EE-222: Microprocessor Systems

Basics of Serial Communication

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NUST

SCHOOL OF ELECTRICAL ENGINEERING &
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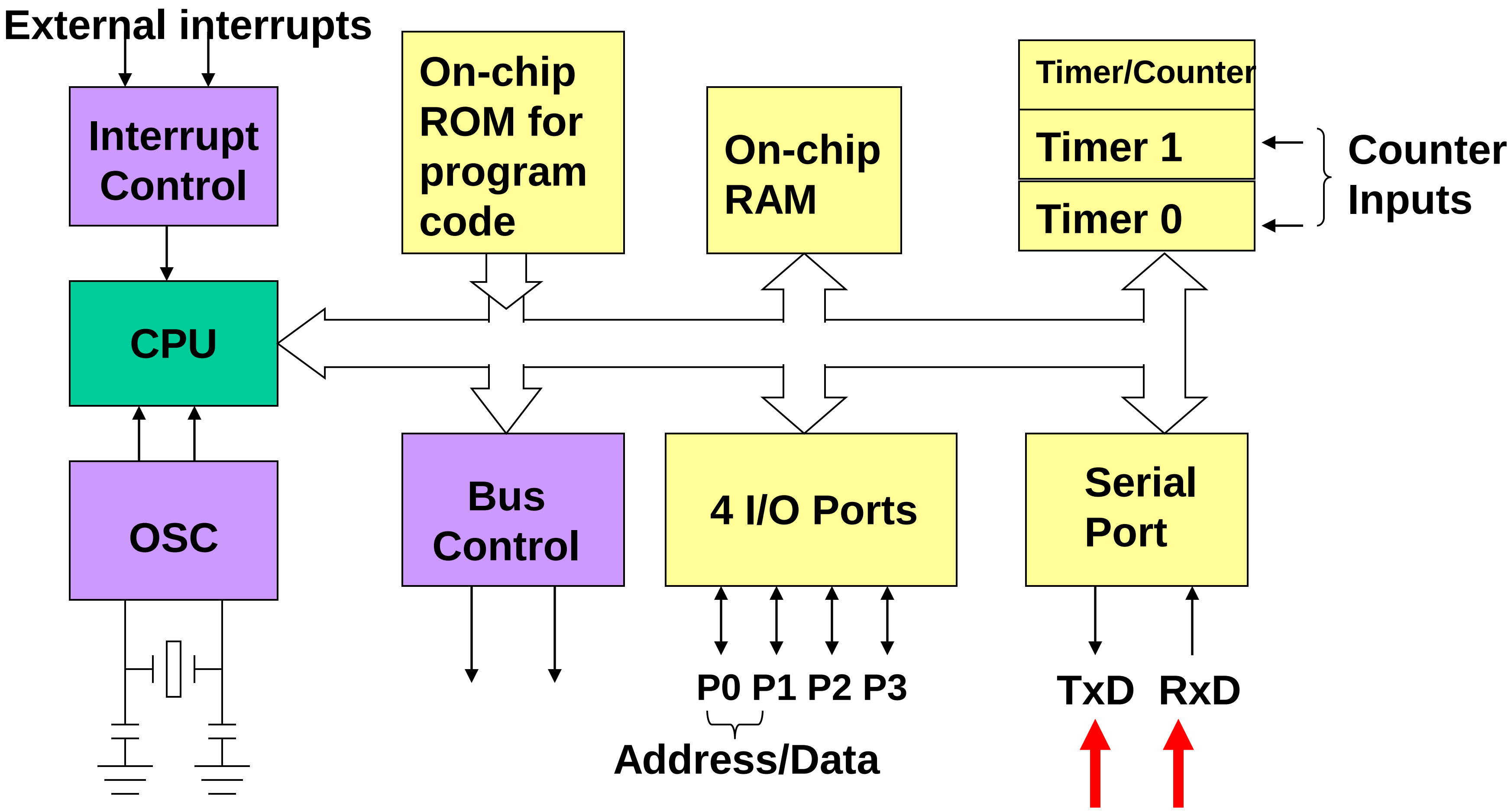
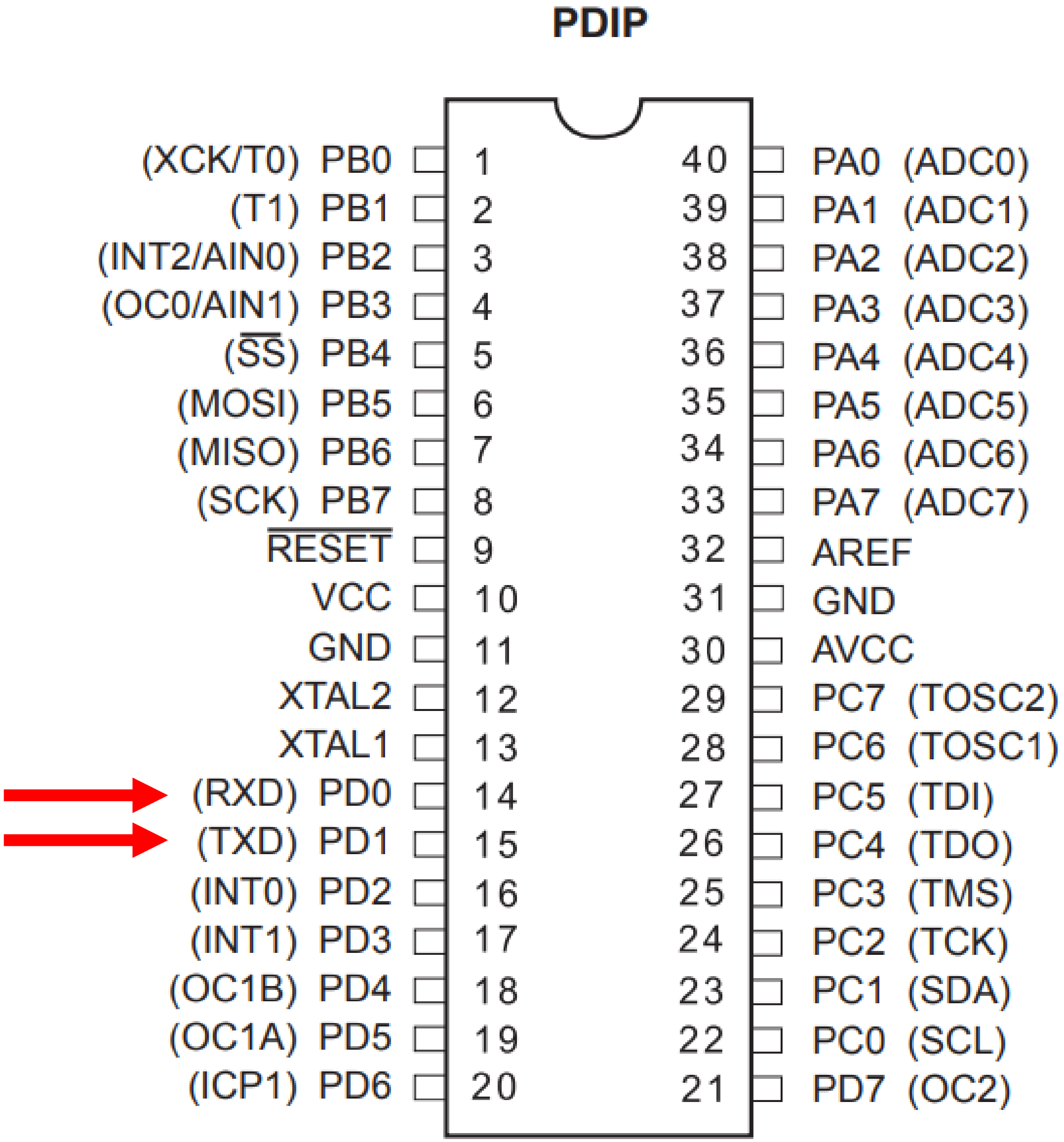
Review: Inside Architecture of AVR



Review: Pin-out ATmega16A

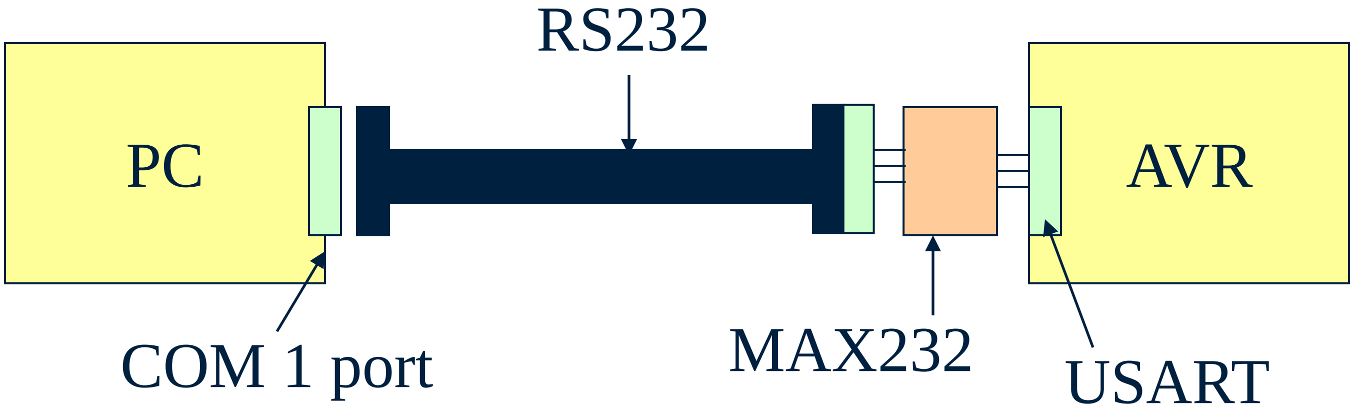


http://ww1.microchip.com/downloads/en/devicedoc/atmel-8154-8-bit-avr-atmega16a_datasheet.pdf

AVR and PC

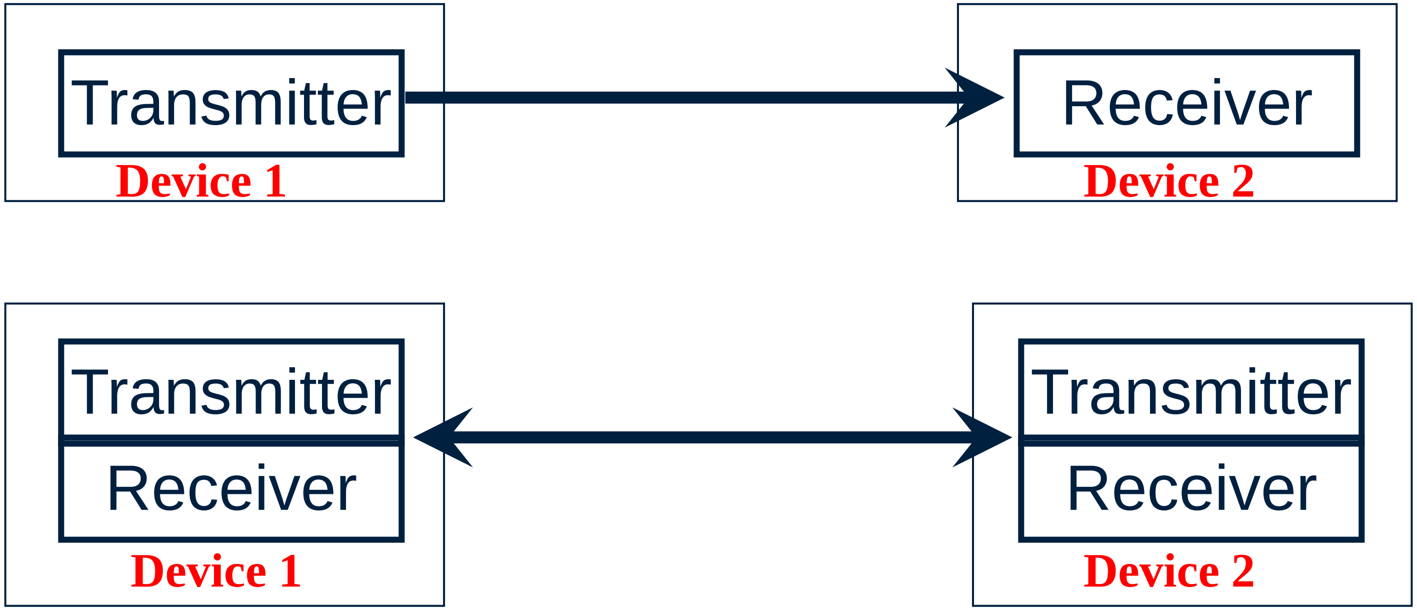
- The AVR module connects to PC by using RS232.

- RS232 is a protocol which supports:
  - Full-duplex and
  - Synchronous/Asynchronous, serial communication.
  - We discuss these terms in following sections.



Simplex vs. Duplex Transmission

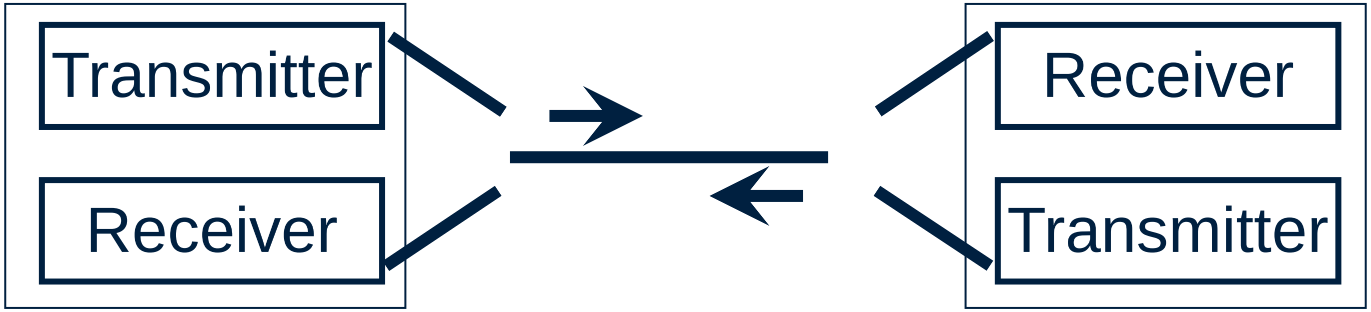
- Simplex transmission: the data can be sent in one direction only,
  - Example: the computer only sends data to the printer.
- Duplex transmission: the data can be transmitted and received, in both directions.

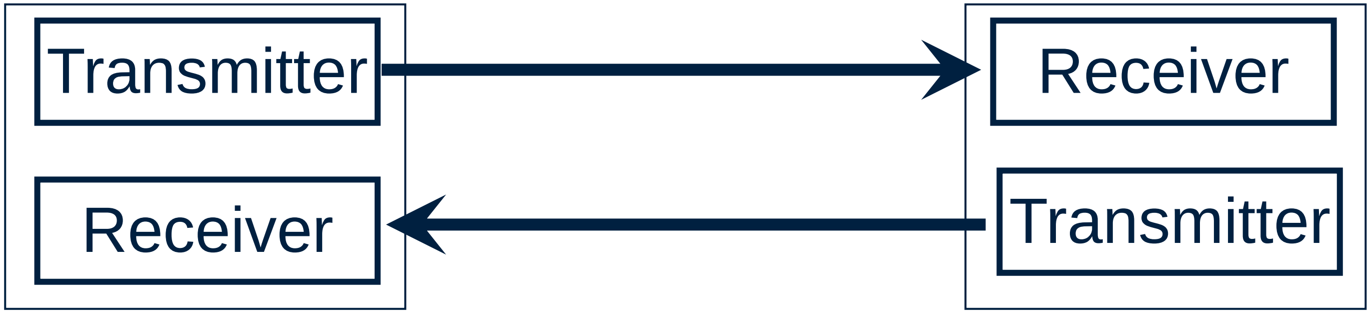


Half vs. Full Duplex

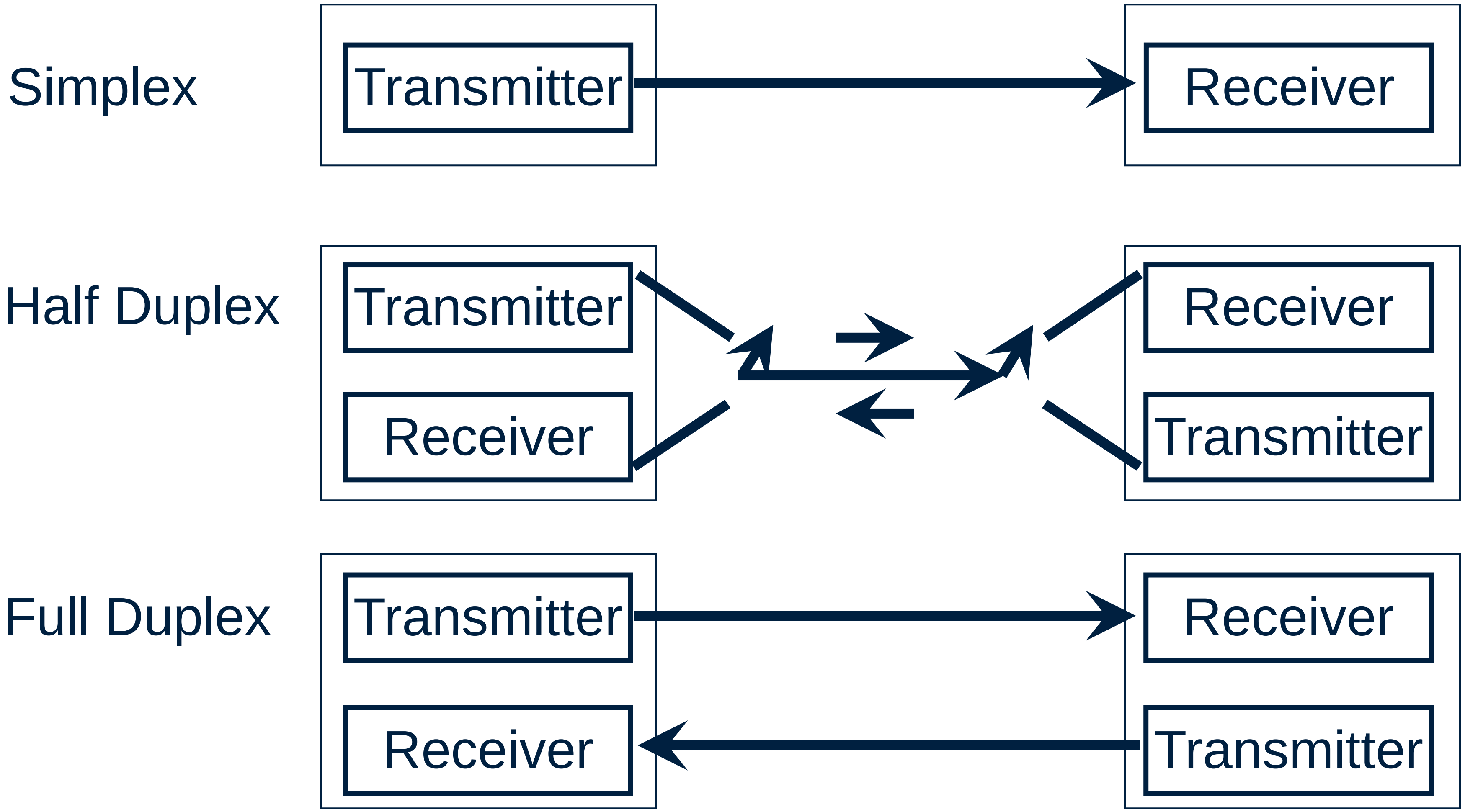
- Half duplex: if the data is transmitted one way at a time.

- Full duplex: if the data can go both ways at the same time.
  - Two wire conductors for the data lines.



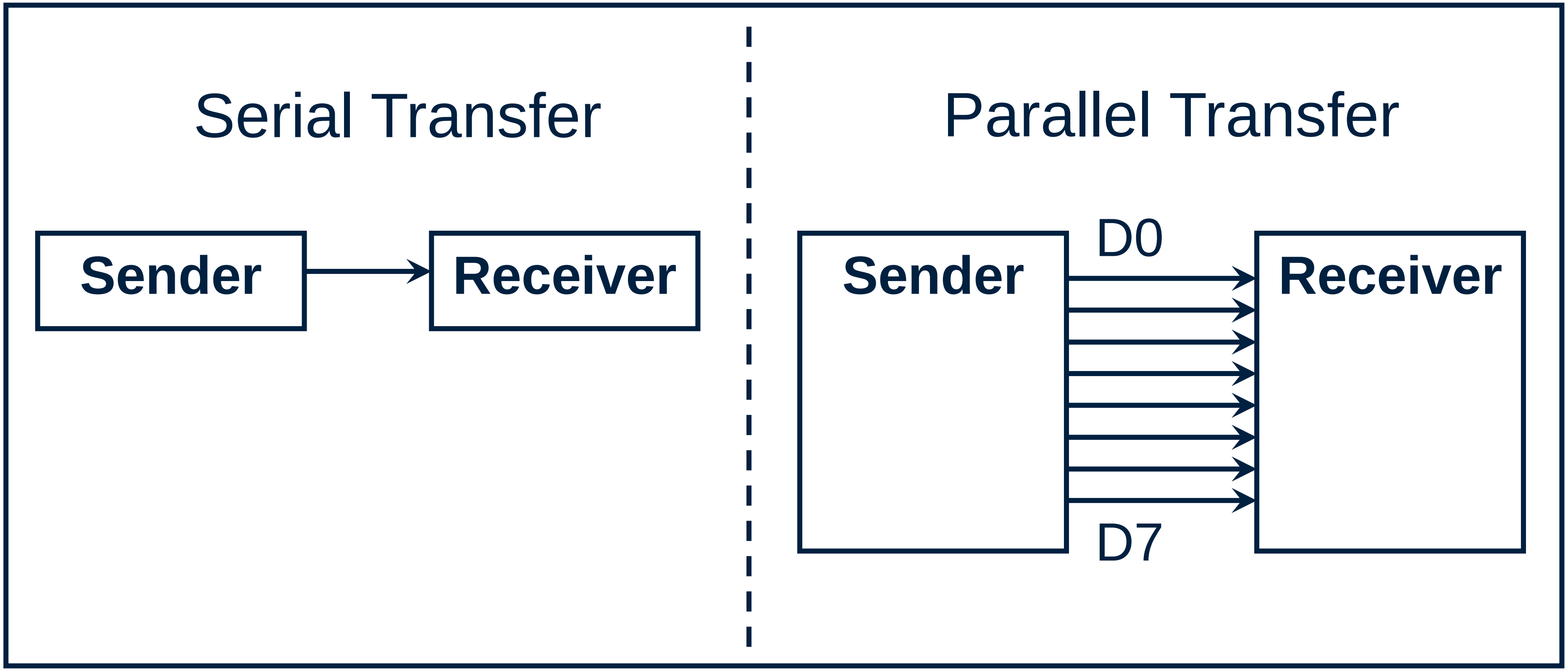


Simplex, Half-, and Full-Duplex Transfers



Serial versus Parallel Data Transfer (1/2)

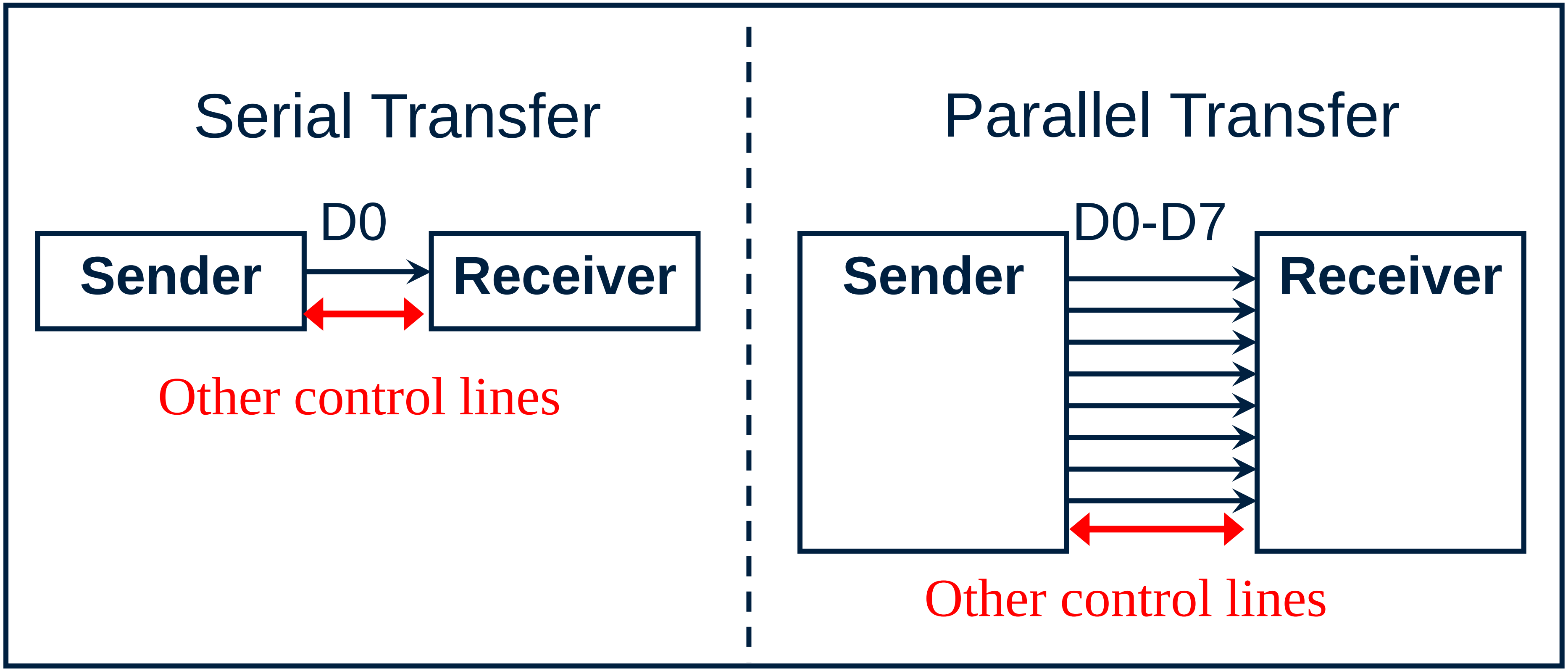
Computers transfer data in two ways:



Parallel vs. Serial

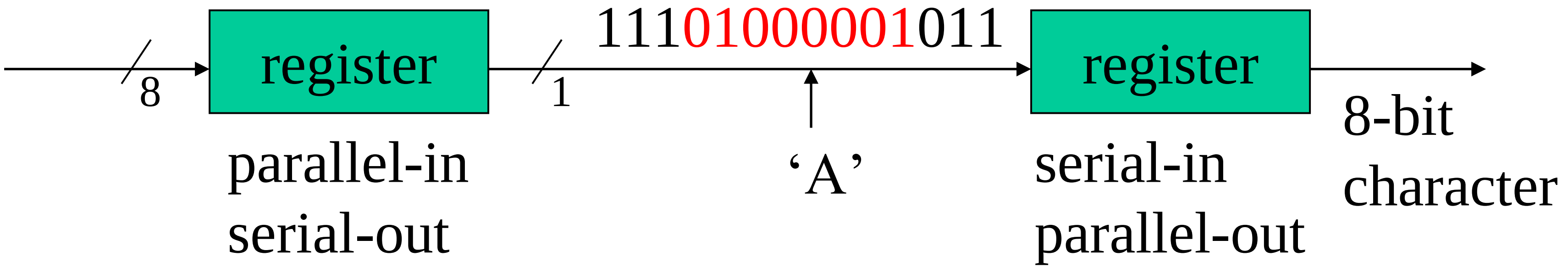
- Computers transfer data in two ways:
  1. Parallel:
     - Data is sent a byte or more at a time (fast)
     - Only very short distance between two systems
     - The 8-bit data path is expensive
     - Example: printer, hard disks
  2. Serial:
     - The data is sent one bit at a time (slow) with simple wire
     - Relative long distance (rarely distortion)
     - cheap
     - For long-distance data transfers using communication lines such as a telephone, it requires a modem to modulate (0/1 to analog) and demoulate (analog to 0/1).

Serial versus Parallel Data Transfer (2/2)



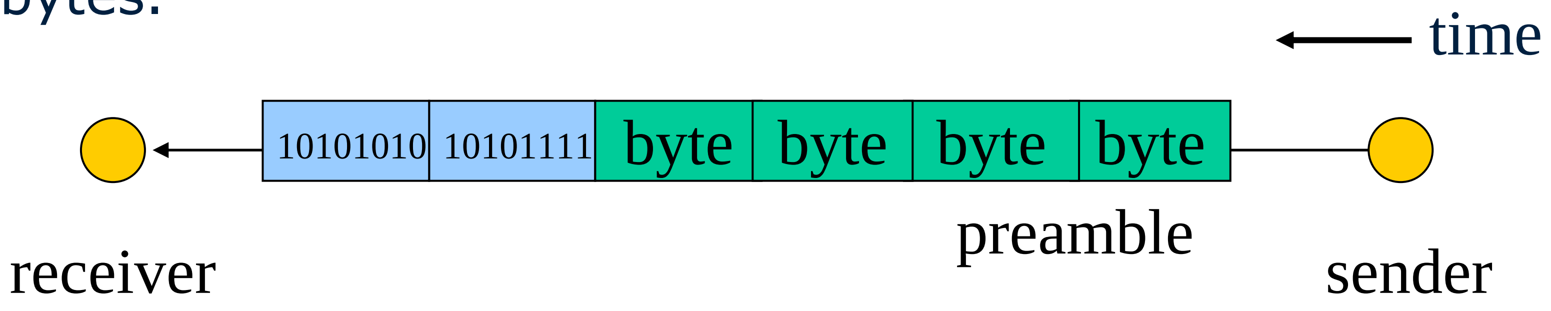
Serial Communication

- How to transfer data?
  - Sender:
    - The byte of data must be converted to serial bits using a parallel-in-serial-out shift register.
    - The bit is transmitted over a single data line.
  - Receiver:
    - The receiver must be a serial-in-parallel-out shift register to receive the serial data and pack them into a byte.

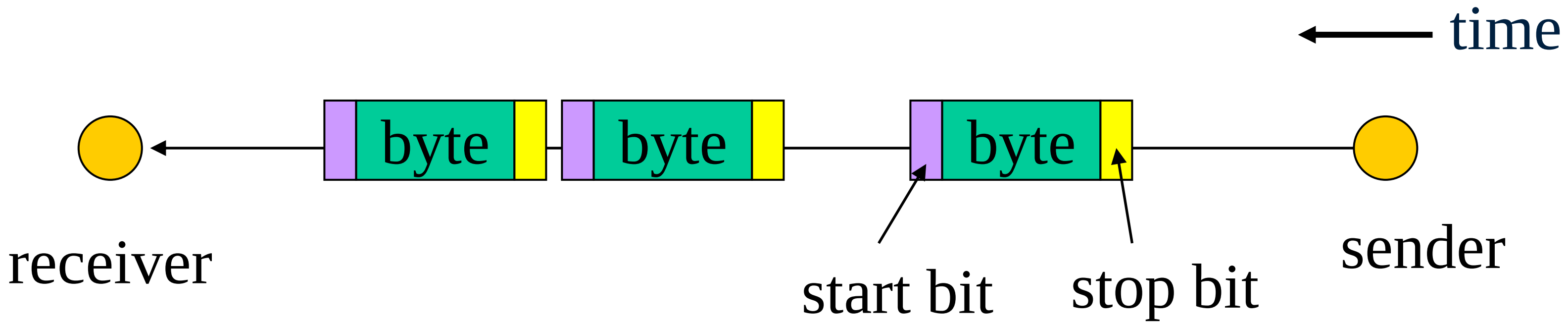


Asynchronous vs. Synchronous

- Serial communication uses two methods:
  - In synchronous communication, data is sent in blocks of bytes.



  - In asynchronous communication, data is sent without continuity.



UART & USART

- It is possible to write software to use both methods, but the programs can be tedious and long.

- Special IC chips are made for serial communication:
  - USART (universal synchronous-asynchronous receiver-transmitter)
  - UART (universal asynchronous receiver-transmitter)

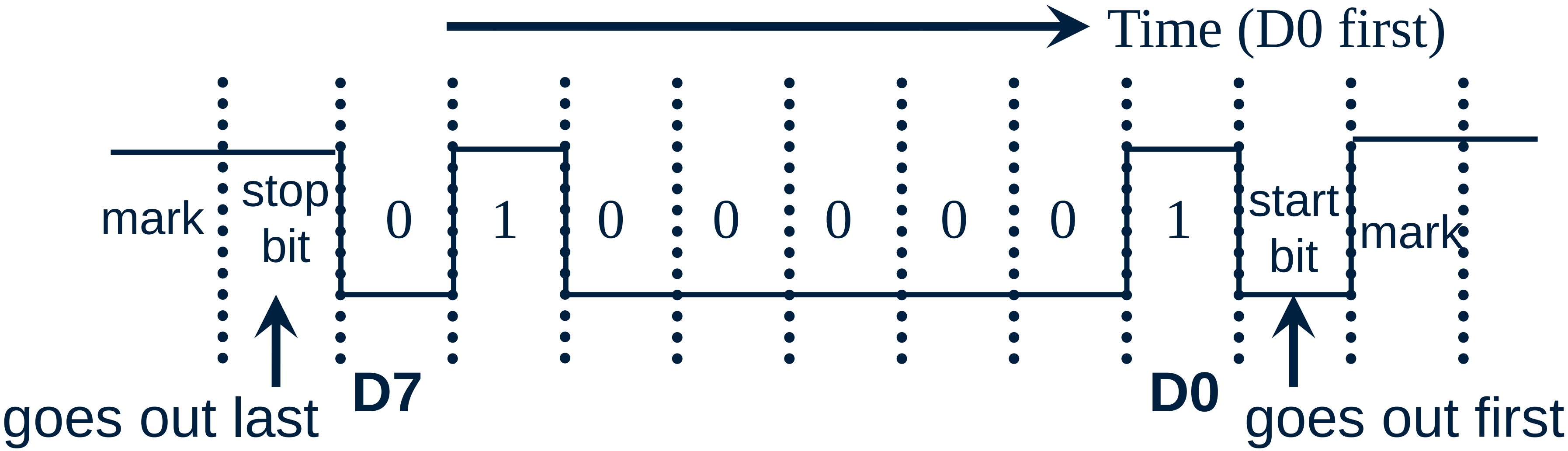
- The AVR chip has a built-in USART.

AVR Serial Communication

- The AVR has serial communication capability built into it:
  - Full-duplex
  - Asynchronous and Synchronous mode supported.
- How to detect that a character is sent via the line in the asynchronous mode?
  - Answer: Data framing!

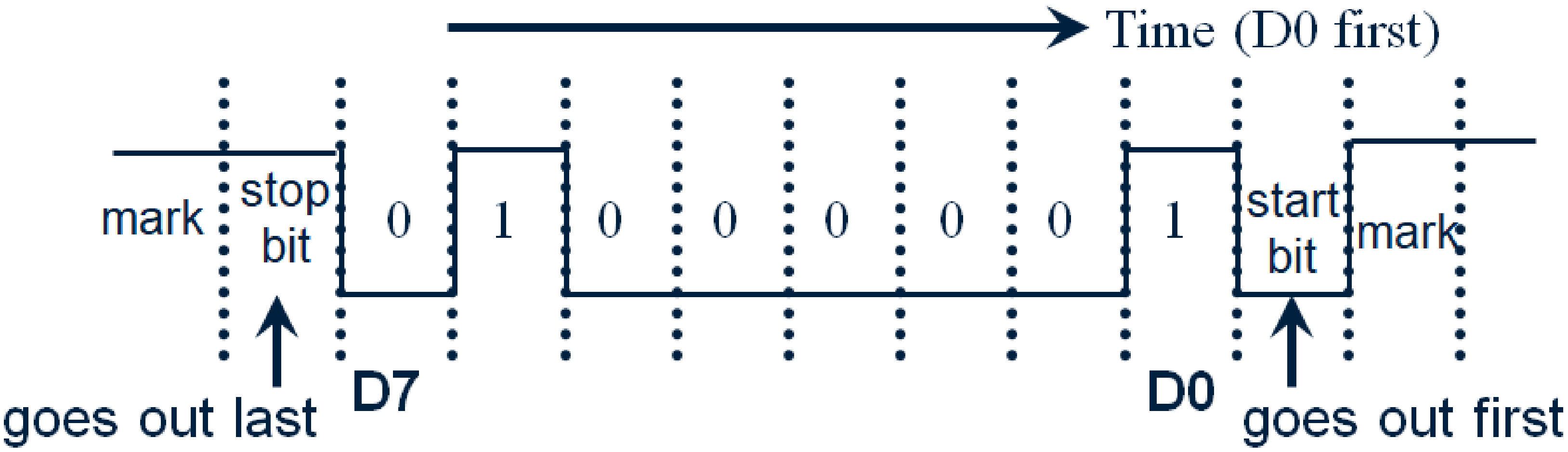
Framing (1/3)

- Each character is placed in between start and stop bits. This is called **framing**.
  - Framing ASCII "A" (41H)



Framing (2/3)

- The start bit is 0 (low) and always one bit.
- The LSB is sent out first.
- The stop bits is 1 (high).
- The stop bit can be one (if 8 bits used in ASCII) or two bits (if 7 bits used in ASCII).
  - It is programmed for data that is 7 or 8 bits.
- When there is no transfer, the signal is 1 (high), which is referred to as mark.



Framing (3/3)

- We have a total of 10 bits for each character:
  - 8-bits for the ASCII code
  - 2-bits for the start and stop bits
  - 20% overhead

- In some systems in order to maintain data integrity, the parity bit is included in the data frame.
  - Even-parity and Odd-parity

  - In an odd-parity bit system the total number of bits, including the parity bit, is odd.

  - UART chips allow programming of the parity bit for odd-, even-, and no-parity options.

Data Transfer Rate

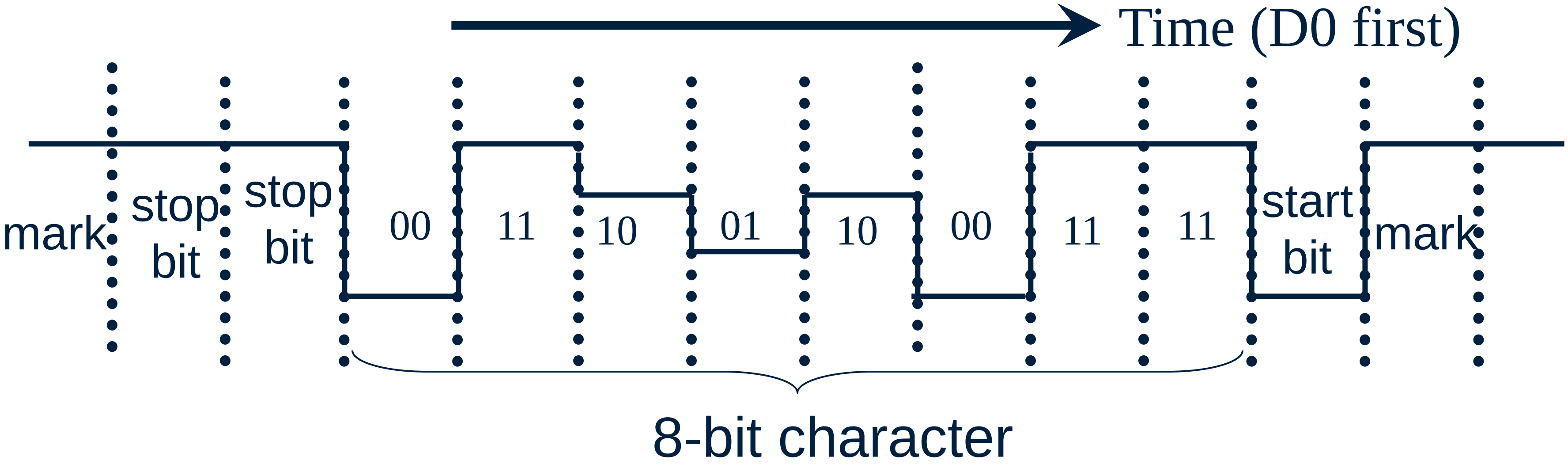
- How fast is the data transferred?

- Two methods to describe the speed:
  1. Data rate is defined as the number of bits transferred per second.
     - Each signal has several voltage levels.
     - The rate of data transfer is stated in *bps* (bits per second).
  2. Baud rate is defined as the number of signal changes per second.
     - The rate of data transfer is stated in *Hz* (used in modem).

- Data rate and Baud rate are not necessarily equal.
  - But as far the conductor goes both are same
    - Therefore (in this course) we use the terms interchangeably.

Example of Data Transfer Rate (1/2)

- Assume that data is sent in the following asynchronous mode:
  - 2400 baud rate
  - each signal has 4 voltage levels (-5V, -3V, 3V, 5V)
  - one start bit, 8-bit data, 2 stop bits



Example of Data Transfer Rate (2/2)

- From the previous example:
  - 2400 baud = 2400 signals per second =2400 Hz
  - 4 voltage level
    - $\text{Log}_2 4=2$, 2 bits is sent in every signal change
    - Data rate = 2 * 2400 Hz = 4800 bps

RS232 Standard

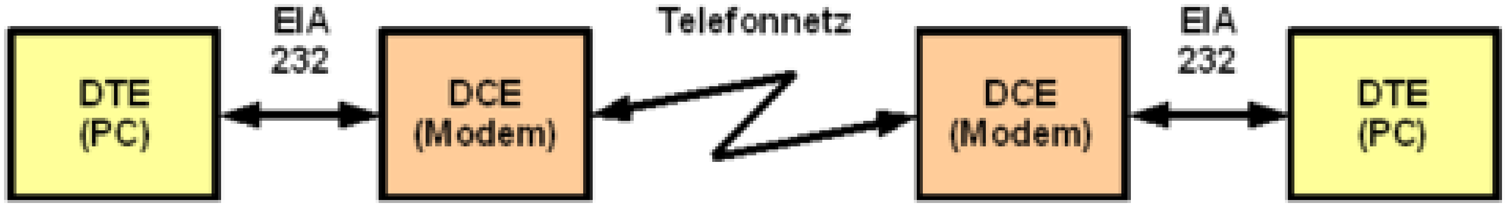
- RS232 (Recommended Standard 232) is an interfacing standard:
  - which is set by the Electronics Industries Association (EIA) in 1960:
  - RS232 is the most widely used serial I/O interfacing standard.
  - RS232A (1963), RS232B (1965) and RS232C (1969), now is RS232E
  - RS-232 is a standard for connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment).

- Define the voltage level, pin functionality, baud rate, signal meaning, communication distance.

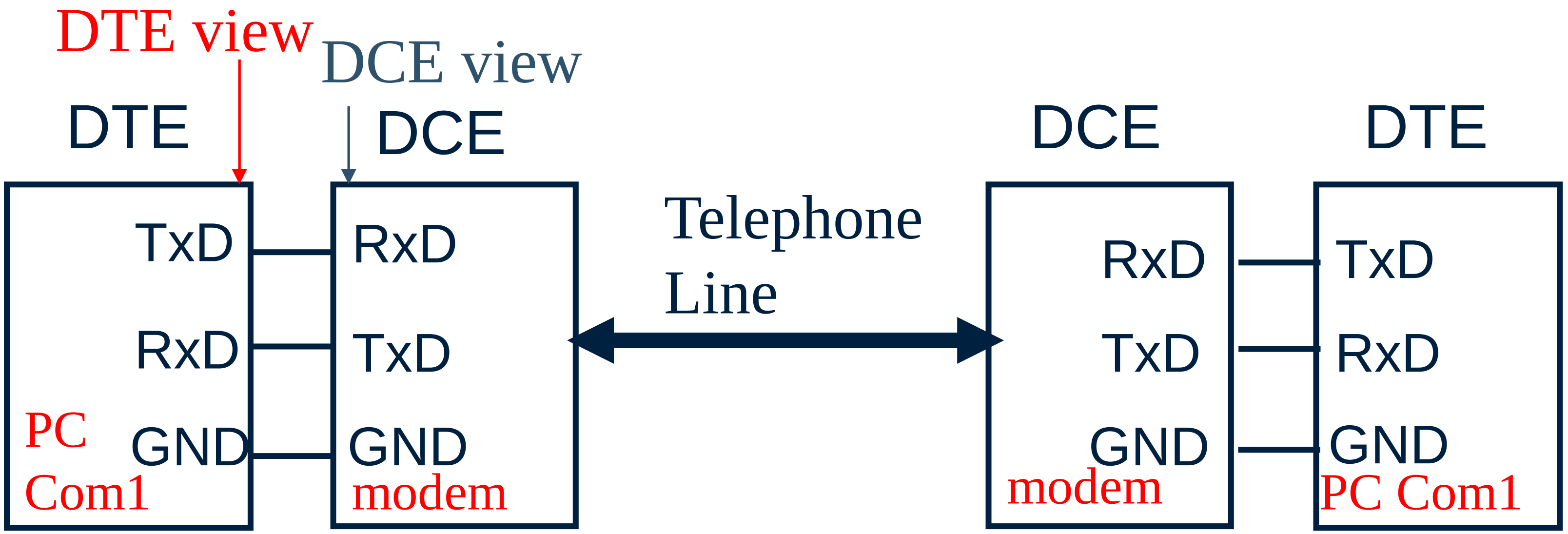
DTE and DCE

- DTE (Data Terminal Equipment):
  - DTE refers to terminals and computers that send and receive data.
    - i.e PC, AVR, 8051, or other equipment.

- DCE (Data Communication Equipment):
  - DCE refers to communication equipment, such as modems, that are responsible for transferring the data.



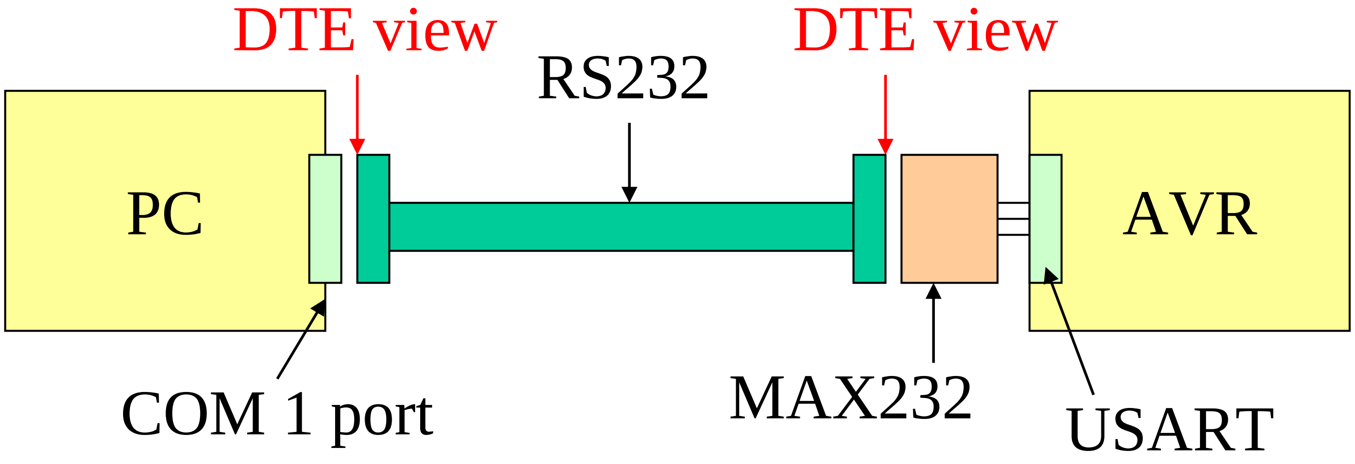
DTE and DCE Connections



IBM PC/compatible COM ports

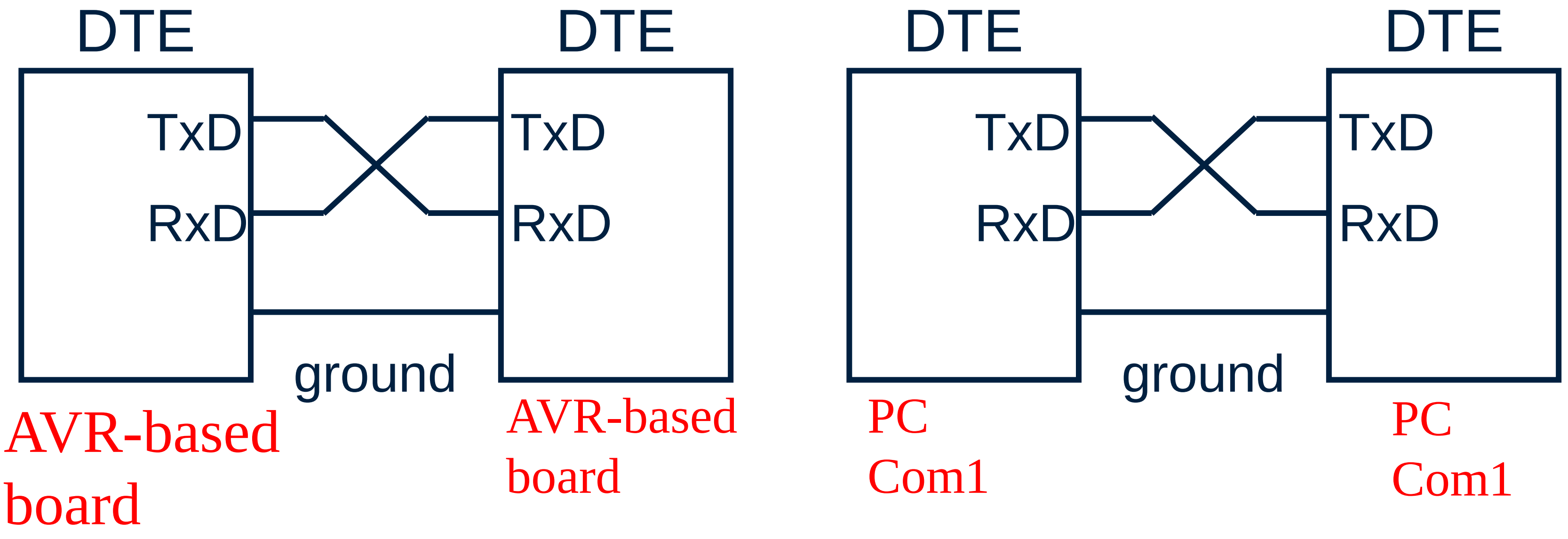
- IBM PC has 2 COM ports.
  - Both COM ports have RS232-type connectors.
  - For mouse, modem

- We can connect the AVR serial port to the COM port of a PC for serial communication experiments.



Null Modem Connection

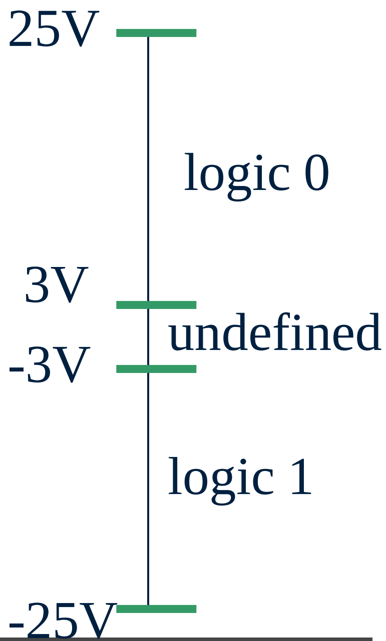
- The simplest connection between a PC and microcontroller requires a minimum of three pins, TxD, RxD, and GND.
  - shows null modem connection



RS232 Voltage Level

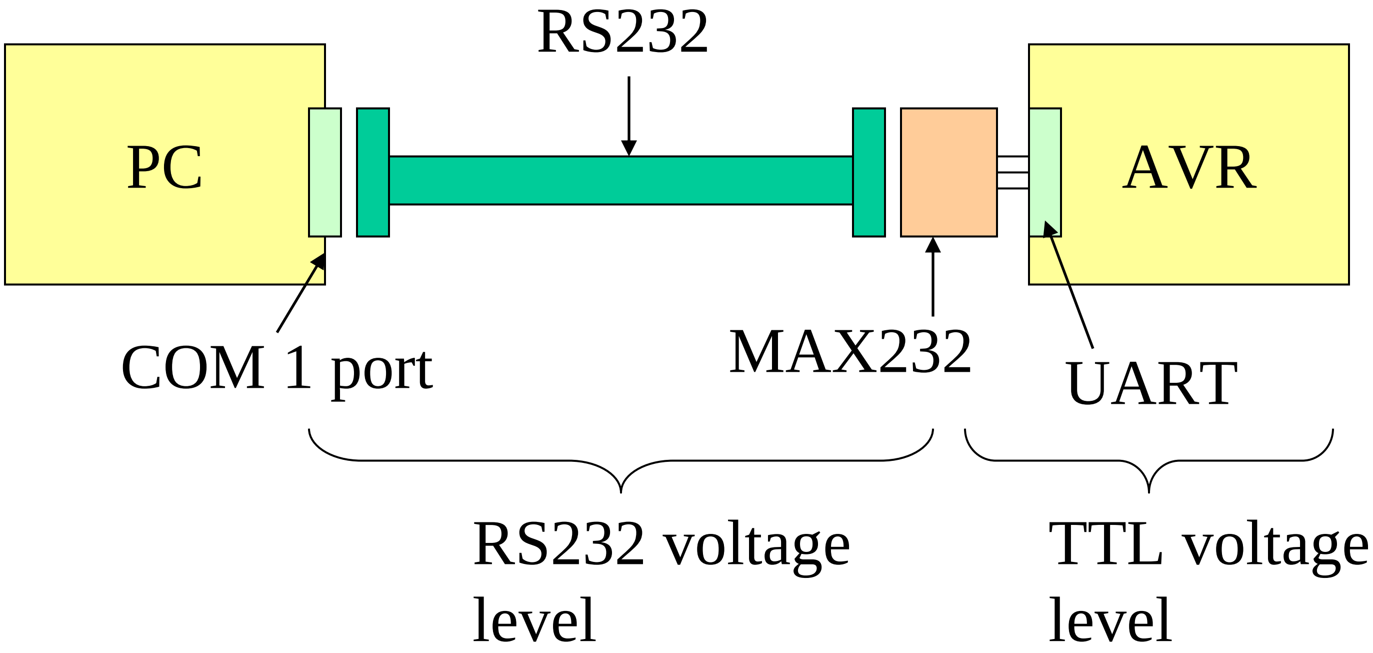
- The input and output voltage of RS232 is not of the TTL (Transistor-Transistor-Logic) compatible.
  - RS232 is older than TTL.
- We must use voltage converter (also referred to as line driver) such as MAX232 to convert the TTL logic levels to the RS232 voltage level, and vice versa.
  - MAX232, TSC232, ICL232

RS 232 Voltage

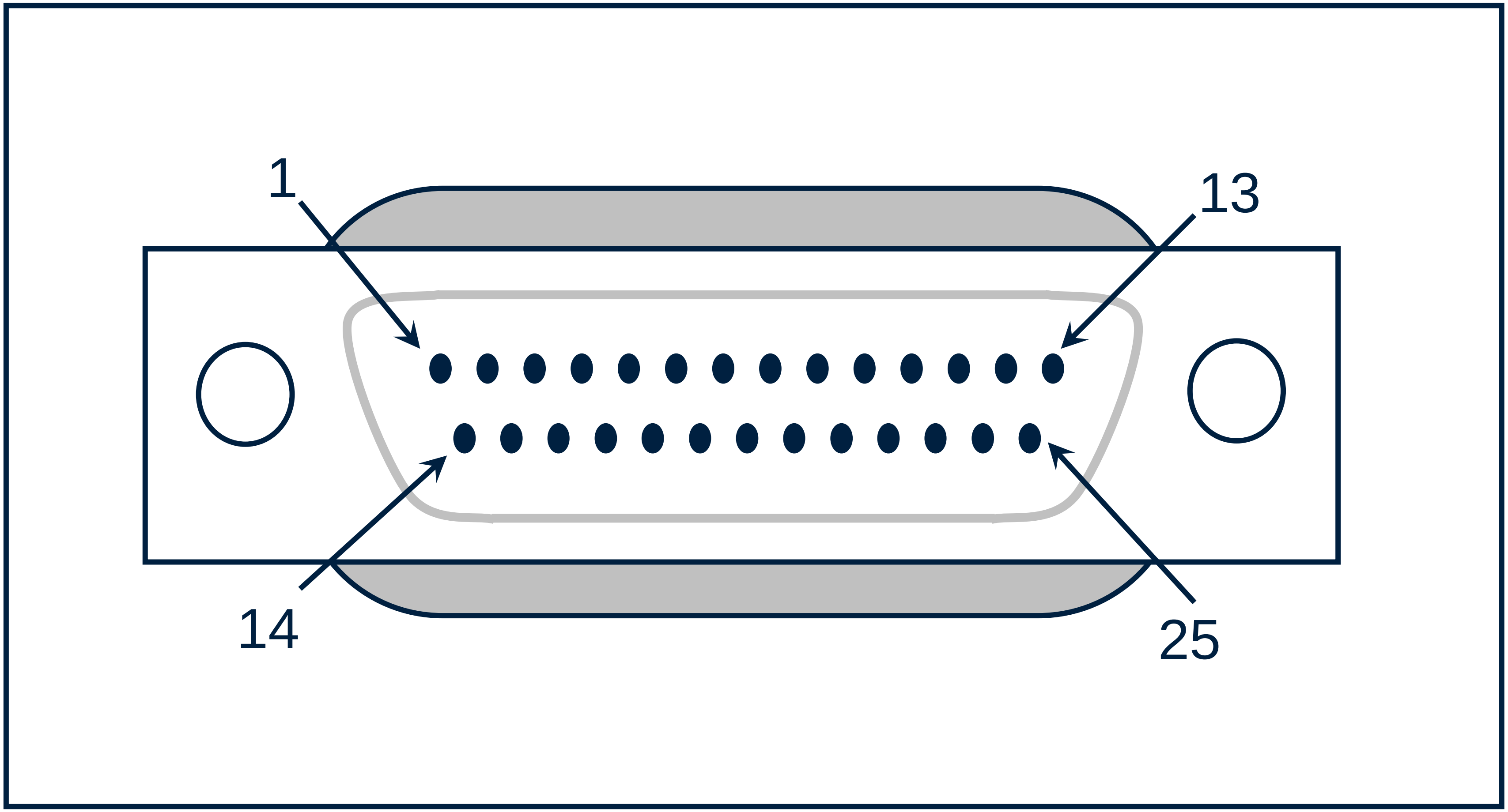


MAX232

- MAX232 IC chips are commonly referred to as line drivers.

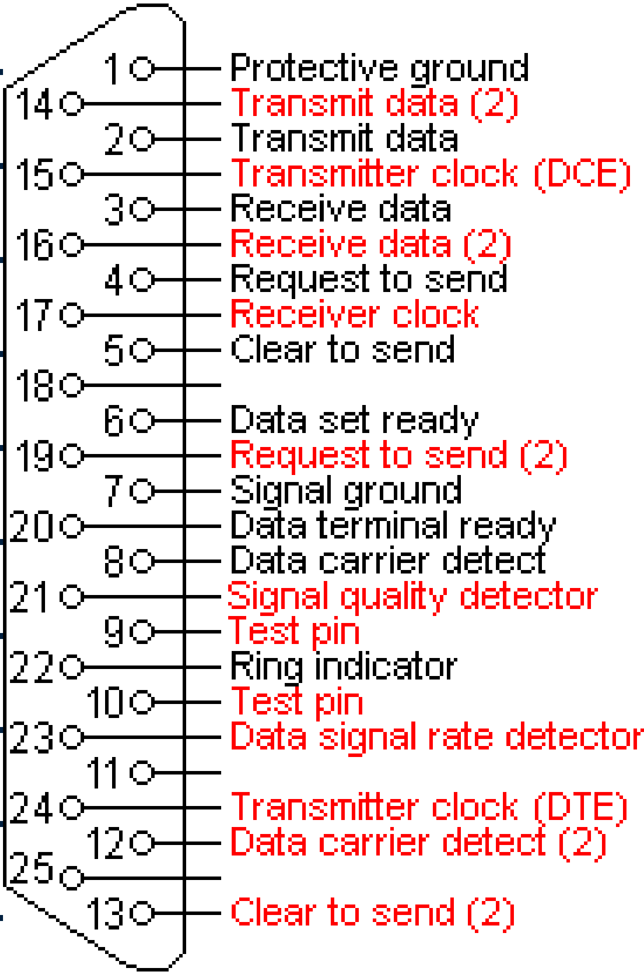


RS232 Connector DB-25



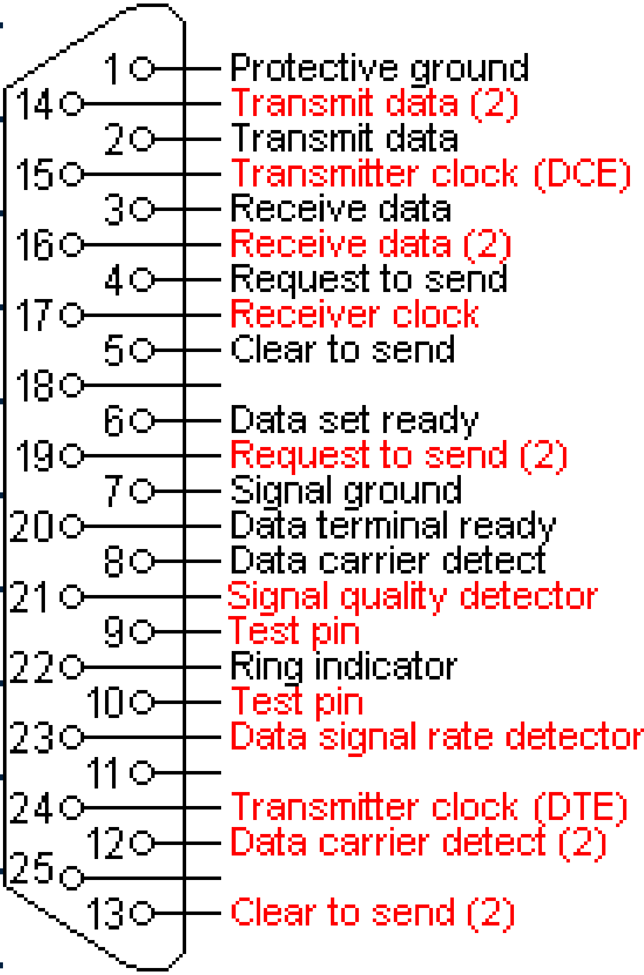
RS232 Pins (DB-25) for DTE (1/2)

Pin	Description
1	Protective ground
2	Transmitted data (TxD)
3	Received data (RxD)
4	Request to send (RTS)
5	Clear to send (CTS)
6	Data set ready (DSR)
7	Signal ground (GND)
8	Data carrier detect (DCD)
9/10	Reserved for data testing
11	Unassigned
12	Secondary data carrier detect
13	Secondary clear to send

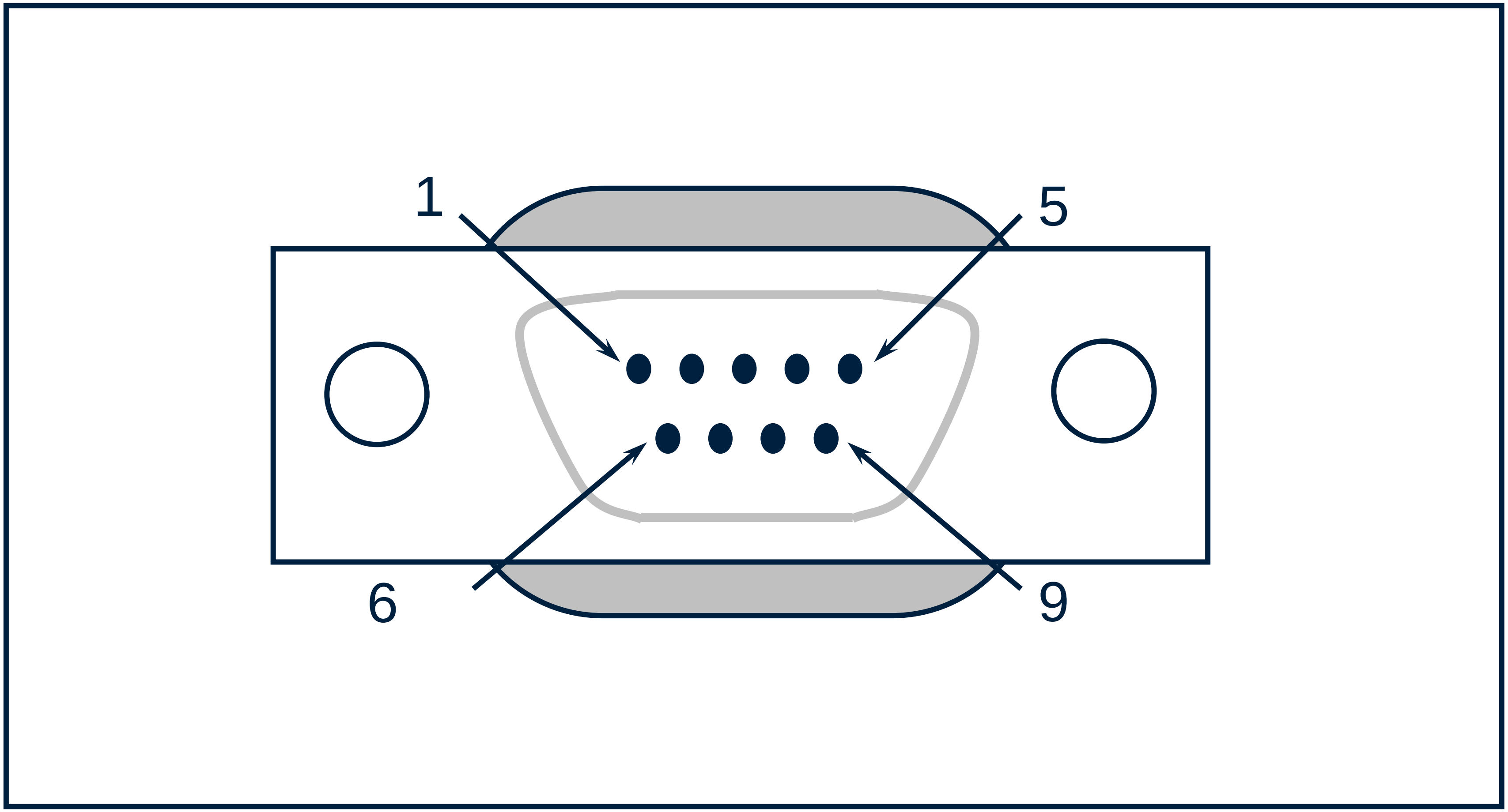


RS232 Pins (DB-25) for DTE (2/2)

Pin	Description
14	Secondary transmitted data
15	Transmit signal element timing
16	Secondary received data
17	Receive signal element timing
18	Unassigned
19	Secondary request to sent
20	Data terminal ready ($\overline{\text{DTR}}$)
21	Signal quality detector
22	Ring indicator (RI)
23	Data signal rate select
24	Transmit signal element timing
25	Unassigned

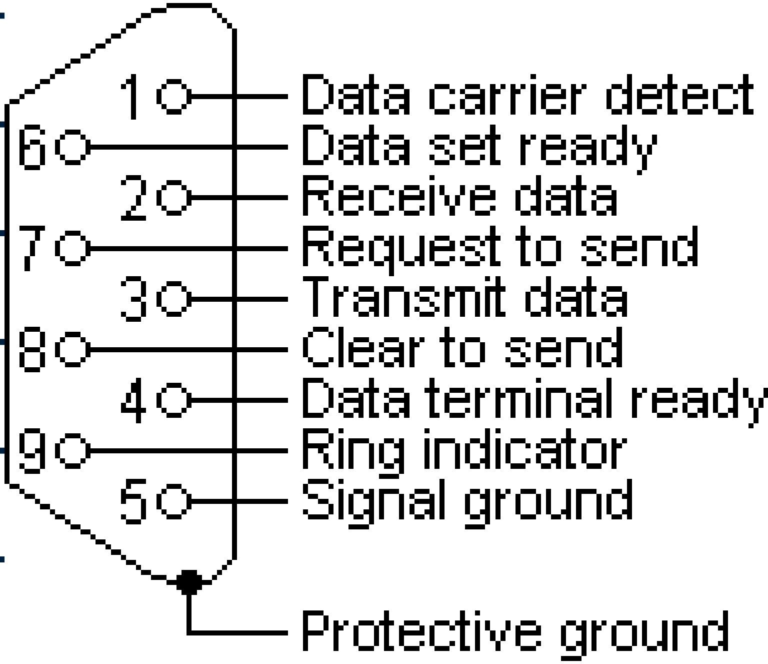


DB-9 9-Pin Connector

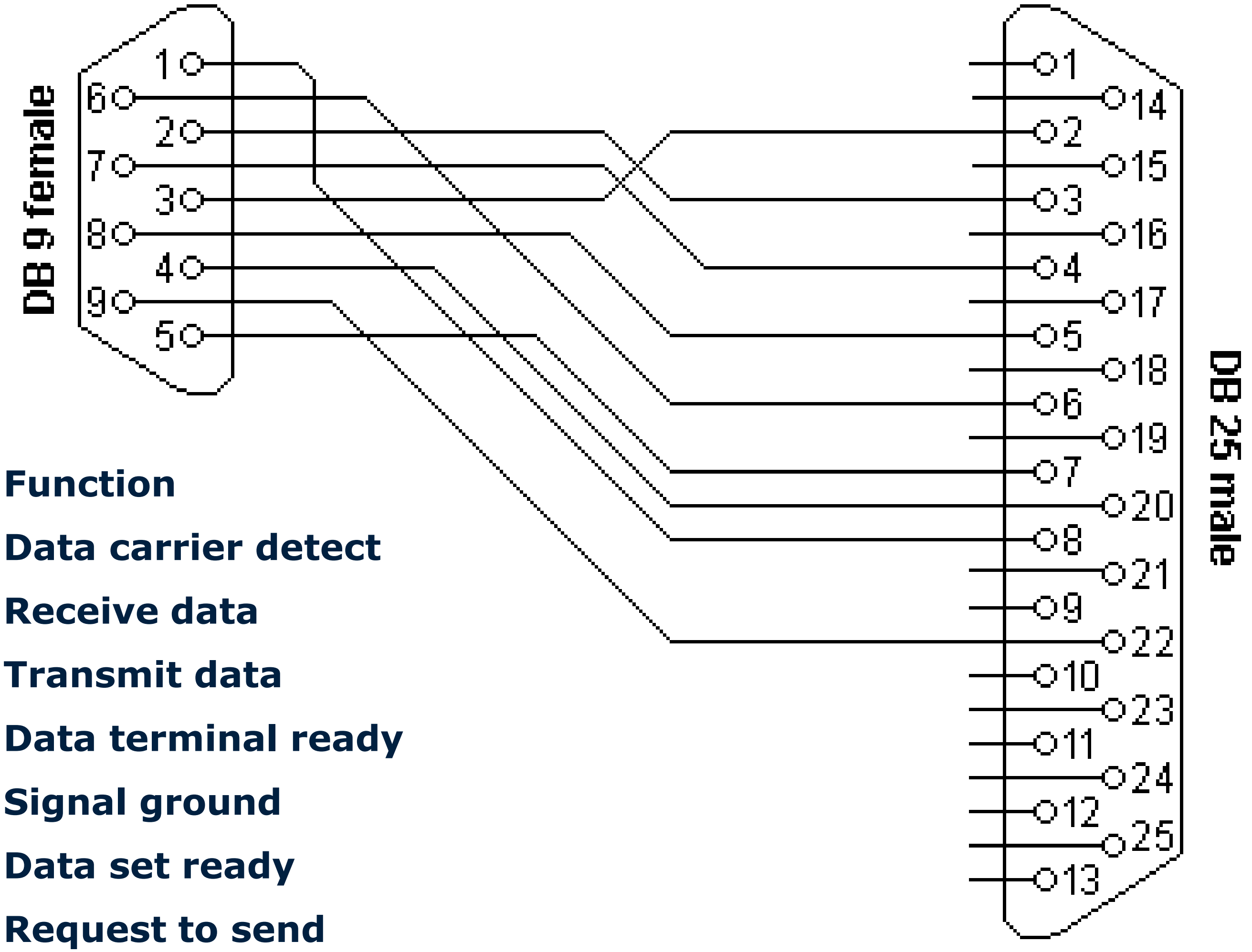


DB-9 Signals for DTE

Pin	Description
1	Data carrier detect (DCD)
2	Received data (RxD)
3	Transmitted data (TxD)
4	Data terminal ready (DTR)
5	Signal ground (GND)
6	Data set ready (DSR)
7	Request to send (RTS)
8	Clear to send (CTS)
9	Ring indicator (RI)



DB9 - DB25 conversion



DB9	DB25	Function
1	8	Data carrier detect
2	3	Receive data
3	2	Transmit data
4	20	Data terminal ready
5	7	Signal ground
6	6	Data set ready
7	4	Request to send
8	5	Clear to send
9	22	Ring indicator

RS232 Handshaking Signals

- Many of the pins of the RS232 connector are used for handshaking signals.
  - DTR (data terminal ready)
  - DSR (data set ready)
  - RTS (request to send)
  - CTS (clear to send)
  - DCD (carrier detect, or data carrier detect)
  - RI (ring indicator)

RS422 & RS485

- By using RS232, the limit distance between two PCs is about 15m.

- It works well even the distance=30m.

- If you want to transfer data with long distance (ex: 300m), you can use RS422 or RS485.

Recommended Reading

- The AVR Microcontroller and Embedded Systems: Using Assembly and C by Mazidi et al., Prentice Hall
  - Chapter 11 -> 11.1

THANK YOU