Industrial Communication

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Contents

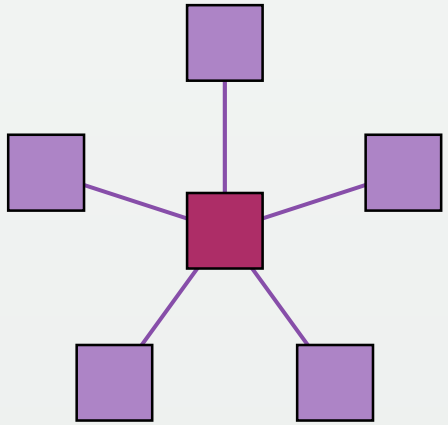
Introduction

Network Topology

Point to Point

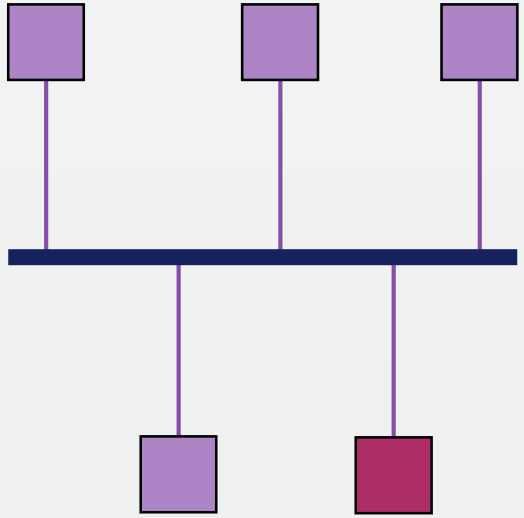
Only two devices are connected together

Star



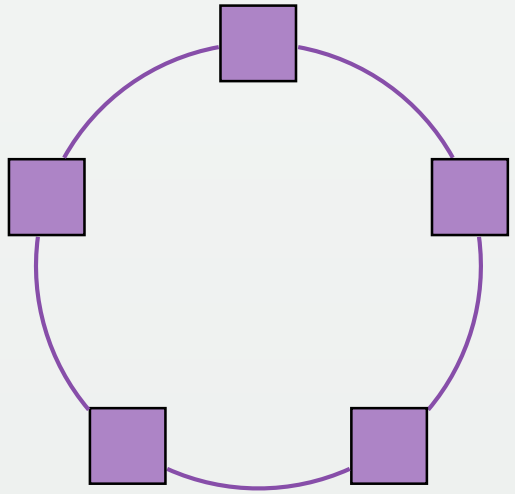
Centralized controller connected to several transmitters and actuators

Bus



Several devices share the same wires

Ring

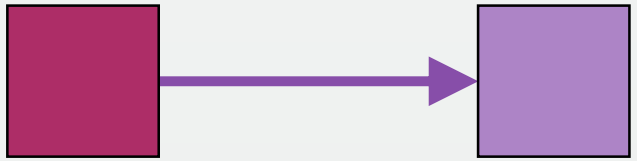


Devices occupying positions along the ring

Topology mainly depends upon the communication method

Communication Modes

Simplex



In one direction

Half duplex

In both directions
Not simultaneously

Full duplex

In both directions
Simultaneously

Open Systems Interconnect (OSI) Reference Model

Universal framework for all communication systems

Not all network protocols use every layer.

OSI Model

Data amount units

Application	Data	Host
Presentation	Data	
Session	Data	
Transport	Segments	
Network	Packets	Media
Data-Link	Frames	
Physical	Bits	

OSI Model

Signal Layer

Electrical specifications

Cable specifications

Physical medium

Copper wires | Optical fibers

Physical

OSI Model

Data-Link

Protocol Layer

Physical addressing

MAC | LLC

Error detection

Media Access Control -**MAC**

Logic Link Control -**LLC**

OSI Model

Network

Packet Layer

Logical addressing

Path determination

Sends data to the correct destination

OSI Model

Transport

Data Transmission

Determines:

- How much data to send
- How fast
- Where it goes

OSI Model

Session

Interhost communication

Data transfer organizing

Determines:

- The start and the end of a specific transmission
- The response rate

OSI Model

Presentation

Data Representation
Encryption

Translating data for the application layer

OSI Model

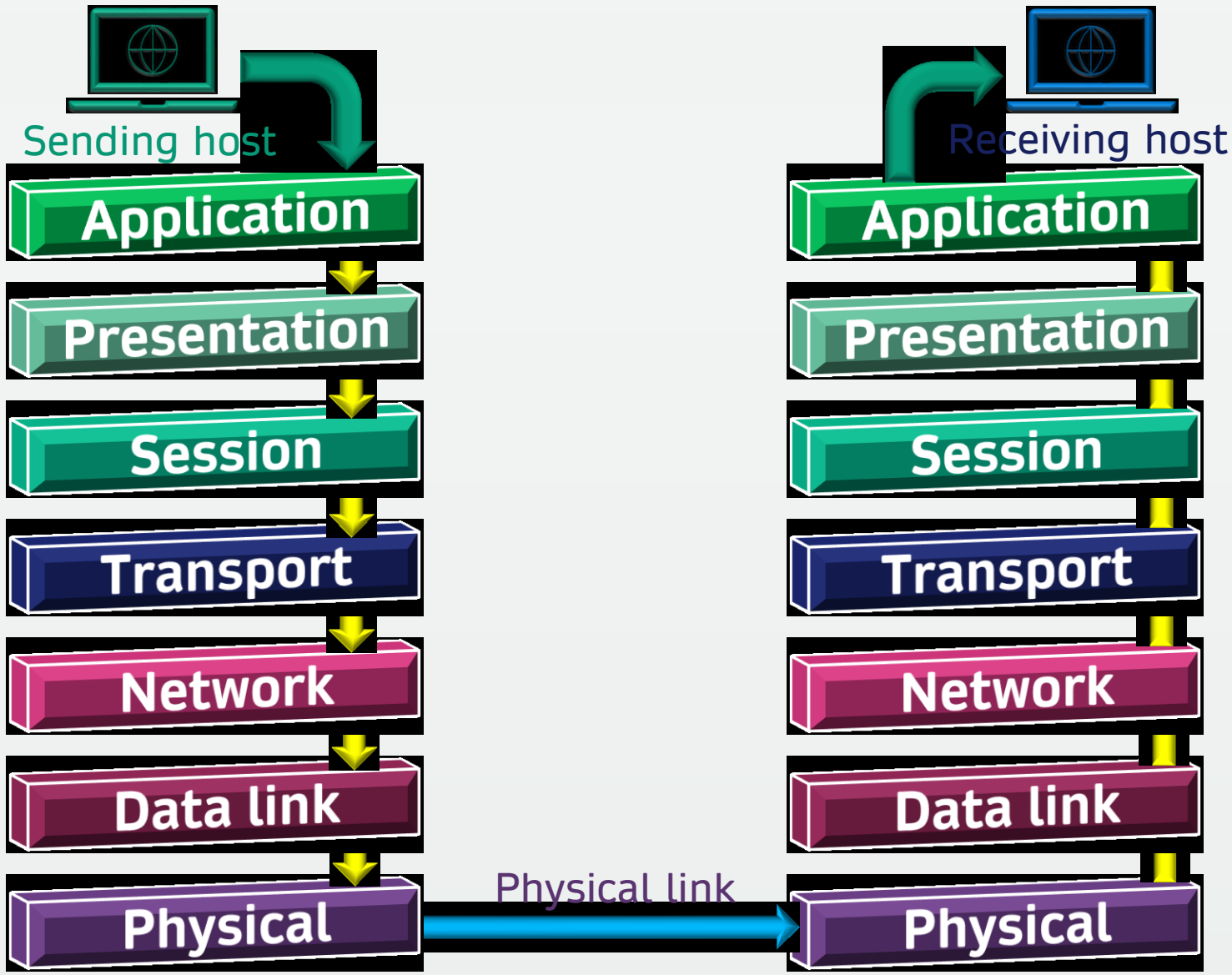
Application

User Interaction

Providing network services to the end user

OSI Model

- Application
- Presentation
- Session
- Transport
- Network
- Data-Link
- Physical



OSI Model

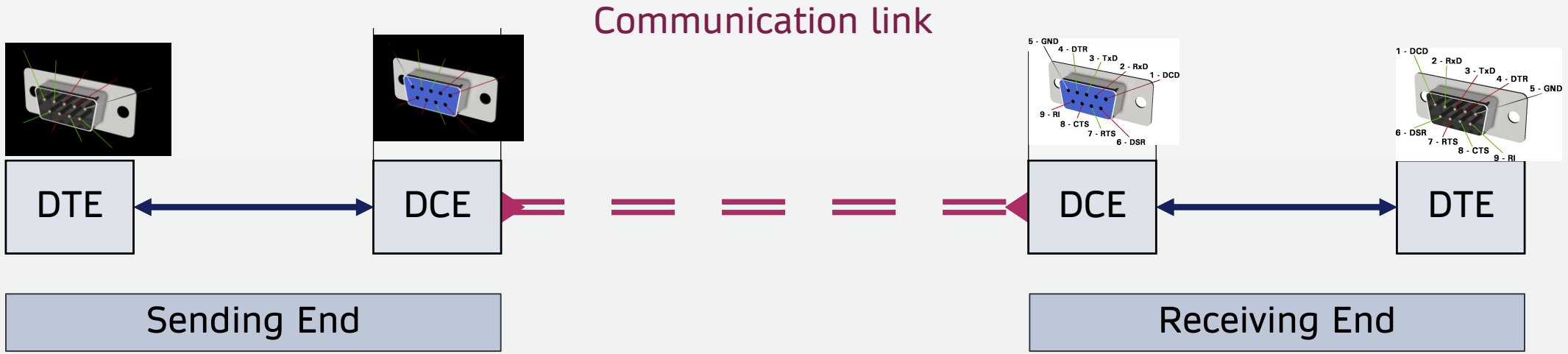
- Application
- Presentation
- Session
- Transport
- Network
- Data-Link
- Physical

Industrial

Serial Communication Standards

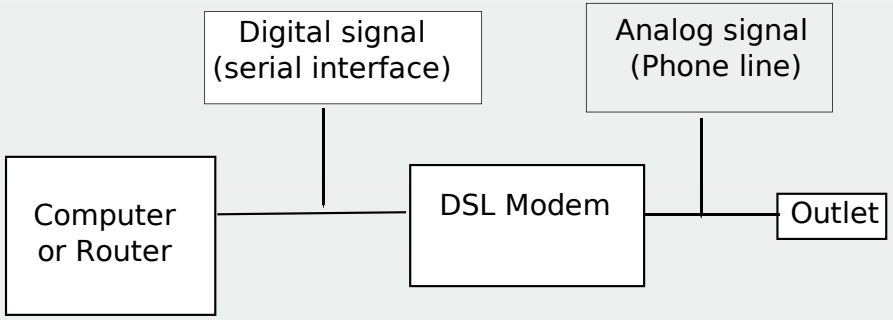
RS-232

Serial data communication



Data Terminal Equipment

Data Terminal Equipment



RS-232

Serial data communication

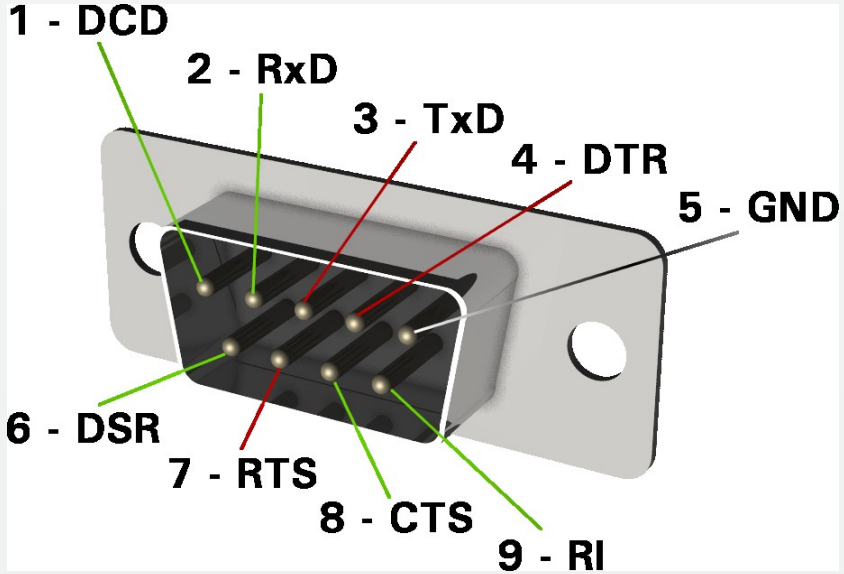
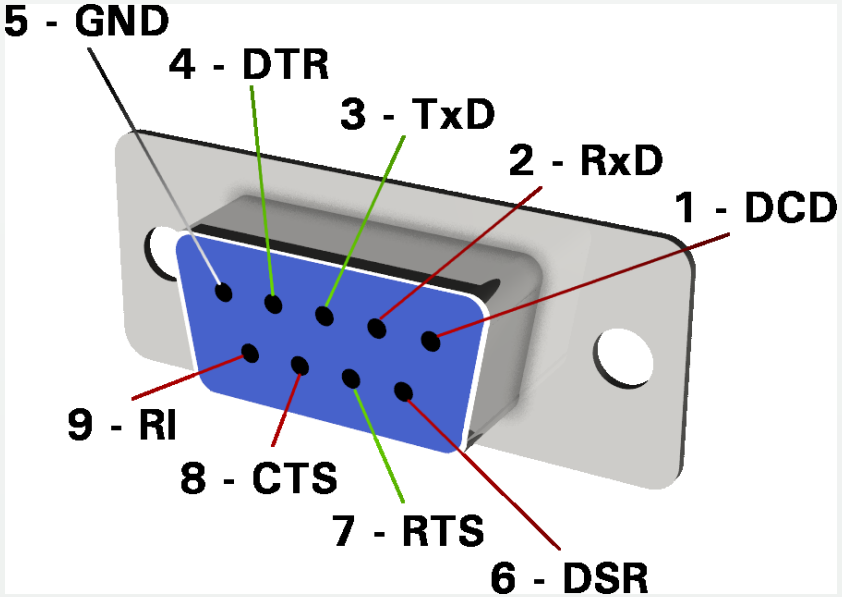
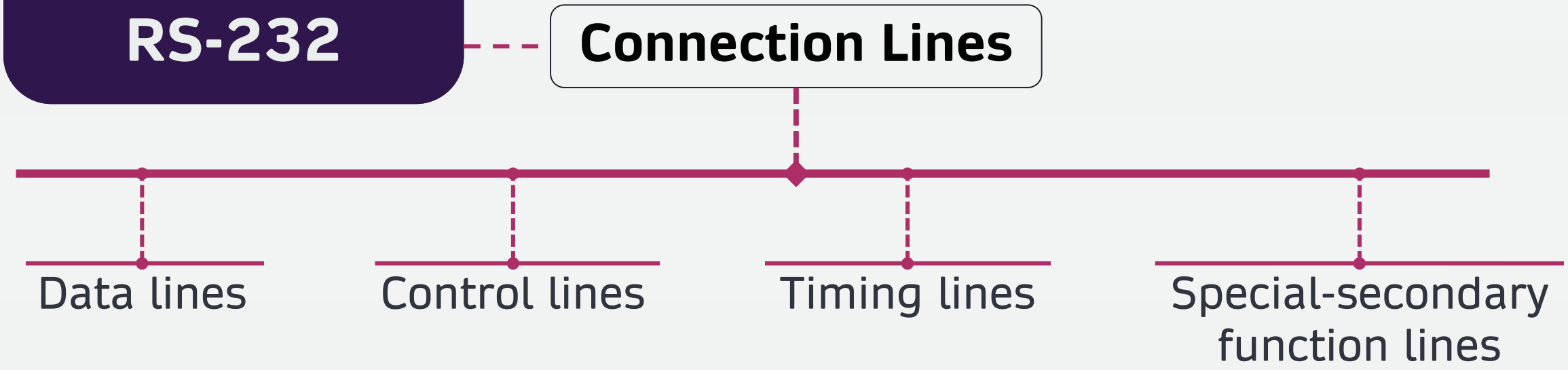


Image: ethernut.de

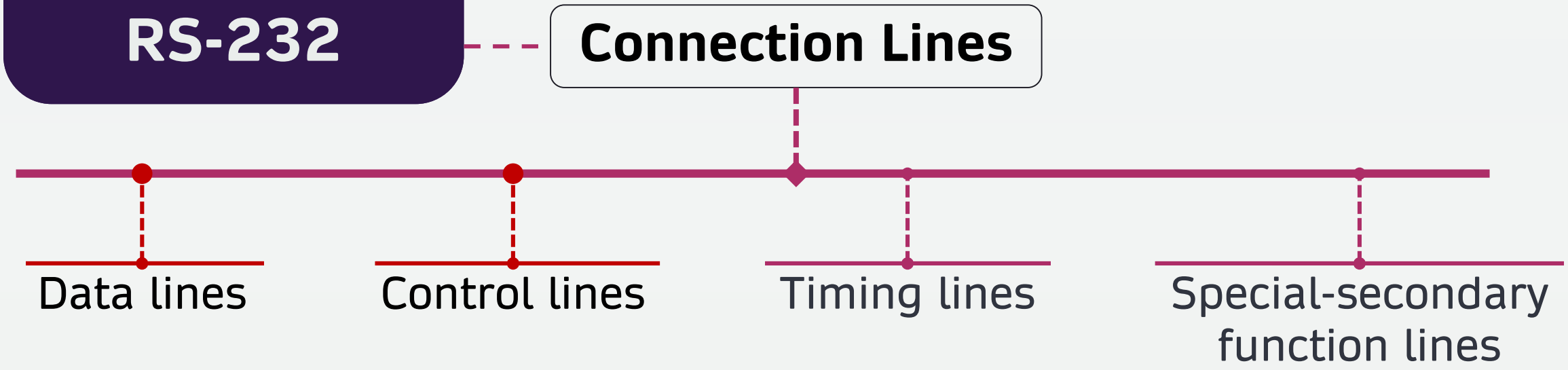


RS-232
DB-9 connector

RS-232

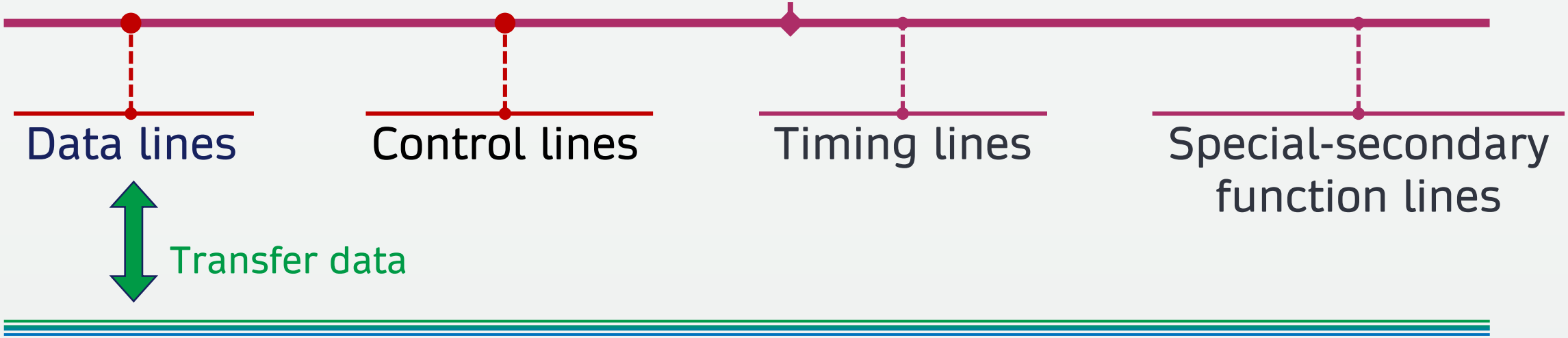

Connection Lines
Data lines
Control lines
Timing lines
Special-secondary function lines

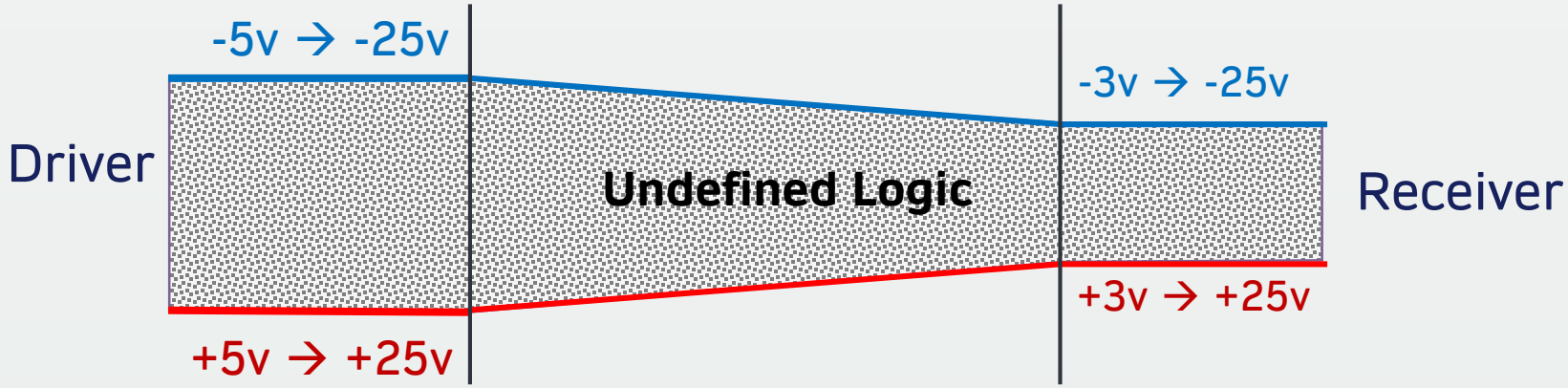
RS-232


Connection Lines
Data lines
Control lines
Timing lines
Special-secondary function lines

RS-232

Connection Lines

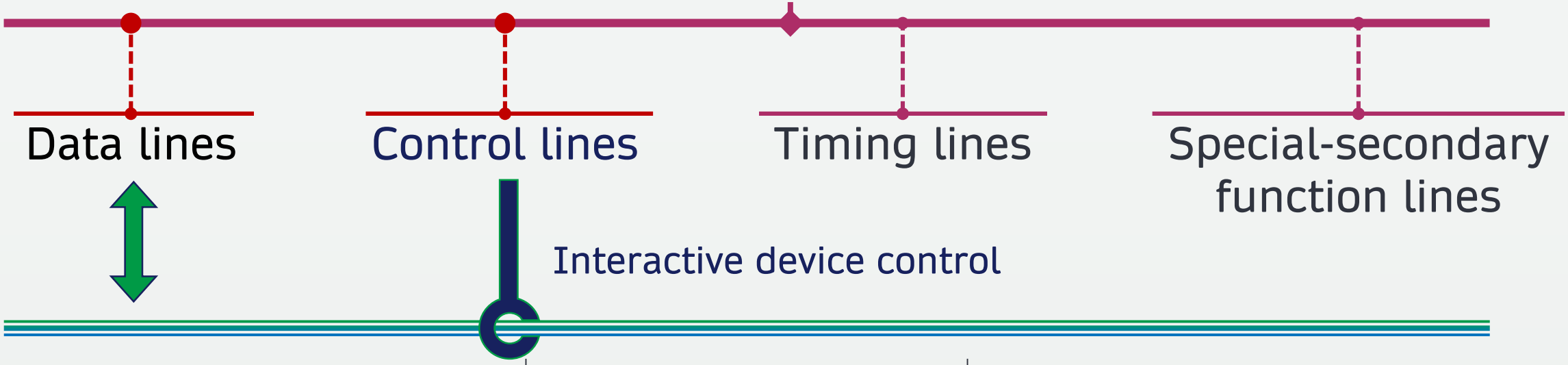




* Logic level referenced to ground

RS-232

Connection Lines



Transmit

Receive

Signal common ground

Hardware Handshaking

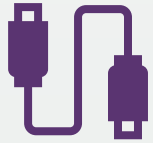
Software Handshaking

RTS	Request to Send
CTS	Clear to Send
DSR	Dataset Ready
DTR	Data Terminal Ready

RS-232 Limitations

Point to Point Restriction

Distance Limitation



20m *

Baud rate

20kbps

Modern Supply Incompatibility

* For baud rate 12kbps

RS-485

Extension of RS-422

- Multi-drop on 2 wires
- Distance up to 1200m **
- Data rates up to 10Mbps **

Supports multiple modules

- Up to 32 driver/receiver on the same line
- Repeater adds more modules

**** Maximum bit rate and maximum length cannot be achieved at the same time**

RS-485

Differential voltage* for logic level

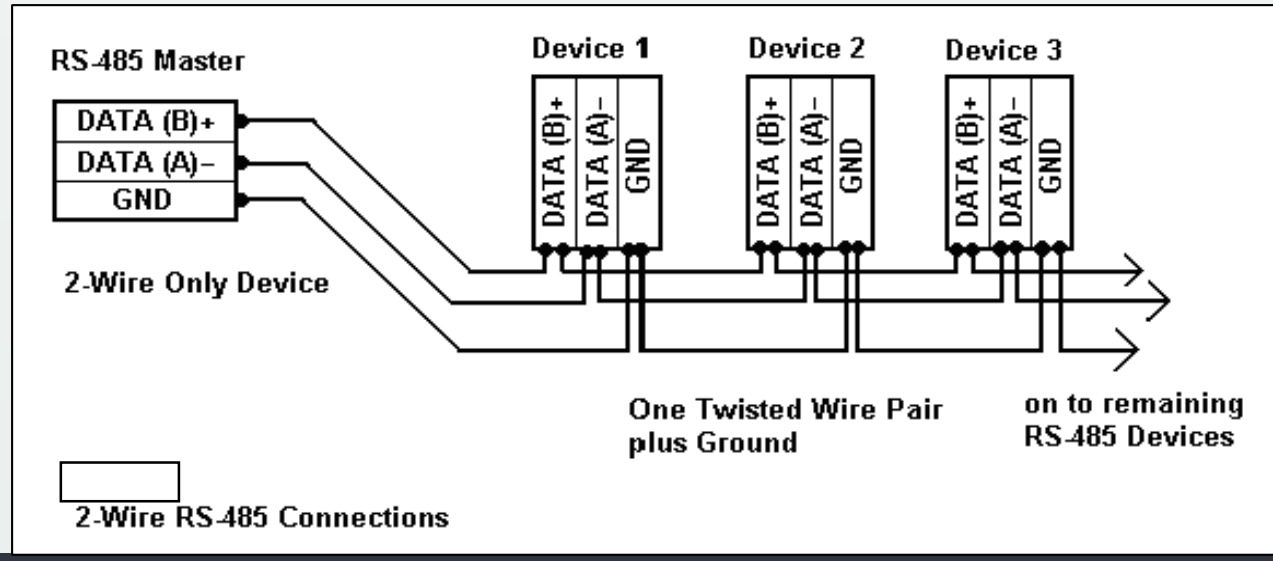
- Less suspectable to noise

Tri-state line driver

- Allows multi-drop

OFF state	ON state	High impedance state
MARK	**SPACE**	
Logic 1	Logic 0	
-1.5 : -6v	+1.5 : +6v	Disabled

*A terminal respect to B terminal



Current loop

~~0 - 20mA~~

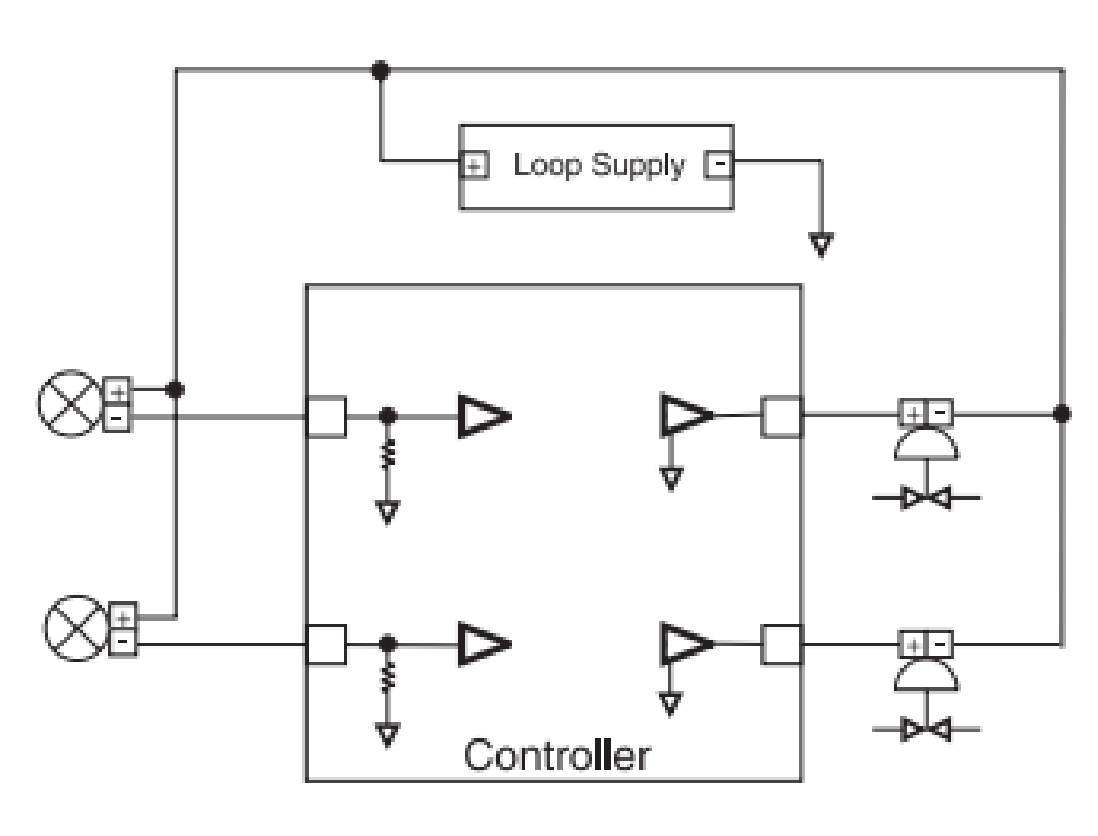
4 - 20mA

On most devices the current powers the device

Requires only two wires

Excessive Field Wiring – Minimum one wire per field device point to the centralized controller

Single loop power supply

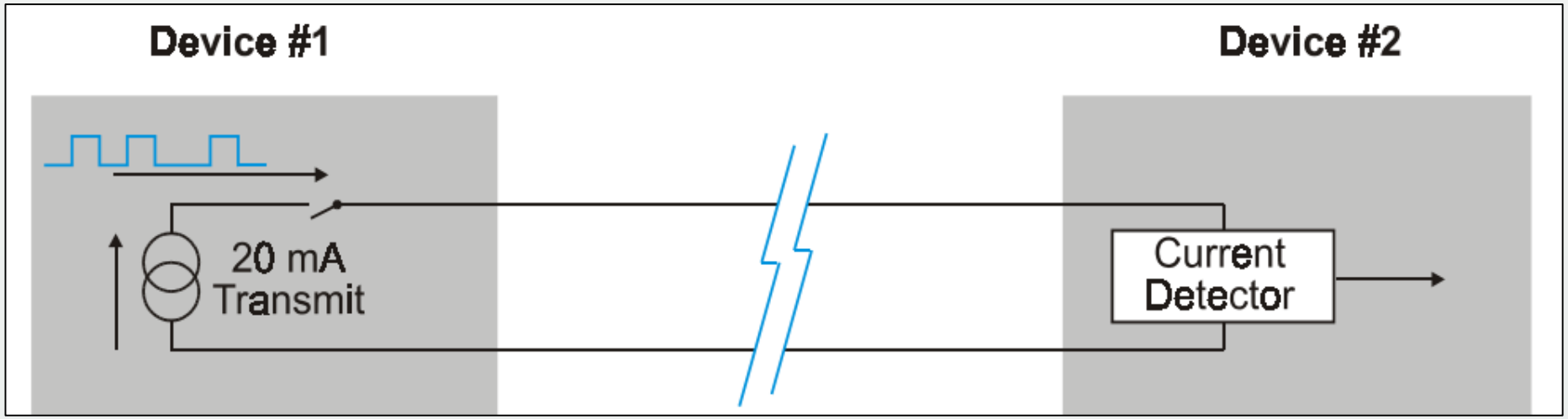


Current loop

Current measurement
Voltage drop due to long distances don't employ measurement error

Can drive lines up to 1km

In reasonably slow bit rates



Industrial Protocols

Industrial Protocols

- Modbus
- HART
- AS-I
- TCP / IP
- Device-Net

Modbus

Modbus

Transmission protocol

Describes the messaging communication dialog

No physical interface

Serial link

- RS-232
- RS-485

Open protocol

Multi-vendor integration

Point-to-Point and Multi-drop

- **Relatively slow**
  - 115200 baud
- **Single master**
- **Multi slaves**

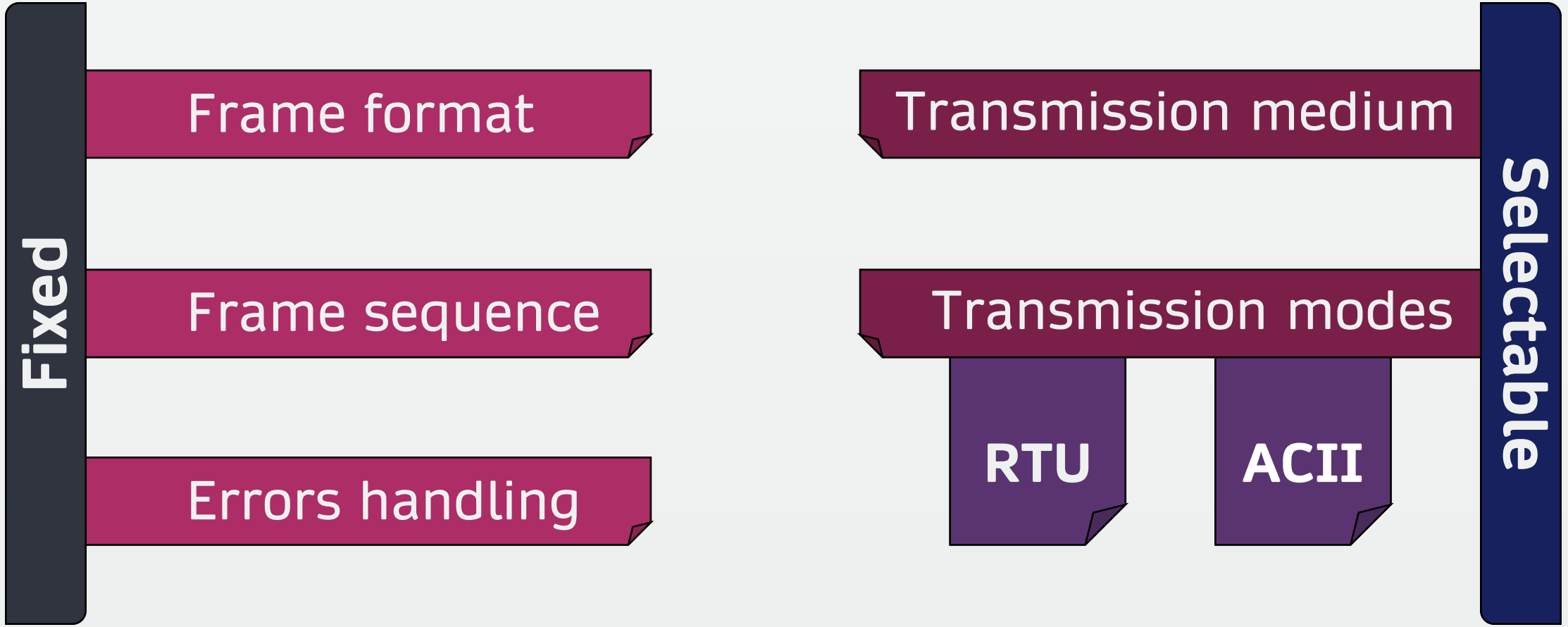
Extension : over Ethernet

Characteristics

Fixed

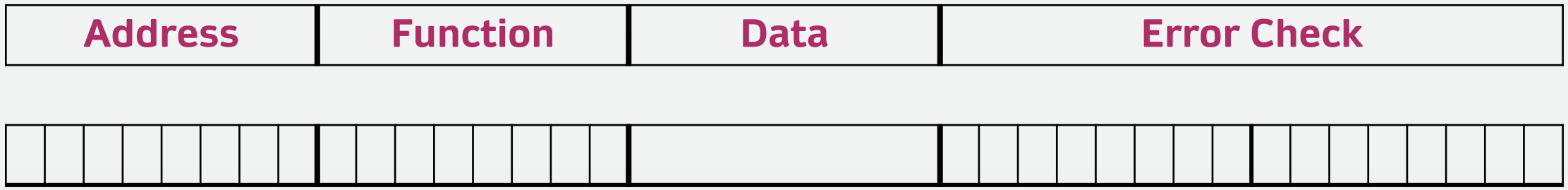
Selectable

Characteristics



Structure

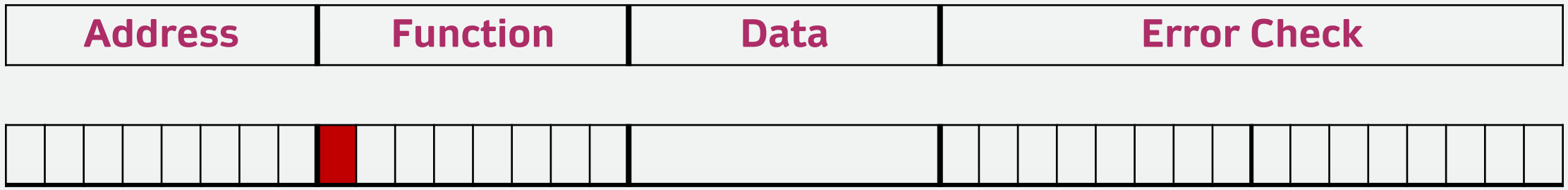
Frame format



1 byte	1 byte	Variable	2 bytes
Target address	A function to perform	The message	
Responding device address	Echo the same		
	Echo the same But **MSB = 1**		

Structure

Frame format



1 byte	1 byte	Variable	2 bytes
Target address	A function to perform	The message	
Responding device address	Echo the same Echo the same But **MSB = 1**		

HART

Challenge

The Knowhow of data transfer for two different types:

Analog Signal

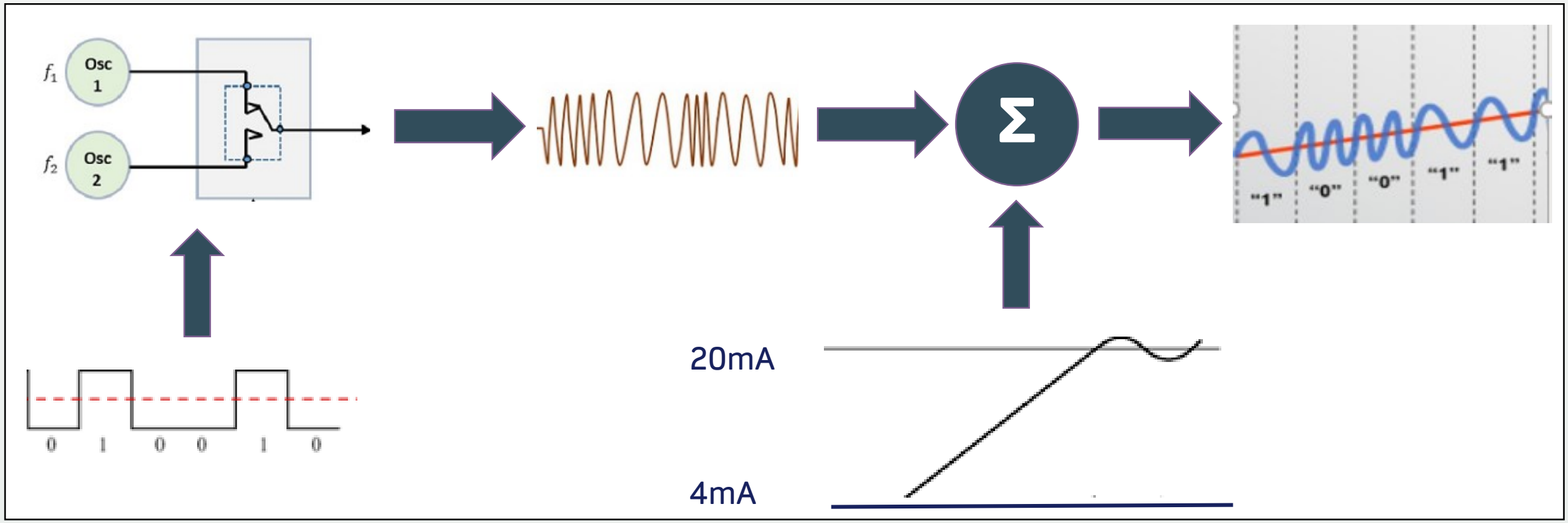
Digital Signal

With no interference

HART: Highway Addressable Remote Transducer

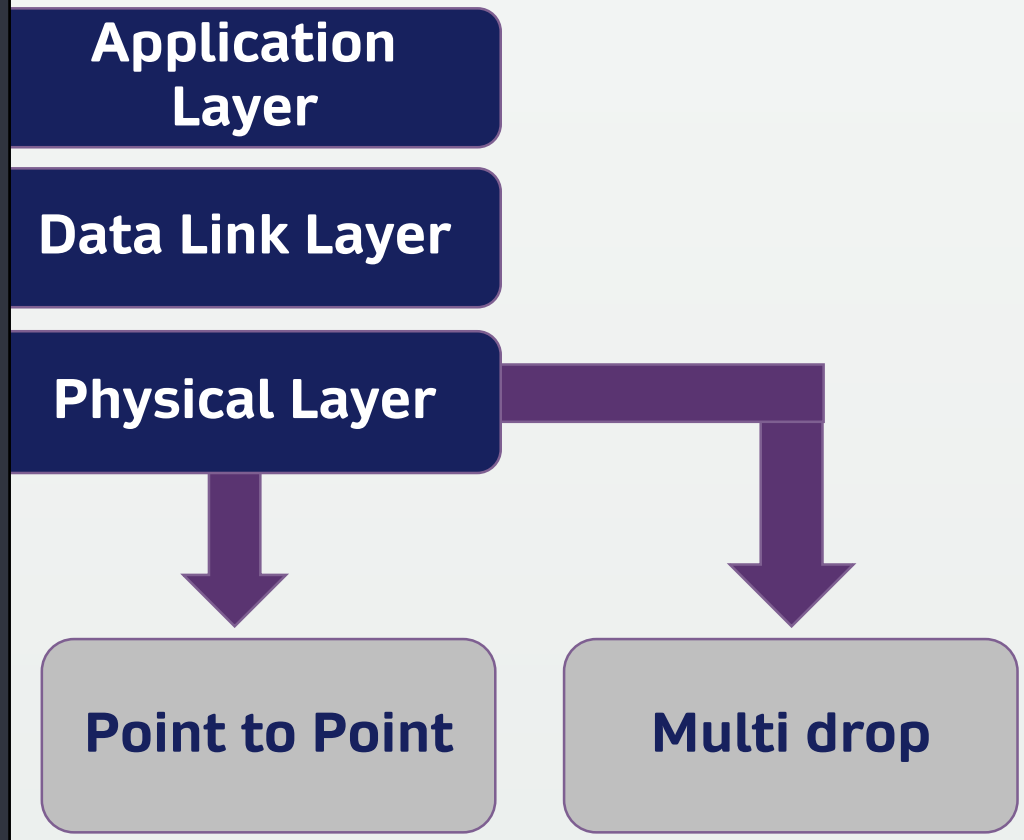
Frequency Shift Keying

In 1990s,
FSK (Frequency Shift Modulation) technique has been certified



Layers Structure

HART Network



HART Network

Hardware Implementation

- **Power Supply**
- **Field Device**

  Smart sensor with an output current signal in range of 4-20mA
- **Host**

  Primary controller can be sufficient, such as PLC or DCS, and a handheld can be a secondary controller

Multi-drop

HART Network

The FSK technique must be used for digital data sharing such as the ID related to each field device

Cat 5 shielded, twisted pair wire is recommended

Communication Modes

Polling / Master-Slave Mode

Burst / Broadcast Mode

Burst Mode

Communication Mode

- No message request needed
- High data transfer rate (3-4 data per second)
- Can be integrated with point to point network

Data Link Layer

- Preamble
- Delimiter
- Address
- Command
- Byte Count
- Command Response Code
- Field Device Status
- Checksum

Data Link Layer

Preamble

- First field in sent message
- Wake up and synchronize all connected receivers in the network

Data Link Layer

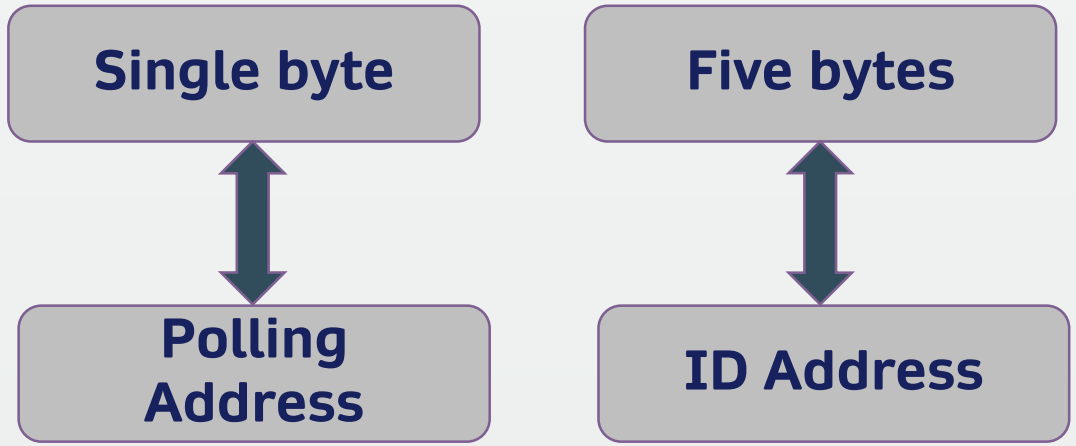
Delimiter

- Single byte field
- Indication to the end of preamble field
- Considered to be the Start field
- Classifies the message type to a :
  - Request from Master
  - Response of Slave

Data Link Layer

Address

Specifies the destination address and its type



Data Link Layer

Command

- Single byte field
- Represents which command to be executed, but without any data analysis

Data Link Layer

Byte Count

- Single byte field
- Counts the rest bytes for the message to be completely received
- Receiver can check the end of the message through the data gathered from this device

Data Link Layer

Command Response Code

- Single byte field
- Error type detection in the received message is available "Response Messages"
- Corrective messages are included as a result of each detected error type

Data Link Layer

Field Device Status

- Single byte field
- Included in the response messages as an indication to the health level of the field device

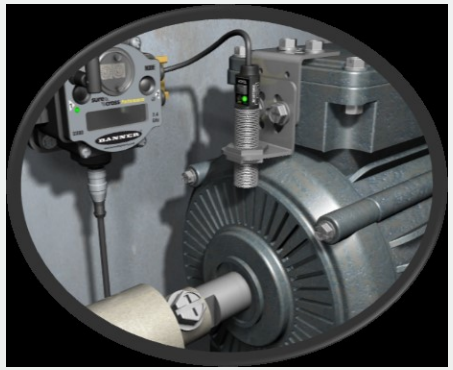
Data Link Layer

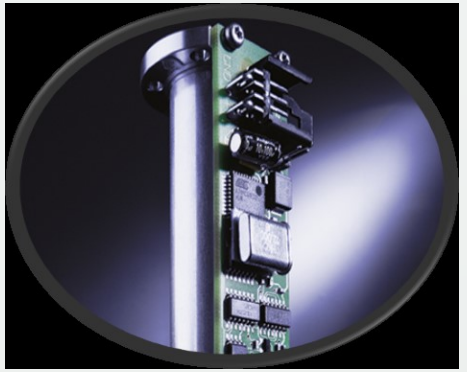
Checksum

- Single byte field
- Correctly received data causes the transmitting end check value to be identical to the receiving end check value

Application Layer

- Universal commands
- Common Practice Command
- Device Specific Command





Application Layer

Universal commands

Provide functions that must be implemented in all field devices such as:

- **Reads manufacturer and device type**
- **Reads primary variable and its unit**
- **Reads current output and its percentage in range**
- **Reads device range**

Application Layer

Common Practice Command

Provides functions that are common to many but not to all field devices:

- **Writes damping time constant**
- **Calibrates (set 0 reference and set span)**
- **Sets fixed output current**
- **Sets DAC** zero and gain**

** Digital to Analog Converter

Application Layer

Device Specific Command

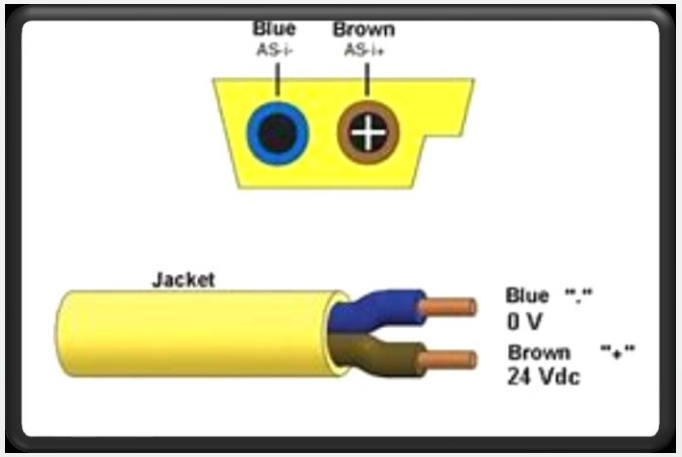
Provides functions that are unique to a particular field device (Specified by the device manufacturer):

- Reads or Writes low flow cut-off value (Flow apps)
- Reads or Writes density calibration value
- Chooses mass flow (density or flow)

AS-Interface

Specifications

- **Master-Slave mode**
- **62 slave devices can be connected**
- **Simultaneously, different data type can be transmitted and received**
- **Can be installed up to 100-600 m with repeaters**



2 Wire untwisted, unshielded cable (16AWG, 1.5mm) can be used

AS-I: Actuator-Sensor Interface

Benefits

Cost Savings

Simplicity of location and wiring

Fast Response

Benefits

Power and data can be merged in the same cable, then:

- **Less cables need to be wired out in the field**
- **No need for external power supply**

Cost Savings

Benefits

Simplicity of location and wiring

Devices can be connected, with a higher flexibility, in multiple wiring systems such as:

- **Star connection**
- **Line arrangement**
- **Line with layer switches**
- **Tree configuration**

Benefits

Response time of slave device is shorter than the single data acquisition cycle of PLC, then it is used in

critical timing applications such as:

- **Packaging systems**
- **Bottling line**
- **Elevators**
- **Safety systems**

Fast Response

Device-Net

Layers Structure

- Network and Transport Layers
- Data Link Layer
- Physical Layer

Layers Structure

Network and Transport Layers

Duplicate the data gathering capability, to get a successful network, then required data are:

- **MAC ID**
- **Message (signal to user)**

Layers Structure

Data Link Layer

- Use CAN protocol (CSMA/CD) to reduce data collisions and increase successful rate of data transmission

Layers Structure

Physical Layer

Main hardware components:

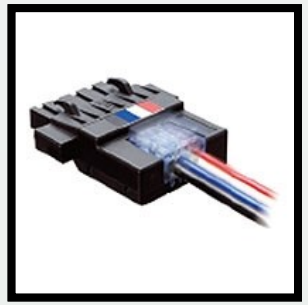
- Cables
- Nodes
- Taps
- Termination resistors
- Trunk line – Drop line topology

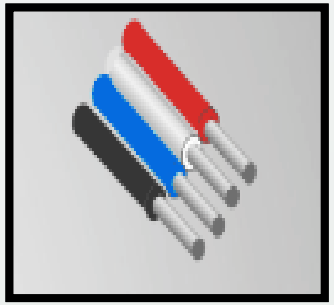
Software interface:

- RS Networx license
- EDS (Electronic Data Sheet)

Physical-Hardware

Data Rate	Thick round	Thin round	Kwik Link flat	Kwik Link lite flat
125 kbps	500 m	100 m	240 m	350 m
250 kbps	250 m	100 m	200 m	150 m
500 kbps	100 m	100 m	75 m	55 m





Physical-Software

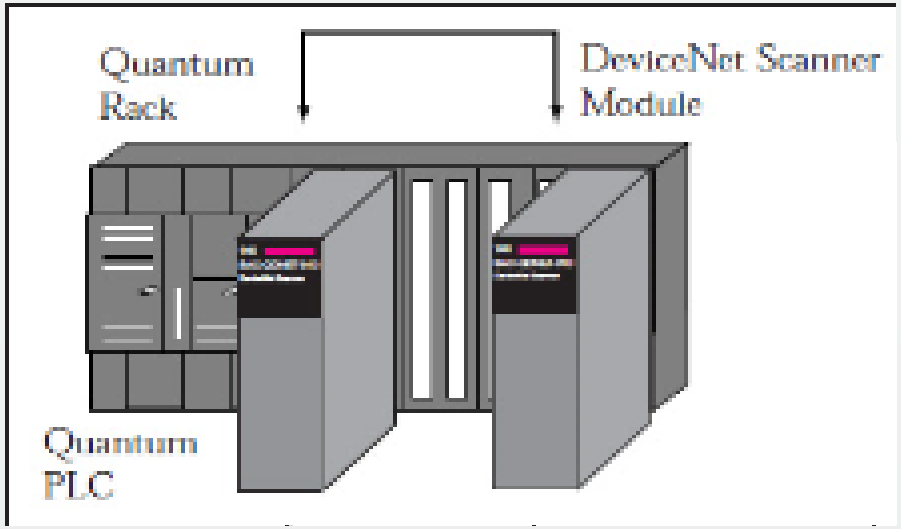
RS Networx license

Map and assign addresses of all devices to the device-net scanner, in the form of:

- **Graphical interface**
- **Spreadsheet layout**

EDS (Electronic Data Sheet)

A text file containing all information about devices



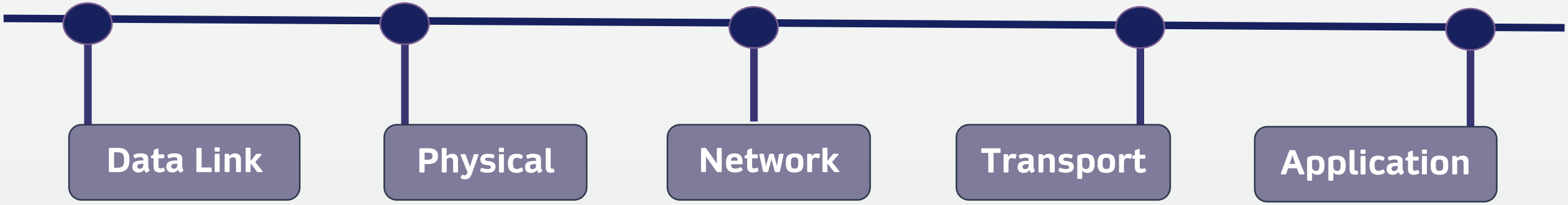
Device-net scanner connected with PLC

Pros and Cons

Pros	Cons
Cost effective	Limited message size
Wide spread acceptance	Limited maximum cable length (6m)
High reliability	
Available power on network	

TCP/IP

Layers Structure



TCP/IP: Transmision Control Protocol/Internet Protocol

Layers Structure

1 **Application Layer**

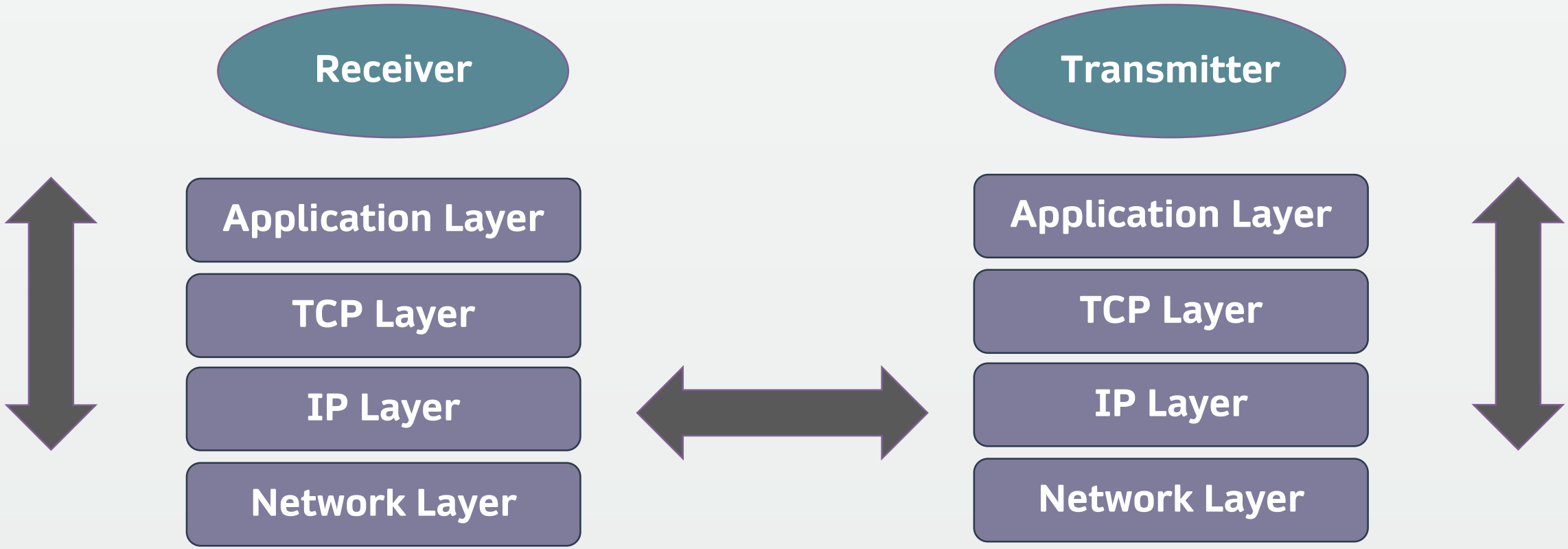
User interface such as web browsers

2 **Transport Layer**

Responsible for chopping data into packets, each packet is labeled with a header for data reception guarantee

TCP Protocol

Send-Receive acknowledge relationship is applicable



Layers Structure

3 Network Layer

IP addresses of the sender and receiver must be shared for accurate data handling

4 Physical Layer

Finally data is transmitted to the controller, via the ethernet packages

Category	Data transfer rate
Cat 6	1 Gbps
Cat 6a & Cat 7	10 Gbps
Cat 5 & Cat 5e	10-100 Mbps
Rj-45	Full-duplex

Summary

Summary

We have introduced a basic knowledge in a large scale of industrial network fields, representing:

- OSI Model
- Serial Link Standards
  - RS-232
  - RS-485
  - Current Loop
- Modbus
- HART
- AS-I
- TCP / IP
- Device-Net

References

References and Published Papers

1.*Practical Data Communications for Instrumentation and Control*, by: Steve Mackay

2.*Practical Industrial Data Networks: Design, Installation and Troubleshooting, by:* Steve Mackay

3.*Publication of International CAN Conference, sponsored by: Motorola Semiconductor, National Semiconductor, Philips Semiconductors*

4.*Advanced Industrial Control Technology, by: Peng Zhang*

5.*Getting Results with RS-Networx for Device –Net, by: Rockwell Automation*

6.TCP/IP Tutorial and Technical Overview, supported by IBM

7.*User Manual for Allen Bradley*

8.*Demystifying the full stack TCP/IP on computer networks*

Thanks