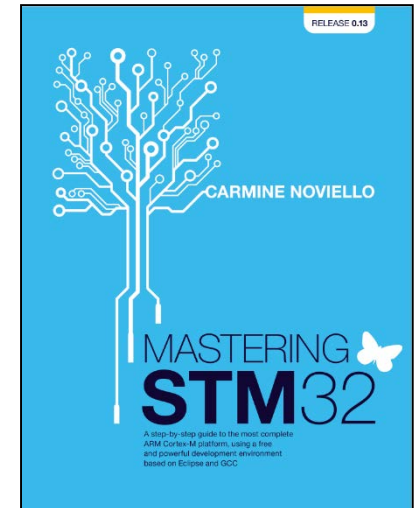


# Embedded Communication

## UART and RS-232

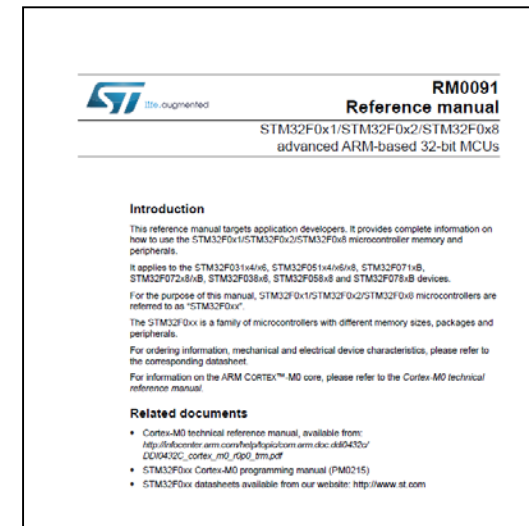


Chapter 8 Universal Asynchronous Serial Communication  
“Mastering STM32” by Carmine Noviello

<https://leanpub.com/mastering-stm32>

Chapter 26 Universal Synchronous Asynchronous Receiver  
Transmitter (USART)

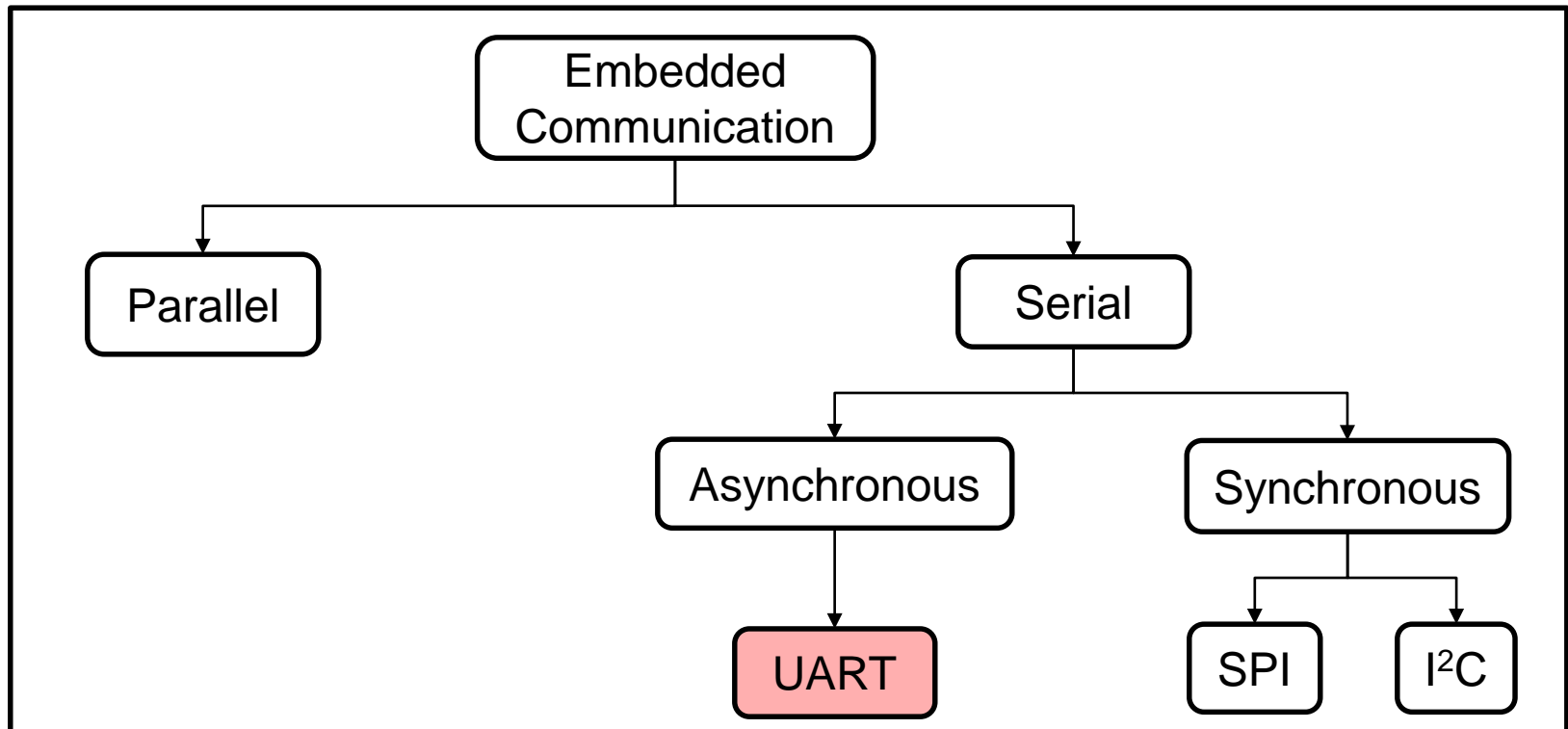
RM0091: STM32F0x1 Reference manual



# UART and the big picture

## Context

- Asynchronous transmission
  - Two devices need to agree on how long it takes to transmit one bit of information

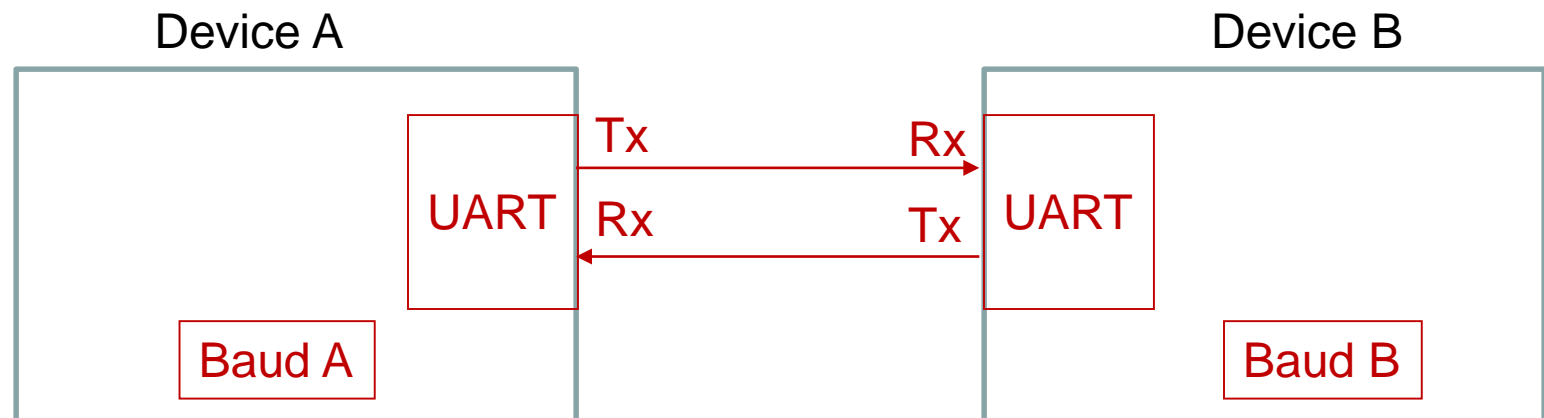


# UART and RS-232

## Basics

# UART and the RS-232 Basics

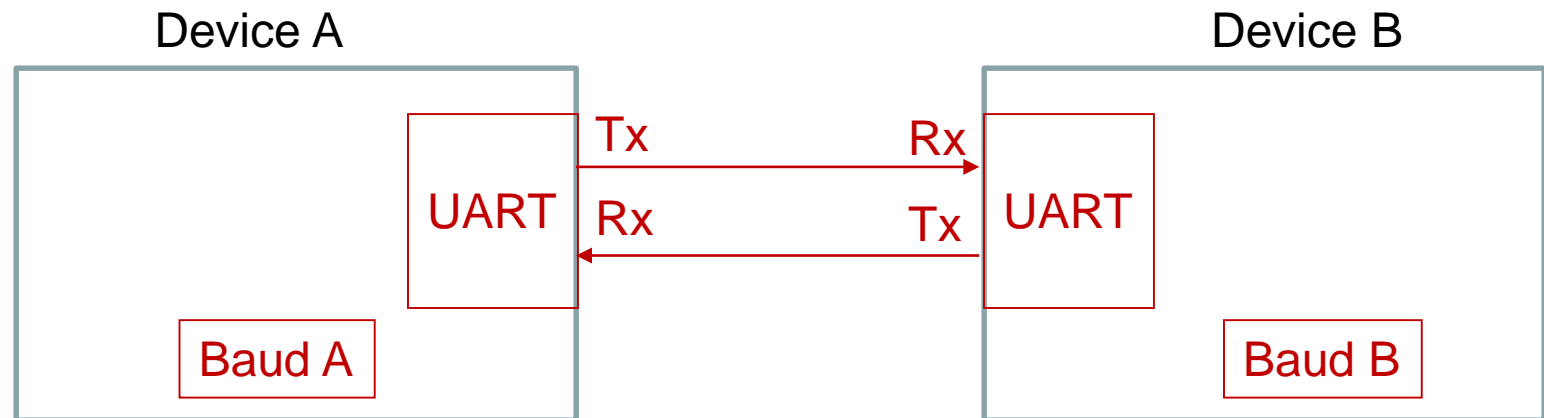
- Universal Asynchronous Receiver Transmitter (UART)
  - UART refers to the hardware interface



# UART and the RS-232

## Basics

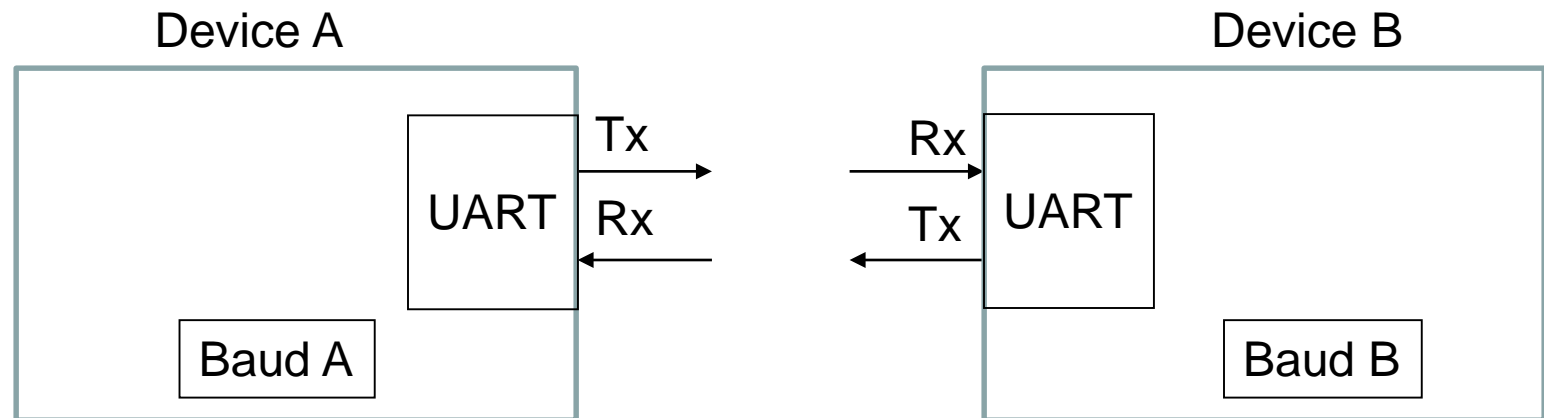
- Universal Asynchronous Receiver Transmitter (UART)
  - UART refers to the hardware interface



# UART and the RS-232

## Basics

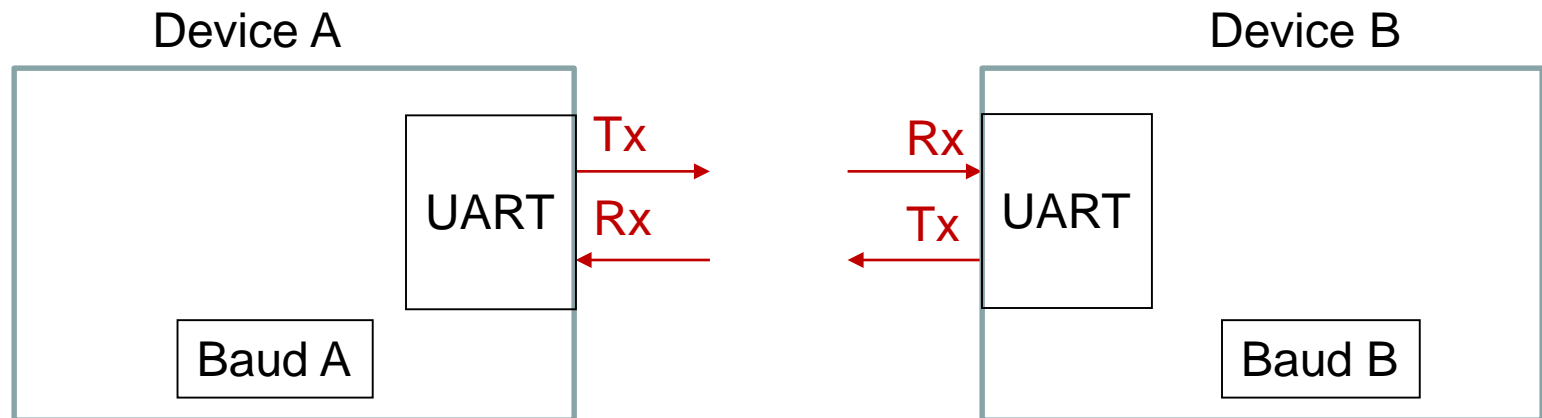
- Universal Asynchronous Receiver Transmitter (UART)
- RS-232
  - RS-232 is an asynchronous serial communication interface standard that uses the UART hardware interface



# UART and the RS-232

## Basics

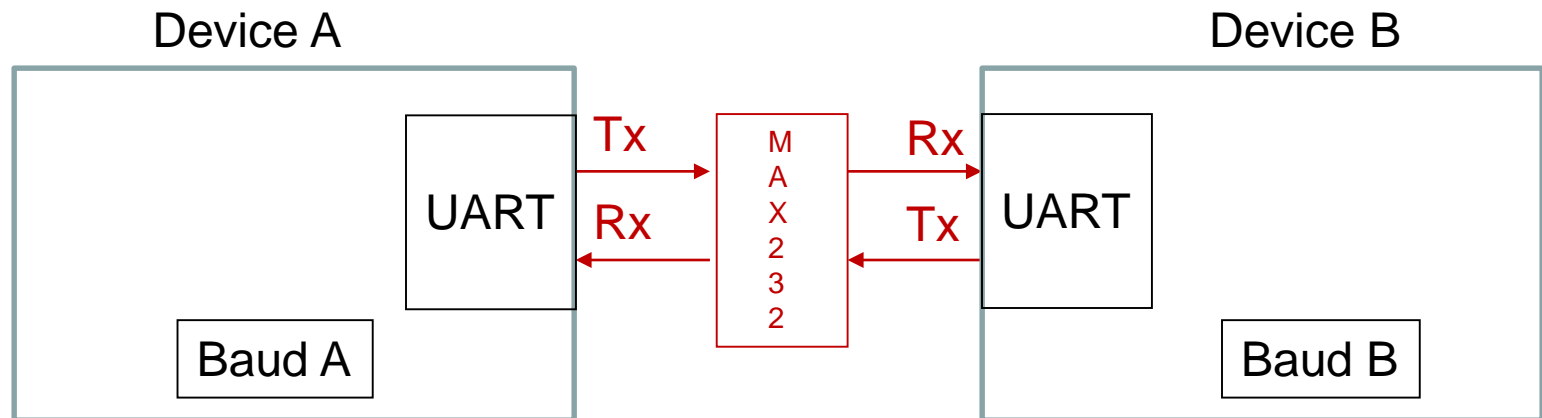
- Universal Asynchronous Receiver Transmitter (UART)
- RS-232
  - RS-232 is an asynchronous serial communication interface standard that uses the UART hardware interface
  - **Voltage levels:** -3V to -15V (logic 1), and +3V to + 15V (logic 0)



# UART and the RS-232

## Basics

- Universal Asynchronous Receiver Transmitter (UART)
- RS-232
  - RS-232 is an asynchronous serial communication interface standard that uses the UART hardware interface
  - **Voltage levels:** -3V to -15V (logic 1), and +3V to + 15V (logic 0)
    - Use a MAX232 to convert:
      - 0 V to +12V
      - 3.3 V to -12V

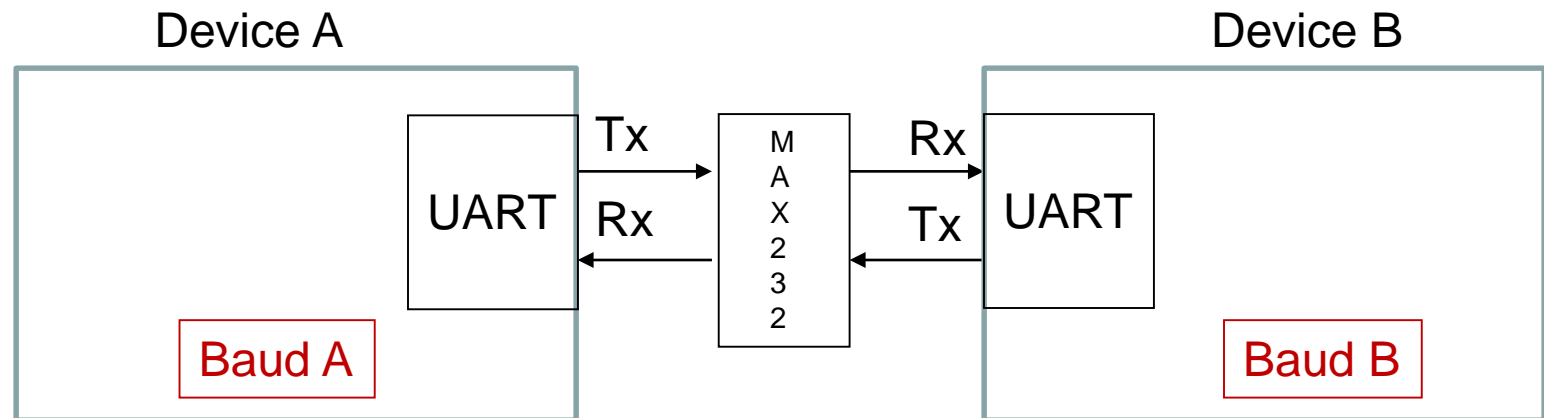




# UART and the RS-232

## Basics

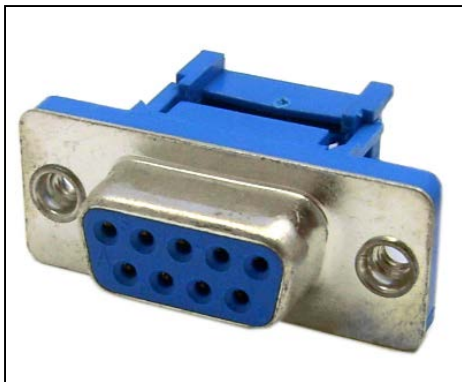
- Universal Asynchronous Receiver Transmitter (UART)
  - RS-232
    - RS-232 is an asynchronous serial communication interface standard that uses the UART hardware interface
    - **Voltage levels:** -3V to -15V (logic 1), and +3V to + 15V (logic 0)
    - **Baud Rate:** 1.2kbps, 2.4kbps, 4.8kbps, 9.6kbps, 14.4kbps, 19.2kbps
- RS232 was intended for bit rates lower than 20kbps



# UART and the RS-232

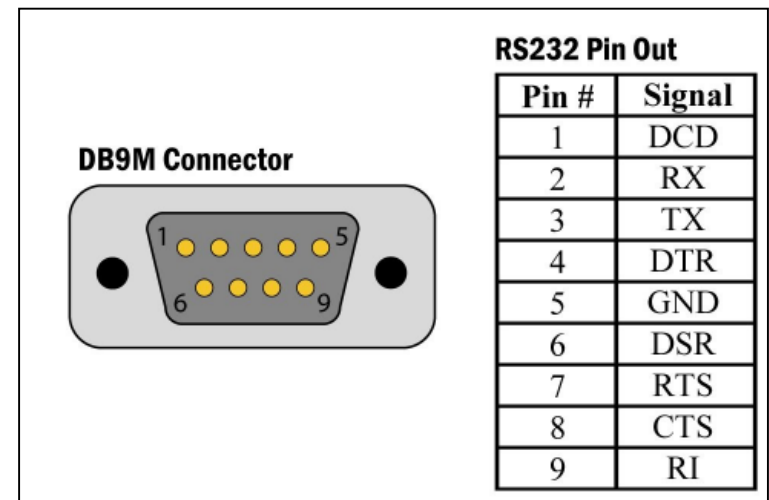
## Basics

- Universal Asynchronous Receiver Transmitter (UART)
- RS-232
  - RS-232 is an asynchronous serial communication interface standard that uses the UART hardware interface
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  - **Connector:** DB9



DB9 female connector

[taken from <http://www.techsupportforum.com/>]



DB9 pinouts

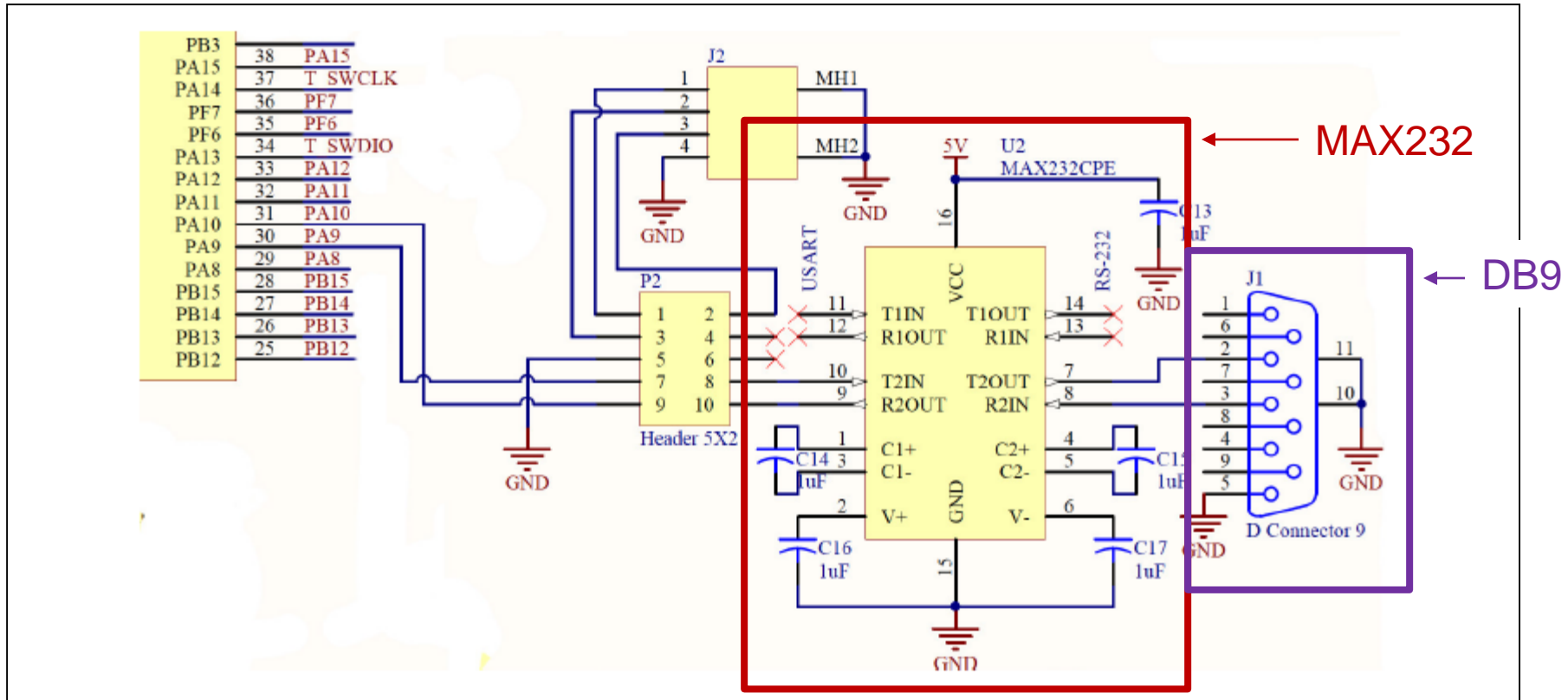
[taken from <http://www.sealevel.com/>]

# UART and RS-232

## STM32F0 development board

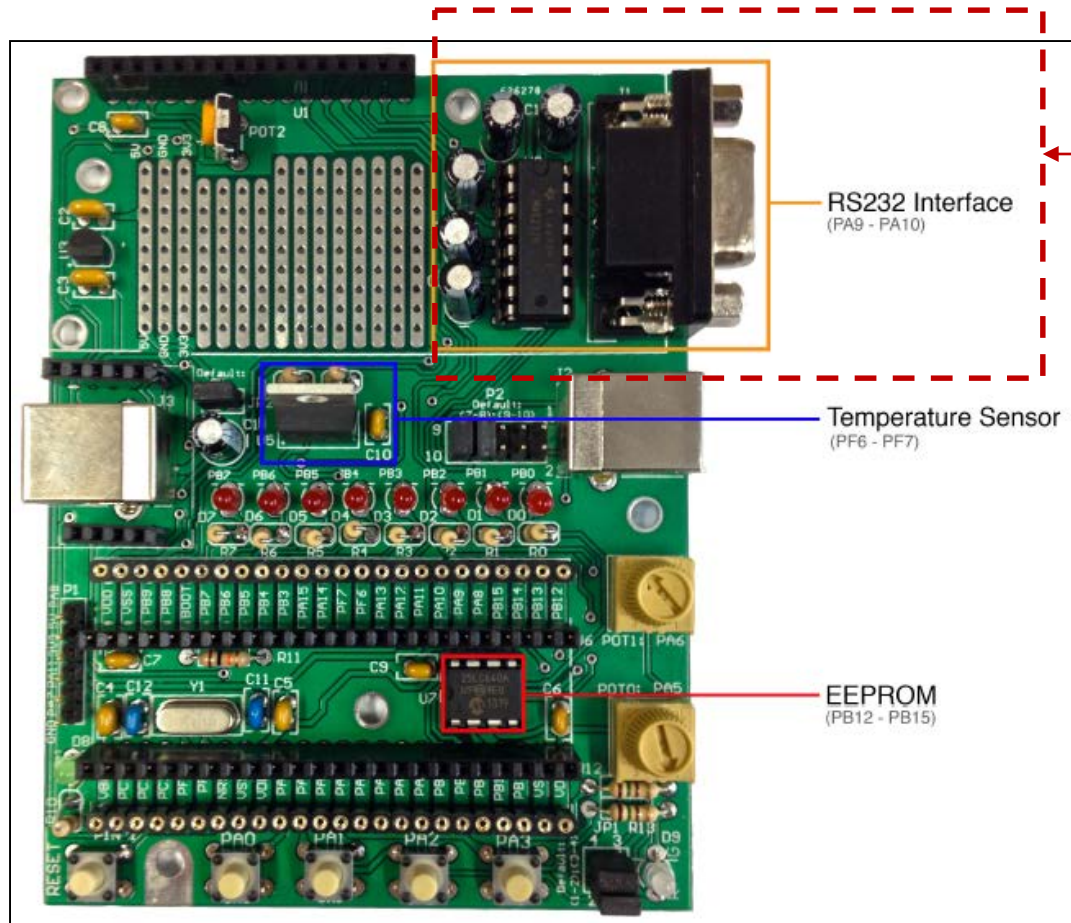
# UART and the RS-232

## STM32F0 development board



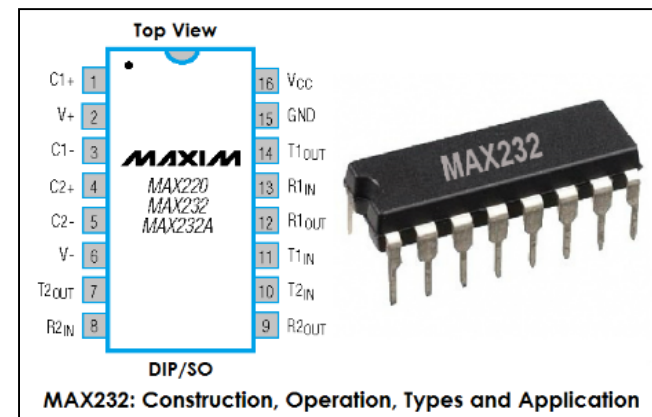
Portion of the full schematic of the STM32F0 development board  
[taken from the Embedded Systems I course notes]

# UART and the RS-232 STM32F0 development board



STM32F0 development board

MAX232  
and  
DB9 connector



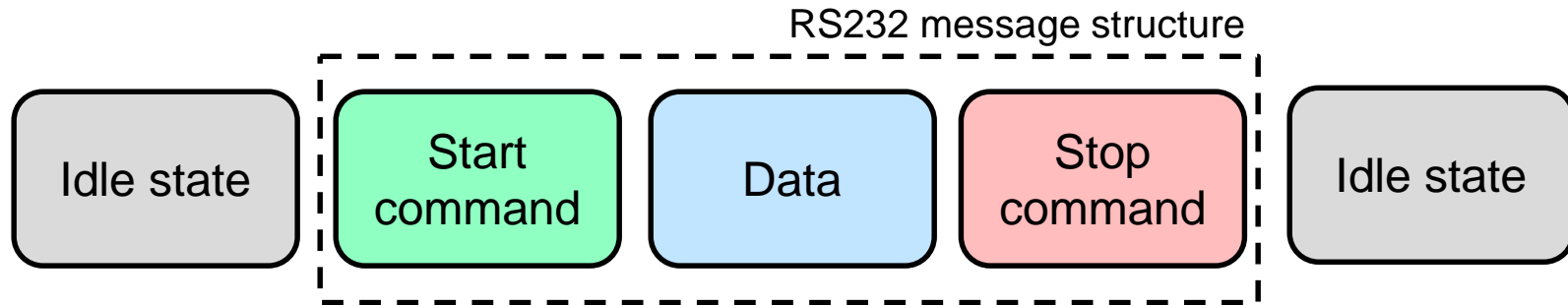
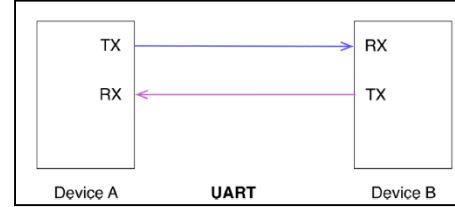
MAX232: 16-pin DIP package  
[taken from <http://www.electricaltechnology.org/>]

# RS-232

## Message structure and Timing

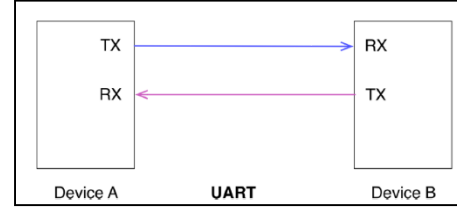
# RS-232

## Basic Message Structure

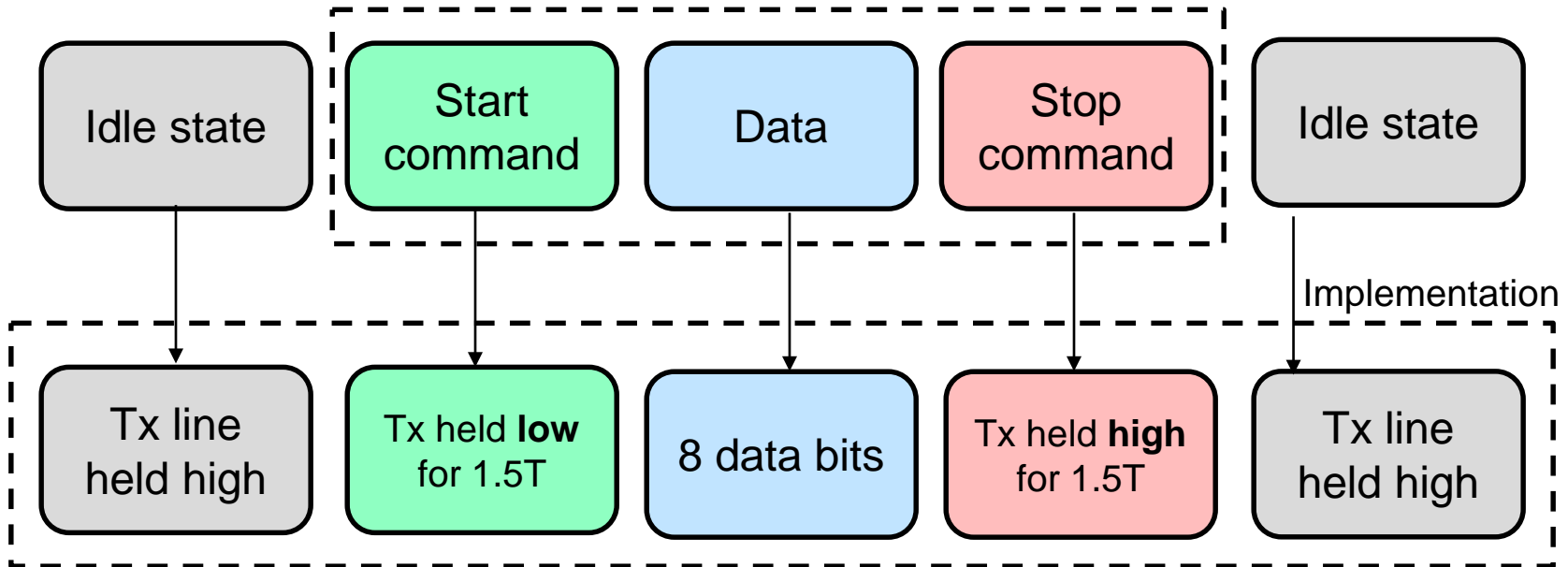


# RS-232

## Basic Message Structure



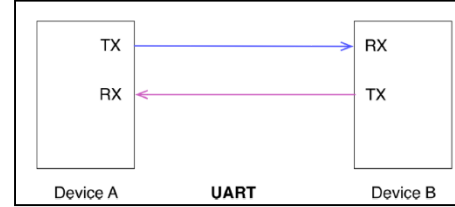
RS232 message structure



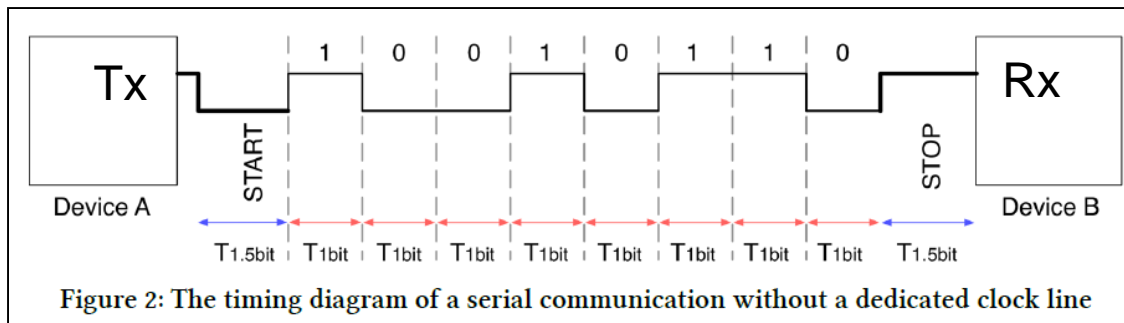
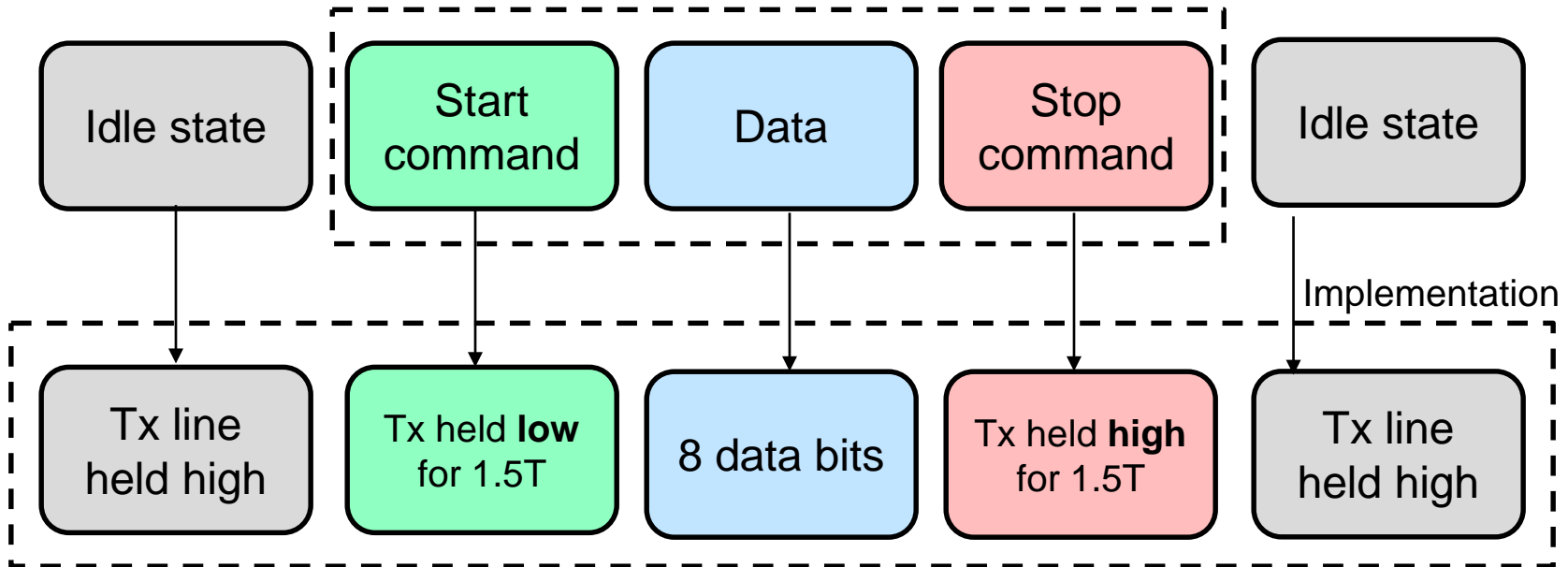


# RS-232

## Basic Message Structure

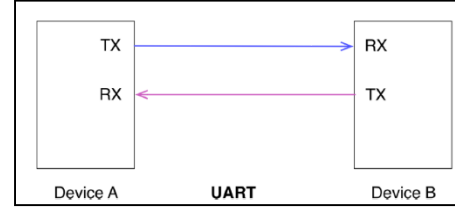


RS232 message structure

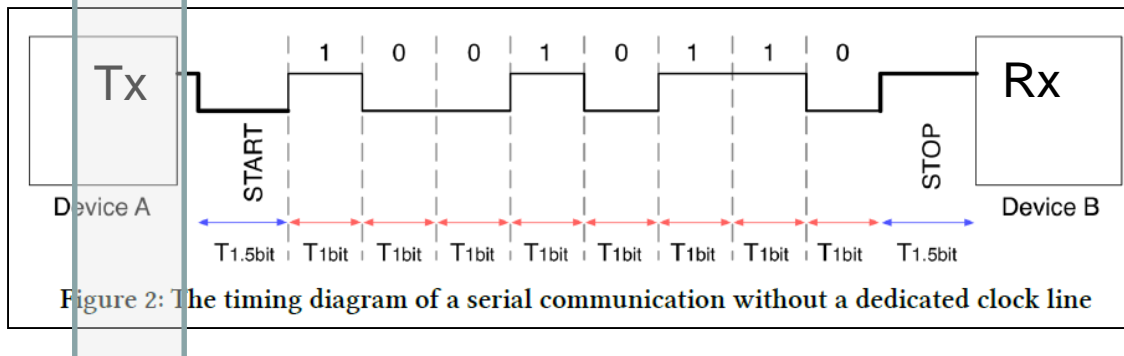
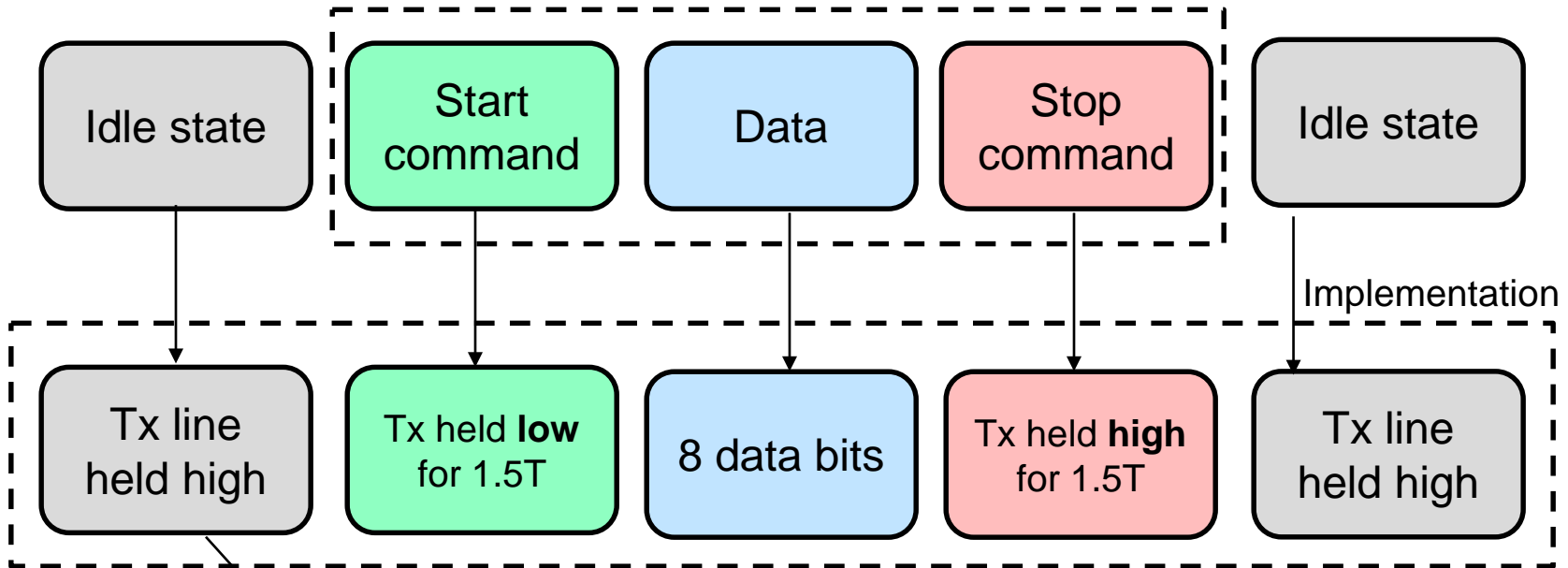


# RS-232

## Basic Message Structure

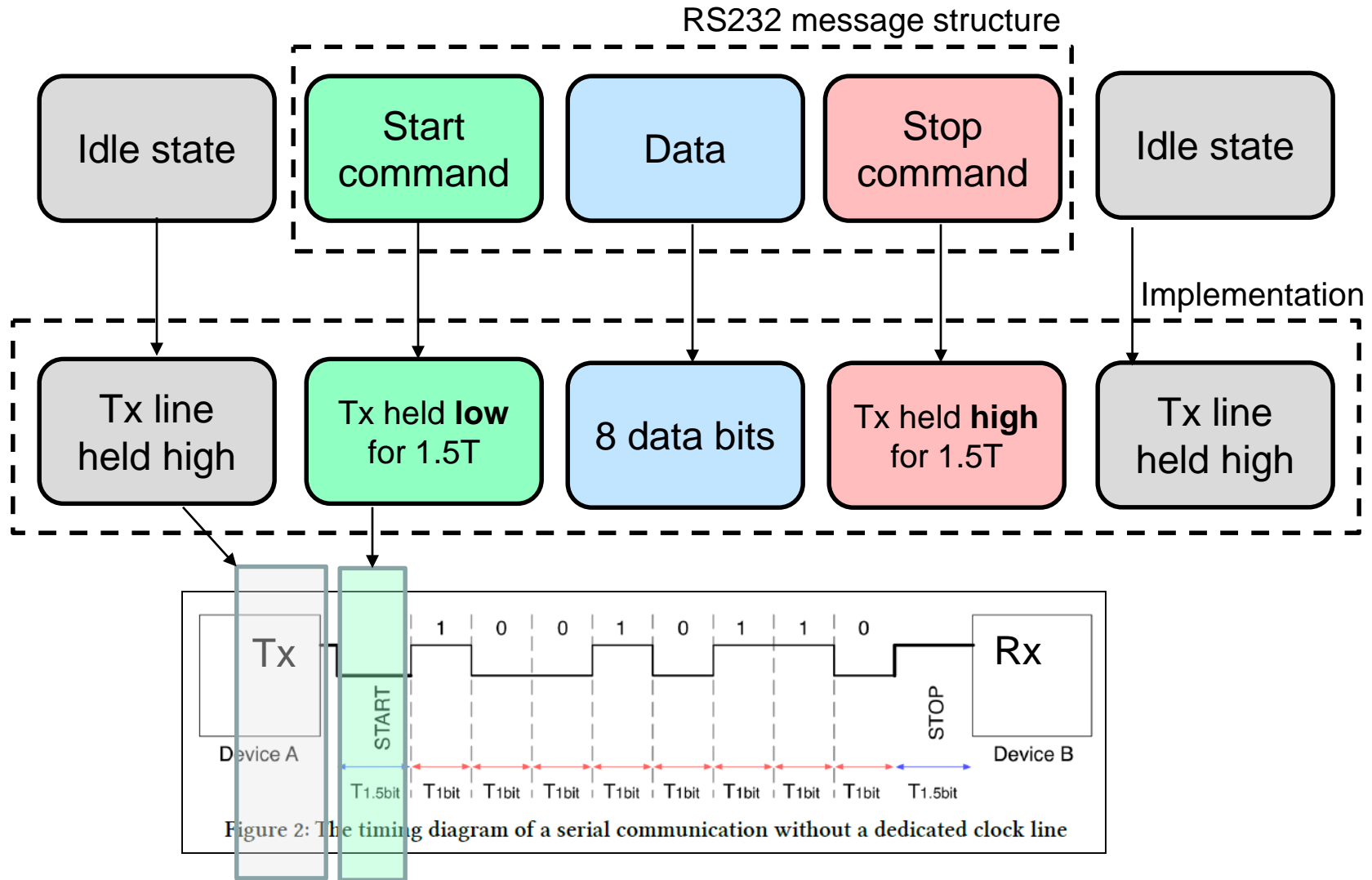
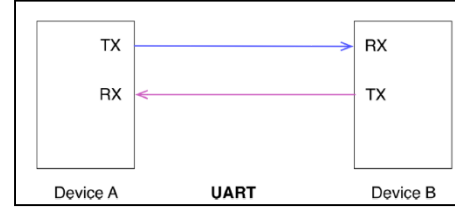


RS232 message structure



# RS-232

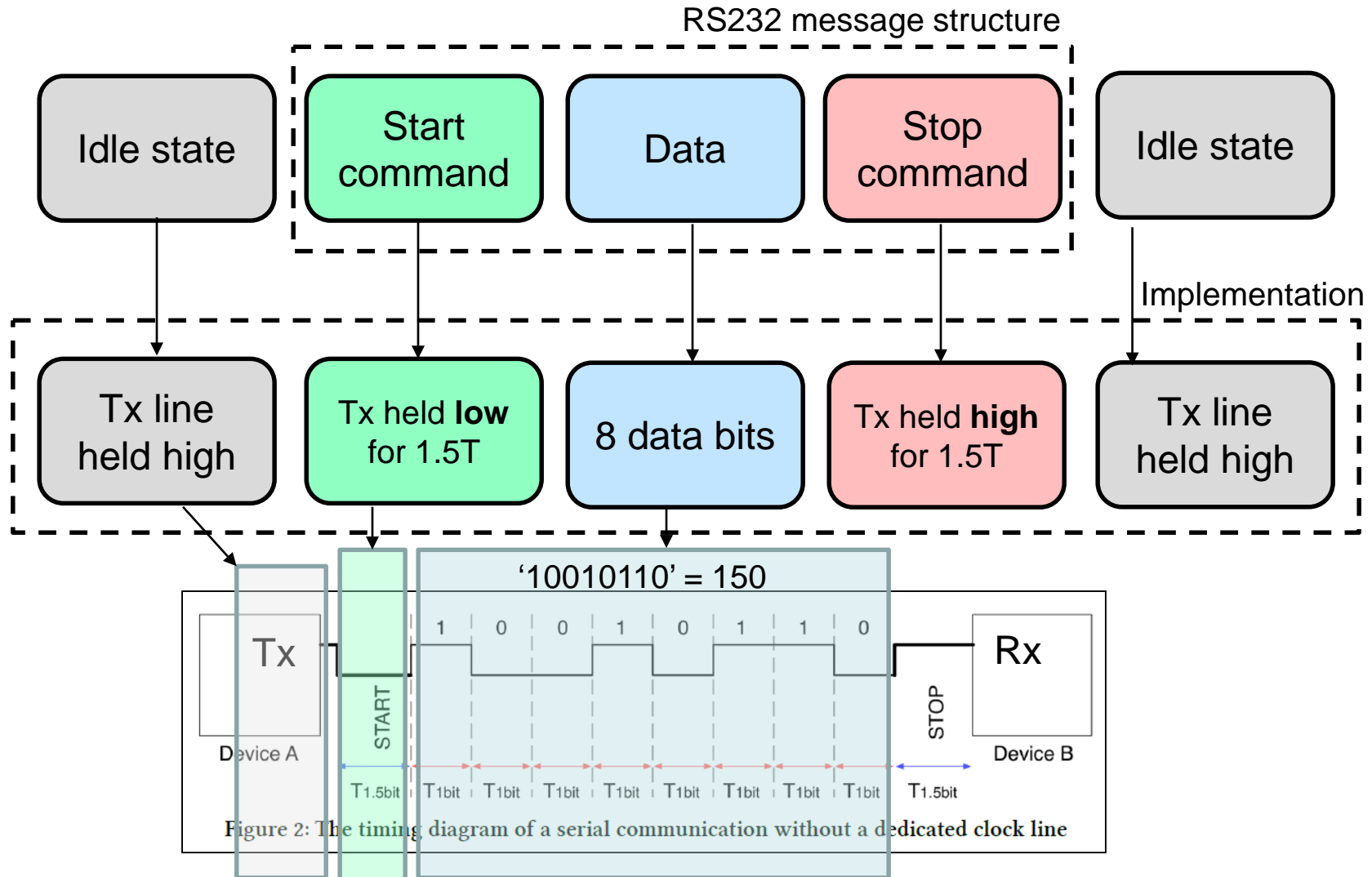
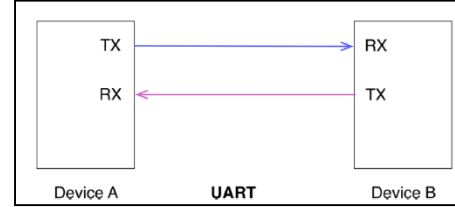
## Basic Message Structure



[taken from "Mastering STM32" by Carmine Noviello]

# RS-232

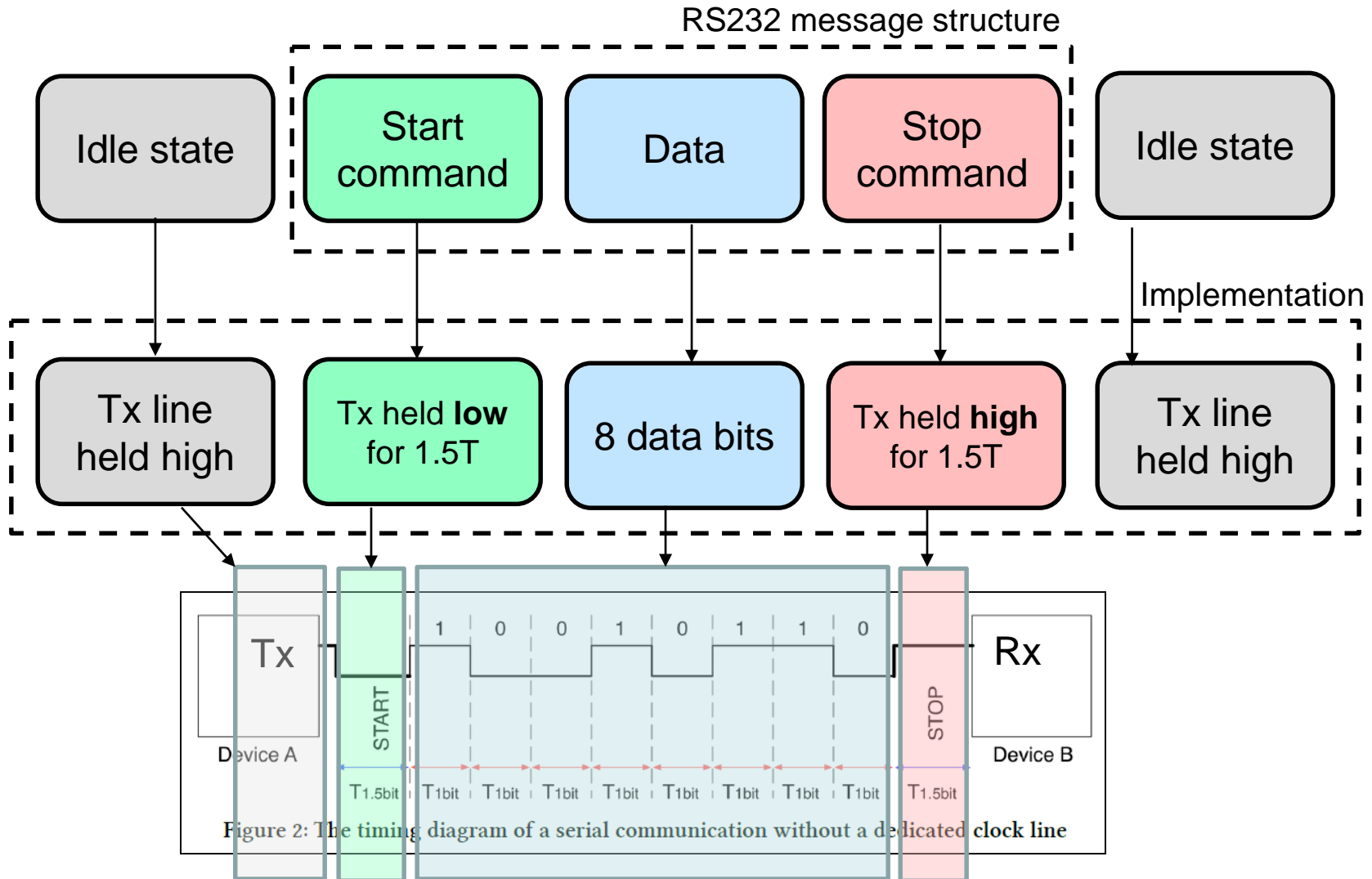
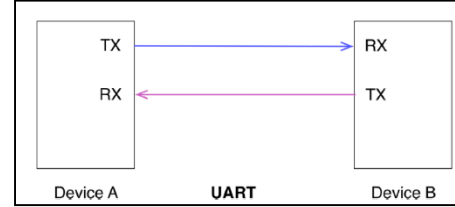
## Basic Message Structure



[taken from “Mastering STM32” by Carmine Noviello]

# RS-232

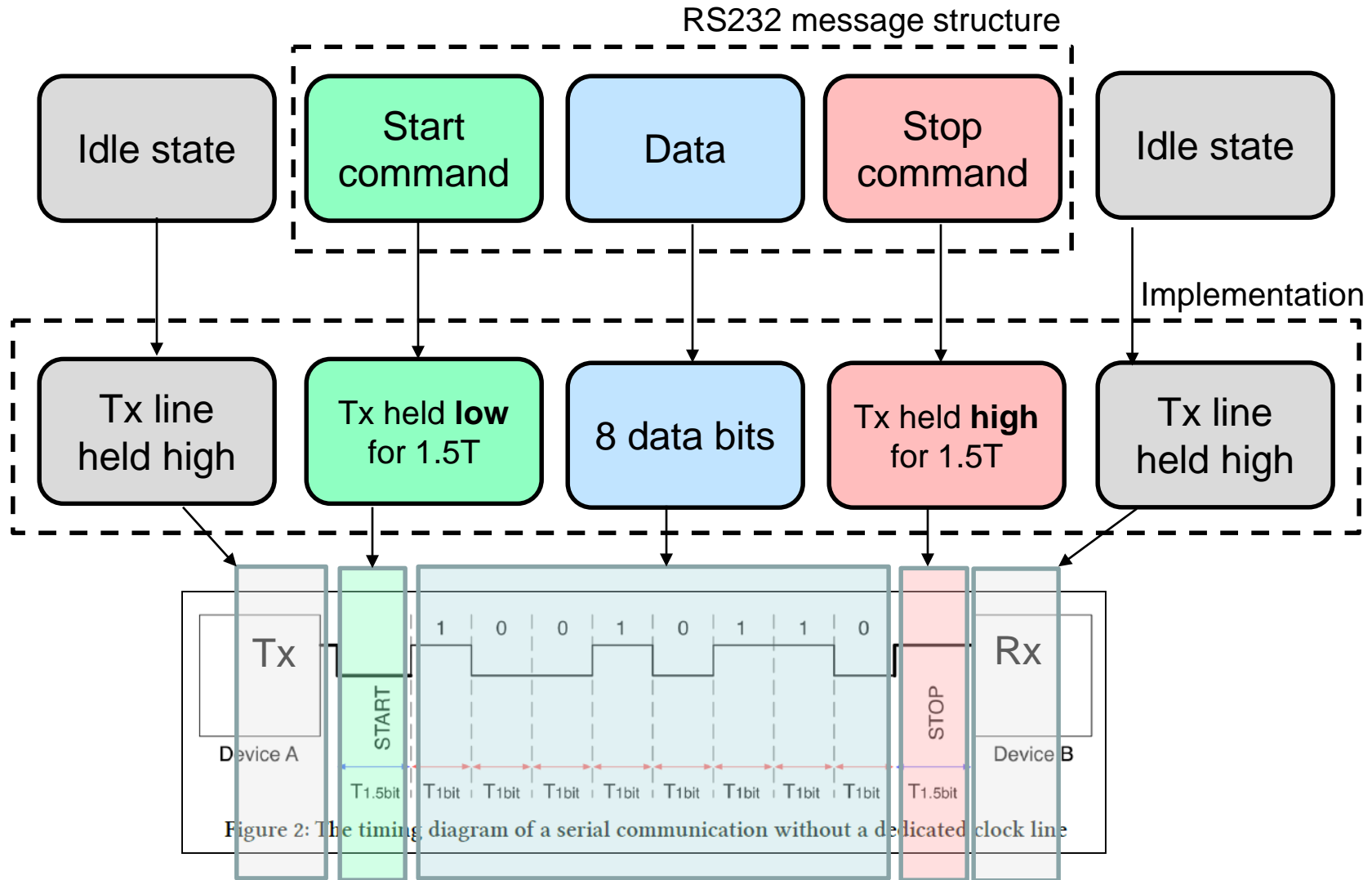
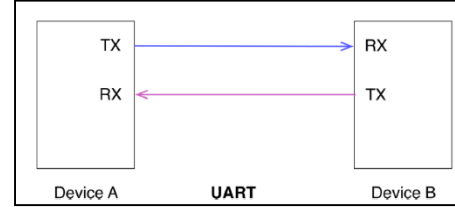
## Basic Message Structure



[taken from "Mastering STM32" by Carmine Noviello]

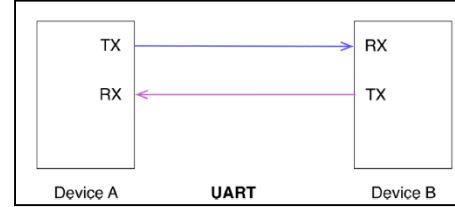
# RS-232

## Basic Message Structure

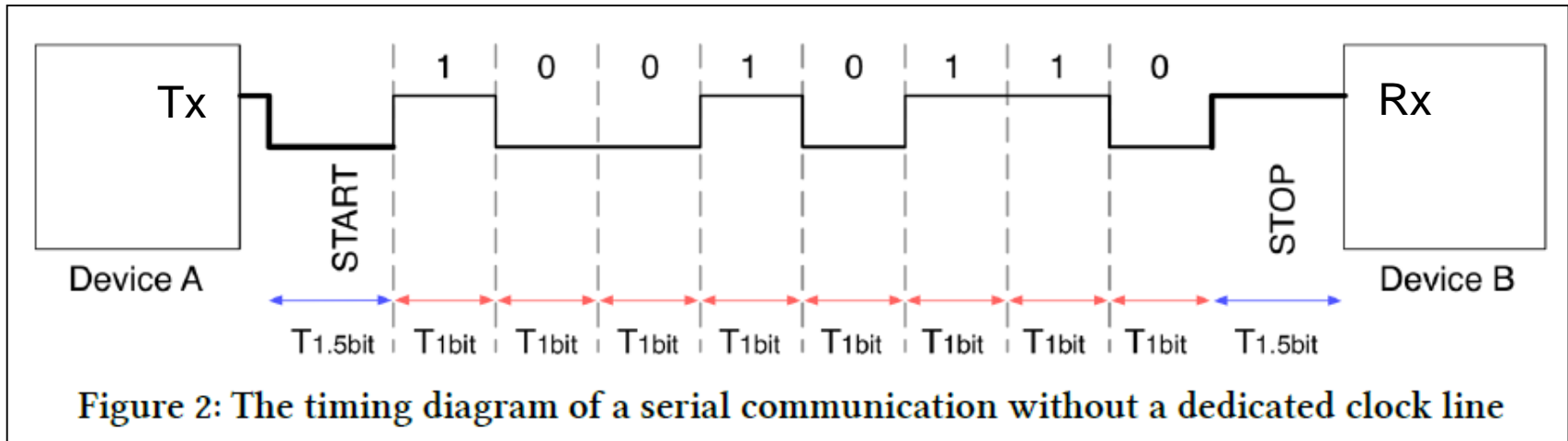


[taken from "Mastering STM32" by Carmine Noviello]

# RS-232 Timing

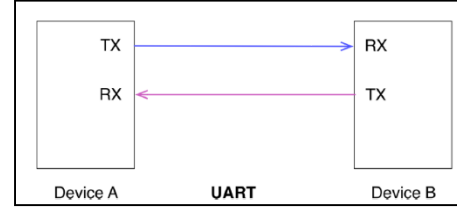


- When is the next bit of data sent?
  - After  $T$  seconds, where  $T = 1/(\text{Baud\_Rate})$



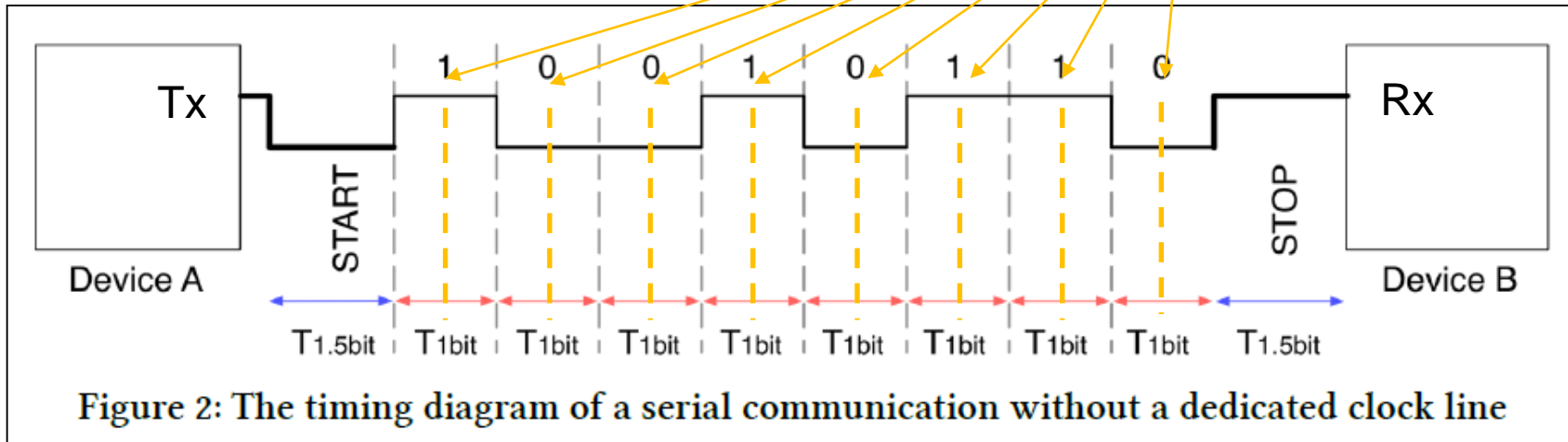
[taken from "Mastering STM32" by Carmine Noviello]

# RS-232 Timing



- When is the next bit of data sent?
  - After  $T$  seconds, where  $T = 1/(\text{Baud\_Rate})$
- When is the received signal sampled?
  - In the middle of the time period  $T$

Sampling of the signal  
from device B

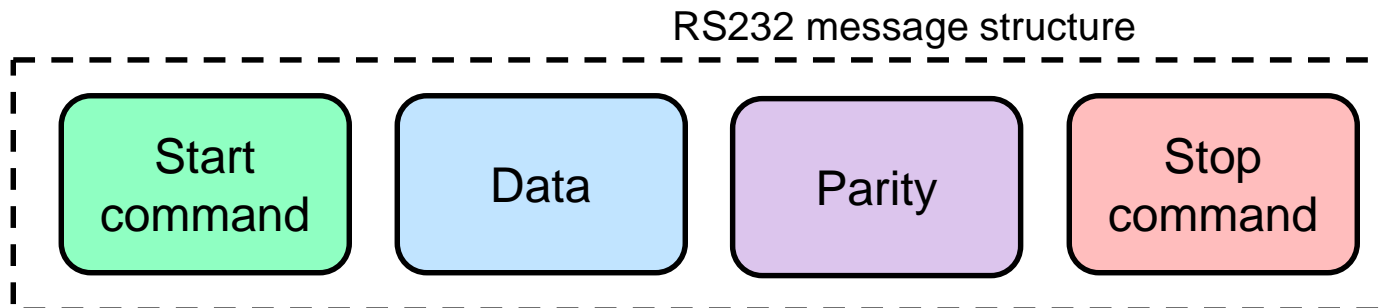




# RS-232

## Message Structure with Parity

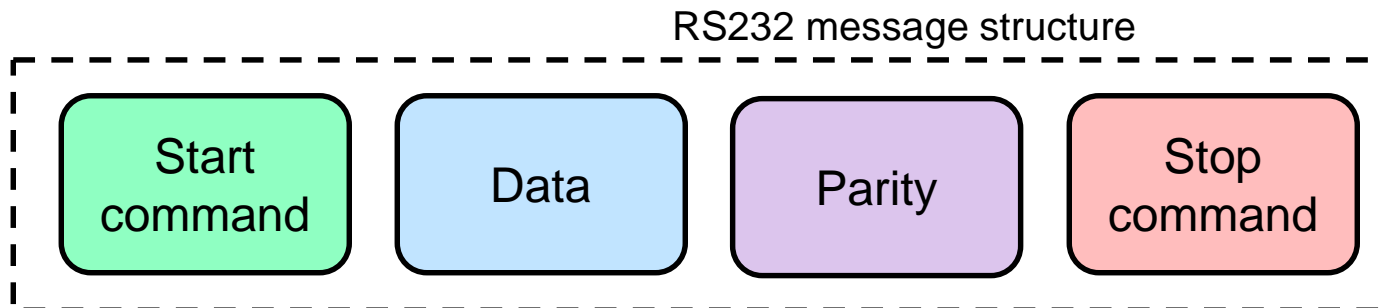
- Parity
  - A single bit: either '1' or '0'
  - **Even parity:** sum of '1's in data and the parity bit is an even number
  - **Odd parity:** sum of '1's in data and the parity bit is an odd number
  - Used to identify errors on reception



# RS-232

## Message Structure with Parity

- Parity
  - A single bit: either '1' or '0'
  - **Even parity**: sum of '1's in data and the parity bit is an even number
  - **Odd parity**: sum of '1's in data and the parity bit is an odd number
  - Used to identify errors on reception
- Example
  - If data was '10101010', then for **even parity**, parity bit = '0'
  - If data was '10101010', then for **odd parity**, parity bit = '1'



# RS-485

## Basics and how it compares to RS232

# RS-485

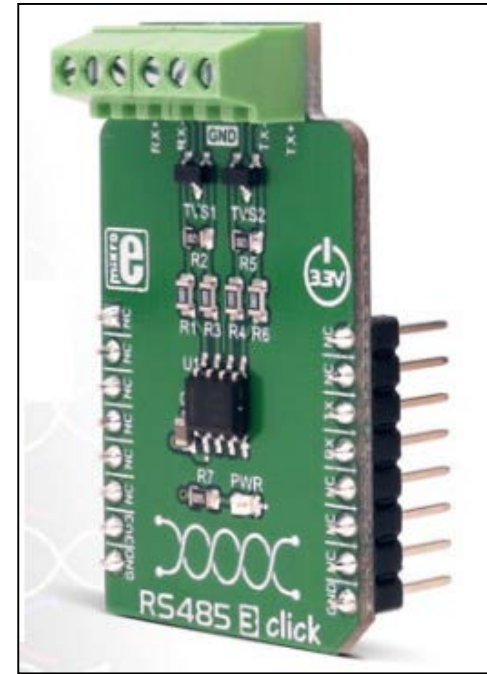
## Introduction

- What is RS-485?
  - It is an electrical interface
  - Typically uses UART hardware interface to exchange data
  - RS-485 was developed to overcome the limitations of RS-232
- How is RS-232 limited?
  - Supports only one transmitter and one receiver on a communication bus
  - Allows data transfer for distances less than 15m. Signal lines (tx and rx) are referenced w.r.t ground and performance degrades quickly when there is noise present.
  - Allows limited speed of data transfer up to 20 kbits/sec



# RS-485 Basics

- How is RS-485 different to RS-232?
  1. RS-485 uses a tri-state differential line driver to provide one of the following three states:
    - Logic low:  $\pm 1.5\text{ V}$  to  $\pm 6\text{ V}$
    - Logic high  $\pm 1.5\text{ V}$  to  $\pm 6\text{ V}$
    - High impedance: Not connected to bus



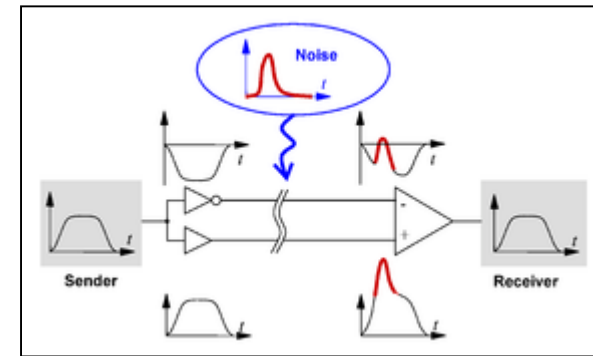
RS484 click board by MikroElektronika used as a transceiver between a UART interface and RS485 communication bus. <https://www.mikroe.com/>

This allows multiple devices to be connected to the same bus. When a device is not transmitting, the transmit line is put to 'High impedance'.

# RS-485 Basics

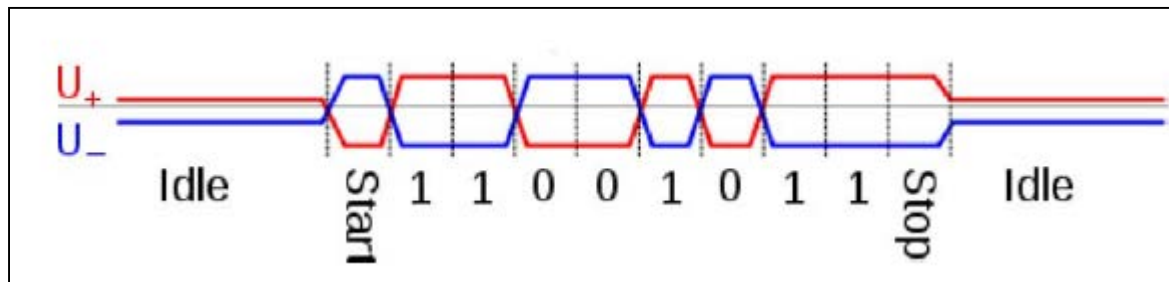
- How is RS-485 different to RS-232?

- RS-485 uses differential signalling on two lines rather than a single-ended with voltage referenced to ground. 'Differential signalling' means that two lines are used, where one line has the negative voltage or the complementary signal of the other line. The receiver amplifies the difference between the two signals.



Differential signaling, where the receiver amplifies the difference between the two signals. In this way, the noise is suppressed

This makes RS-485 more noise immune than RS-232



Voltages on the U+ and the U- signal lines during transmission of one byte ( 0xD3 or b11001011)

# RS-485

## Basics

- How is RS-485 different to RS-232?
  3. It is recommended to use a twisted pair cable to transmit RS-485 signals. A twisted pair minimises the gap between the two wires, which minimises noise picked up by both the wires and immunity against interference.

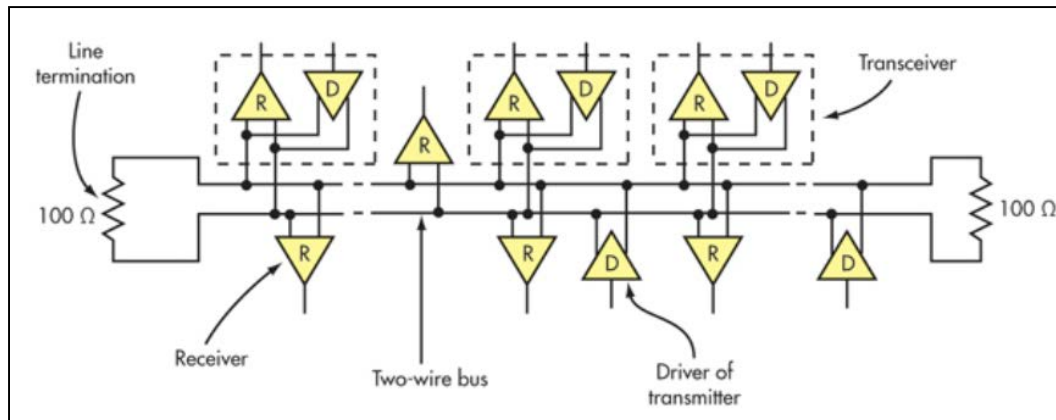


Components of a half duplex RS-485 network, where a twisted pair cable is recommended to improve noise immunity

# RS-485

## Basics

- How is RS-485 different to RS-232?
  4. Supports up to 32 transmitters and 32 receivers on one communication bus
    - All receivers are fully connected to the communication bus
    - Line drivers are disconnected or put in a 'high impedance' state when they are not transmitting
    - The communication bus line is terminated in a load matching resistance, to minimise signal reflections from the end of the line



A RS-485 network showing many receivers(R) and transmitters/drivers (D) connected to the same communication bus



# RS-485 versus RS232

## Summary

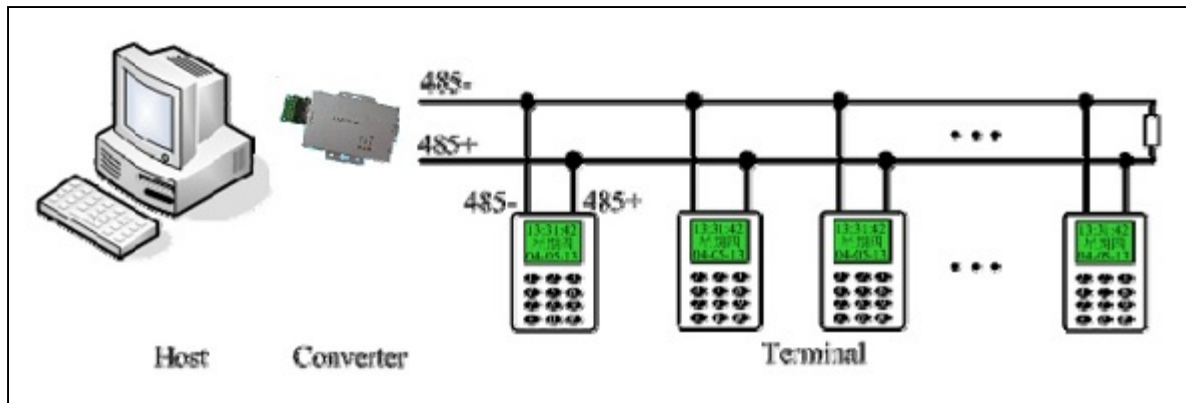
Characteristics of RS232 and RS485		
Parameter	RS232	RS485
Cabling	Single-ended	Differential
Numbers of devices	1 transmitter 1 receiver	32 transmitters 32 receivers
Mode of operation	Simplex or full duplex	Simplex or half duplex
Maximum cable length	50 feet	4000 feet
Maximum data rate	20 kbits/s	10 Mbits/s
Signaling	unbalanced	balanced
Typical logic levels	$\pm 5 \sim \pm 15V$	$\pm 1.5 \sim \pm 6V$
Minimum receiver input impedance	$3 \sim 7k\Omega$	$12k\Omega$
Receiver sensitivity	$\pm 3V$	$\pm 200mA$



# RS-485

## Applications

- Where is RS-485 used?
  - Commercial aircraft cabins
  - Building automation
  - Connecting electrical meters
  - Industrial control systems
  - Security electronics



Multiple devices connected to the same RS-485 network. A RS-485 to RS232 convertor may be used to interface to a host