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Overview of Communication Systems

About Me

- Studying towards the Masters of Applied Science in Electrical and Computer Engineering.

- My research area is about implementing a communication framework (software and hardware) for the control of multiple civil UAV dirigibles.

- The framework will let multiple UAVs to exchange data, from different sensors, among themselves and the control station.

- Using DigiMesh technology (manufacturer of Xbee modules).

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Summary

- General representation of a communication system
- Brief description of fundamental elements in the system
- Analog and Digital signals in communication
- Bandwidth: Baseband and Broadband signals
- Wired Communication
- Wireless Communication
- Communication Systems in Mechatronics
- Networks
- Wired protocols
- Wireless protocols

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Elements of a Communication System
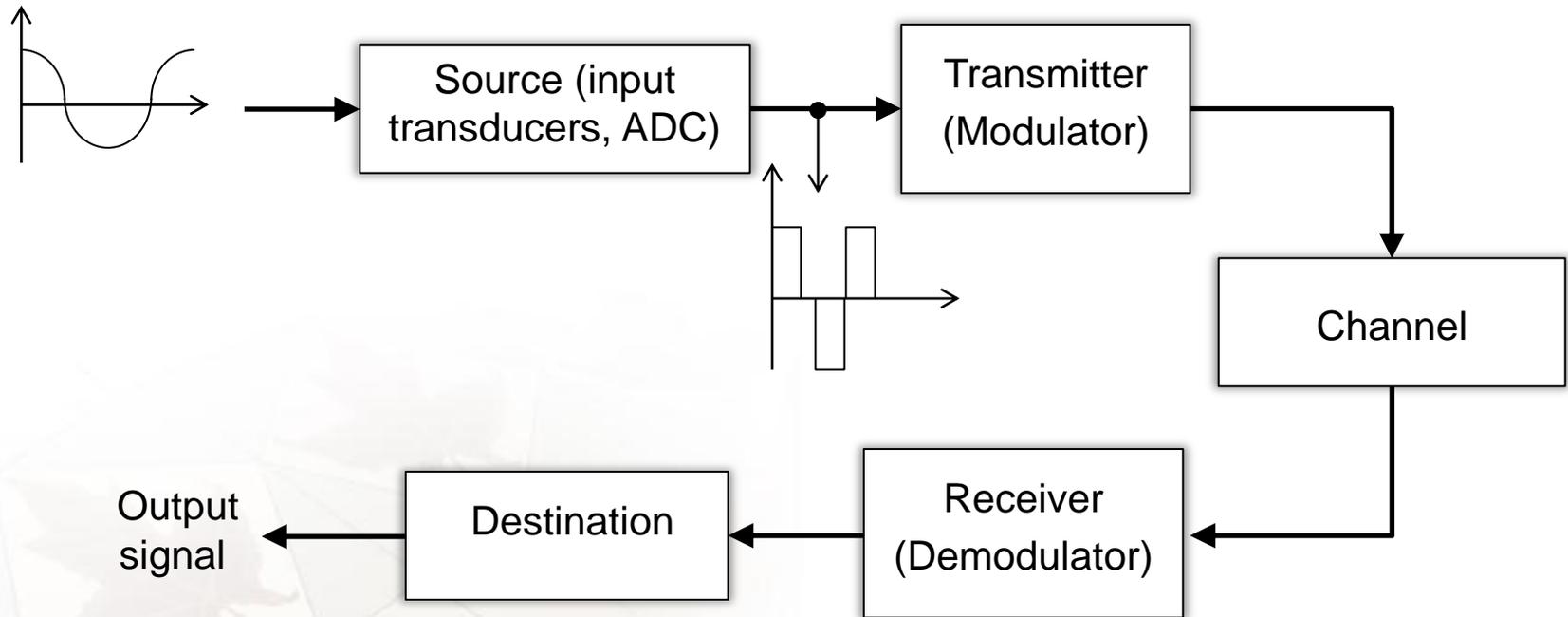
- Referenced text book: *Fundamentals of Communications Systems* by J. G. Proakis

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Definitions

- **Transmitter or Modulator:** Prepares the information to for transmission over the channel. This process is called modulation.

- **Channel:** Is a physical medium used to transfer the data to the receiver. This is where the transmitted information can get corrupted.

- **Receiver or Demodulator:** Removes the work of the modulator to find the transmitted information.

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Bandwidth

- In digital communication bandwidth represents how fast the information can be transferred. The speed of transmission is represented as bits per second. (example the Internet connection speed)

- In analog communication bandwidth represents the difference between the highest and the lowest frequencies in the signal. (example voice has a bandwidth of 3kHz, letters of alphabet generate different frequencies when pronounced)

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Baseband and Broadband Signals

- Baseband is a signal that has frequencies close to zero; frequency is at the "base". Similar to a bass sound in music which describes a tone with low frequency. Example of baseband signal is audio sound which has frequencies of 20Hz to 20kHz.

- Broadband is a channel which can transfer several signals. Therefore it occupies more frequency range (more bandwidth). Today most of the Internet connections are broadband. It can transmit several baseband signals simultanously.

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Single-Ended Data Transmission

- The data is transmitted by varying voltage on a wire with respect to ground. For example high voltage means 1, low voltage means 0.

- Noise on the wire can corrupt the signal.

- Simple in implementation and less expensive

Single wire

Voltage

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Data Transmission with Differential Signals

- The data is transmitted as a difference in voltage between two wires. Wires are chosen to be identical to each other and have opposite voltages.

- Both wires are affected by noise in the same way. By taking the difference between voltages the effect of noise is eliminated.

- RS-422 and RS-485 (extension of RS-232) use differential signals

+Voltage ⟨⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⟩

↕ Difference

-Voltage ⟨⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⟩

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Wireless Data Transmission

- Information is transmitted by using antennas on transmitter and receiver. Channel is the free space.

- Wireless medium (air) introduces more noise and can significantly corrupt the transmitted data compared to wired communication because no control over the channel.

- Antenna size is inverse proportional to the frequency used for transmission.

- Frequency of the transmitted signal is typically much higher than that of the data being sent.

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Communication in Mechatronics

- System buses

- Serial and Parallel data transmission

- Synchronous vs. Asynchronous

- Network topologies (hierarchy, network access)

- Device interfaces (serial and parallel interfaces)

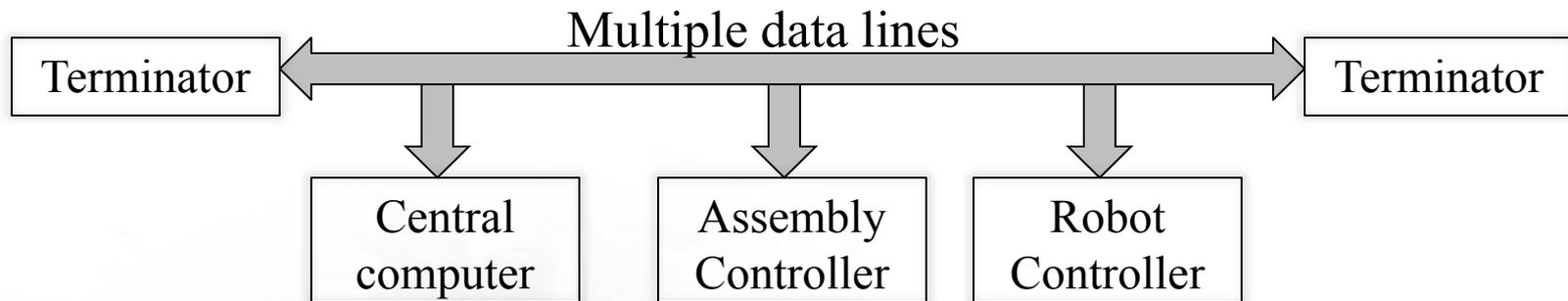- Wireless protocols (wi-fi, bluetooth, xbee)

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System Buses

- In computing devices buses transfers information among multiple devices.

- Buses can use several cables to transmit multiple information simultaneously (parallel data transmission).

- Buses provide power for the connecting devices (difference between Ethernet).

- Each bus specifies its signals and type of connectors used.

- Buses are widely used in industrial plants for connecting equipment to microprocessors, computers to provide high data rates for real-time decision making

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Parallel Data Transmission

- Multiple data is transmitted simultaneously using parallel wires.

Multiple data lines

| Terminator | ←———————————————→ | Terminator |

| Central computer | Assembly Controller | Robot Controller |

- Terminators absorb electric signals stopping them from bouncing on the bus.

- Old printers used parallel data connections.

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Serial Data Transmission

- In serial transmission data bits are sent one after another.

- In contrast to parallel transmission it takes longer time to transmit information but simpler to work with.

- Number of wires required depends on the mode of transmission:
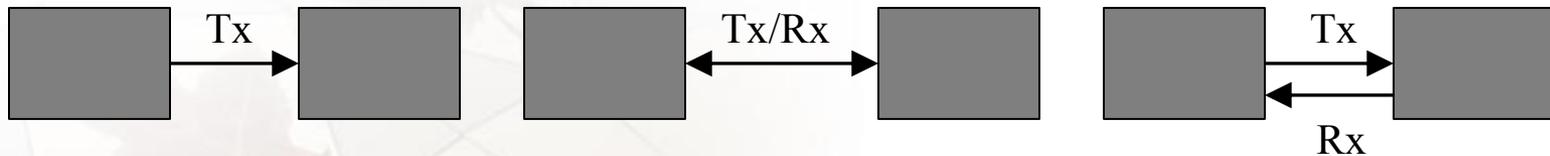
- Example of a serial data transmission is a USB interface

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What is USB?

- Universal Serial Bus – USB

- Data is transmitted using differential signals

- Devices can be powered from a USB (RS-232 does not provide power option). The specifications allows connected devices to draw no more than 0.5A at 5V.

- Much higher data rates than RS-232 (USB v3.0 has a max data rate of 5 Gigabit per second).

- USB devices are easy to interface with (e.g. Arduino).

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Asynchronous Transmission

- When the Receiver does not know when the information will be arriving it is called Asynchronous Transmission.

- In asynchronous transmission some kind of starting indicator is used to show that there is an incoming data. This also requires to use a stop indicator when there is no more incoming data.

- Depending on what kind of indicators are used it takes more bits to send in asynchronous transmission.

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Synchronous Transmission

- In a Synchronous Transmission Receiver knows when the data will be arriving. Therefore there is no need for a start/stop indicator.

- Receiver and Transmitter must be synchronized to avoid data errors.

- Synchronization signal is either same for transmitter and receiver or it is transmitted on a separate wire to the receiver.

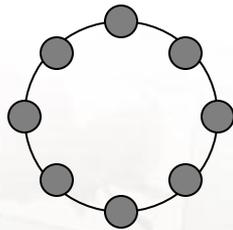- Synchronization signal is called the clock signal.
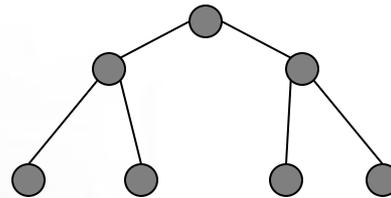
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Networks

- System Bus is a type of a network. Typically system buses are used on a short distance.
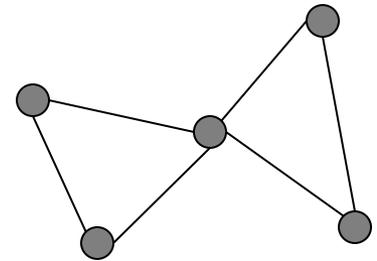
- Another types of a network:
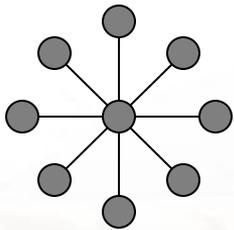
| Star
(Point to
multipoint) | Ring
(Point to point) | Tree
(Hierarchy) | Mesh |

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Rules for Communication in Networks

- In networks a set of rules describe how information is transmitted from the source to the destination. This set of rules is called protocols.

- All protocols have fundamental functions (layers) for establishing communication with the destination, catching errors in the information, and presenting the information in a meaningful way.

- Open System Interconnection model (OSI) is a 7 layer protocol which is used as a standard for development of other protocols.

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Wireless Communication

- Wireless protocols are responsible for the transmission of the information over-the-air.

- The most popular wireless protocols are Wi-Fi (802.11), Bluetooth, ZigBee.

- Arduino can be connected wirelessly using "Arduino WiFi Shield", "Arduino BT" (Bluetooth), "Arduino Xbee Shield"(ZigBee).

- A set of standards is currently being developed for mesh protocols.

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References

- John. G. Proakis, Masoud Salehi,
  "Fundamentals of Communications Systems", 2005

- W.Bolton,
  "MECHATRONICS Electronic Control Systems in Mechanical and Electrical Engineering", 2011

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