ATmega328P USART0

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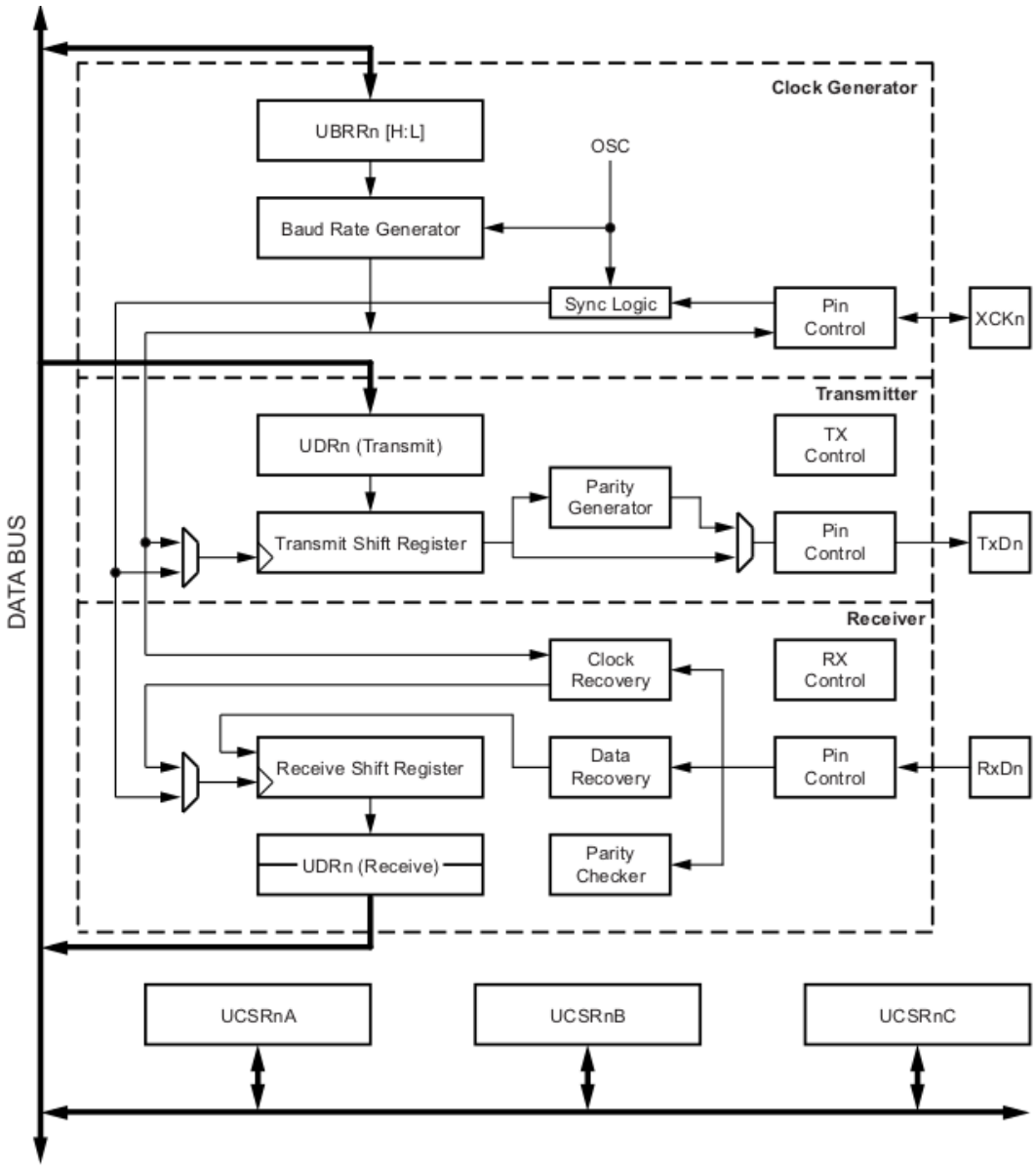
July 28, 2020

1 Features

- Full duplex operation (independent serial receive and transmit registers).
- Asynchronous or synchronous operation
- High resolution baud rate generator
- Serial frame with 5,6,7,8,9 data bits and 1 or 2 stop bits
- Odd or even partiy generator and checker by hardware
- Double speed asynchronous communication mode

2 Block Diagram



2.1 Clock Generator Block

- Consist of sync. Logic for external clock input for usage in sync. slave operation
- Consist of Baud rate Generator.
- Uses the *XCKn* pin for sync. Transfer mode

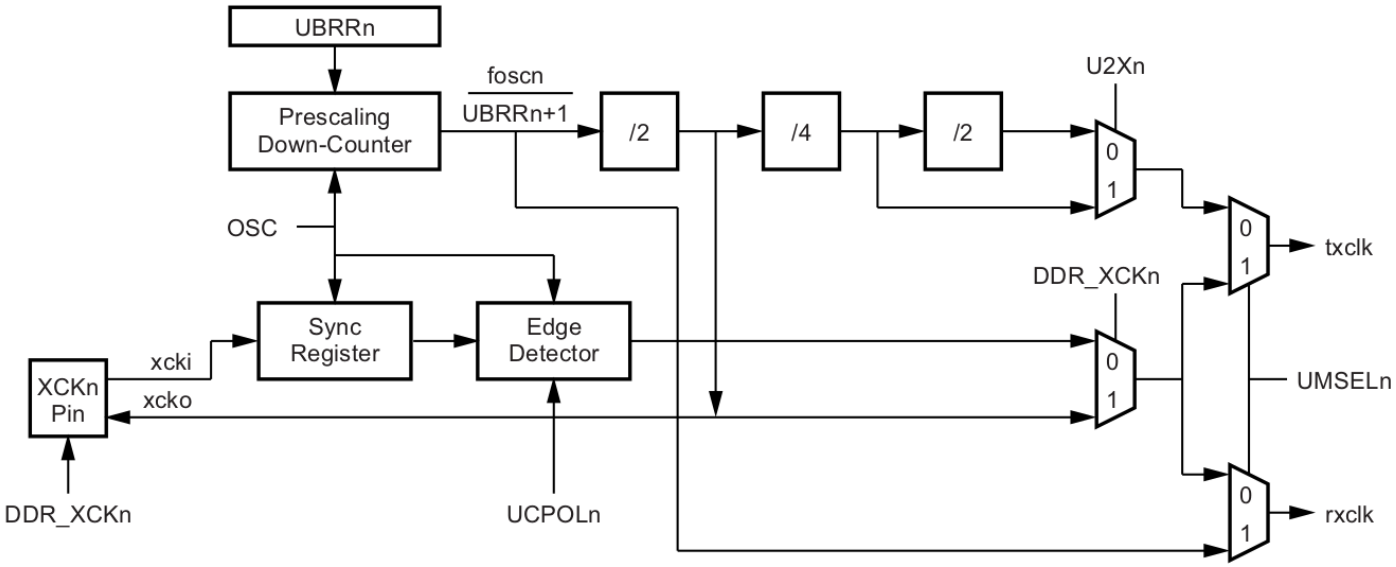
2.2 Transmitte Block

- Consist of singe write buffer – continuous transfer of data without delay between frames
- Consist of Serial Shift register and Parity Generator
- Also, Control logic for handling different serial frame format.

2.3 Receiver Block

- Consist of Clock and data recovery unit – uses for Asynchronous reception
- Consist of Parity Checker, Control Logic, Shift Register, Two level Receiver buffer
- Can support frame error, data overrun parity error

3 Clock Genration



- Generates Base Clock for Transmitter and Receiver.
- USART supports four modes of clock operation
  - (i) Normal Asynchronous
  - (ii) Double Speed Asynchronous
  - (iii) Master synchronous
  - (iv) Slave synchronous
- Selection between Asynchronous and Synchronous is done by ***UMSELn*** bit in ***UCSRnC*** - USART Control and Status Register C.
- The Double Speed is selected by ***U2Xn*** bit in ***UCSRnA*** - USART Control and Status Register A.
- In Synchronous Mode, the master or slave mode is selected by ***DDR_XSCn*** bit direction. [external - slave mode; internal - master mode]

Signals	Description
txclk	Transmitte Clock
rxclk	Receiver Base Clock
xclki	Input from *XCK* pin - used for synchronous slave operation.
xclko	Clock output to *XCK* pin - used for synchronous master operation.
fosc	*XTAL* pin freqency (System clock).

3.1 Internal Clock Generation - The Baud Rate Generator

- Used for Asynchronous and Synchronous Master modes of operation.
- Programmed using **UBRRn** register.

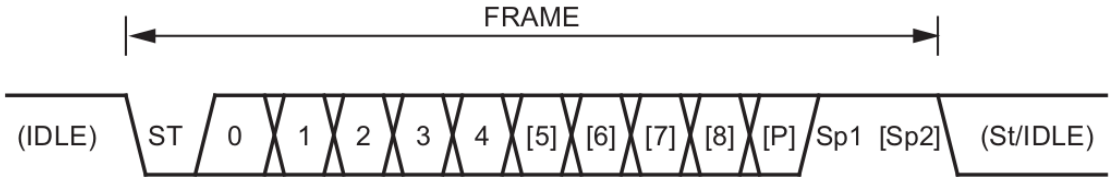
Operating Mode	UBRRn calculation
Asynchronous Normal Mode(***U2Xn*** == 0)	$UBRRn = \frac{f_{OSC}}{16*BAUD} - 1$
Asynchronous Double Speed Mode(***U2Xn*** == 1)	$UBRRn = \frac{f_{OSC}}{8*BAUD} - 1$
Synchronous Master Mode	$UBRRn = \frac{f_{OSC}}{2*BAUD} - 1$

3.2 External Clock

- Used by synchronous Slave mode.
- External clock input from *XCKn* pin is used and should

$$f_{XCK} < \frac{f_{OSC}}{4}$$

4 Frame Format



St	Start bit, always low.
(n)	Data bits (0 to 8).
P	Parity bit. Can be odd or even.
Sp	Stop bit, always high.
IDLE	No transfers on the communication line (RxDn or TxDn). An IDLE line must be high.

- A serial frame is defined to be one character of data bits with synchronization bits (start and stop bits), and optionally a parity bit for error checking.
- The combinations can be
  - 1 start bit
  - 5 or 6 or 7 or 8 or 9 data bits
  - no or even or odd parity bits
  - 1 or 2 stop bits
- A frame starts with start bit followed by LSB data bits.
- Next the data bet can be from 5 to 9 ending with MSB data bits.
- Parity bits may be added if enabled.
- Finally, stop bit of 1 or 2 size is added.
- Generally, the line is idel with high Logic.

5 Register Description

UDRn – USART I/O Data Register n

7	6	5	4	3	2	1	0
RXB[7:0]							
TXB[7:0]							

UCSRnA – USART Control and Status Register n A

7	6	5	4	3	2	1	0
RXCn	TXCn	UDREn	FEn	DORn	UPEn	U2Xn	MPCMn

UCSRnB – USART Control and Status Register n B

7	6	5	4	3	2	1	0
RXCIEn	TXCIEn	UDRIEn	RXENn	TXENn	UCSZn2	RXBn	TXB8n

UCSRnC – USART Control and Status Register n C

7	6	5	4	3	2	1	0
UMSELn1	UMSELn0	UPMn1	UPMn0	USBSn	UCSZn1	UCSZn0	UCPOLn

- ***RXCn*** - USART Receive Complete - Set when there are unread data in receive buffer.
- ***TXCn*** - USART Transmit Complete - Set when the entire frame in the transmit shift register has been shifted out and there are no new data currently present in the transmit buffer.
- ***UDREn*** - USART Data Register Empty - indicates if the transmit buffer is ready to receive new data. A one indicates buffer is expty and ready to transmit.
- ***U2Xn*** - Double the USART Transmission Speed - Affects only the asynchronous operation. One will increase the speeed of transfer rate in asynchronous opration.
- ***RXCIEn*** - RX Complete Interrupt Enable n - Writing one will enabled Receive Complete intterrupt.
- ***TXCIEn*** - TX Complete Interrupt Enable n - Writing one will enabled Transmit Complete intterrupt.
- ***UDRIen*** - USART Data Register Empty Interrupt Enable n - Enable data register empty intterrupt.
- ***RXENn*** - Receiver Enable - enable the receiever for reception.
- ***TXENn*** - Transmitter Enable - enable the Transmitter for Transmission.
- ***UCSZn[2:0]*** - Character Size n - select the number of data bits in a frame.
- ***RXB8n*** - Receive Data Bit 8 n - it's the actual 9th bit received.
- ***TXB8n*** - Transmit Data Bit 8 n - it's the actual 9th bit to tbe trasnmitted.
- ***UMSELn[1:0]*** - USART Mode Select - Select the mode.
- ***UPMn[1:0]*** - Parity Mode - Disable or set the parity mode type.
- ***USBSn*** - Stop Bit select - Selects the number of stop bits to be inserted by transmitter.

UMSELn[1:0]	Mode
00	Asynchronous USART
01	Synchronous USART
10	Reserved
11	Master SPI

UPMn[1:0]	Parity Mode
00	Disabled
01	Reserved
10	Even Parity
11	Odd Parity

USBSn	Stop Bit(s)
0	1-bit
0	2-bit

UCSZn[2:0]	Character Size
000	5-bit
001	6-bit
010	7-bit
011	8-bit
111	9-bit

UBRRnL and UBRRnH – USART Baud Rate Registers

15	14	13	12	11	10	9	8
-	-	-	-	UBRRn[11:8			
UBRRn[7:0							
7	6	5	4	3	2	1	0

UBRRn[11:0] - the actual 12-bit USART Baud Rate Registers.

6 Configurint USART

- First, the mode is selected by confguring the *UMSEL0[1:0]* bits in **UCSR0C** register.
- Next, the Baud rate is choosen and set in *UBRR0[11:0]* bits in **UBRR0H** and **UBRR0L** registers.
- Next, the frame format is set by confguring,
  - Data Length - by confguring *UCSZ0[2:0]* bit in **UCSR0B** and **UCSR0C** register.
  - Parity - by confguring *UPM0[1:0]* bit in **UCSR0C** register.
  - Stop bits - by confguring *USBS0* bit in **UCSR0C** register.
- Interrupt may be anabled by setting bits in *UCSR0A* register and ISR are wirtten.
- Finally, the Transmitter and Receiver are enabled by setting *TXEN0* and *RXEN0* bits in **UCSR0B**.
- The data can be sent by checking if the *UDRE0* bit is set in **UCSR0A** register and wiring the 8-bit data into **UDR0** register.
- The data can be received by checking if the *RXC0* bit is set in **UCSR0A** register and reading the 8-bit data from **UDR0** register.
- The code for a simple USART is seen below,

```
// Setting up the Mode
// Select the Asyncronous Master Mode.
// Setting UMSEL0[1:0] in UCSR0C to 00
UCSR0C &= ~(1<<UMSEL00);
UCSR0C &= ~(1<<UMSEL01);

// setting up the Buad rate
// Due to The Clock rate being 8MHz, for a buad rate of 9600
// UBRR0 = (fosc / (16*BAUD)) -1
// So UBRR0 = (8000000 / (16 * 9600)) - 1 = 0x33
UBRR0H = 0x00;
UBRR0L = 0x33;

// setting up the Frame Format
```

```
// Let's select 8-bit data bits, no parity, and 1 stop bit
// 8 - bit data bits
// By selecting UCSZ0[2:0] in UCSR0C and UCSR0B register to be 011
UCSR0B &= ~(1<<UCSZ02);
UCSR0C |= (1<<UCSZ01);
UCSR0C |= (1<<UCSZ00);
// No parity
// By selecting UPM0[1:0] in UCSR0C to 00
UCSR0C &= ~(1<<UPM01);
UCSR0C &= ~(1<<UPM00);
// 1 stop bit
// By selecting USBS0 in UCSR0C to 0
UCSR0C &= ~(1<<USBS0);

// Disabling any interrupts
UCSR0B &= ~(1<<7);
UCSR0B &= ~(1<<6);
UCSR0B &= ~(1<<5);

// Enabling Transmitter
UCSR0B |= (1<<TXEN0);
// Enabling Receiver
UCSR0B |= (1<<RXEN0);
```

```
void USART0sendChar(uint8_t data_)
{
        //cHECKING if transmitet buffer is empty
        while((UCSR0A & (1<<UDRE0)) == 0x00){};
        UDR0 = data_;
}
uint8_t USART0receiveChar()
{
        // wait for thedate to be recied
        while((UCSR0A & (1<<RXC0)) == 0x00){};
        return UDR0;
}
```