

Osnove mikroprocesorske elektronike

Marko Jankovec

Asinhrona serijske komunikacije - Primeri

... STM32 G4

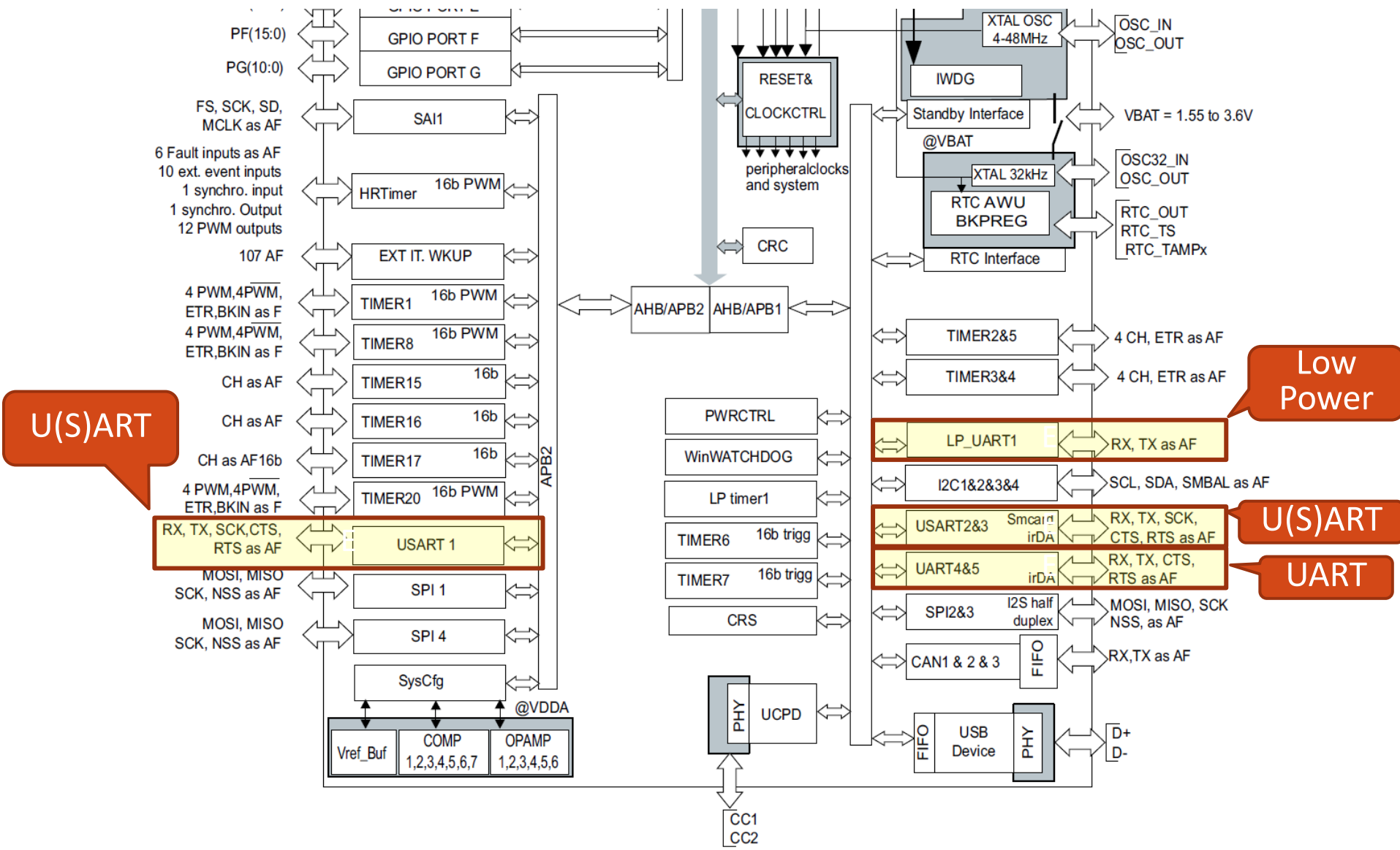


Figure 530. USART block diagram

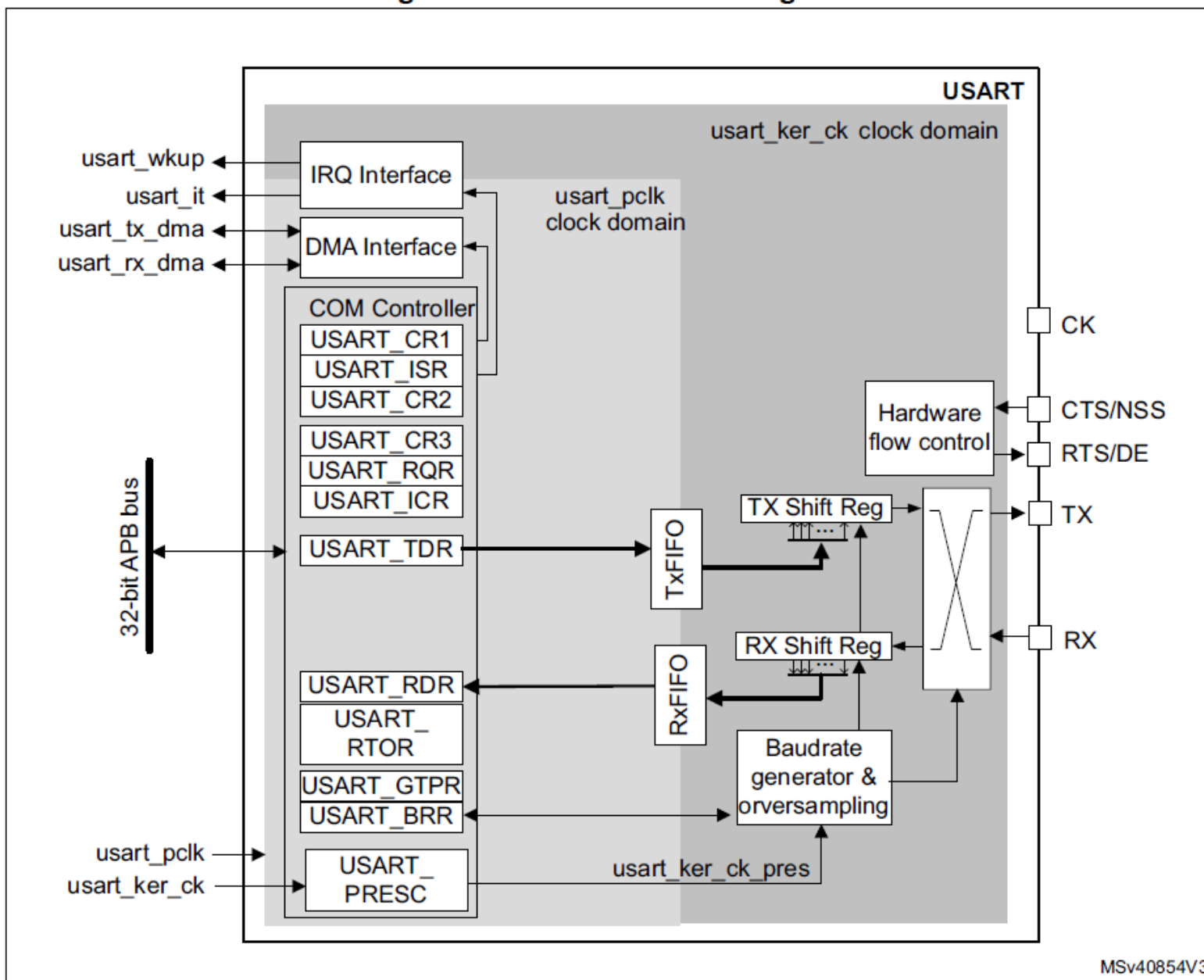
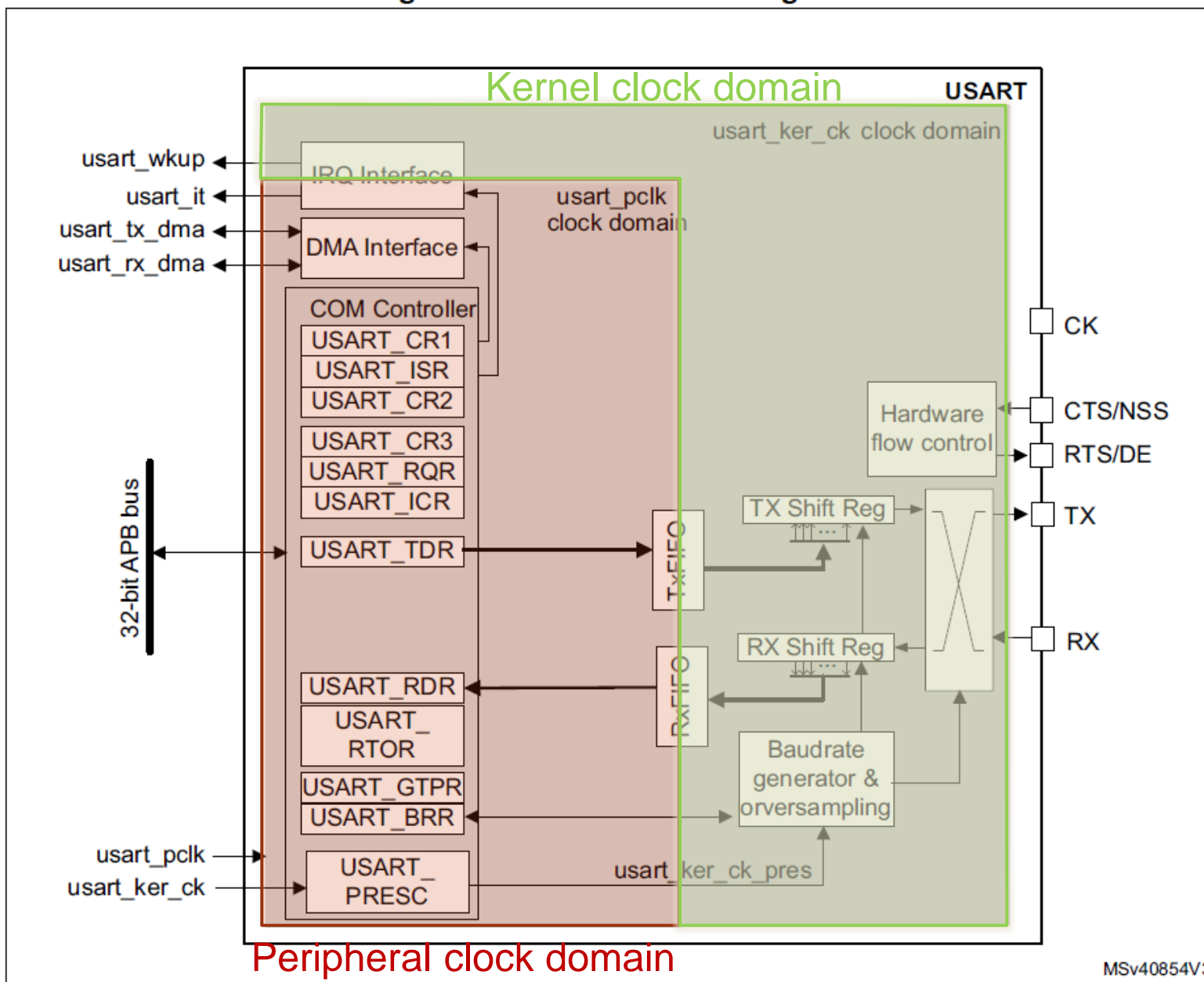
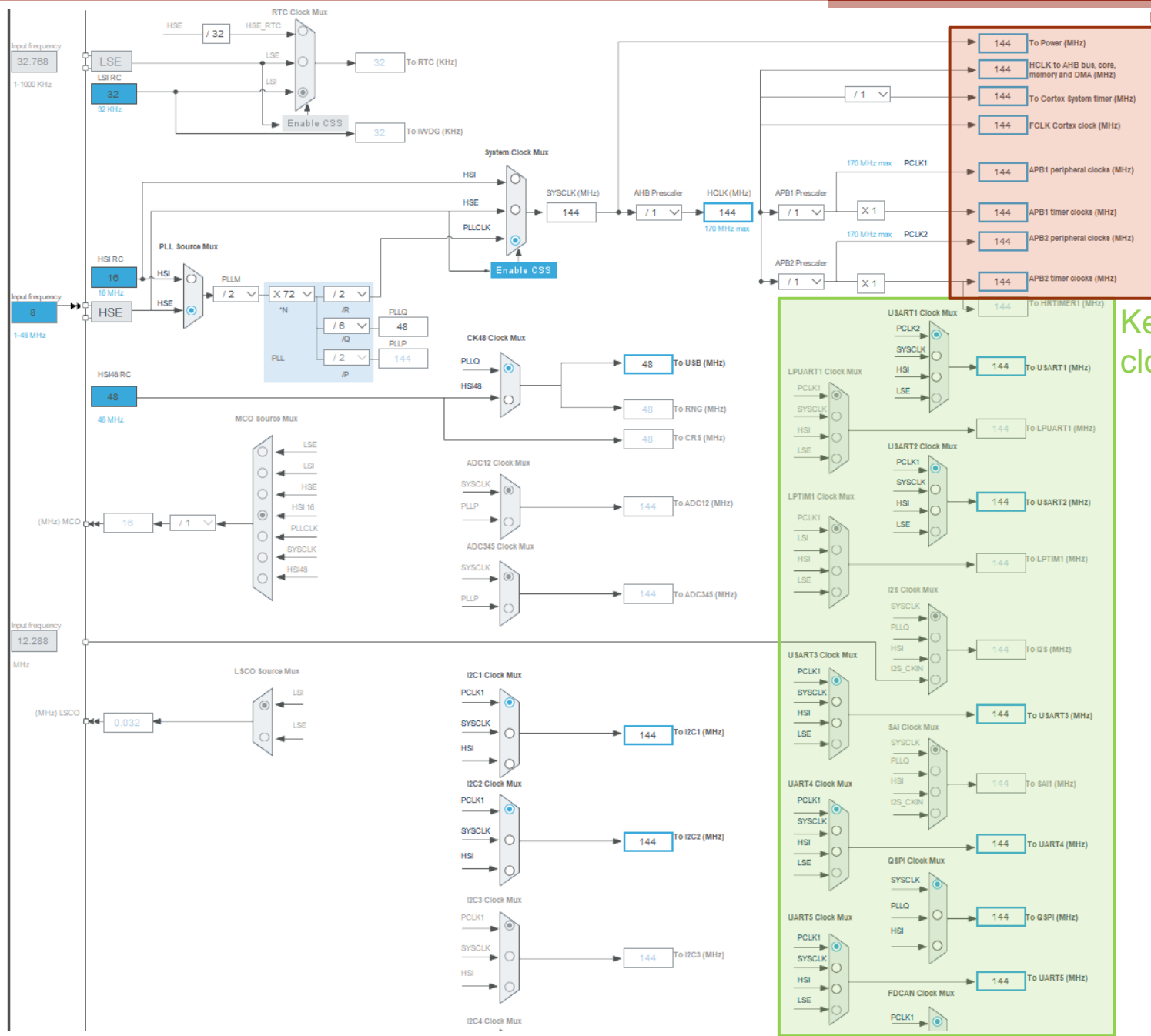


Table 9. USART/UART/LPUART features

USART modes/features⁽¹⁾	USART1	USART2	USART3	UART4	UART5	LPUART1
Hardware flow control for modem	X	X	X	X	X	X
Continuous communication using DMA	X	X	X	X	X	X
Multiprocessor communication	X	X	X	X	X	X
Synchronous mode	X	X	X	-	-	-
Smartcard mode	X	X	X	-	-	-
Single-wire half-duplex communication	X	X	X	X	X	X
IrDA SIR ENDEC block	X	X	X	X	X	-
LIN mode	X	X	X	X	X	-
Dual clock domain	X	X	X	X	X	X
Wakeup from Stop mode	X	X	X	X	X	X
Receiver timeout interrupt	X	X	X	X	X	-
Modbus communication	X	X	X	X	X	-
Auto baud rate detection	X (4 modes)					-
Driver Enable	X	X	X	X	X	X
LPUART/USART data length	7, 8 and 9 bits					
Tx/Rx FIFO	X					
Tx/Rx FIFO size	8					

Figure 530. USART block diagram





Peripheral clock domain

Kernel clock domain

Hitrost prenosa (baud rate)

Figure 535. usart_ker_ck clock divider block diagram



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PRESCALER[3:0]			
												rw	rw	rw	rw

Bits 31:4 Reserved, must be kept at reset value.

Bits 3:0 **PRESCALER[3:0]**: Clock prescaler

The USART input clock can be divided by a prescaler factor:

- 0000: input clock not divided
- 0001: input clock divided by 2
- 0010: input clock divided by 4
- 0011: input clock divided by 6
- 0100: input clock divided by 8
- 0101: input clock divided by 10
- 0110: input clock divided by 12
- 0111: input clock divided by 16
- 1000: input clock divided by 32
- 1001: input clock divided by 64
- 1010: input clock divided by 128
- 1011: input clock divided by 256

Prevzorčenje

ONEBIT

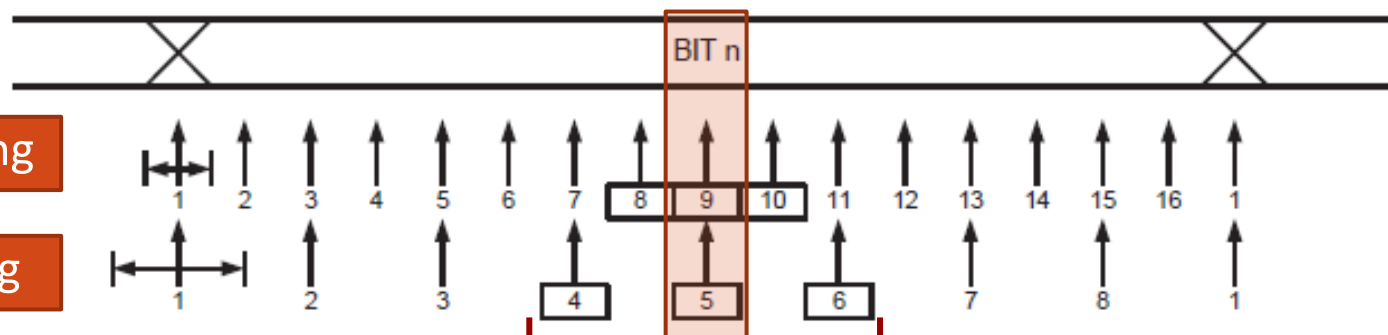
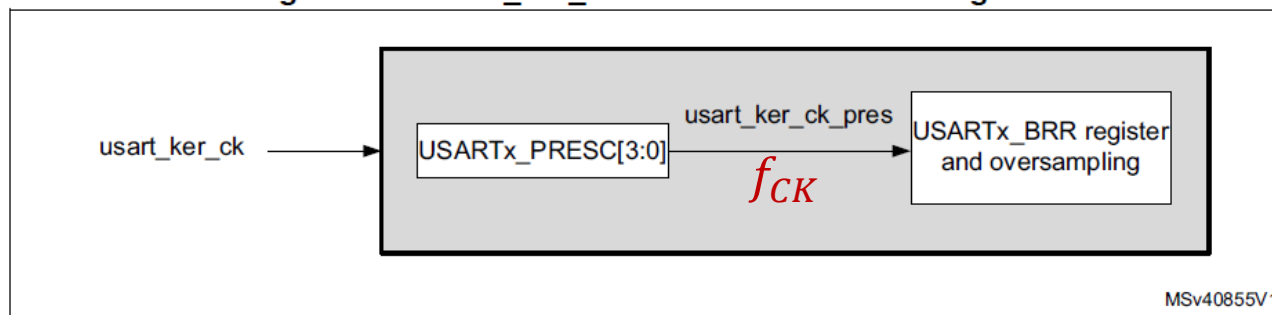
Noise
errorMajority
vote

Table 344. Noise detection from sampled data

Sampled value	NE status	Received bit value
000	0	0
001	1	0
010	1	0
011	1	1
100	1	0
101	1	1
110	1	1
111	0	1

Hitrost prenosa (baud rate)

Figure 535. usart_ker_ck clock divider block diagram



OVER8=0

OVER8=1

$$BAUD = \frac{f_{CK}}{16 \cdot USARTDIV}$$

$$BAUD = \frac{f_{CK}}{8 \cdot USARTDIV}$$

$$\mathbf{BRR}[15:4] = USARTDIV$$

$$\mathbf{BRR}[3:0] = USARTDIV \cdot 16$$

$$\mathbf{BRR}[3:0] = USARTDIV \cdot 8$$

[illegible]

Primer izračuna

$$\begin{aligned}BAUD &= 9600 \\usart_ker_ck &= 144\text{ MHz} \\OVER8 &= 0\end{aligned}$$



$$USARTDIV = \frac{f_{CK}}{16 \cdot BAUD} = 937,5$$



$$USARTx \rightarrow BRR = 937 \cdot 16 + 0,5 \cdot 16 = 15000$$

Maksimalne hitrosti

- Pri maksimalni frekvenci ure

$$\begin{aligned} \text{usart_ker_ck} &= 170 \text{ MHz} \\ \text{OVER8} &= 1 \\ \text{USARTDIV}_{\min} &= 1 \end{aligned}$$



$$\text{BAUD} = \frac{f_{CK}}{8 \cdot \text{USARTDIV}} = 21,25 \text{ Mbit/s}$$



$$\text{USART}_x \rightarrow \text{BRR} = 0x0010$$

Dopustne tolerance ure

16x oversampling

8x oversampling

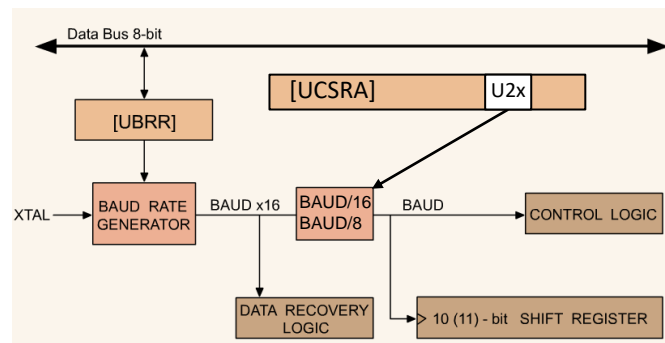
Table 345. Tolerance of the USART receiver when BRR [3:0] = 0000

M bits	OVER8 bit = 0		OVER8 bit = 1	
	ONEBIT = 0	ONEBIT = 1	ONEBIT = 0	ONEBIT = 1
00	3.75%	4.375%	2.50%	3.75%
01	3.41%	3.97%	2.27%	3.41%
10	4.16%	4.86%	2.77%	4.16%

Število
bitov
podatka

Primer pri Atmel AVR

- Za 8 podatkovnih bitov brez paritete, 1 stop bit
 - $\pm 2\%$ napaka frekvence za normalen način
 - $\pm 1.5\%$ napaka za dvojno hitrost



Baud Rate (bps)	$f_{osc} = 16.0000 \text{ MHz}$				$f_{osc} = 18.4320 \text{ MHz}$				$f_{osc} = 20.0000 \text{ MHz}$			
	$U2Xn = 0$		$U2Xn = 1$		$U2Xn = 0$		$U2Xn = 1$		$U2Xn = 0$		$U2Xn = 1$	
	UBRR	Error	UBRR	Error	UBRR	Error	UBRR	Error	UBRR	Error	UBRR	Error
2400	416	-0.1%	832	0.0%	479	0.0%	959	0.0%	520	0.0%	1041	0.0%
4800	207	0.2%	416	-0.1%	239	0.0%	479	0.0%	259	0.2%	520	0.0%
9600	103	0.2%	207	0.2%	119	0.0%	239	0.0%	129	0.2%	259	0.2%
14.4k	68	0.6%	138	-0.1%	79	0.0%	159	0.0%	86	-0.2%	173	-0.2%
19.2k	51	0.2%	103	0.2%	59	0.0%	119	0.0%	64	0.2%	129	0.2%
28.8k	34	-0.8%	68	0.6%	39	0.0%	79	0.0%	42	0.9%	86	-0.2%
38.4k	25	0.2%	51	0.2%	29	0.0%	59	0.0%	32	-1.4%	64	0.2%
57.6k	16	2.1%	34	-0.8%	19	0.0%	39	0.0%	21	-1.4%	42	0.9%
76.8k	12	0.2%	25	0.2%	14	0.0%	29	0.0%	15	1.7%	32	-1.4%
115.2k	8	-3.5%	16	2.1%	9	0.0%	19	0.0%	10	-1.4%	21	-1.4%
230.4k	3	8.5%	8	-3.5%	4	0.0%	9	0.0%	4	8.5%	10	-1.4%
250k	3	0.0%	7	0.0%	4	-7.8%	8	2.4%	4	0.0%	9	0.0%
0.5M	1	0.0%	3	0.0%	—	—	4	-7.8%	—	—	4	0.0%
1M	0	0.0%	1	0.0%	—	—	—	—	—	—	—	—
Max. ⁽¹⁾	1 Mbps		2 Mbps		1.152 Mbps		2.304 Mbps		1.25 Mbps		2.5 Mbps	

Table 9. USART/UART/LPUART features

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Continuous communication using DMA	X	X	X	X	X	X
Multiprocessor communication	X	X	X	X	X	X
Synchronous mode	X	X	X	-	-	-
Smartcard mode	X	X	X	-	-	-
Single-wire half-duplex communication	X	X	X	X	X	X
IrDA SIR ENDEC block	X	X	X	X	X	-
LIN mode	X	X	X	X	X	-
Dual clock domain	X	X	X	X	X	X
Wakeup from Stop mode	X	X	X	X	X	X
Receiver timeout interrupt	X	X	X	X	X	-
Modbus communication	X	X	X	X	X	-
Auto baud rate detection	X (4 modes)					-
Driver Enable	X	X	X	X	X	X
LPUART/USART data length	7, 8 and 9 bits					
Tx/Rx FIFO	X					
Tx/Rx FIFO size	8					

Avtomatska detekcija hitrosti komunikacije (**ABREN**)

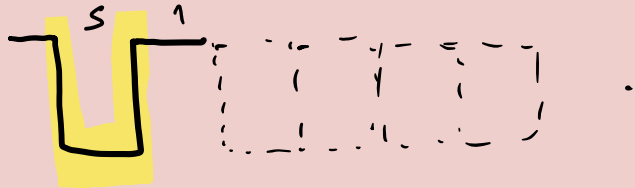
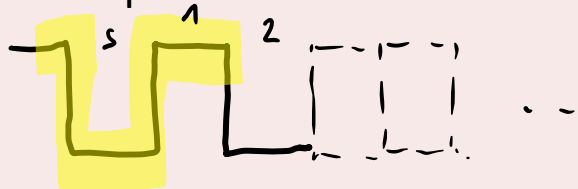
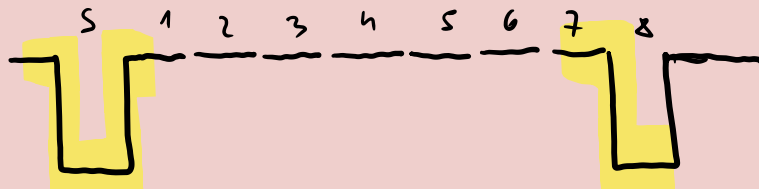

ABRMODE [1 : 0]	Vzorec	Meritev
00	1xxx xxxx	Dolžina START bita 
01	10xx xxxx	Dolžina START bita + prva "1" podatka 
10	0xFE	Dolžina START bita + dolžina do konca bita 6 
11	0x55	Dolžina START bita + bit 0 + bit 6 

Table 9. USART/UART/LPUART features

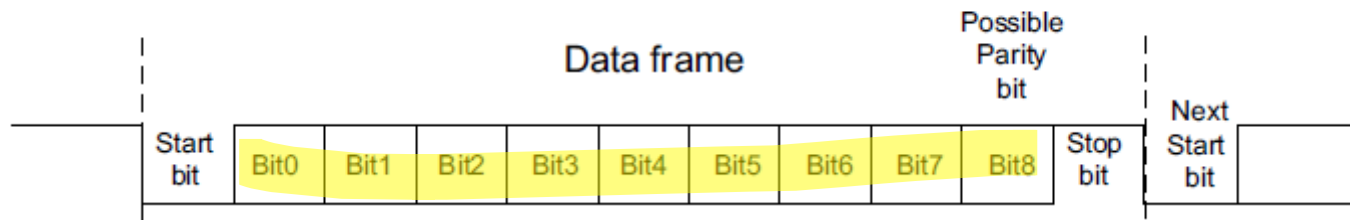
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Continuous communication using DMA	X	X	X	X	X	X
Multiprocessor communication	X	X	X	X	X	X
Synchronous mode	X	X	X	-	-	-
Smartcard mode	X	X	X	-	-	-
Single-wire half-duplex communication	X	X	X	X	X	X
IrDA SIR ENDEC block	X	X	X	X	X	-
LIN mode	X	X	X	X	X	-
Dual clock domain	X	X	X	X	X	X
Wakeup from Stop mode	X	X	X	X	X	X
Receiver timeout interrupt	X	X	X	X	X	-
Modbus communication	X	X	X	X	X	-
Auto baud rate detection	X (4 modes)					-
Driver Enable	X	X	X	X	X	X
LPUART/USART data length	7, 8 and 9 bits					
Tx/Rx FIFO	X					
Tx/Rx FIFO size	8					

Možnosti podatkovnega okvirja

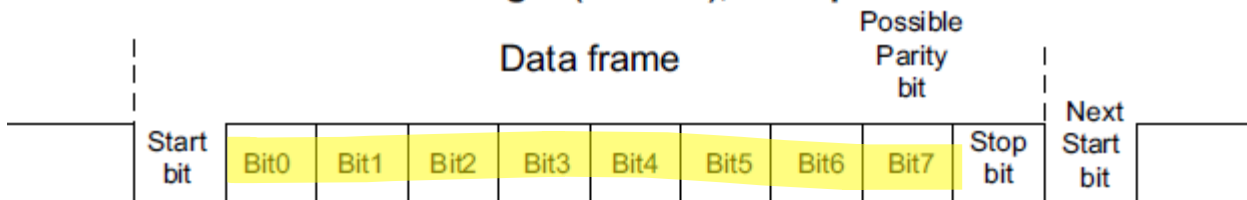
- 7,8 ali 9-bit dolžina podatka (**M[1 : 0]**)

Figure 531. Word length programming

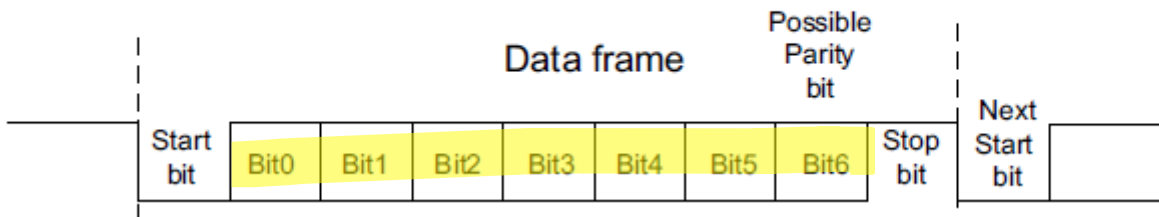
9-bit word length (M = 01), 1 Stop bit



8-bit word length (M = 00), 1 Stop bit



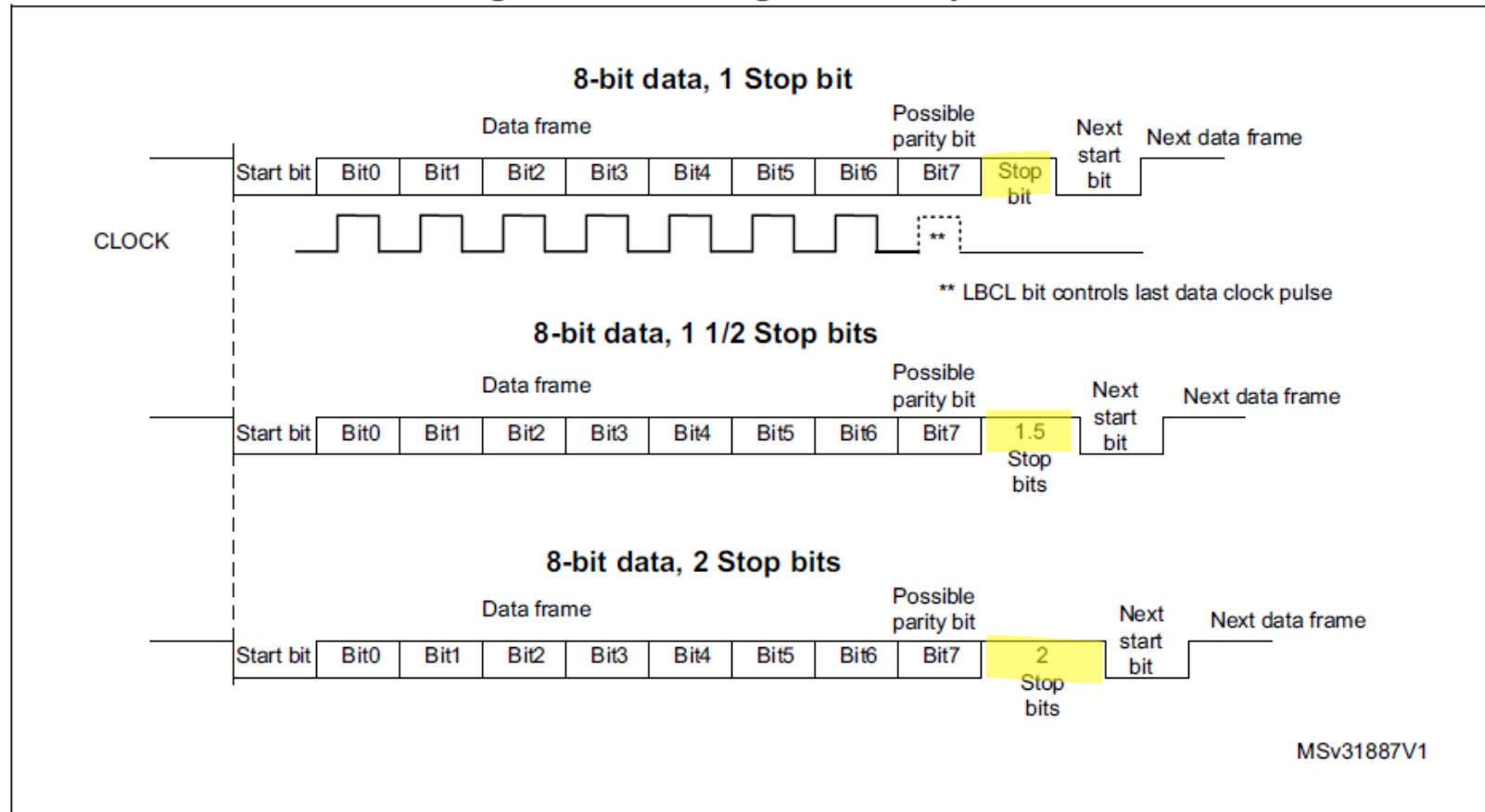
7-bit word length (M = 10), 1 Stop bit



Možnosti podatkovnega okvirja

- 1, 1.5 ali 2 stop bita (**STOP [1 : 0]**)

Figure 532. Configurable stop bits



Možnosti podatkovnega okvirja

- Liha ali soda pariteta (**PS** in **PCE**)

PS: Parity selection
 0: Even parity
 1: Odd parity

Table 347. USART frame formats

M bits	PCE bit	USART frame ⁽¹⁾
00	0	SB 8 bit data STB
00	1	SB 7-bit data PB STB
01	0	SB 9-bit data STB
01	1	SB 8-bit data PB STB
10	0	SB 7bit data STB
10	1	SB 6-bit data PB STB

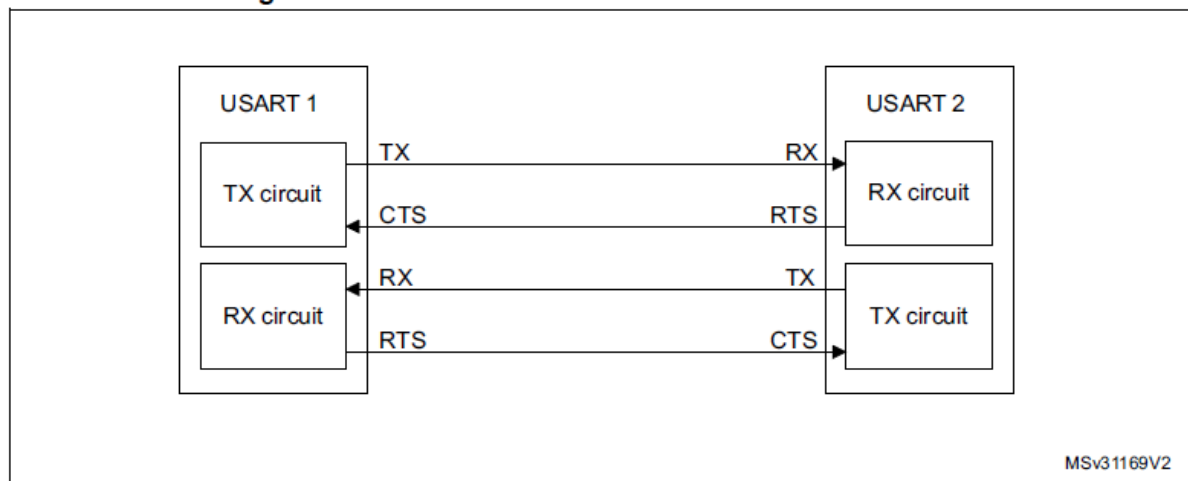
1. Legends: SB: start bit, STB: stop bit, PB: parity bit. In the data register, the PB is always taking the MSB position (8th or 7th, depending on the M bit value).

Nekatere ostale možnosti

- Zaporedje bitov: prvi MSB ali prvi LSB (**MSBFIRST**)
- Zamenjava Tx in Rx pinov (**SWAP**)
- Invertiranje Tx in Rx pinov (**TXINV, RXINV**)
- Invertiranje podatkov (**DATAINV**)
- Signali za rokovanje (**CTSE, RTSE**)
- RS485 signali (**DEM, DEP, DAT, DEDT**)
- Half-duplex način delovanja (**HDSEL**)

Rokovanje - handshaking

Figure 552. Hardware flow control between 2 USARTs



CTS - Vhod, visoko stanje ustavi oddajo (**CTSE**)

RTS - Izhod, nizko stanje pomeni pripravljenost za sprejem (**RTSE**)

Figure 554. RS232 CTS flow control

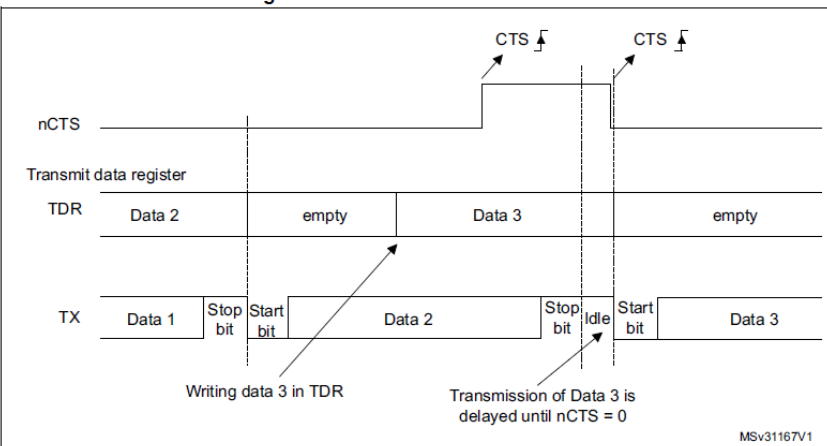
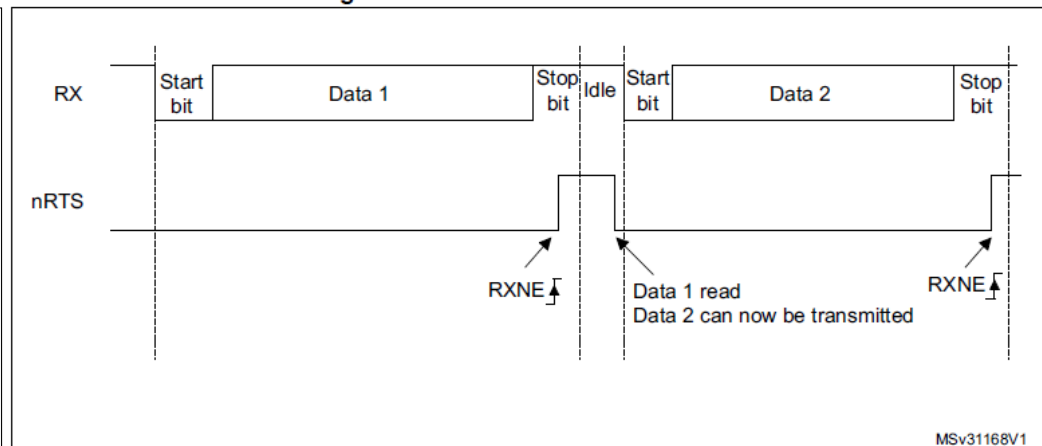


Figure 553. RS232 RTS flow control



Pošiljanje podatka

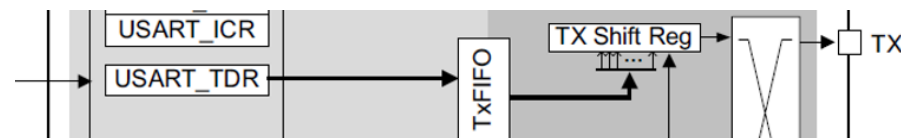
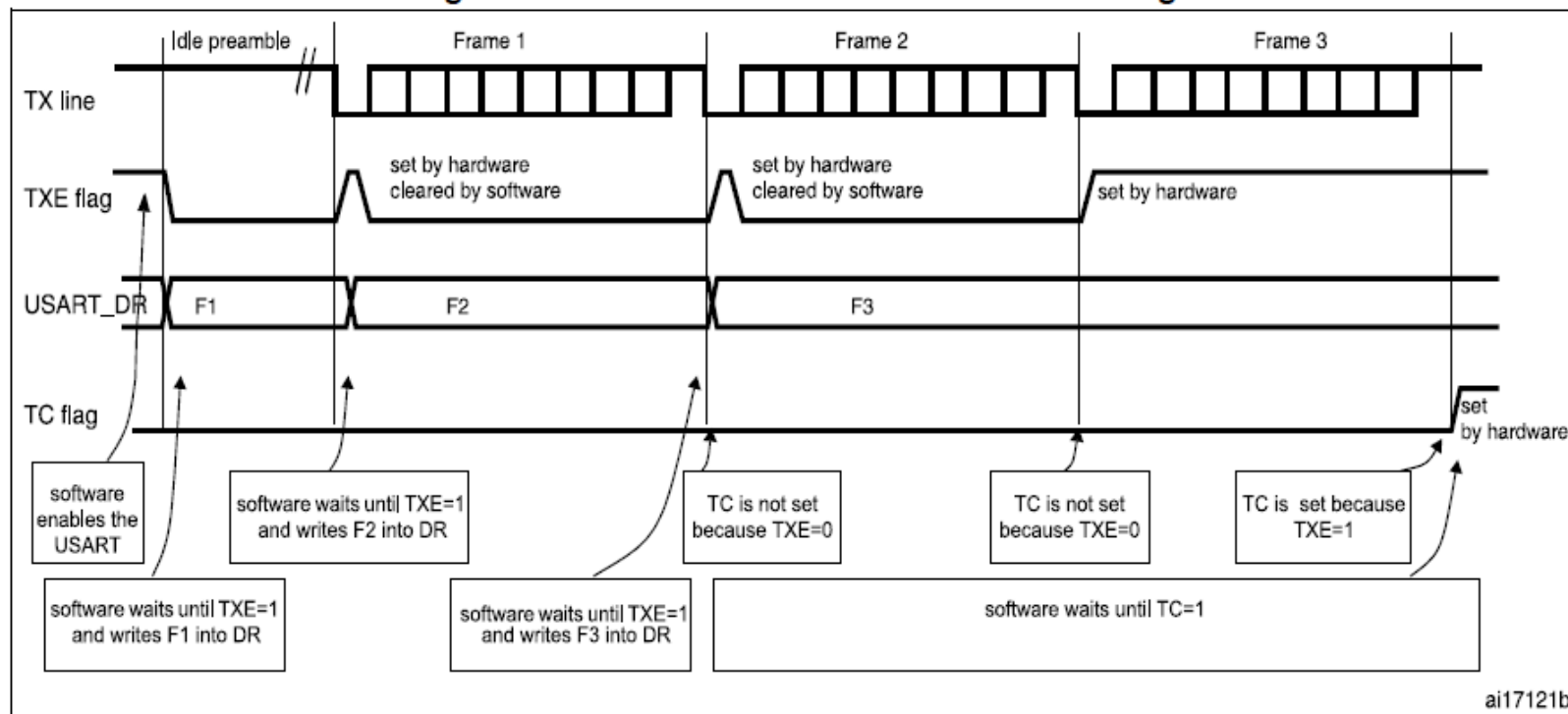


Figure 533. TC/TXE behavior when transmitting



- Omogoči oddajnik (**TE = 1**)
- Preveri, če je **USART_TDR** prazen (**TXE==1?**)
- Vpiši podatek v **USART_TDR**
 - Avtomatsko postavi **TXE = 0**
 - Ko se podatek dejansko pošlje se postavi **TC = 1**

Poizvedovanje -
polling

Sprejem podatka

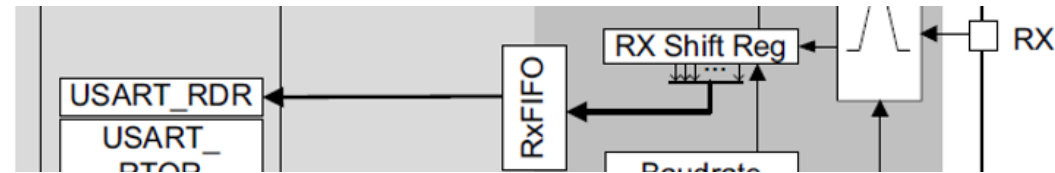
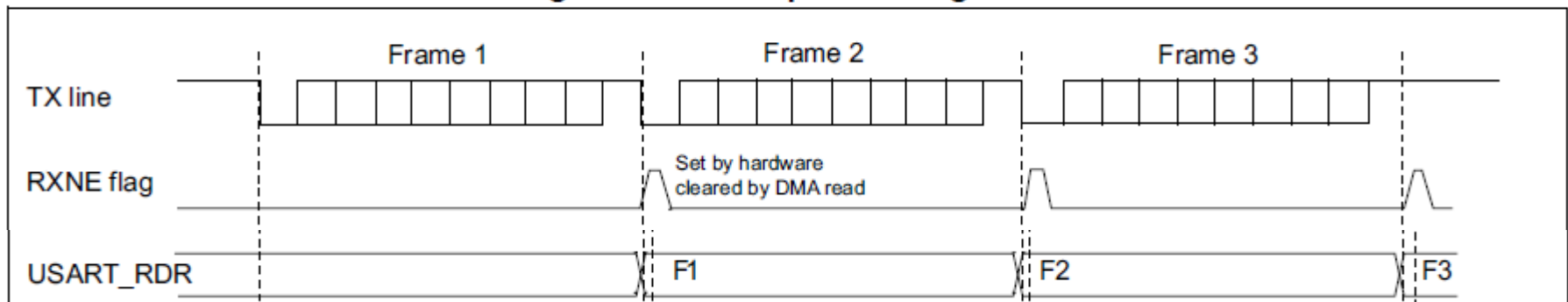


Figure 551. Reception using DMA



- Omogoči sprejemnik (**RE=1**)
- Preveri, če je v **USART_RDR** nov podatek (**RXNE==1**)
- Preberi podatek iz **USART_RDR**
 - Avtomatsko postavi **RXNE=0**

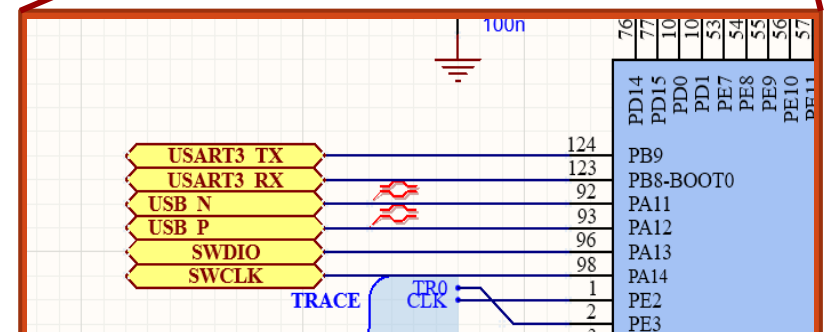
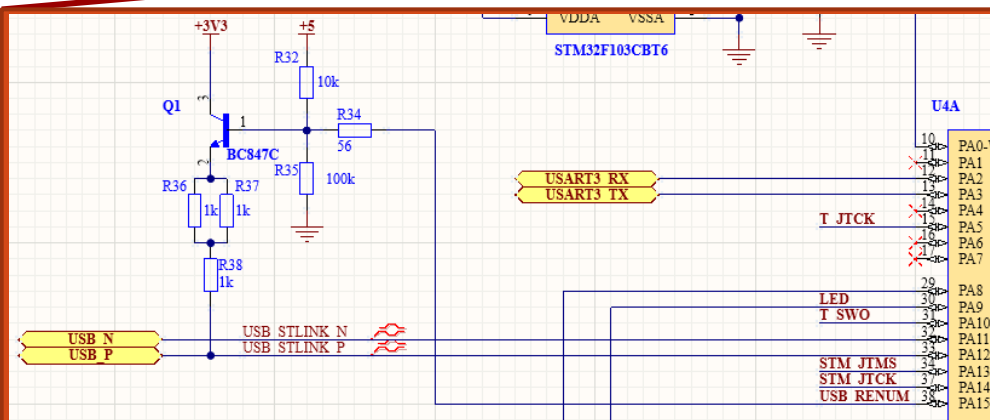
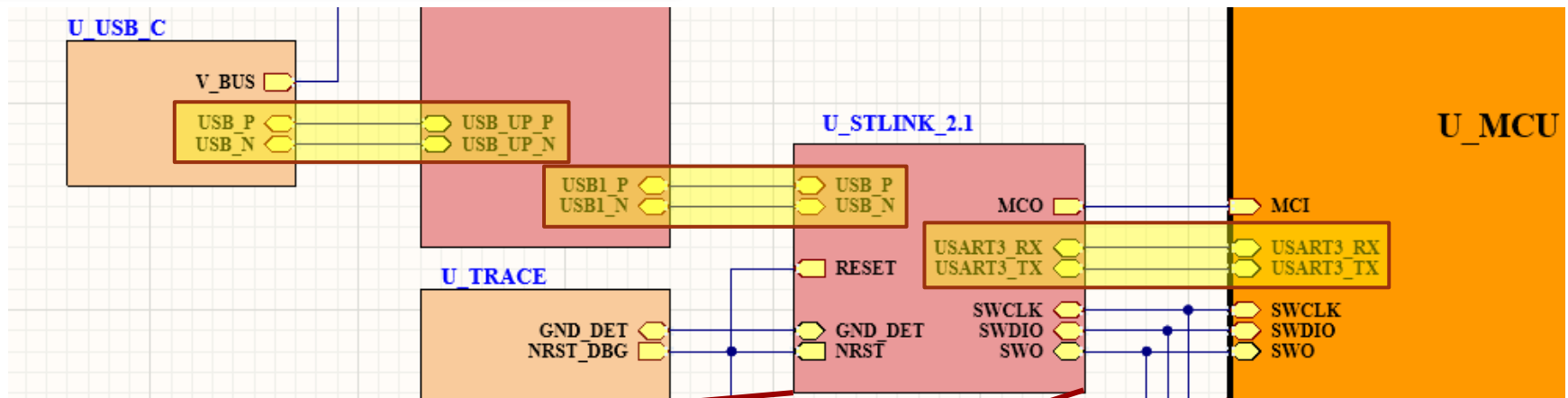
Poizvedovanje -
polling

Detekcija napak pri sprejemu

- Overrun
 - Če je **RXNE==1** in pride nov podatek
 - Postavi se **ORE=1**
 - Vsebina **USART_RDR** se ohrani
- Noise error (**NE**)
 - Pri prevzorčenju trije sredinski biti niso bili enaki
- Framing error (**FE**)
 - Napaka pri okvirju (npr. ni zaznan stop bit)
- Parity error (**PE**)
 - Napaka pri preverjanju paritete sporočila

UART pri MiŠKo 3

- > Other devices
- > Portable Devices
- ✓ Ports (COM & LPT)
 - STMicroelectronics STLink Virtual COM Port (COM21)



Primer FT232R kot USB-UART vmesnika

7.4 USB to MCU UART Interface

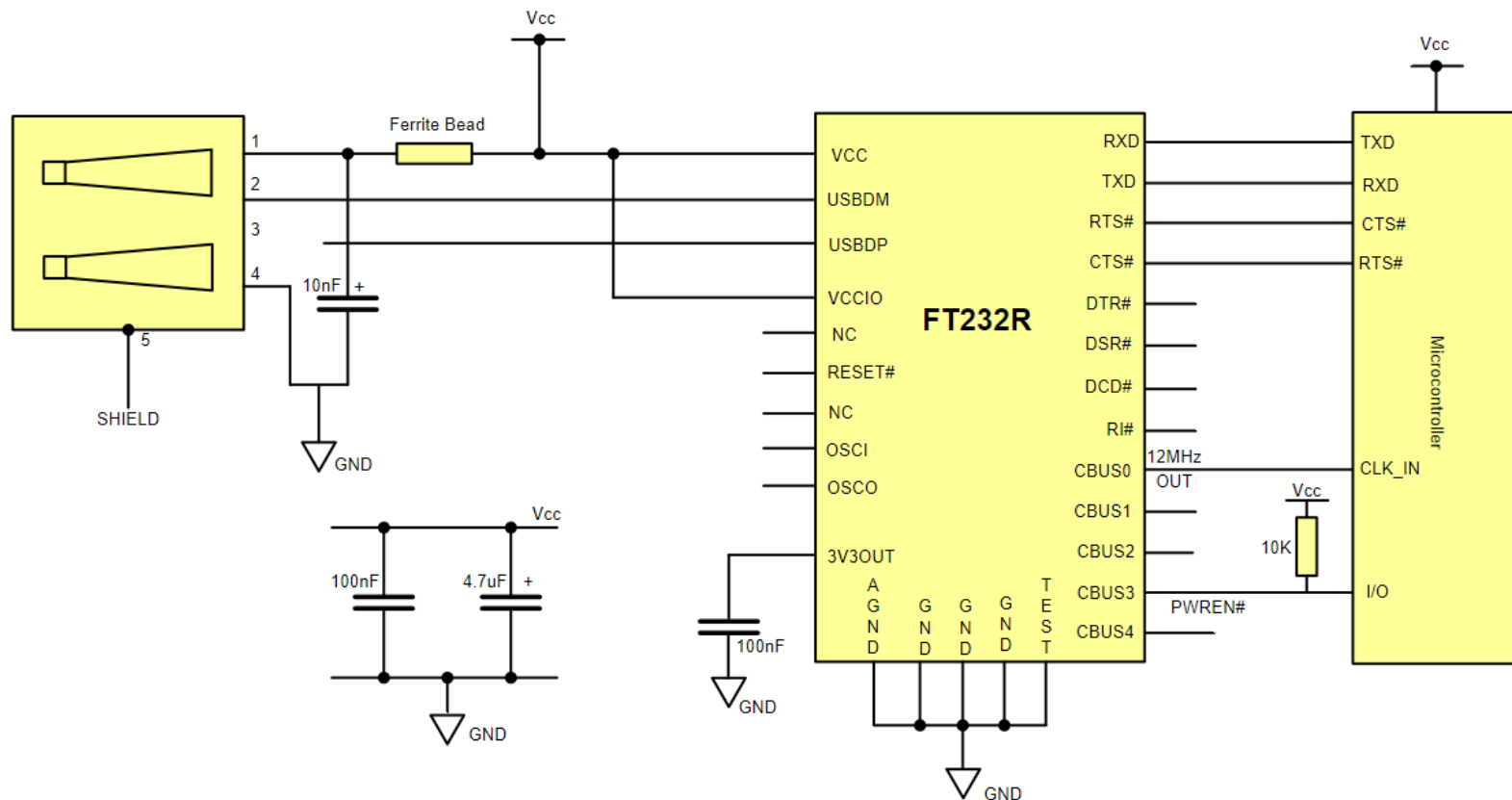
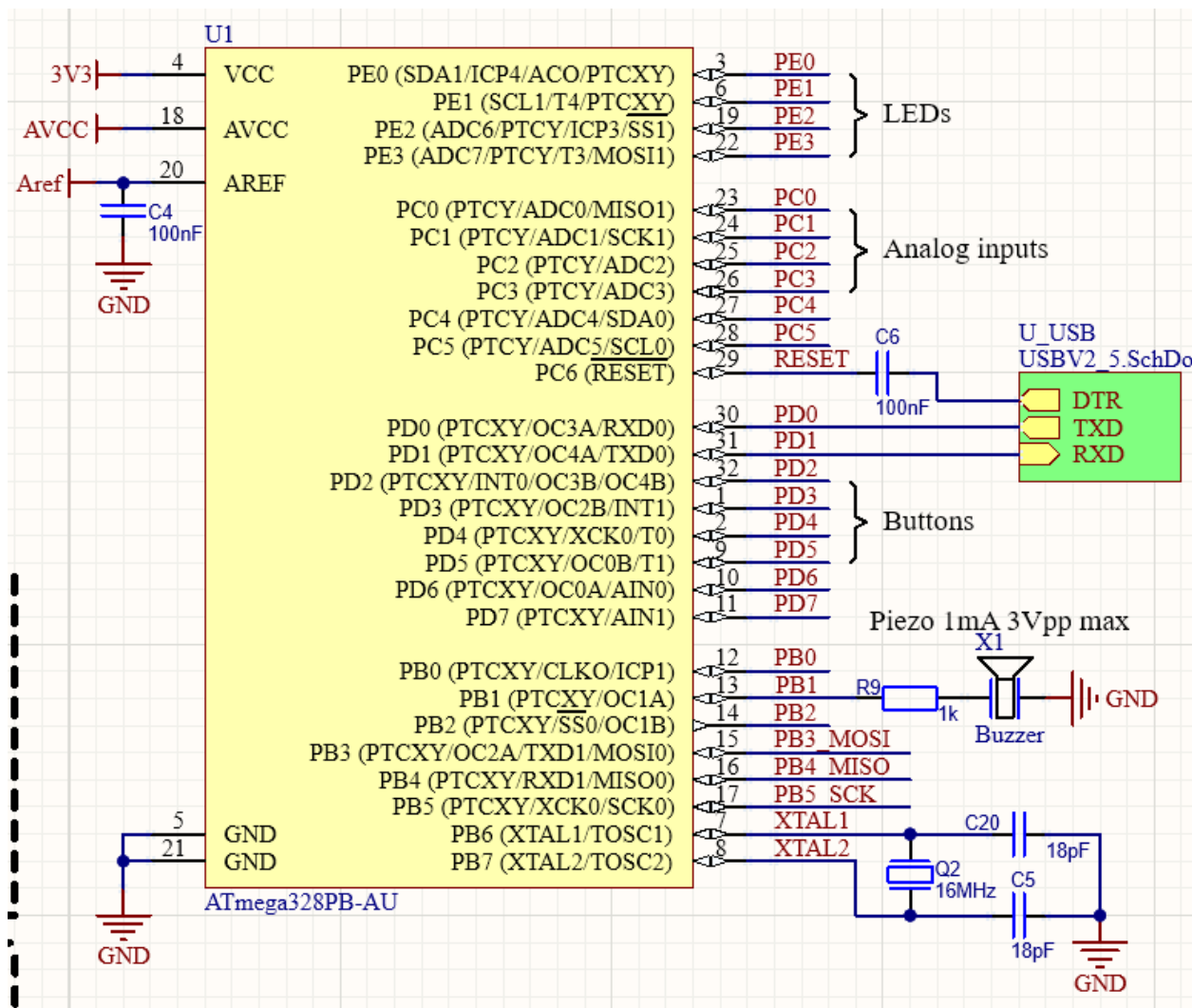
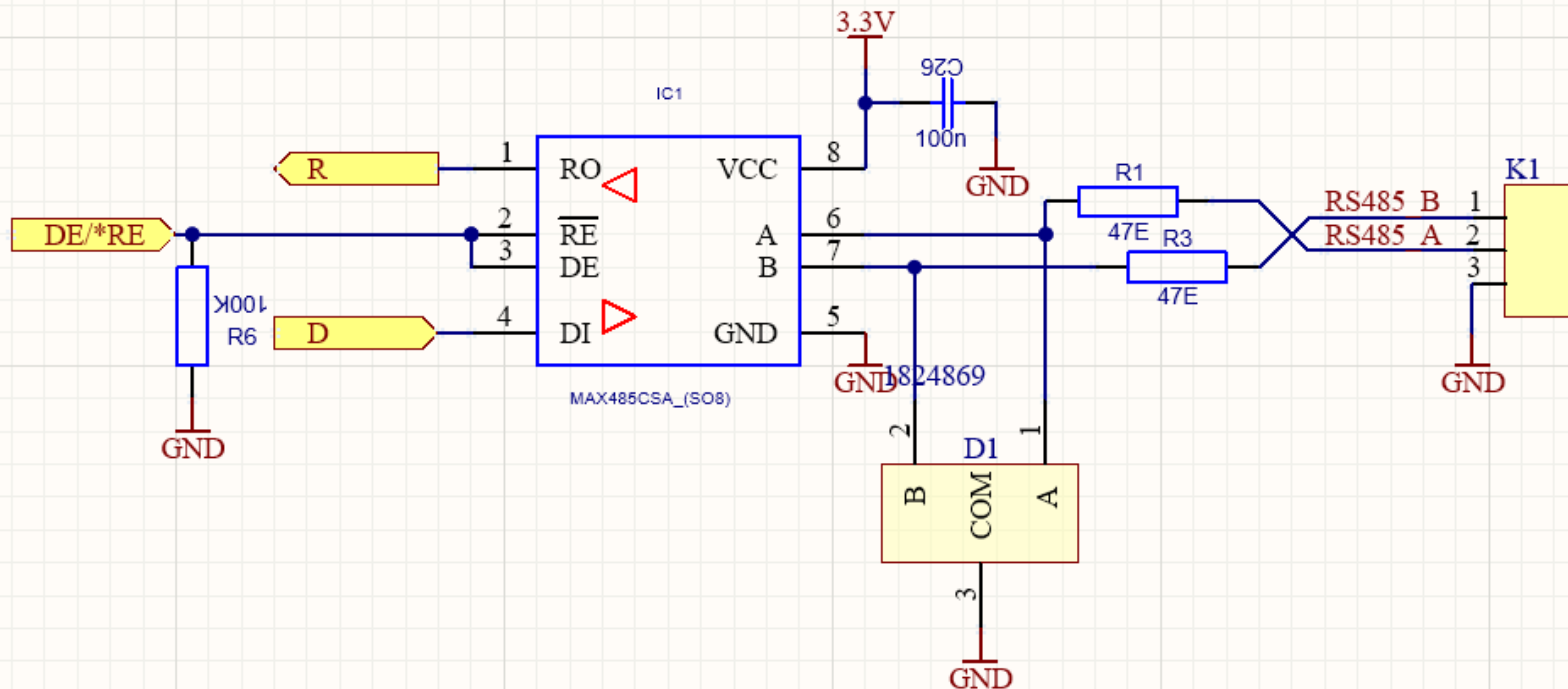
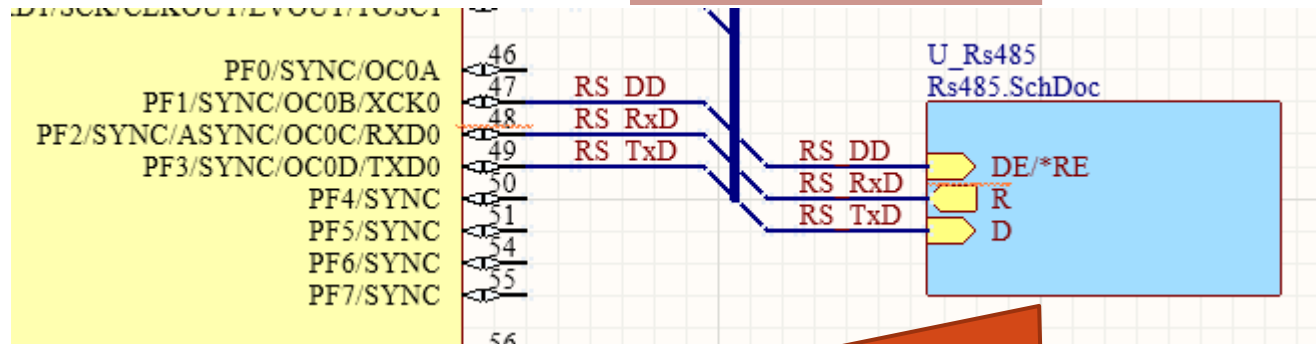


Figure 7.4 USB to MCU UART Interface

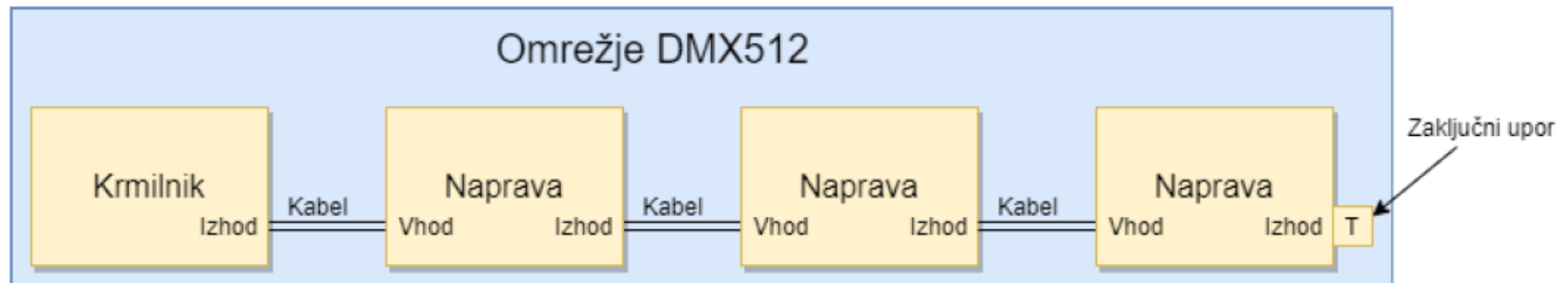
Primer FT232R pri MiŠKo 2 in Arduino



RS-485

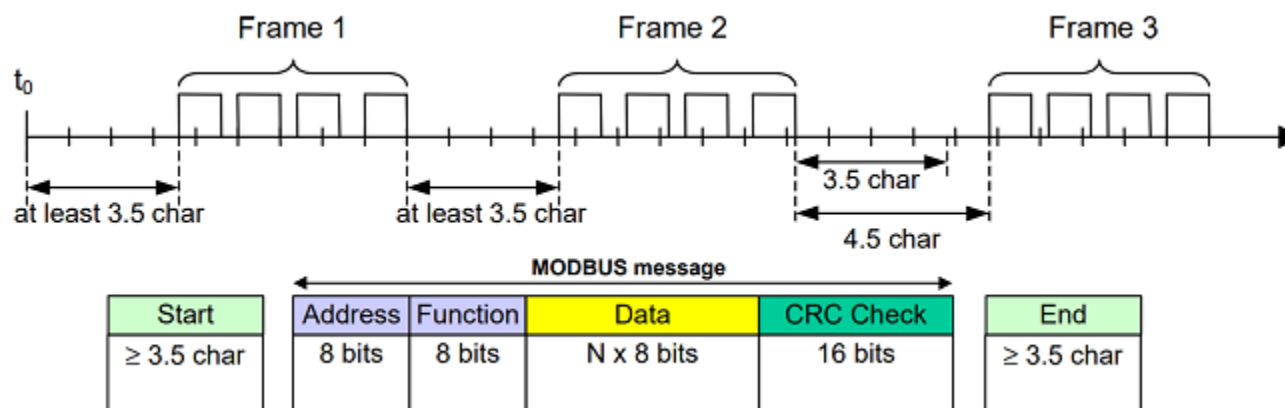
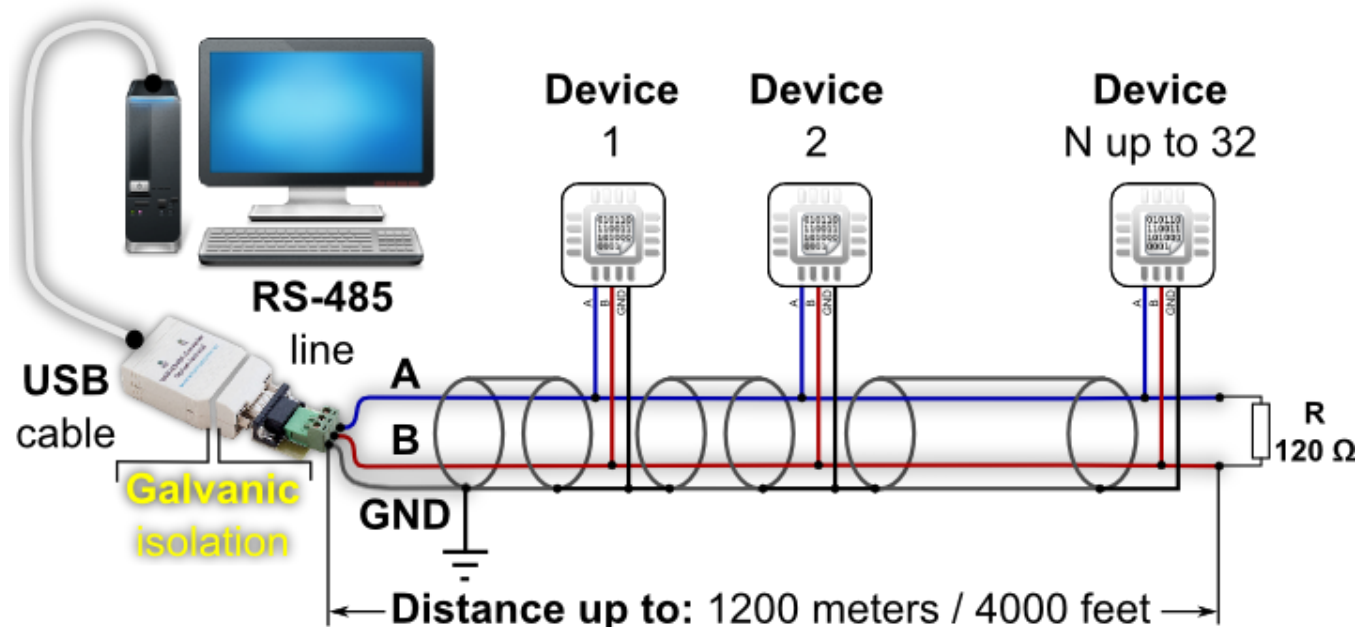


Primeri uporabe RS-485 – DMX512



Easy to set up and use,
perfect for DJs, Bands, Bars,

Primeri uporabe RS-485 – MODBUS



Primer



Vmesnik LIN

