the transmission medium. Versions of cables up to 40 Gb/s.
Baseband transmission method (BASE). No carrier Frequencies → Transmitted directly.

Coaxial Cables:


Twisted Pair cables: Assures that the wires are on average the interfering source are affected equally. The noise produces a common mode signal which can be cancelled by the receiver by only regarding the differential signal level.

Fiber-Optics cables: typically from plastics or glass. Consists of light-transmitting core. **Adv.**: 1) you can transfer diff. (high) wave-length easily in it, therefore you get multiple channels. 2- They are immune to electromagnatic interference & radio freq. interference. 3- Low allenuation ⟶ long distance can be realized.

WLAN: **Challenges**: 1- Interference with other sources. 2- Multipath propagation. 3- Hidden Terminal. 4- Fading.
↳ need collision detection & avoidance to avoid it.

Bluetooth: Is a wireless network system for data transmission over short distances to replace short cables.
The freq. levels are changing up to 1600 times per second. Organized in so called Piconet. A Piconet consists of max. 255 participants, of which a max. of 8 may be active. One active node is the master and the remaining 7 active nodes are slaves.

Baseline Wander: We usually take the mean value between High & Low to know the threshold voltage. When transmitting long sequences of zero- or one-bits, the average may shift so much that it becomes difficult to detect a significant change of the signal. To prevent a shift of the average (Baseline Wander) when using a line code With two signal levels, the usage of both signal levels must be evenly distributed.

Clock Recovery (Synchronization): If the clocks of the Sender and the receiver drift apart, the receiver may become confused during a long sequence of logic zero- or one-bits.

NRZ-M: 1-bit = signal change ⟶ 0-bit = no change.
NRZ-I: 0-bit = signal change ⟶ 1-bit = no change.
MLT-3: 3 signal levels (+1, 0, and -). Same as NRZ-M.

Manchester: Each data bit is encoded by a combination of high/low or low/high bit sequence. Because of not more than two consecutive bits which have the level, the clock synchronisation is possible. As the number of low and high values are the same, the code result is balanced for any input data and no baseline wander can occur.
* It doubles the necessary data bandwidth. (means 50% efficiency)

Linecode	Signal level	Baseline Wander possible	Signal level change	Self-synchronizing possible	Efficiency	Directly transferable	Additional encoding
NRZ	2	yes	at changes	no	100%	no	
NRZI	2	yes	for 1-bits	no	75%	no	
MLT-3	3	yes	for 1-bits	no	100%	no	
RZ	3	yes	always	yes	50%	no	
Unip. RZ	2	yes	for 1-bits	no	75%	no	
Manchester	2	no	always	yes	50%	yes	
4B5B	2 or 3, depending on additional encoding	no	–	yes	80%	no	NRZI or MLT3
8B10B	2	no	–	yes	80%	no	NRZ
8B6T	3	no	–	yes	100%	yes	

Data Encoding: Why self-synchronous?
* To avoid clock draft, and therefore to avoid a wrong bit sampling.
* For short packets and if the sampling point is in the middle of a bit, a small clock drift doesn't shift the sampling point that much, and the bits are still correctly sampled.

Data link Layer: Main tasks: Error detection, & if possible error correction. Also, the protocols control the access to the transmission medium (for example, via CSMA/CD or CSMA/CA)

Error-detection codes are used instead of error-correction codes in many applications, Why? = It is often more efficient to re-transmit an erroneous message than to add the necessary additional bits for the error-correction in every single transmitted message.
Example of useful error-correction usage? = Simplex communication apps. With no possibility for re-transmission, data storing.

Why do we use Hybrid not the others?
The Hybrid reference model illustrates the functioning of Computer networks in a more realistic way compared to:
- The TCP reference model:
As it comes up with different functionalities and tasks of the Physical layer and data link layer by splitting the link layer in TCP/IP reference model.
- The OSI reference model:
Because the functionalities, which are intended for session layer and presentation layer are implemented today by the Application layer Protocols in most cases.

Advantages of layered Reference Models: Changes on one layer don't affect the other layers, Provided that the interfaces between the layers don't Change. The diff. layers seperate services, interfaces, and protocols, so they are more flexible and less complex than a network Combining all Characteristics and functionalities in one.

Bit Stuffing: If HDLC (High-Data-Link-Layer) Protocol of the receiver discovers a five consecutive one-bits, followed by a zero-bit in the bitstream from the physical layer, the stuffed zero-bit is removed.

Byte (character) Stuffing: If STX (02) or ETX (03) occurs in the Payload (body), it must be escaped (quoted) by a stuffed DLE (10) (Data Link Escape) in the Data link layer. If DLE appears in the payload, it is also escaped by an additional stuffed DLE.
We add DLE (0x10) before the byte (character) we want to stuff!

WLAN uses CSMA/CA instead of CSMA/CD, because with WLAN it is not possible to detect all collisions. Why not possible?
= Because of decreasing signal strengths, in some cases a node intending to transmit a message and therefore sending the carrier, can not receive messages from other nodes outside it's reception range. So, a hidden station problem might occur.

For which conditions, we use CSMA/CA RTS/CTS instead of CSMA/CA?
= Transmission of long packets / high payloads.

What drawback of CSMA/CA RTS/CTS compared to CSMA/CA?
= The exchange of the RTS & CTS messages adds additional payload to the network and decreases the overall latency of a data transmission.

CRC Calculation:
Example: $x^5 + x^2 + x$
100110

```
1 1 1 0 1 0 0 1 1 1 0 0 1 0 0 0 0 0
1 0 0 1 1 0                          XOR
0 1 1 1 0 0 0                        operation
  1 0 0 1 1 0
  0 1 1 1 0 1
    1 0 0 1 1 0
    0 1 0 0 0 1 1
      1 0 0 1 1 0
      0 0 0 1 0 1 0 0 1
        1 0 0 1 1 0
        0 0 1 1 1 1 0 0
          1 0 0 1 1 0
          0 1 1 0 1 0 0
            1 0 0 1 1 0
            0 1 0 0 1 0 0
              1 0 0 1 1 0
              0 0 0 0 1 0 0
                ↙
```

must be added to the right end of the data before sending it.

Network layer: Called internet layer in TCP/IP reference model. Its task is to forward packets between logical networks over physical network segements. The network layer defines logical addresses (IP addresses). Gateways, or routers are used to forward packets on their way from the send to the distination.

Usually, the connectionless Internet Protocol (IP) is used. **Advantages of IP**: Low overhead, allow multicast and broadcast operations

Disadvantages of IP: No acknowledgement from the receiver, that the packet has been received, risk of packet loss.

	Network length (without prefix)	Host length (no. of devices)
Class A	7 bit (⇒ 128 nets)	24 bit (⇒ 16.777.214)
Class B	14 bit (⇒ 16384 nets)	16 bit (⇒ 65534 hosts)
Class C	21 bit (⇒ 2.097152 nets)	8 bit (⇒ 254 host)

Why since $2^8 = 256$? 2 address always reserved.
- broadcasting ID (set to 0)
- Identifying the host ID

Why **UDP** is often used for video telephony? and **TCP** for Webserver?

= **UDP** is connectionless. Its Low overhead makes it ideal for time-sensitive applications like Video-telephony, where single erroneus messages are not critical.
(It is better to ignorge a package if it didn't arrive)

= **TCP** is connection-oriented. It guarantees the correct transport between a send and a receiver, like it is necessary for a website.

IP address: 153. 213.11. 213 /27 (Host)
- Network (doesn't change)
- /27 → how many ones in the Subnet mask (Netmask)

Subnet (network) address: 153. 213.11. XXX
- this e.g. 192
- by taking the first n-num. of bits from the last 8-bits (host) from the IP address. (in this case n = 27-24 = 3)
- +1 for the first host address

Broadcast address: 153. 213.11. XXX (same; 223)
- The rest of the 8-bits to the right are ones.
- -1 for the last host address.

Differences between an IP address, a port, and a socket?

= IP addresses are used on the network layer by the internet protocol for addressing, whereas ports are used on the transport layer for addressing. A socket is a combination of an IP address and a port number.

193.99.144.85 : 8080
IP address | Port
Socket

Application Layer (highest layer): Contains all protocols that interact with the user application programs (e.g., browser or email client). The messages (e.g., HTML pages or emails) are located according to the respective Application Layer Protocol.

Transport layer: (End-to-End protocols)
- Connection-oriented communication. (Receiver has to acknowledge)
- Reliability
- Flow control

} Services

How to avoid physical layer collision?
= Only the bit with a Token can send data (all nodes are equal)

CAN Bus: In the Controller Area Network (CAN) bus arbitration process, the node with lowest indentifier will win the bus and be able to transmit the message. The lower the ID, the higher the priority of the message.

Why can't have 2 nodes with the same ID?
= If both nodes starts transmitting at the same time, the arbitration process will fail. In addition, if a message with acknowledgement does not work properly (as a dominant ACK will "overwrite" a recessive NACK).

Bit Stuffing: CAN uses NRZ coding with bit stuffing (after five equal bits, an inverse bit is added) to allow the synchronization of nodes without stable oscillators. (Start of fram bit is not counted from the five)