PROJECT 1-1: APB-UART IP CORE (RESEARCH)

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- UART Functions
- UART IP core
  - Feature
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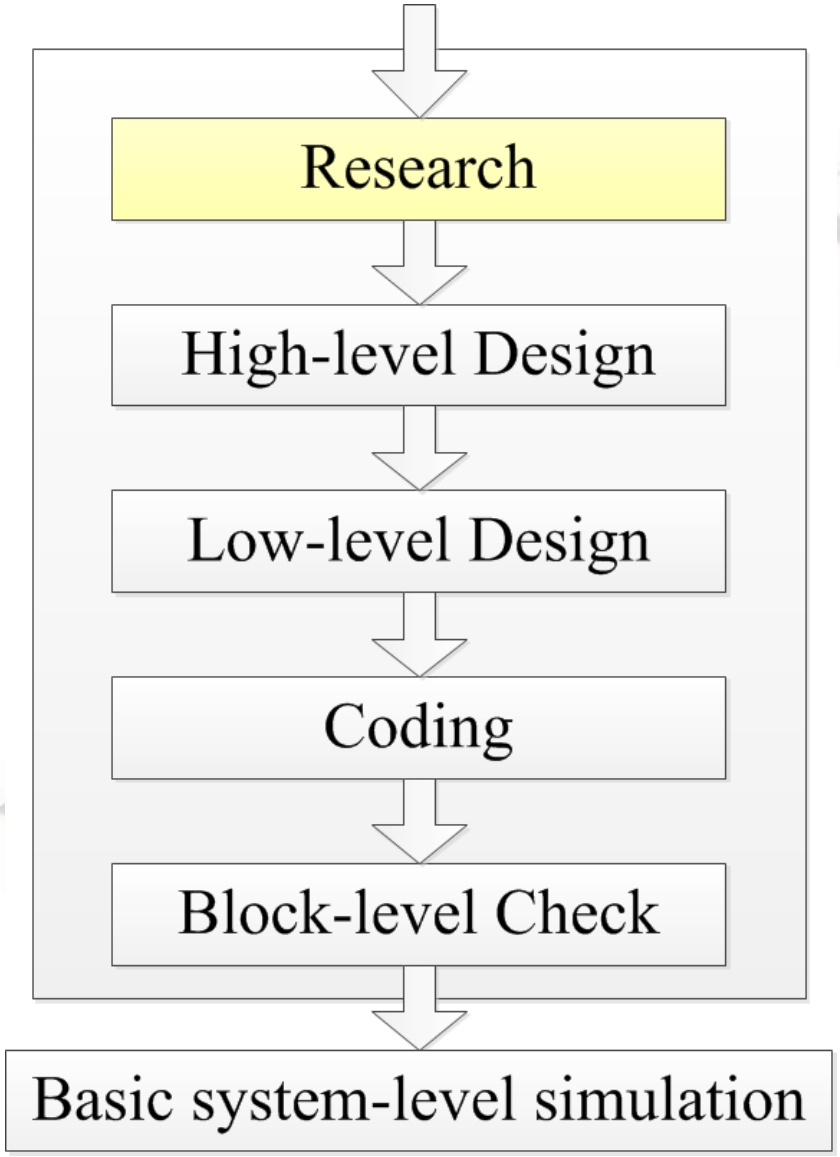
  - Block details
- RTL code
- Block-level simulation
- Basic system-level simulation

Step-by-step


Research
High-level Design
Low-level Design
Coding
Block-level Check
Basic system-level simulation

PROJECT 1: APB-UART IP CORE

UART FUNCTIONS

CONTENTS

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- Basic functions
  - Data format
  - Transfer modes
  - Bit rate and baud rate
  - Basic structure
- Other functions
  - APB interface
  - Interrupt signals
  - DMA interface
  - Auto flow control

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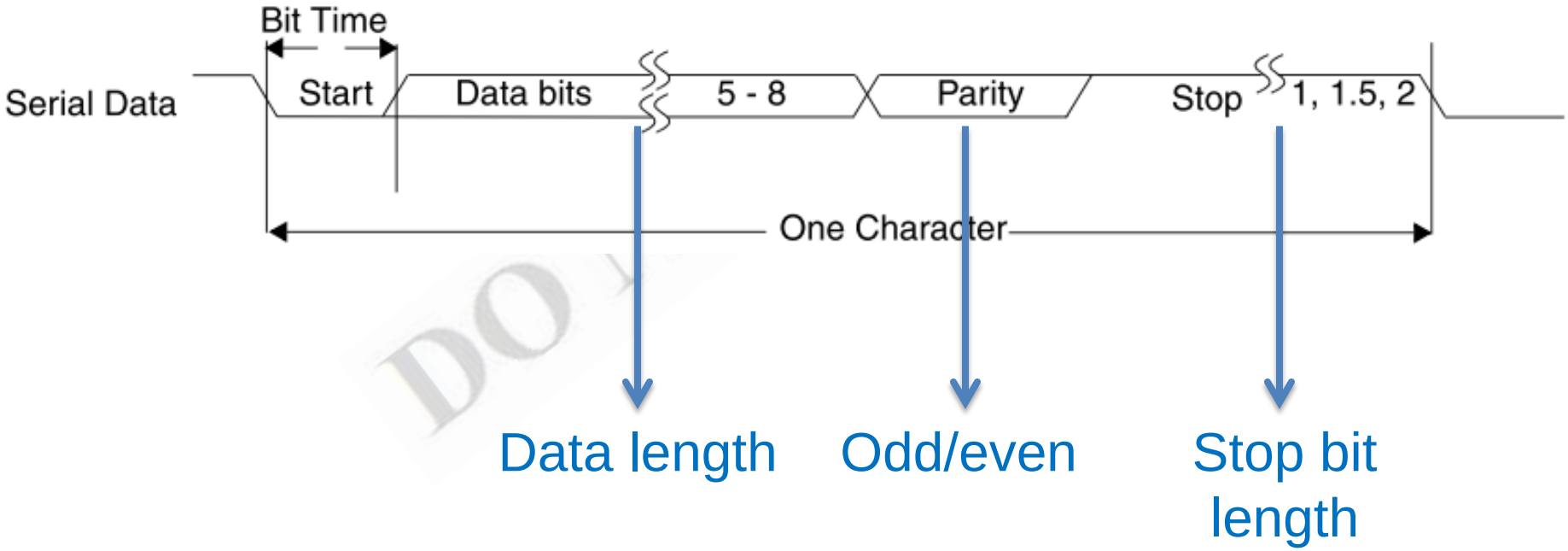
BASIC FUNCTIONS

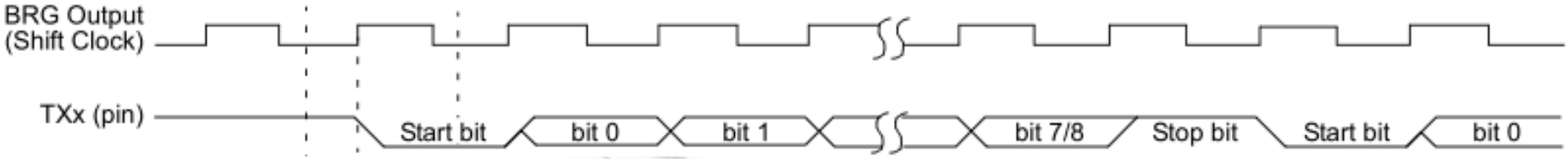
Data format

- UART – Universal Asynchronous Receiver Transmitter
- Communicate with peripheral devices.



Transfer modes

- Single transfer
- Back-to-back transfer



Baud rate (bps)

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- Fixed Formula: $Desired\ baud\ rate = \frac{fosc}{64,32,16,8,4}$
- Variable Formula: $Desired\ baud\ rate = \frac{fosc}{64,16,8,4\times(BRG+1)}$
- Variable baud rate is based on Timer/Counter

SM0	SM1	Mode	Description	Baud Rate
0	0	0	Shift register	$f_{osc}/12$
0	1	1	8-bit UART	Variable
1	0	2	9-bit UART	$f_{osc}/32$ or $/64$
1	1	3	9-bit UART	Variable

Mode	Baud Rate	
Mode0	$f_{osc}/12$	
Mode1,3	Time1 overflow rate or Timer2 overflow rate	
Mode2	SMOD0 = 0	$f_{osc}/64$
	SMOD0 = 1	$f_{osc}/32$

Baud rate error (%)

- $Desired\ baud\ rate = \frac{fosc}{64,16,8,4(BRG+1)}$
- $BRG\_cal = \frac{fosc}{64,16,8,4 \times Desired\ Baud\ rate} -$

fosc = 14Mhz
Baud rate = 2400bps
BRG_used?
Used baud rate?
Baud rate error?

- Choices the nearest integer value: BRG_used

- $Used\ baud\ rate = \frac{fosc}{64,16,8,4(BRG\_used+1)}$

BRG_used = 364
Used baud rate = 2397
Baud rate error = 0.125%

- $Baud\ rate\ error = \frac{|Used\ baud\ rate - Desired\ baud\ rate|}{Desired\ baud\ rate}$

Bit rate and baud rate

- Bit rate or Data rate: The speed of the data is expressed in bits per second (bits/s or bps).
- $Bit\ rate = \frac{1}{T\_bit}$
- Example: T_bit = 20ns => Bit rate = 50 Mbps

Bit rate and baud rate (cont)

- Baud rate: is measured in symbols per second or baud (Bd)
  - 1 symbol = 1 or multiple bits

- $Baud\ rate = \frac{Bit\ rate}{N}$
  - n: the number of bits per symbol

- UART: Baud rate is the same as bit rate (Why??)

- **Note: the used unit**

UART structure example

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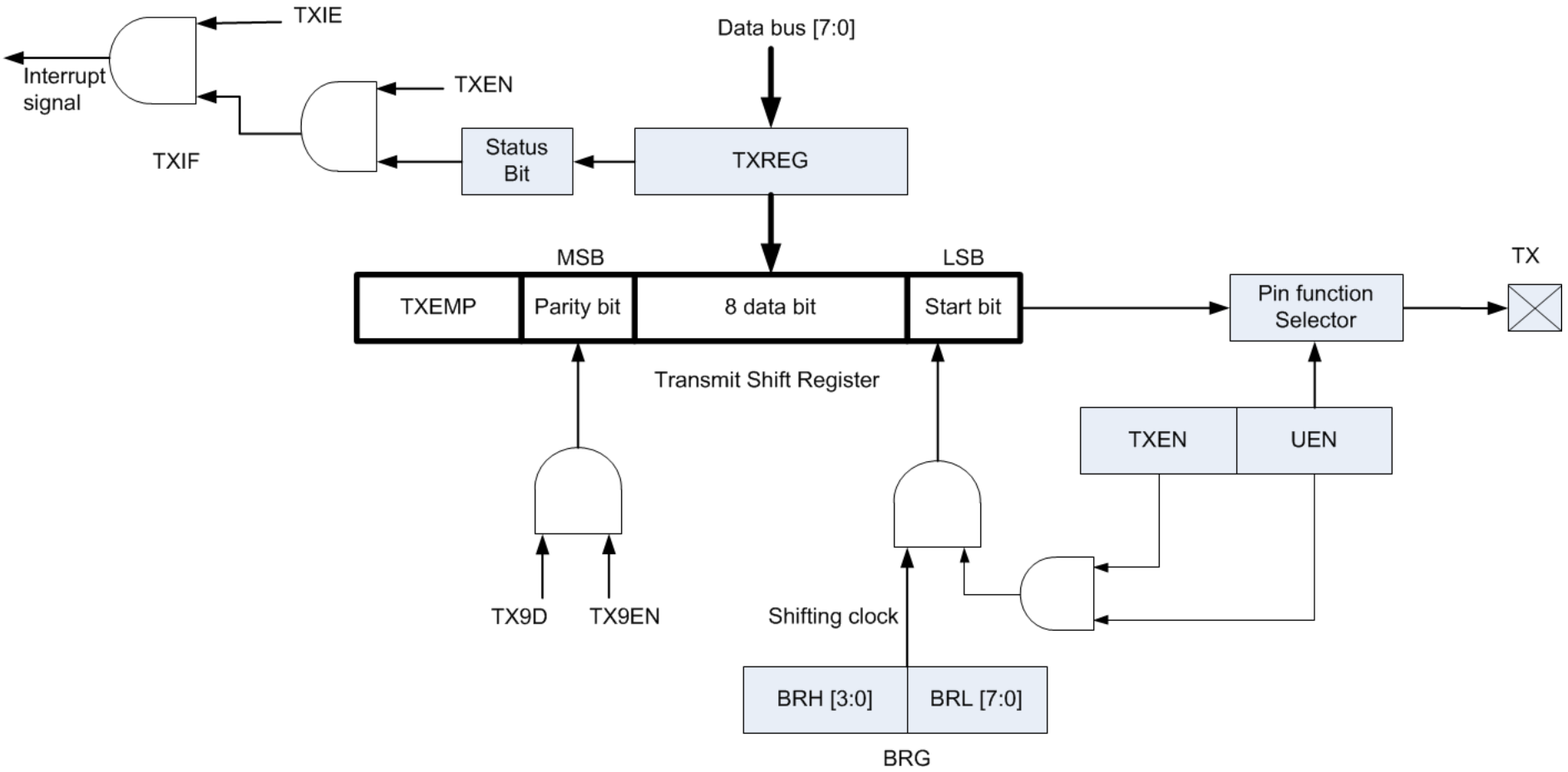
- Transmitter



UART structure example (cont)

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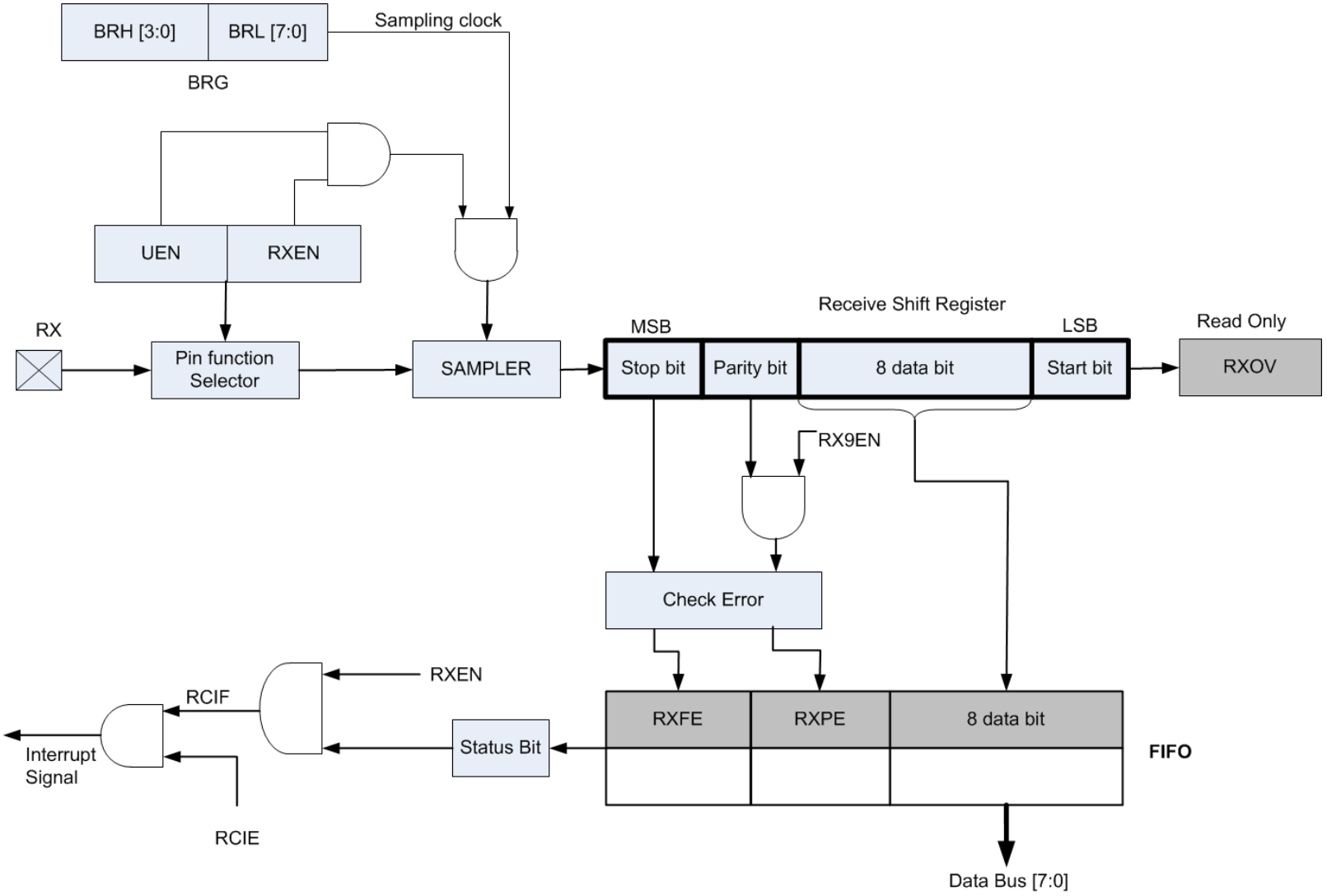
- Receiver



CONTENTS

- Basic functions
  - Data format
  - Transfer modes
  - Bit rate and baud rate
  - Basic structure
- Other functions
  - APB interface
  - Interrupt signals
  - DMA interface
  - Auto flow control
  - Auto baud detection

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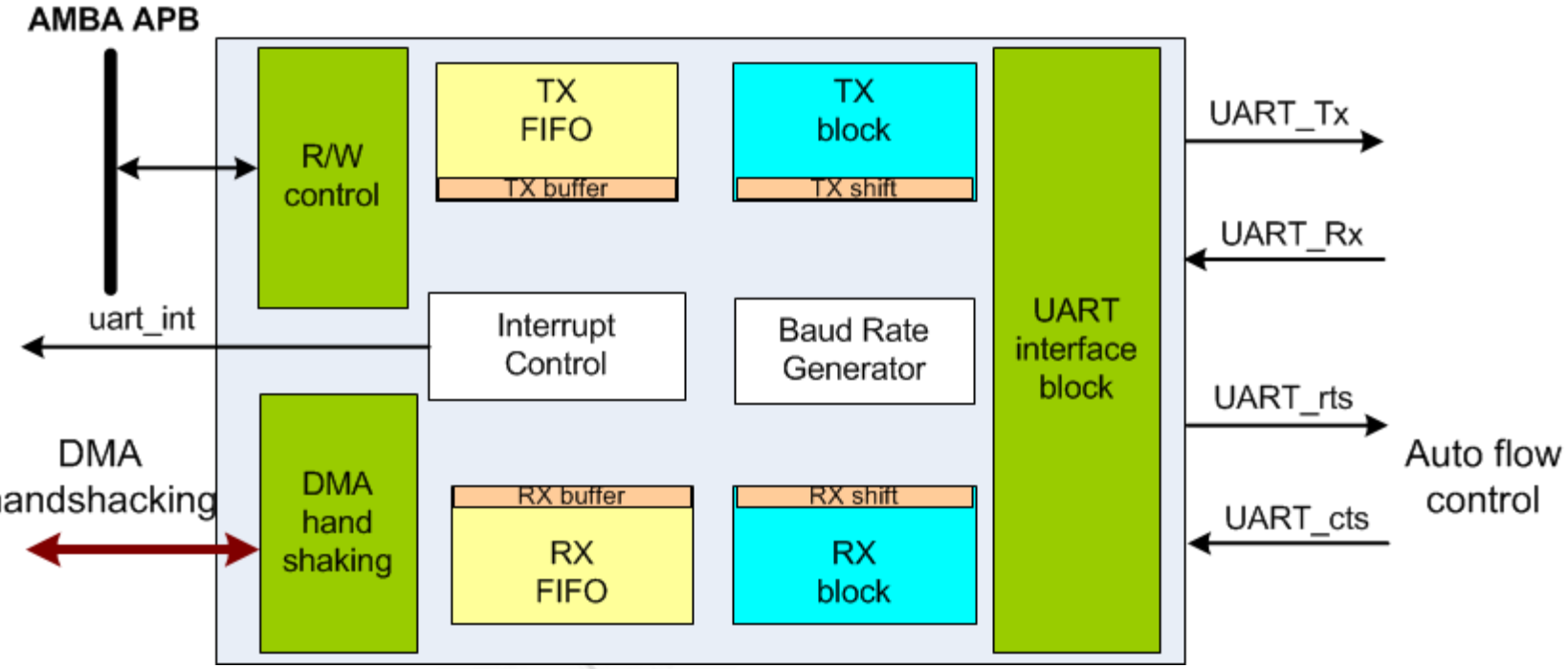
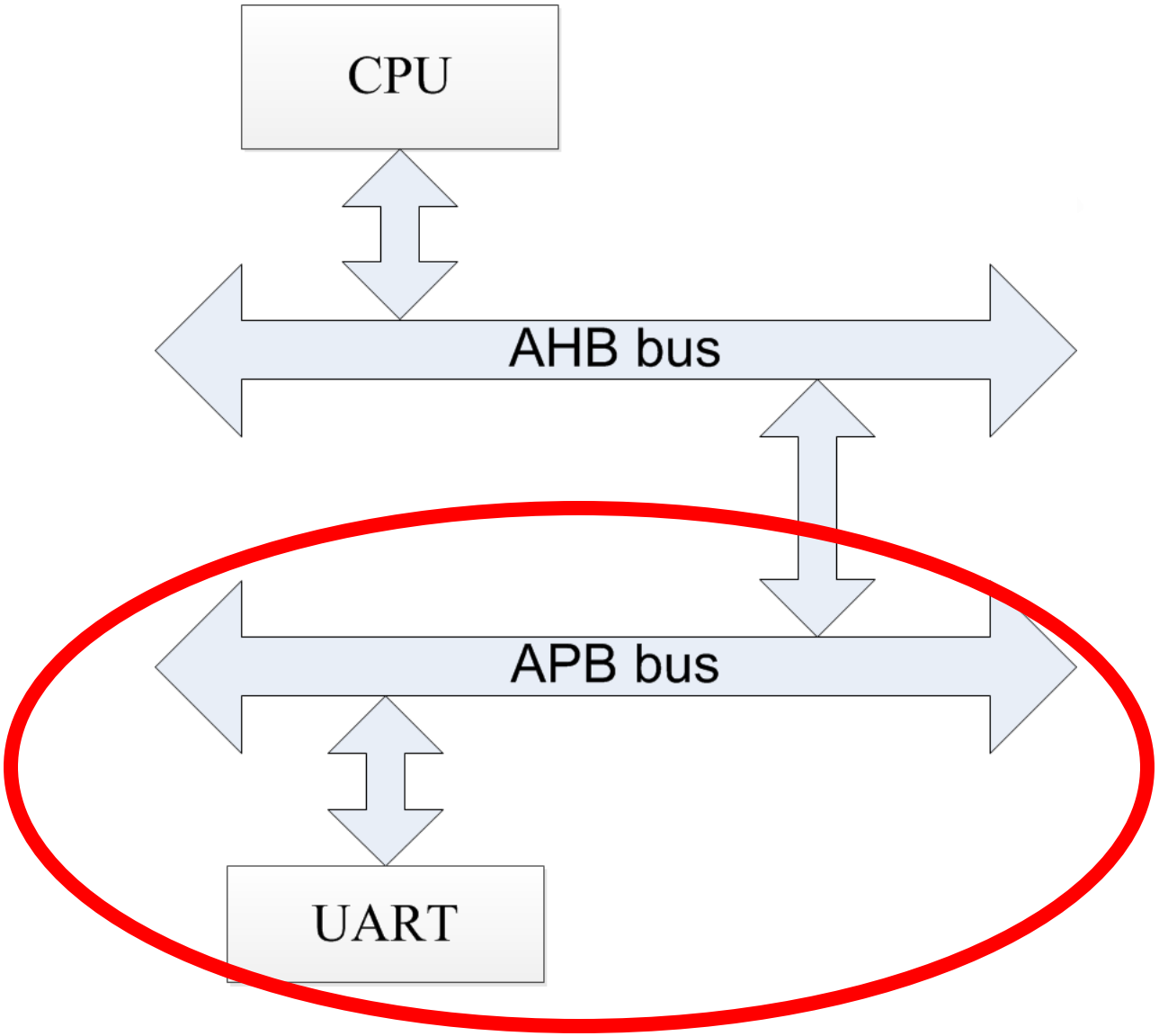
OTHER FUNCTIONS

UART IP core example

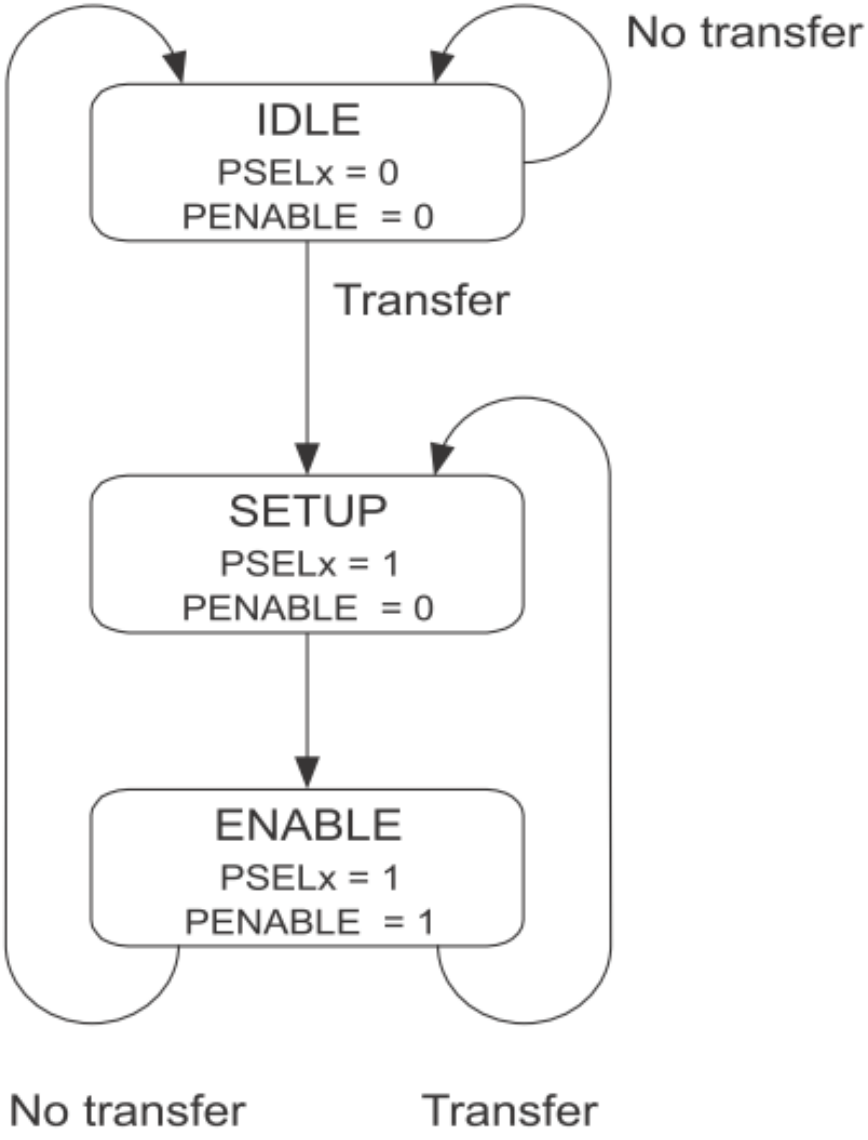


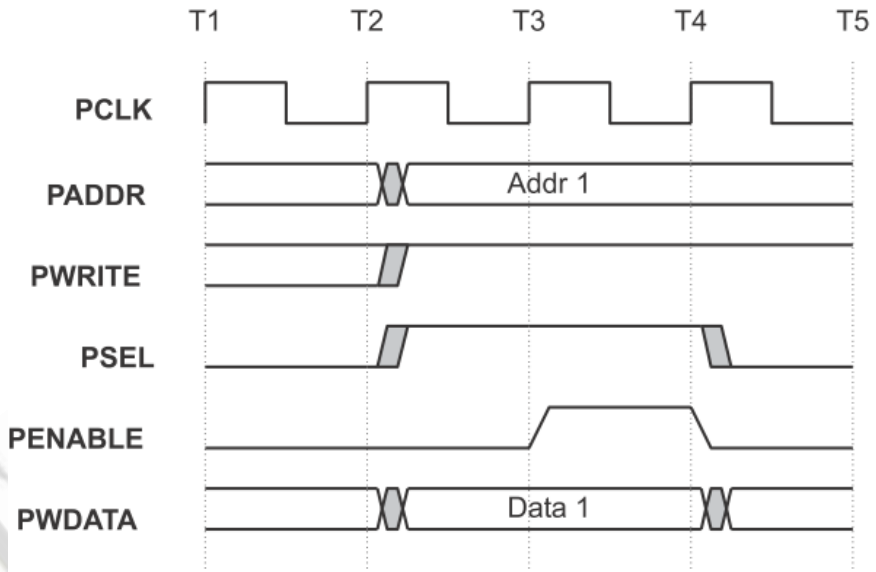
- APB Interface
- Interrupt signals
- DMA interface
- Auto Flow Control

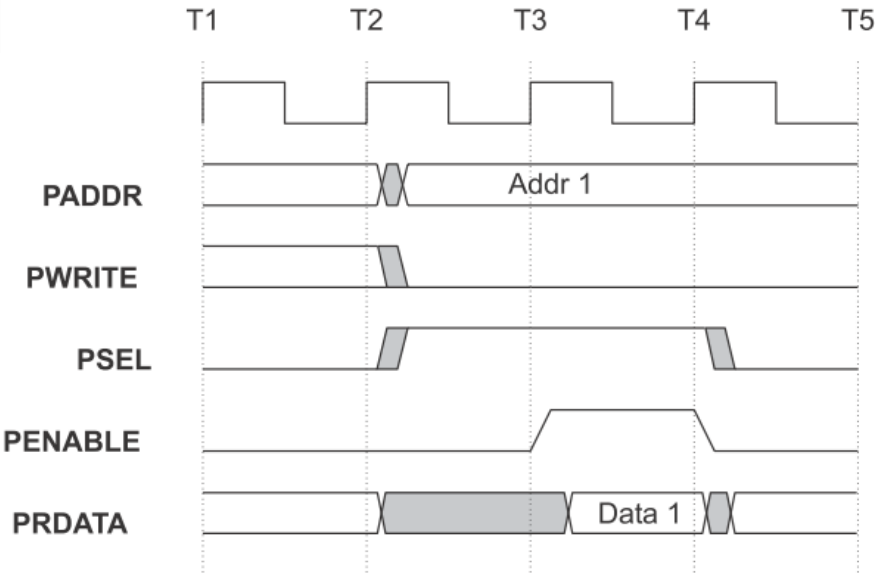
APB interface



APB interface (cont)



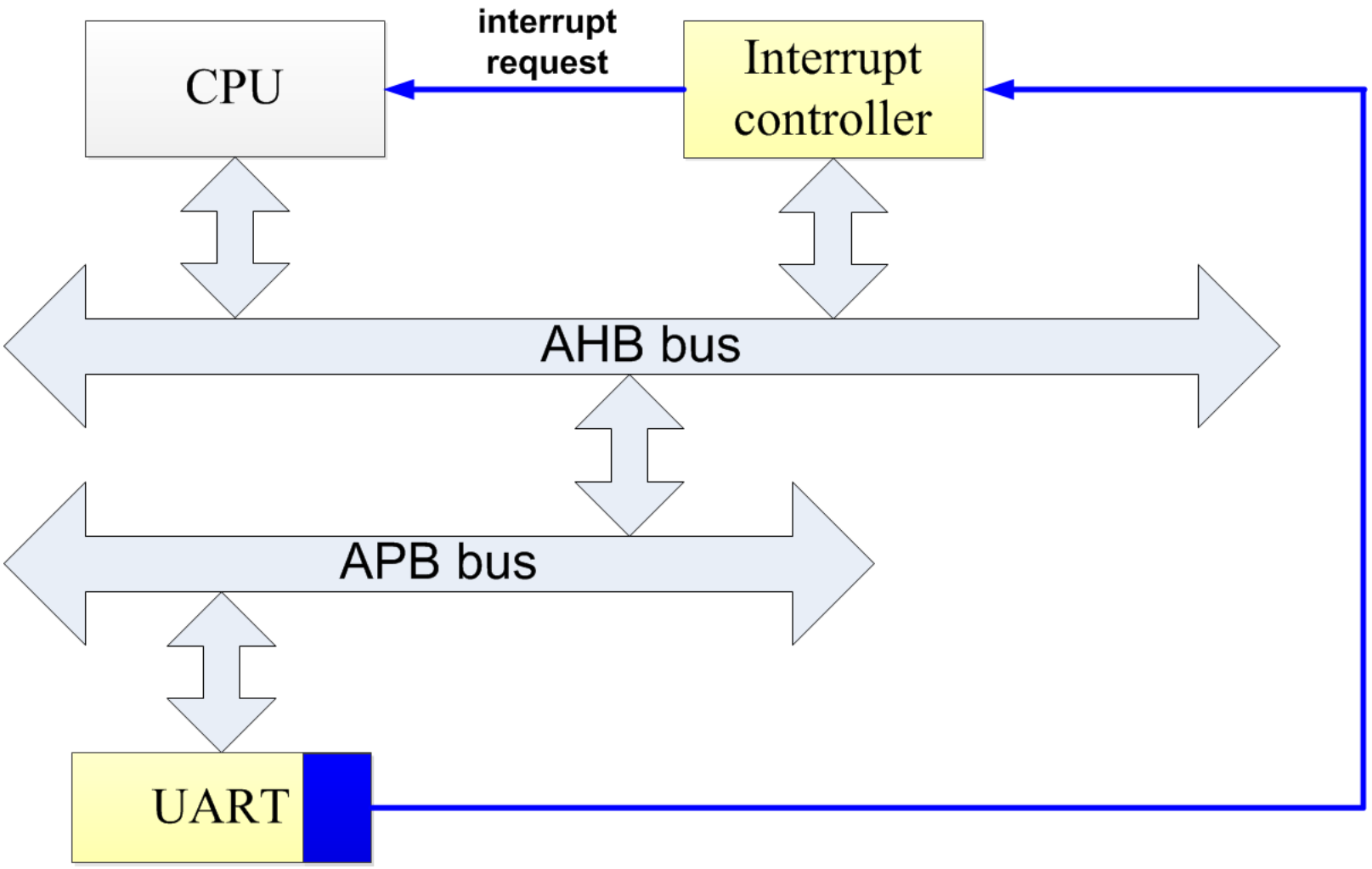




Interrupt signals

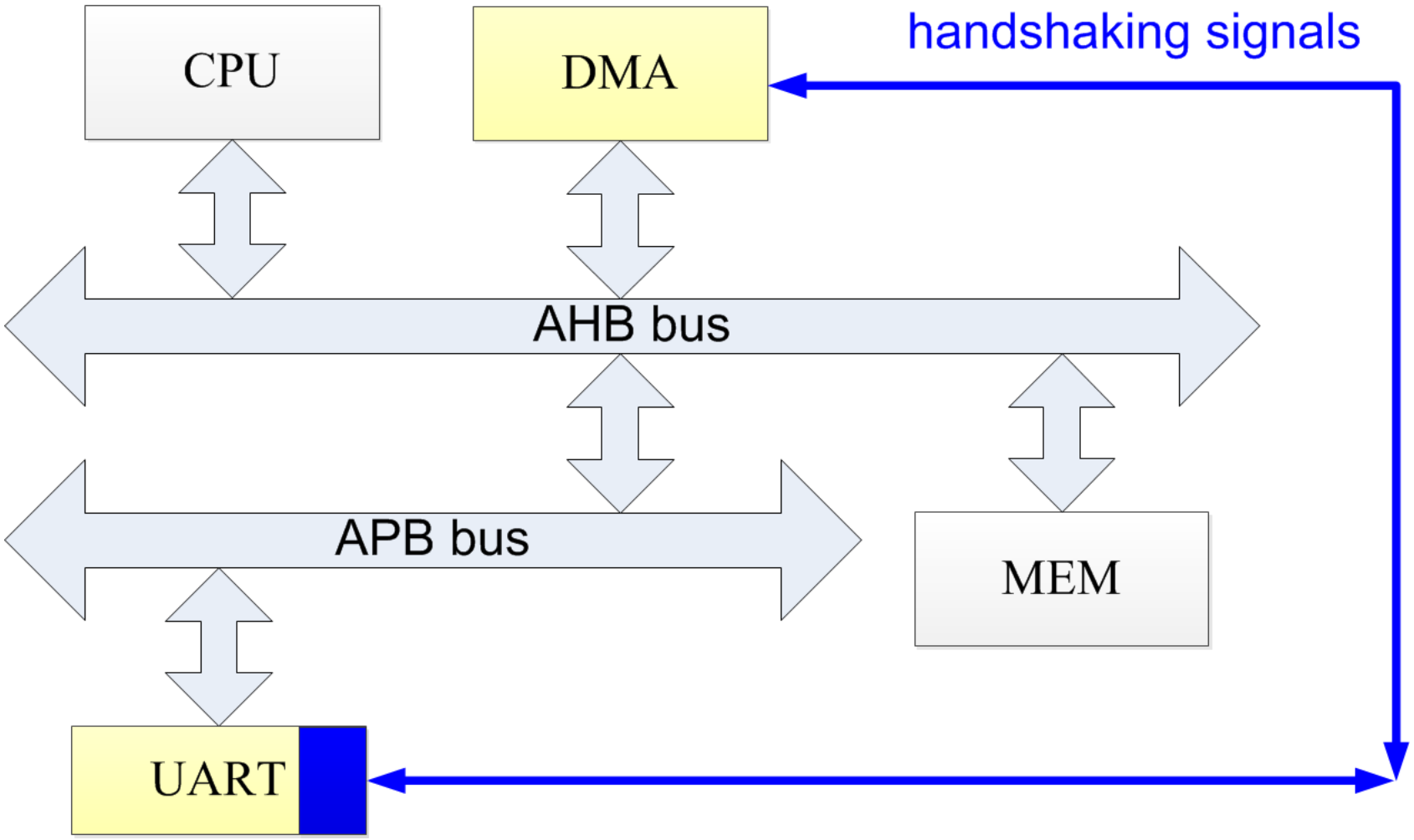
- To signal the special status to CPU core
- Interrupt types:
  - Separate interrupts
  - Combined interrupt
- Example:
  - Transmit interrupt
  - Receive interrupt
  - Receive error (overrun/parity/framing/break condition)
  - Character timeout (CTI)

Interrupt connection



DMA interface (System connection)

- Direct memory access (DMA)



DMA interface (signals)

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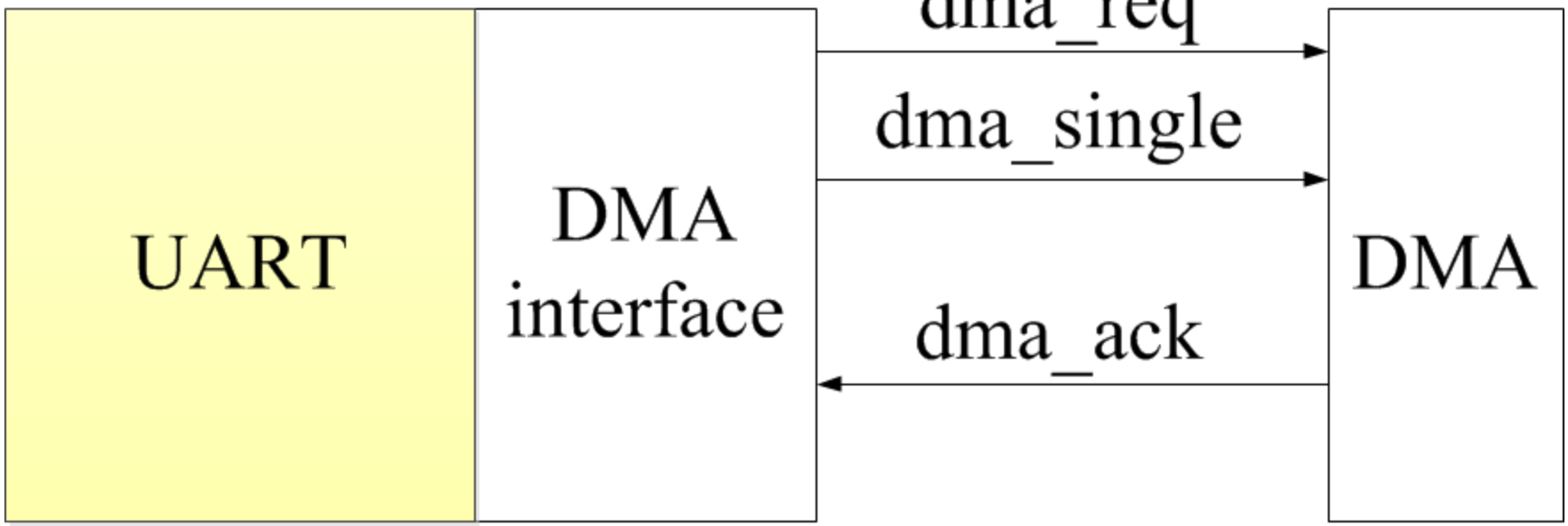

DMA interface (Timing diagram)

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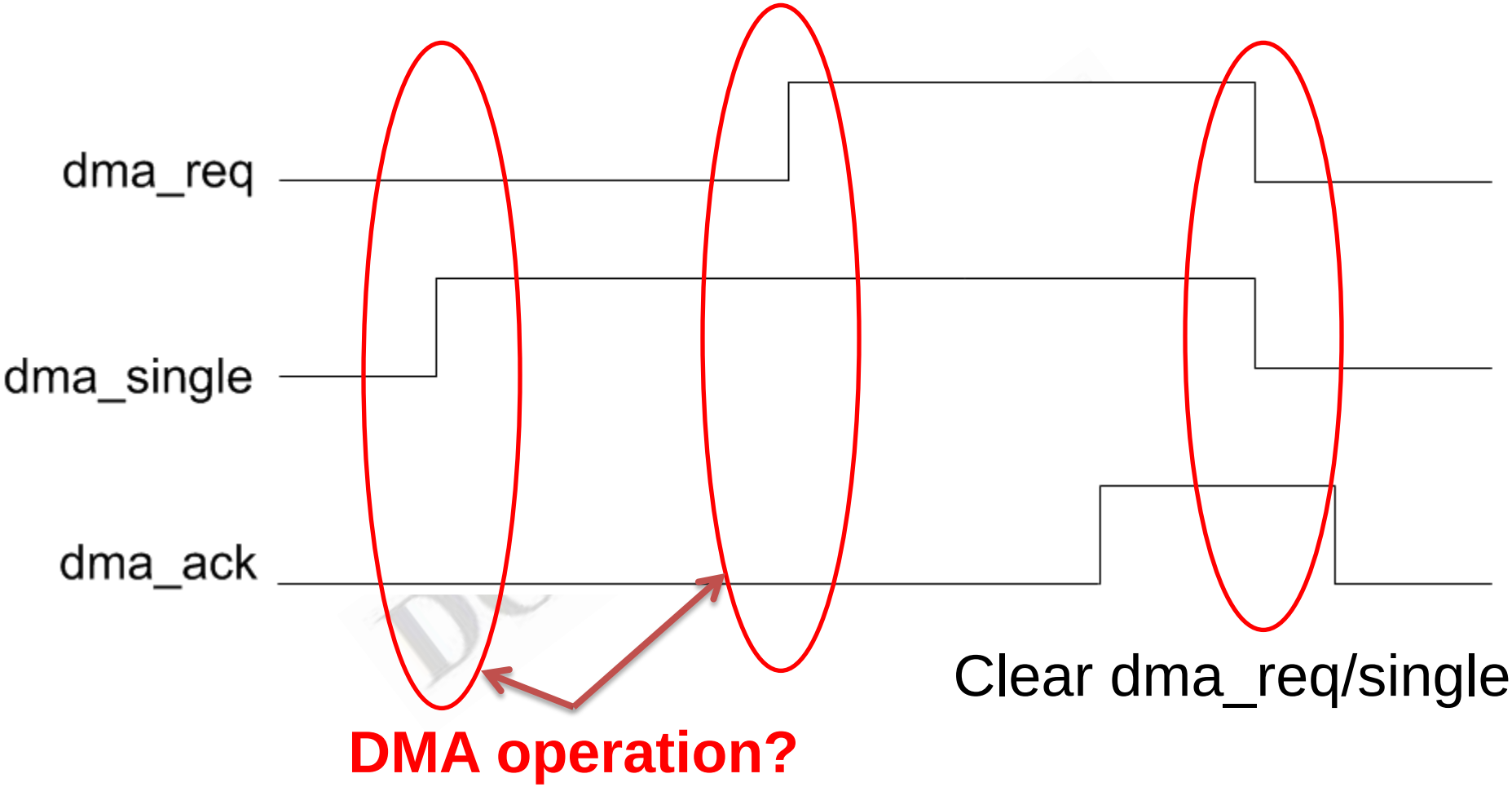

DMA interface (Master)

- The number of requested data: 200 byte
- The configuration of DMA:
  - Burst size: 4
  - Transfer size: 32 bit (4 byte)
- The number of burst transfers: 200/16 = 12 bursts (192 byte)
- The number of single transfers: 200 – 192 = 8 byte (2 singles)

DMA interface (Slave)

- Transmitter requests
  - The transmitter FIFO is not full.
  - The transmitter FIFO is **at or below** the programmed threshold.
  - The transmitter FIFO is empty.
- Receiver
  - The transmitter FIFO is not empty.
  - The transmitter FIFO is **at or above** the programmed threshold.
  - The transmitter FIFO is full.

Auto flow control (signals)

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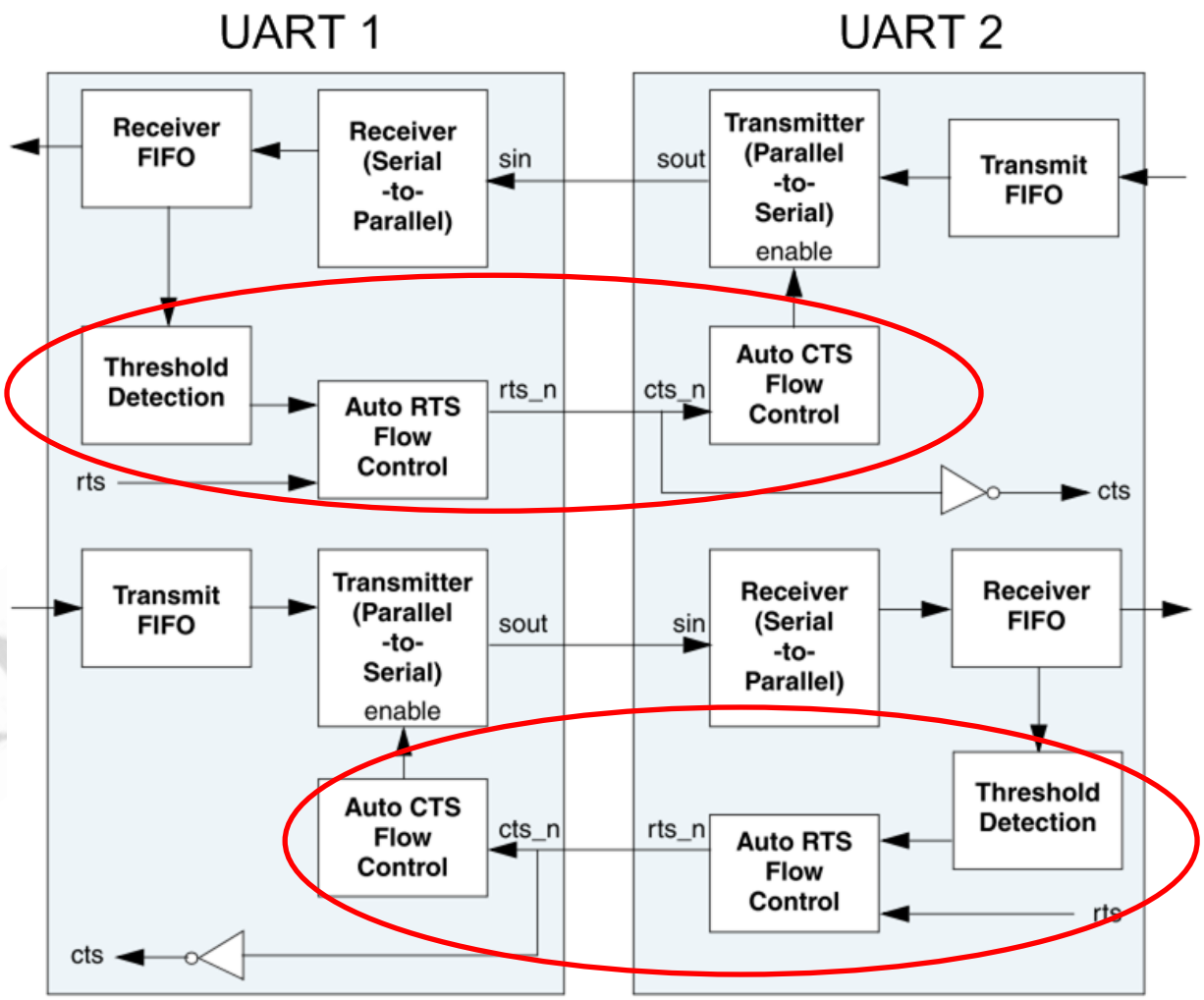
- Supporting Auto RTS (Request To Send) and Auto CTS (Clear To Send)
- Using with FIFOs



Auto flow control (Auto RTS)

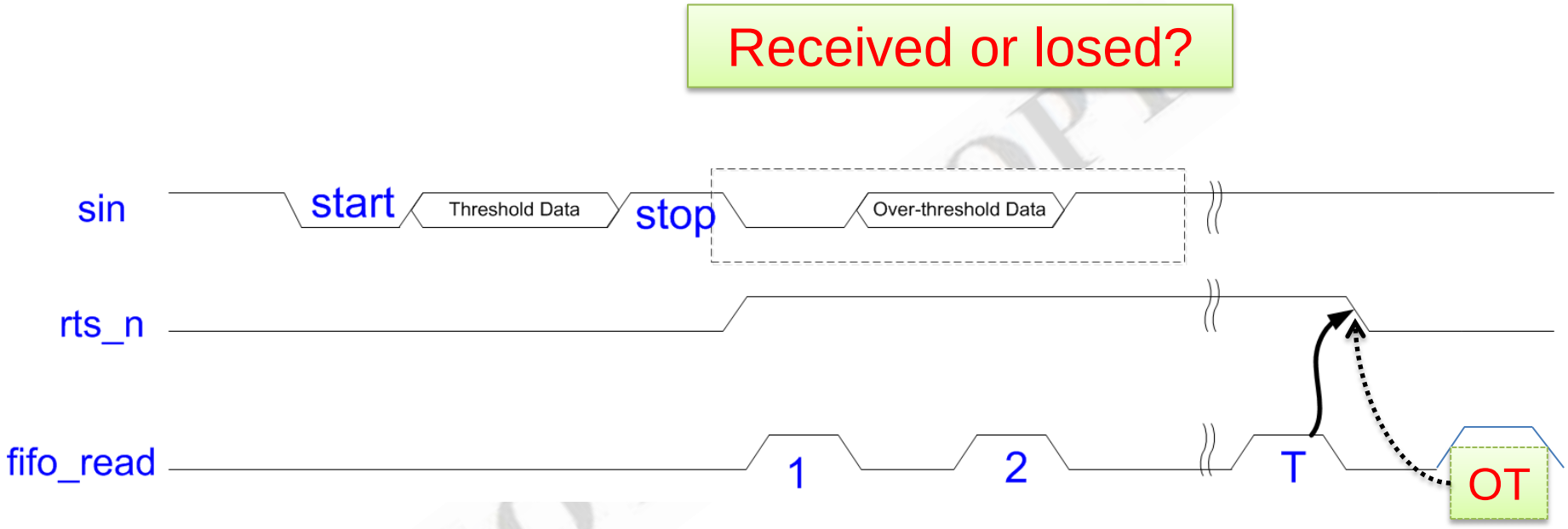
- The **rts_n output** is forced **inactive (high)** when the receiver FIFO level reaches the threshold.

- **rts_n is connected to the cts_n input** of another UART device, the other UART stops sending serial data until the receiver FIFO has available space (until it is completely empty)

- The receiver FIFO becomes completely empty by reading, **rts_n** again becomes **active (low)**, signalling the other UART to continue sending data.

Auto flow control (Auto RTS)

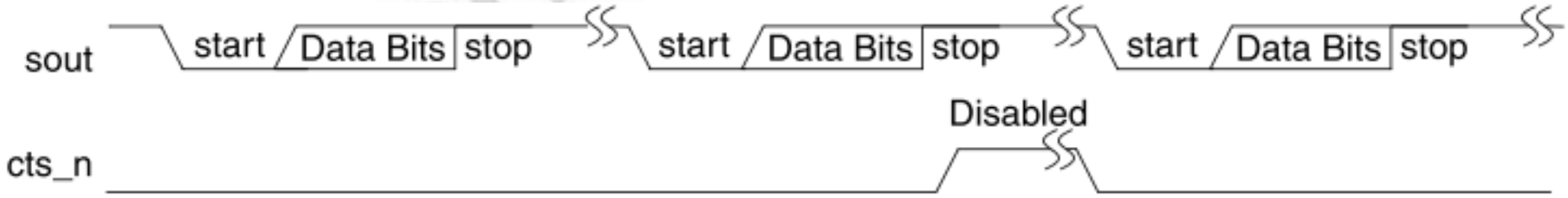
- Timing



Auto flow control (Auto CTS)

- Transmitter is disabled whenever the **cts_n input** becomes **inactive (high)**.

- If the **cts_n input** is not inactivated **before the middle of the last stop bit**, another character is transmitted before the transmitter is disabled



Questions and Discussion