

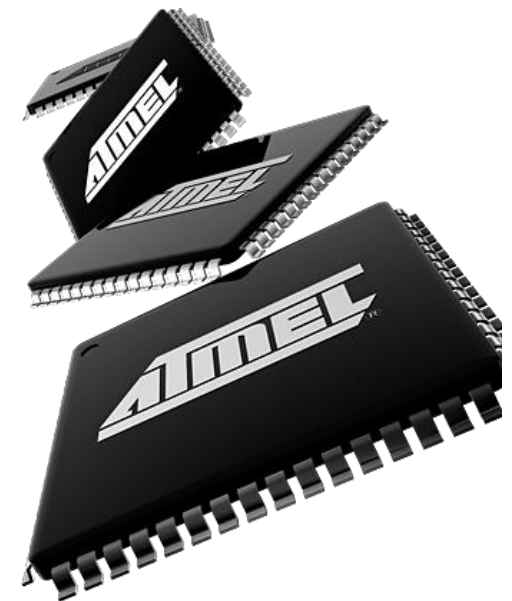
Principles and Applications of Microcontrollers

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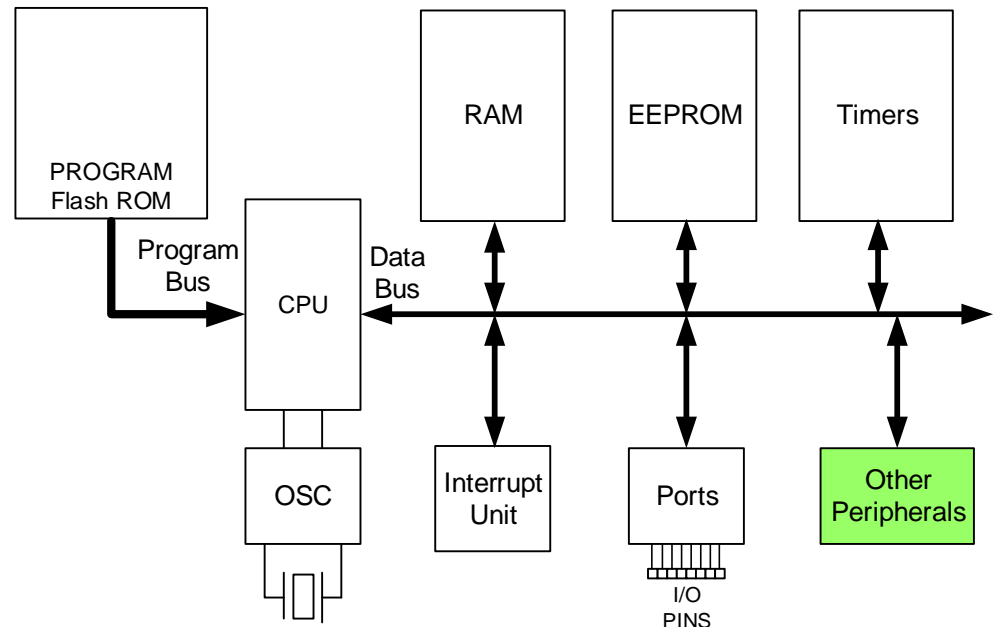
Today:

- Serial communication

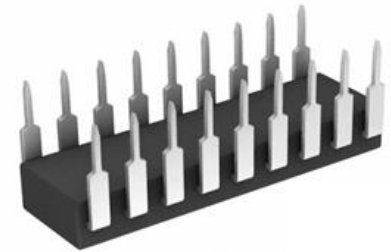


Outline

- Considerations
- Wiring
- Baudrate and data framing
- AVR USART programming
- Synchronous data transmission
 - SPI
 - I²C
- Getting started



Considerations



Outline (Cont'd)

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Transmission Modes

- Simplex, half-duplex, and full-duplex

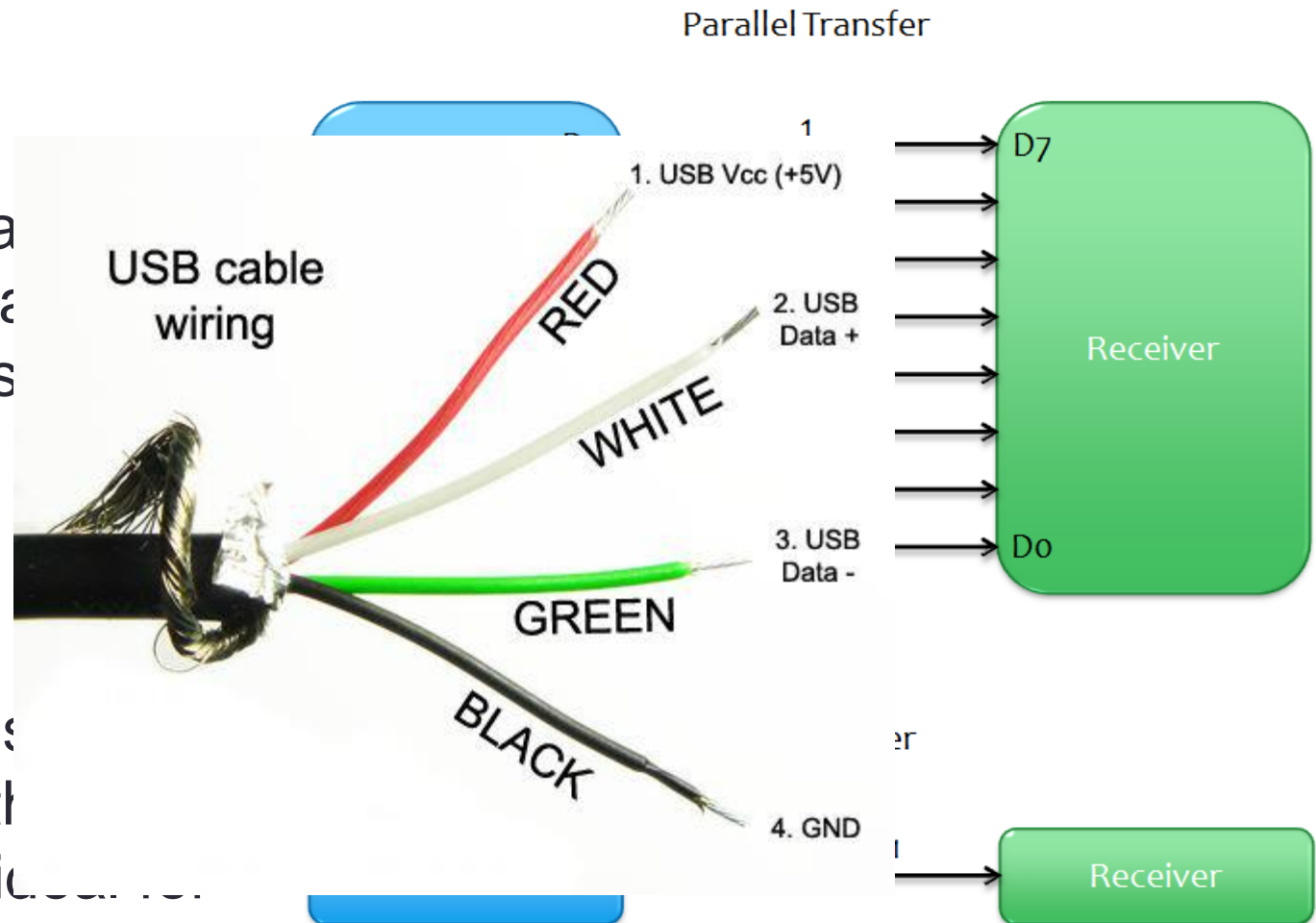
Simplex



Parallel vs. Serial

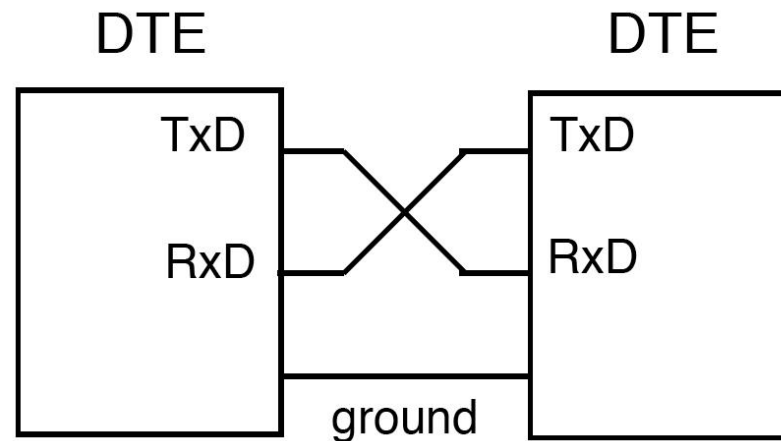
- **Parallel** – transfer a whole byte of data at once
→ faster, easier

- **Serial** – transfer one bit after another
→ cheaper, ideal for long distance transfer



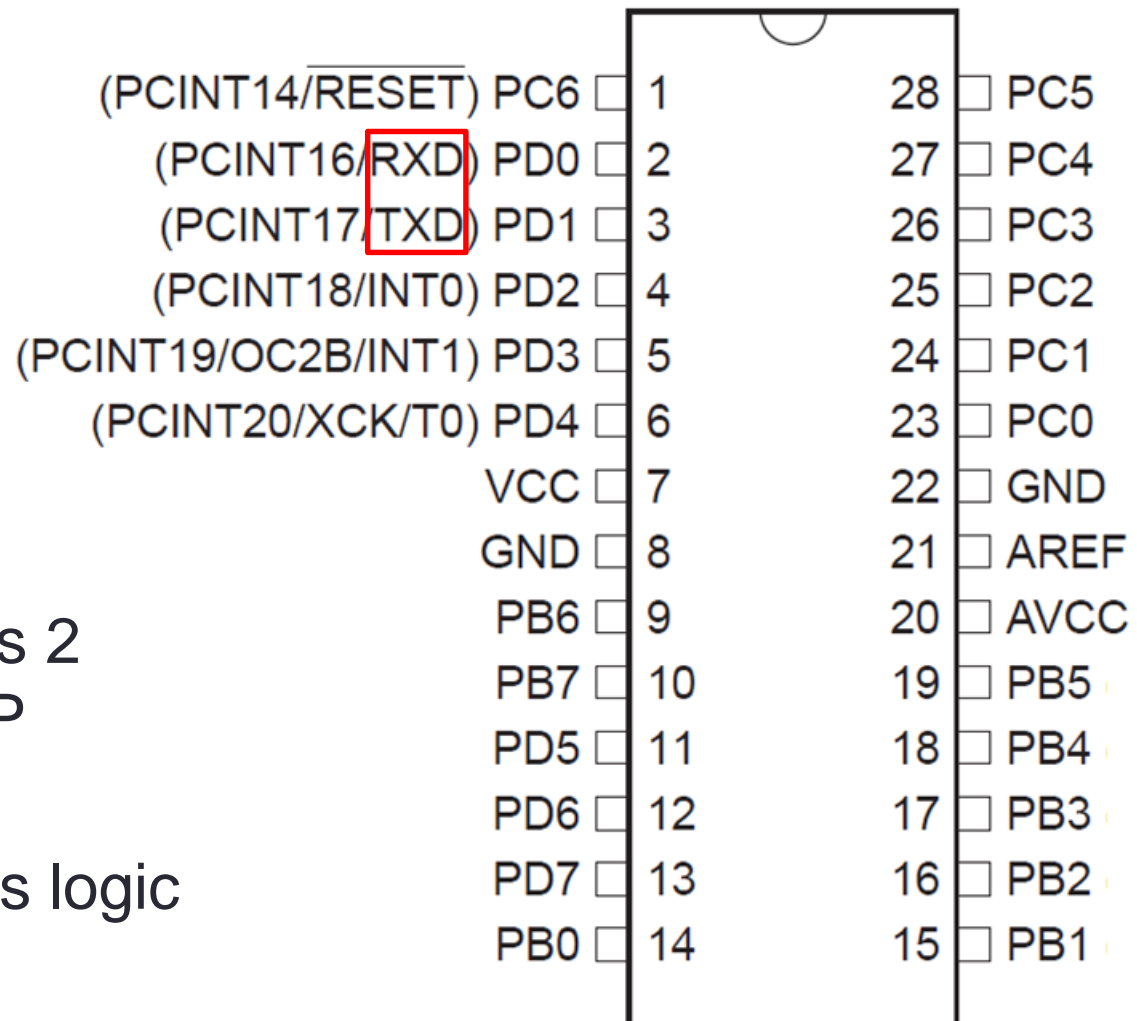
Null Modem Connection

- The transmit data (TxD) and receive data (RxD) lines are crosslinked
- Used for transmitting data between 2 data terminal equipment (DTE) devices (e.g., MCU and computer)



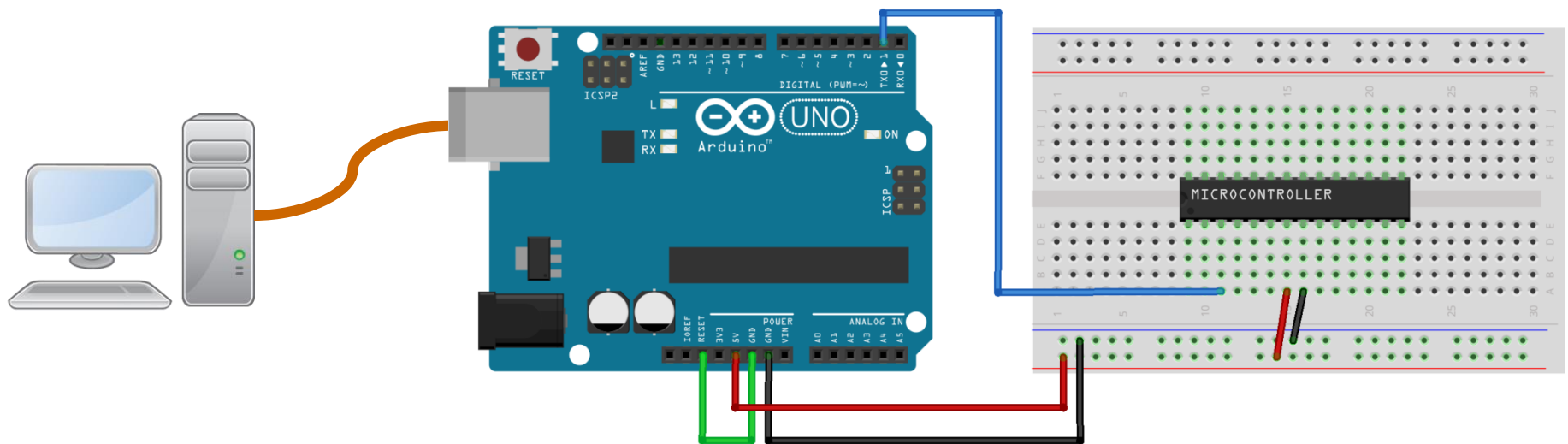
RxD and TxD Pins in ATmega328P

- TxD and RxD are pins 2 and 3 in ATmega328P
- These pins are TTL compatible (i.e., 5V as logic HIGH)



Arduino as An RX/TX Adapter

- Wiring RESET to GND turns Arduino into an adapter
- Wiring: Arduino Tx to AVR Tx, and Arduino Rx to AVR Rx
- Display readings on Arduino serial monitor



Outline (Cont'd)

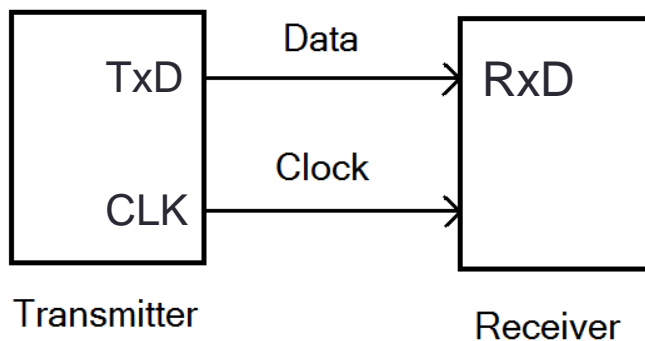
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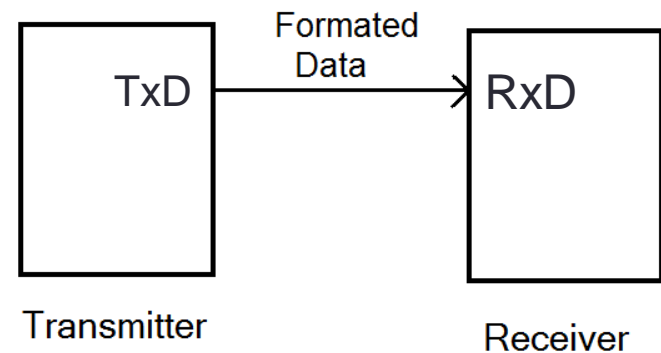
Synchronous vs. Asynchronous

- Synchronous:
 - Clock pulse is transmitted during data transmission
- Asynchronous:
 - Clock pulse is not transmitted
 - The two sides generate clock pulses at “the same” speed

Synchronous



Asynchronous

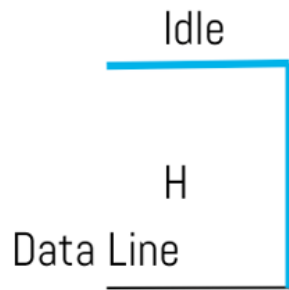


Baud Rate

- Number of symbols transferred per second
- The same as bit rate (bps) for USART
- Baud rate is NOT data rate
- Both sides of communication should use the same baud rate
- Standard baud rates: 110, 150, 300, 600, 900, 1200, 2400, 4800, 9600, 14400, 19200, 38400, 57800

Data Framing

- Framing determines what bits to read/write:
 - Start bit: a logic LOW
 - Data: 5-9 bits
 - Parity bit: optional
 - Stop bit: a logic HIGH



Outline (Cont'd)

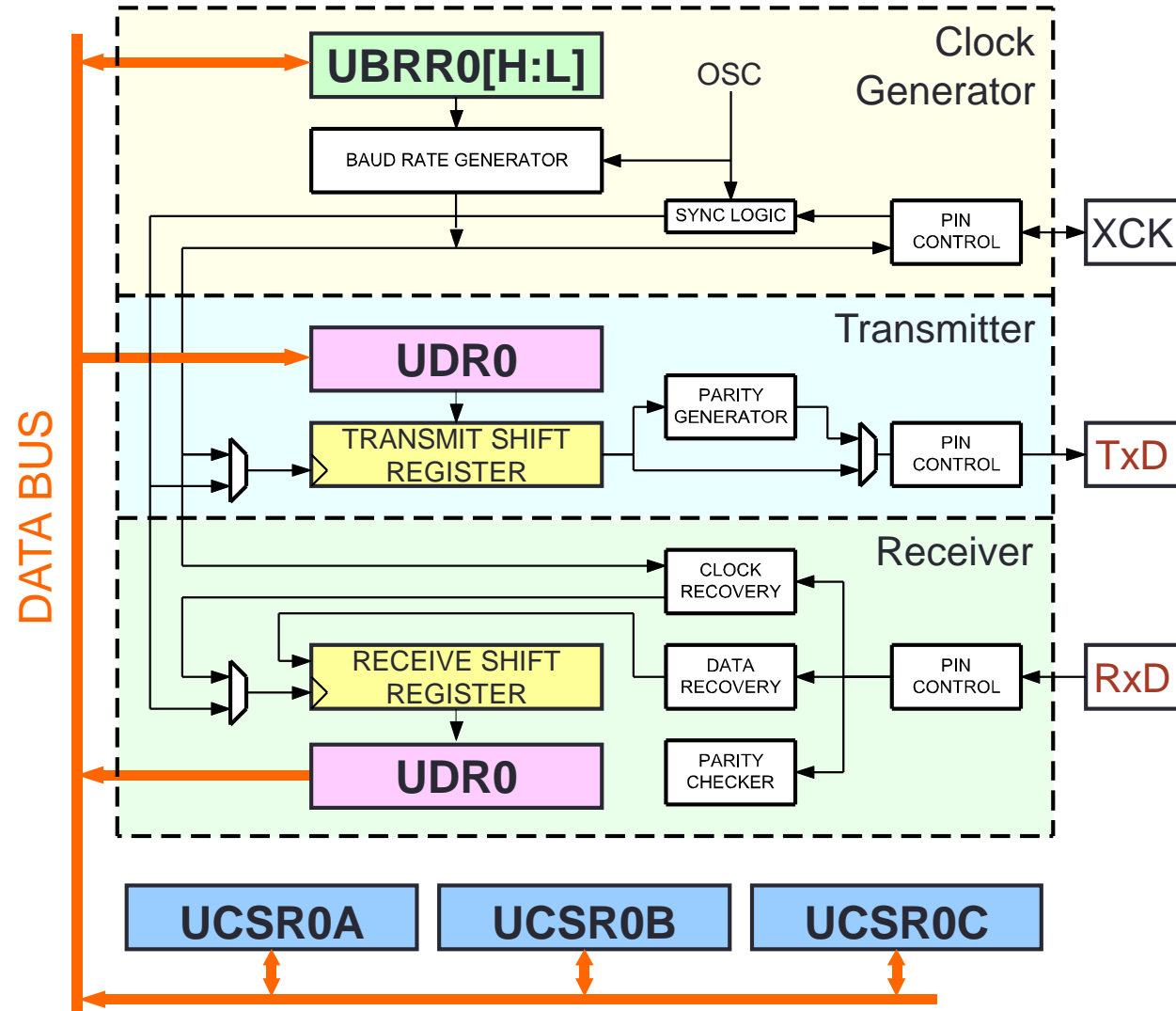
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USART in AVR

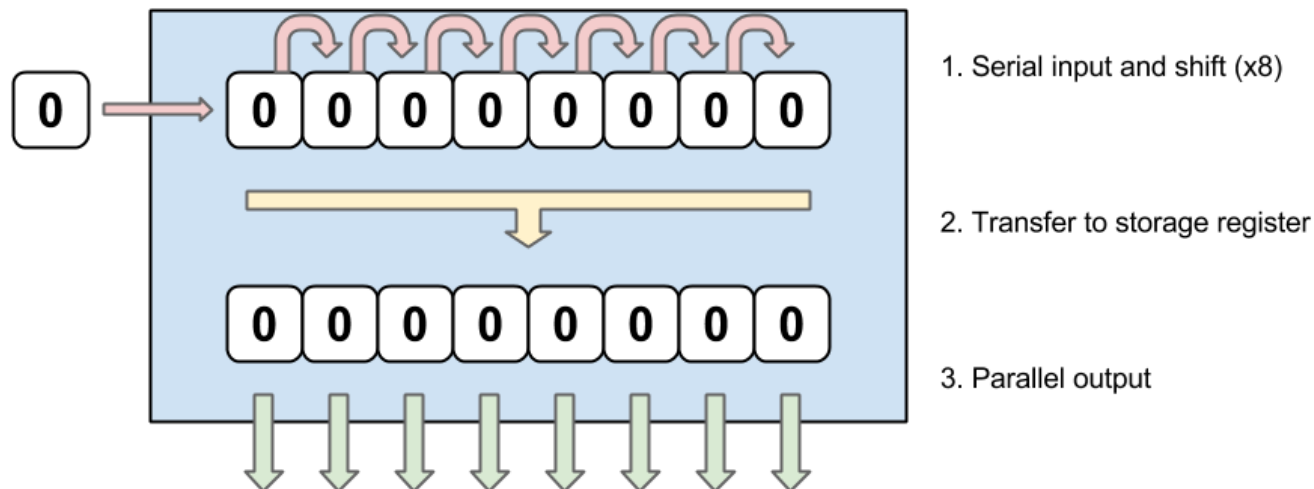
- 5 registers

- UDR0
- UBRR0H
- UBRR0L
- UCSR0A
- UCSR0B
- UCSR0C



Shift Register: Buffer for Conversion

- A shift register is required for converting serial to/from parallel
- Data is push onto the beginning of the register, one bit at a time
- Serial-to-parallel shift register (SIPO)
- Parallel-to-serial shift register (PISO)



USART Registers

UDR0

- Shift (data) register

UBRR0H

- Baud rate setup

UBRR0L**UCSR0A**

- Status

UCSR0B

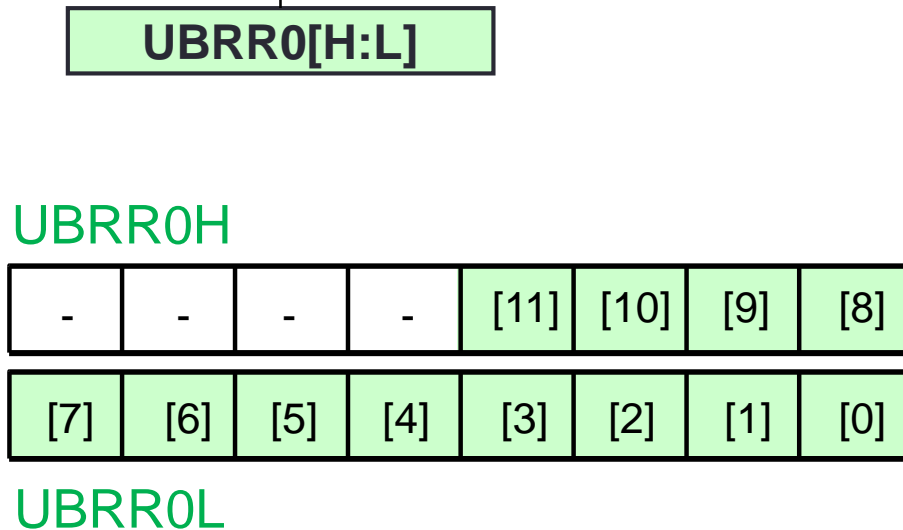
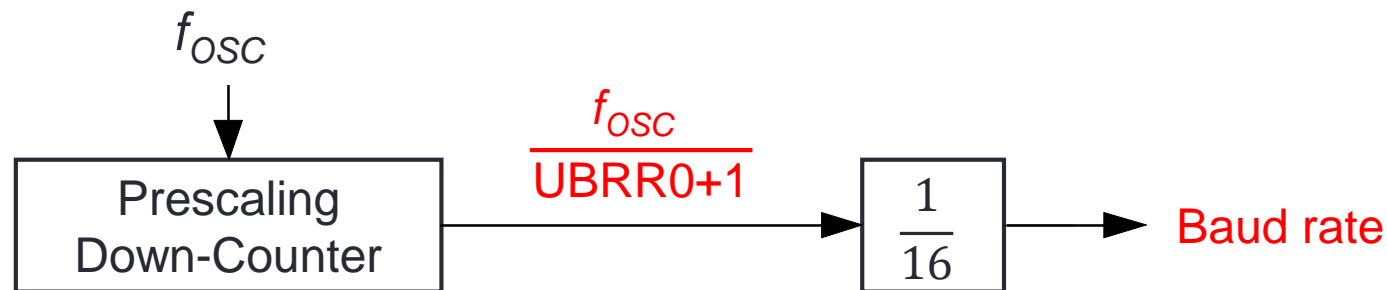
- Mode control

UCSR0C

- Asynchronous/synchronous, parity, stop bit, and data size

UBRR0: Baud Rate Setup

- Set the value of UBRR0 to set baud rate

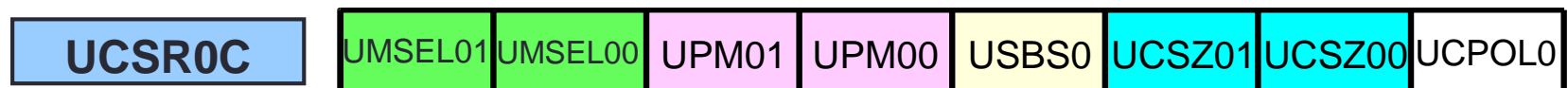


$f_{osc} = 8 \text{ Mhz}$

Baud	UBRR0	Error (%)
2400	207	0.2
4800	103	0.2
9600	51	0.2
14.4k	34	-0.8
19.2k	25	0.2

UCSR0C: Asynchronous or Synchronous

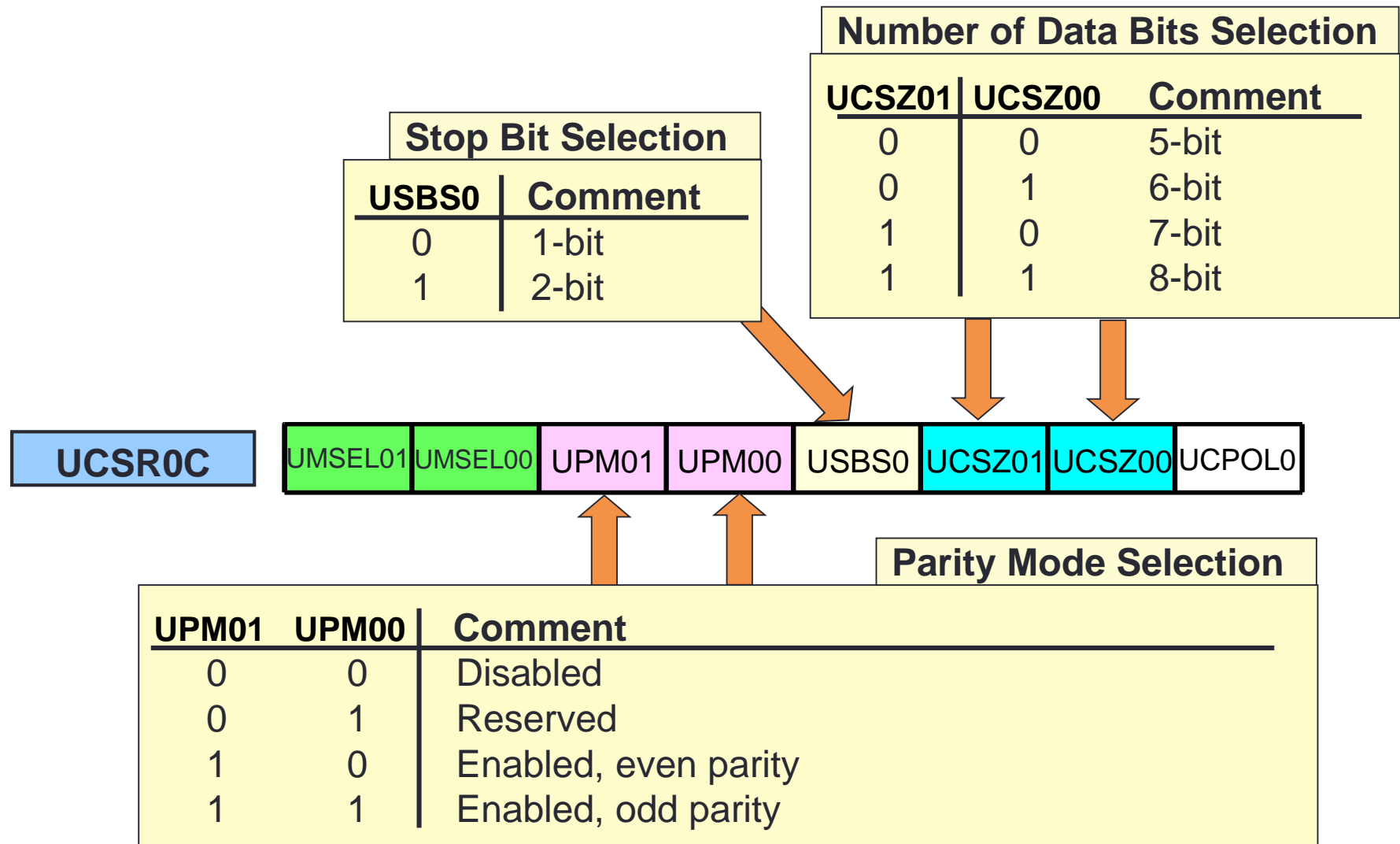
- Asynchronous or synchronous
- Parity
- Stop bit(s) size
- Character size



USART Mode Selection

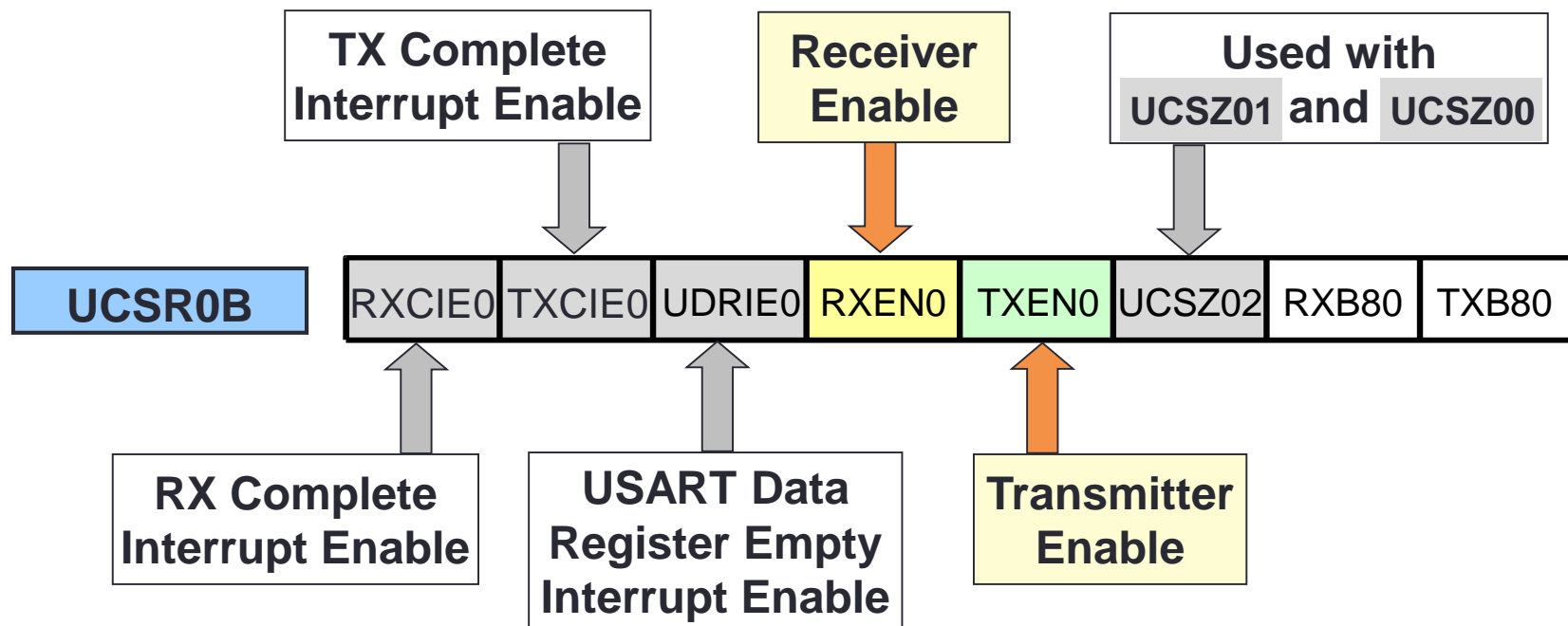
UMSEL01	UMSEL00	Comment
0	0	Asynchronous USART
0	1	Synchronous USART
1	0	Reserved
1	1	Master SPI

UCSR0C: Parity, Stop Bit, and Data Size



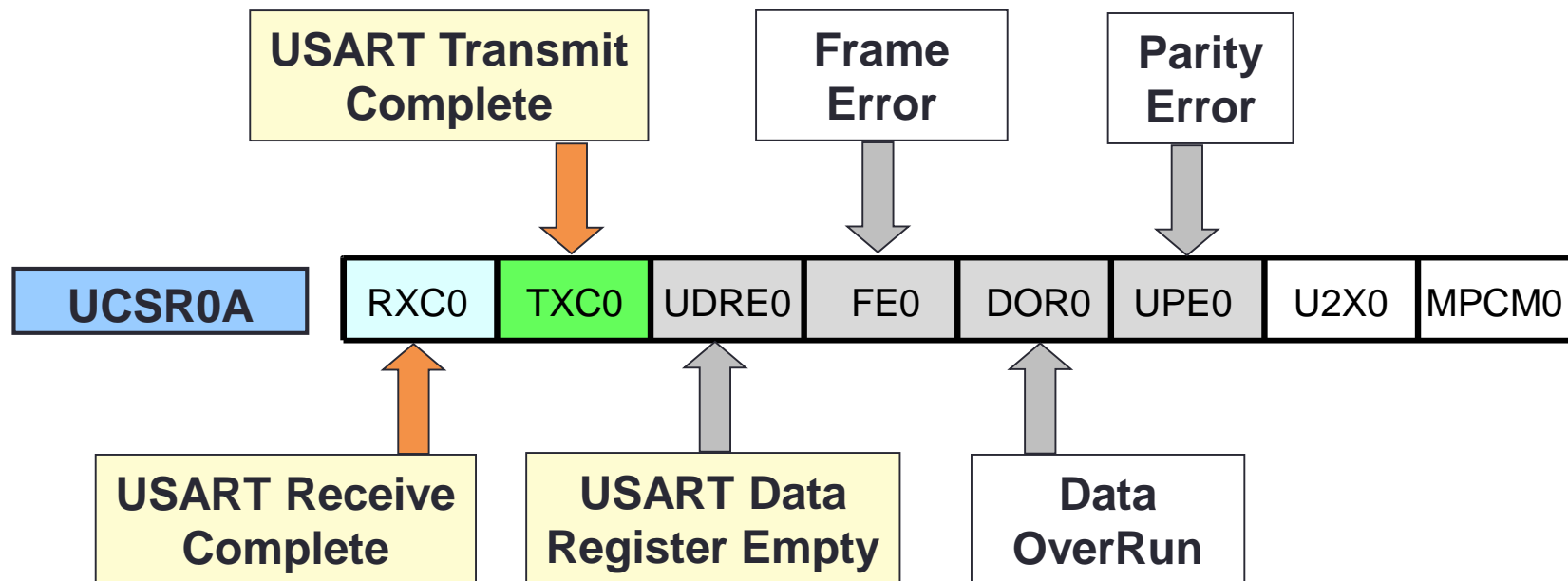
UCSR0B: USART Mode Control

- Interrupt enable
- Receiver and transmitter enable



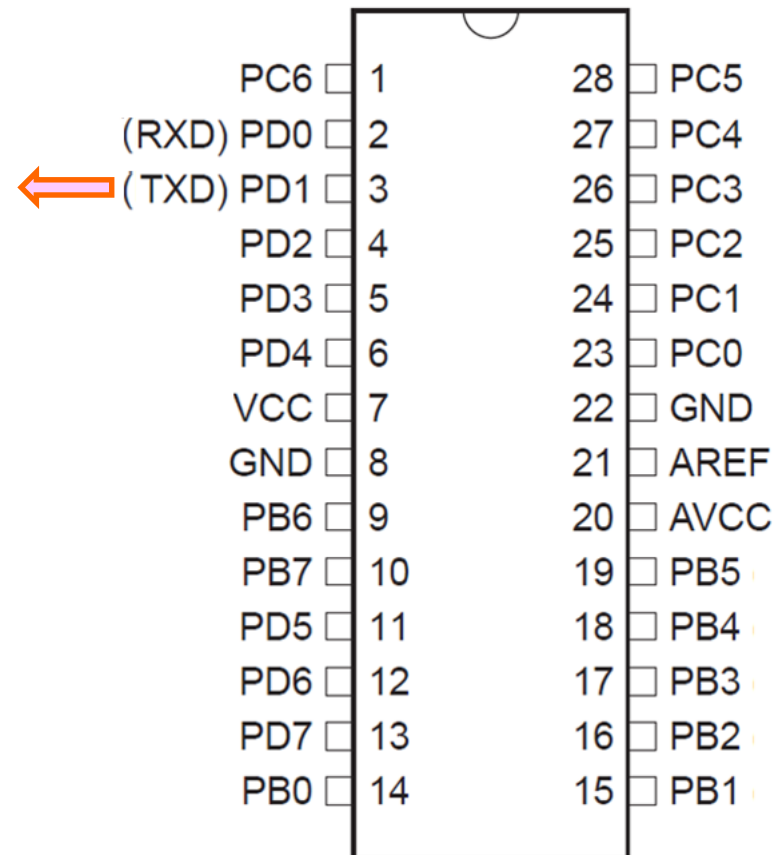
UCSR0A: USART Status

- Status flags



Example: Transmit Letter 'A' through 'Z'

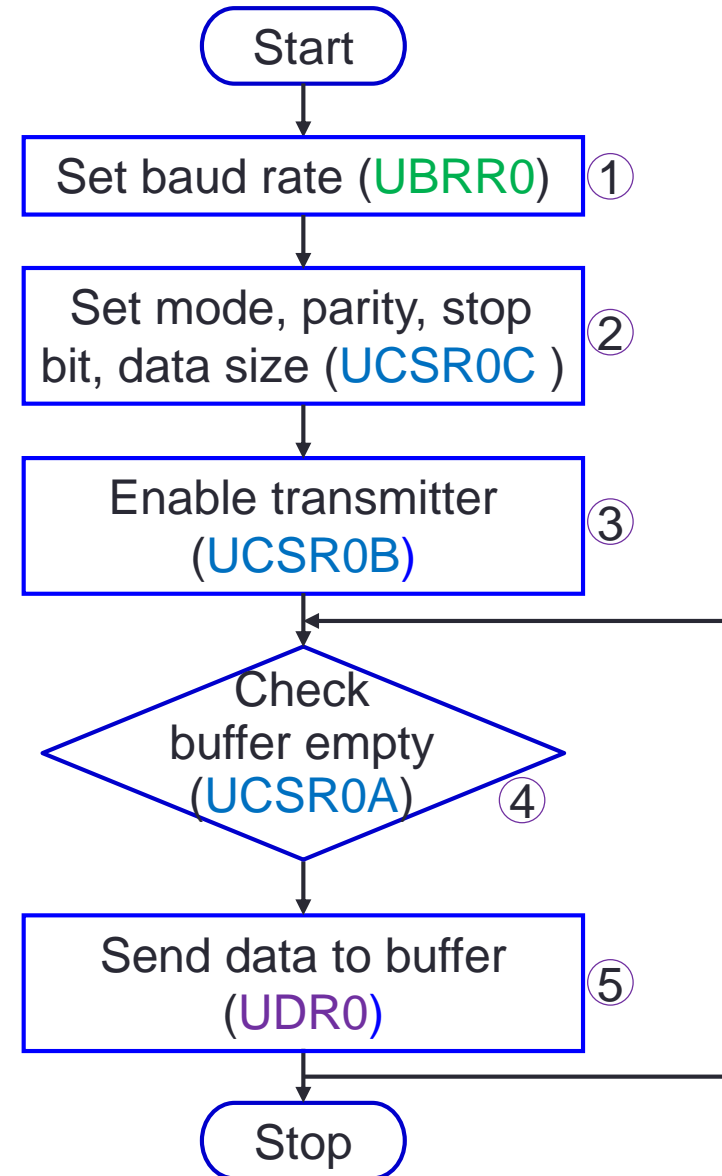
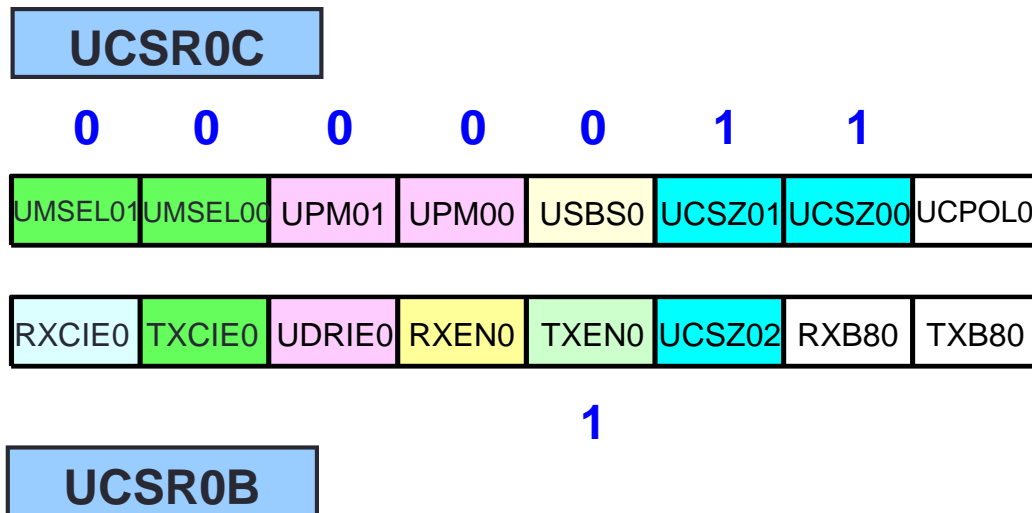
- Continuously transmit letter 'A' through 'Z' at $\frac{1}{2}$ Hz
- Baud rate 9600
- Asynchronous
- No parity
- 8 data bits
- 1 stop bit



Flowchart

- What value do we set the controller registers?

$$\frac{f_{osc}}{16(UBRR + 1)} = Baud$$



Transmit Letter 'A' through 'Z'

```
#define F_CPU 8000000UL
#include <avr/io.h>
#include <util/delay.h>

int main(void)
{
    CLKPR=0b10000000;
    CLKPR=0b00000000;
    unsigned int BaudR = 9600;
    unsigned int Ubrv = (F_CPU / (BaudR*16UL))-1;
    UBRR0H=(unsigned char) (Ubrv>>8);    // set Baud rate
    UBRR0L=(unsigned char) Ubrv;
    UCSRC|=(1<<UCSZ01) | (1<<UCSZ00);    // normal mode, int clk
    UCSRB|=(1<<TXEN0);                    // enable transmit
    while (1){
        for (char i='A'; i<='Z'; i++){
            while(!(UCSR0A&(1<<UDRE0))); // wait for empty
            UDR0=i;
            while(!(UCSR0A&(1<<UDRE0))); // wait for empty
            UDR0='\n';
            _delay_ms(500);
        }
    }
}
```

Hello World

```
#define F_CPU 8000000UL
#include <avr/io.h>
#include <util/delay.h>
void USART_putstring(char* StringPtr);

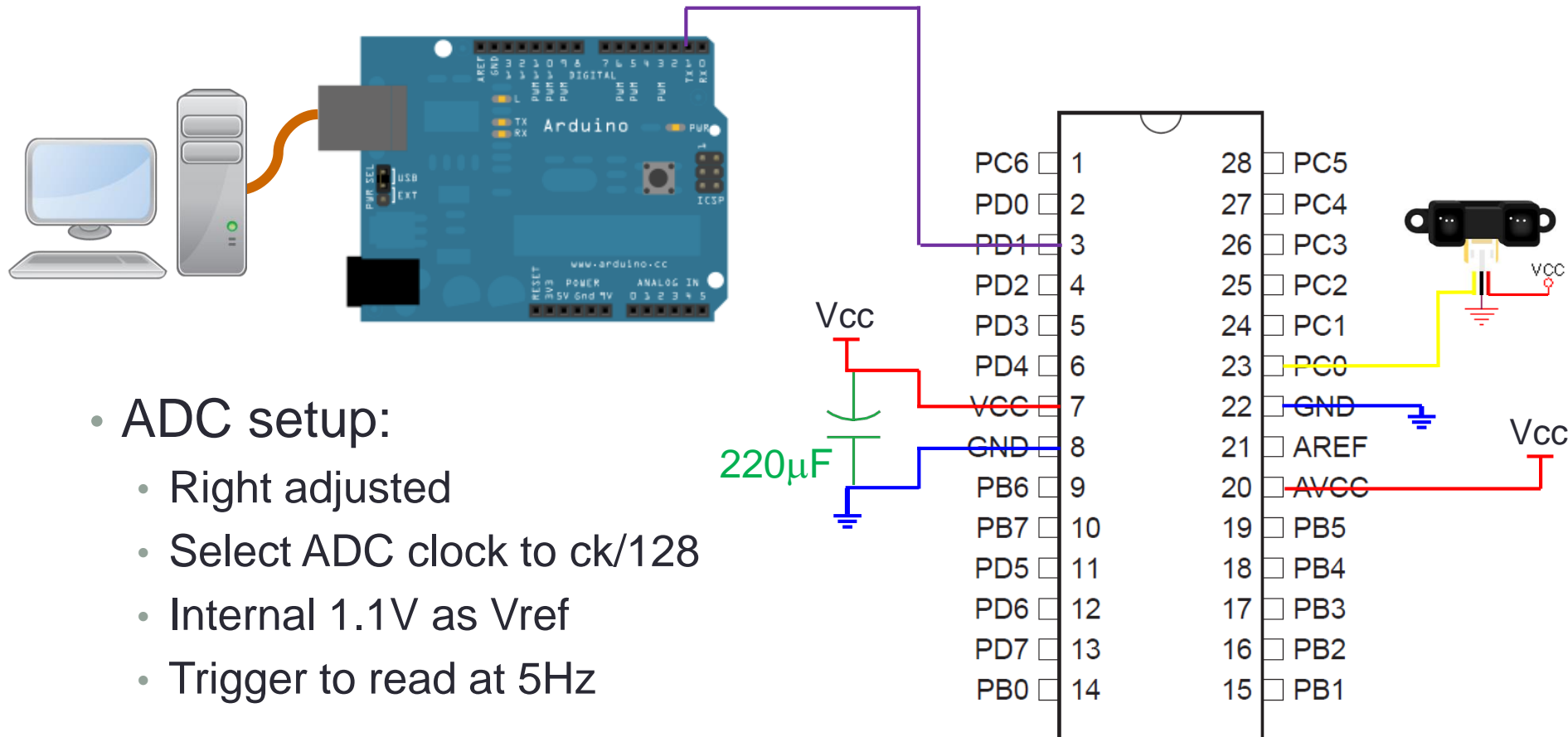
int main(void)
{
    unsigned int BaudR=9600;
    unsigned int ubrr=(F_CPU / (BaudR*16UL))-1;
    char String[]="Hello world!!\n";
    CLKPR=0b10000000;
    CLKPR=0b00000000;
    UBRR0H=(unsigned char)(ubrr>>8);
    UBRR0L=(unsigned char)ubrr;
    UCSR0B=(1<<TXEN0);
    UCSR0C=(1<<UCSZ01)|(1<<UCSZ00);

    while (1){
        USART_putstring(String);
        _delay_ms(1000);
    }
}

void USART_putstring(char* StringPtr)
{
    while(*StringPtr != 0x00){
        while(!(UCSR0A & (1<<UDRE0)));
        UDR0 = *StringPtr;
        StringPtr++;
    }
}
```

Example: Read DMS Sensor

- Read from ADC0 (PC0) and display the result on computer screen



```

#define F_CPU 8000000UL
#include <avr/io.h>
#include <util/delay.h>
#include <stdlib.h>
#include <string.h>

uint16_t ADCRead(const int);
void USART_putstring(char* StringPtr);

int main(void){
    CLKPR=0b10000000;
    CLKPR=0b00000000;
    DDRC = 0;
    ADCSRA |= (1<<ADEN);
    unsigned int BaudR = 9600;
    unsigned int ubrr = (F_CPU / (BaudR*16UL))-1;
    UBRR0H = (unsigned char)(ubrr>>8);
    UBRR0L = (unsigned char)ubrr;
    UCSR0C |= (1<<UCSZ01)|(1<<UCSZ00);
    UCSR0B |= (1<<TXEN0);

    while(1){
        float sumVal = 0;
        char Buffer[]="          ";
        for(int i = 0; i < 10; i++)
            sumVal += (float)ADCRead(0);
        sumVal /= 10; //mean of 10 readings
        char *intStr = itoa((int)sumVal, Buffer, 10);
        strcat(intStr, "\n");
        USART_putstring(intStr);
        _delay_ms(500);
    }
}

```

Display DMS Readings on PC Screen

```

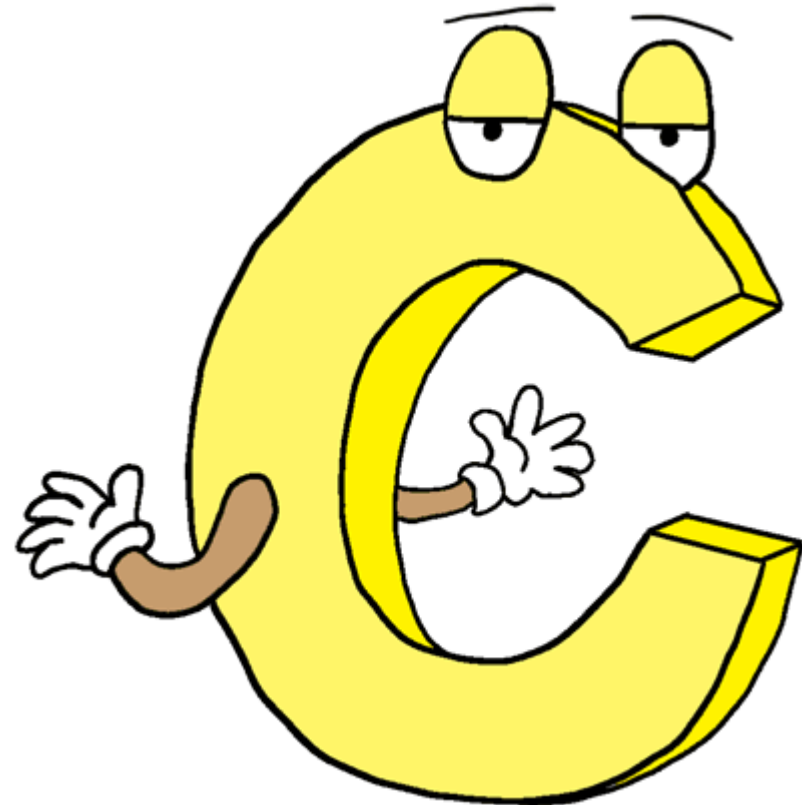
uint16_t ADCRead(const int channel) {
    ADMUX = 0b01000000;
    ADMUX |= channel;
    ADCSRA |= (1<<ADSC) | (1<<ADIF);
    while ( (ADCSRA & (1<<ADIF)) == 0 );
    ADCSRA &= ~(1<<ADSC);
    return ADC;
}

void USART_putstring(char* StringPtr){
    while(*StringPtr != 0x00){
        while(!(UCSR0A & (1<<UDRE0)));
        UDR0 = *StringPtr;
        StringPtr++;
    }
}

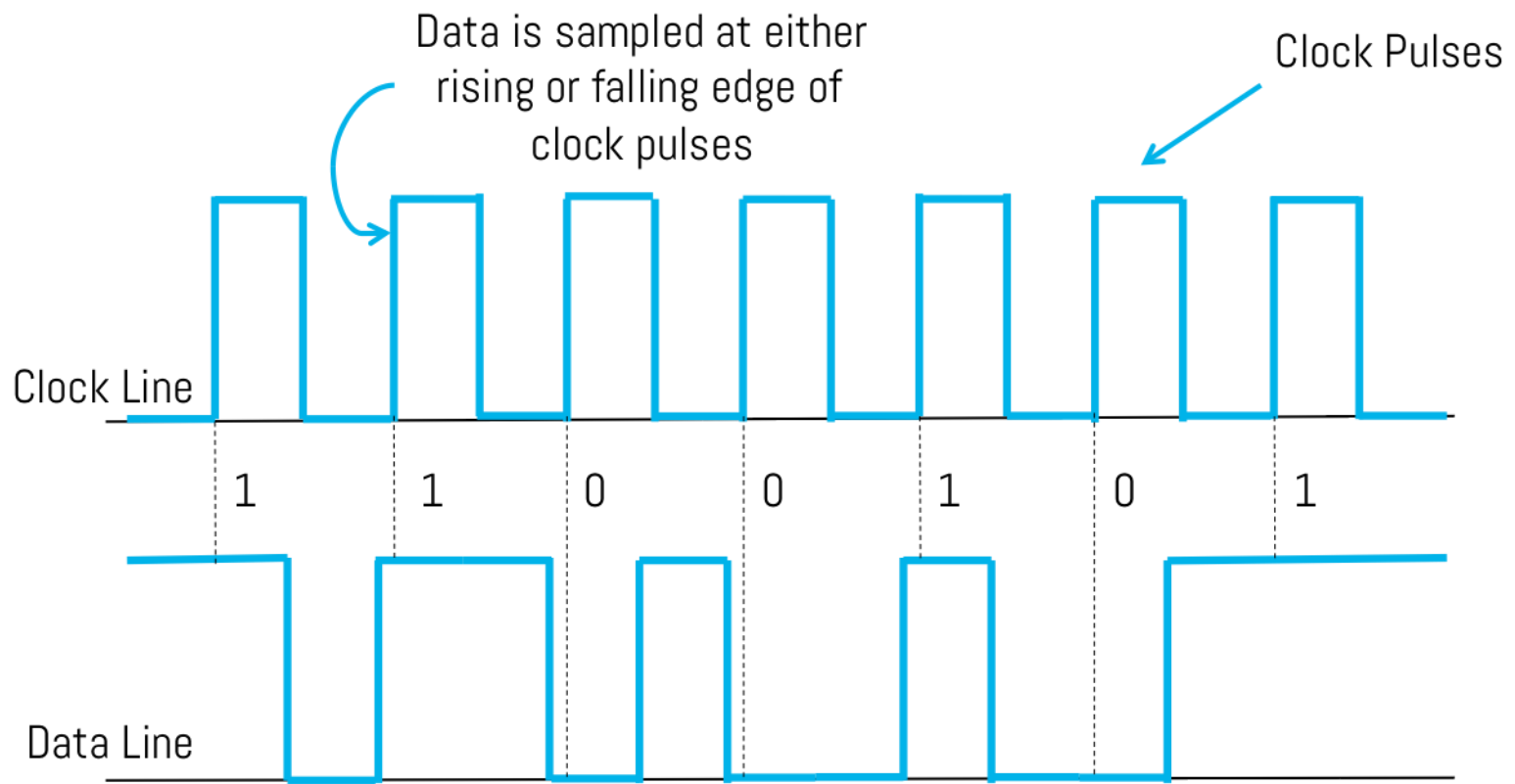
```

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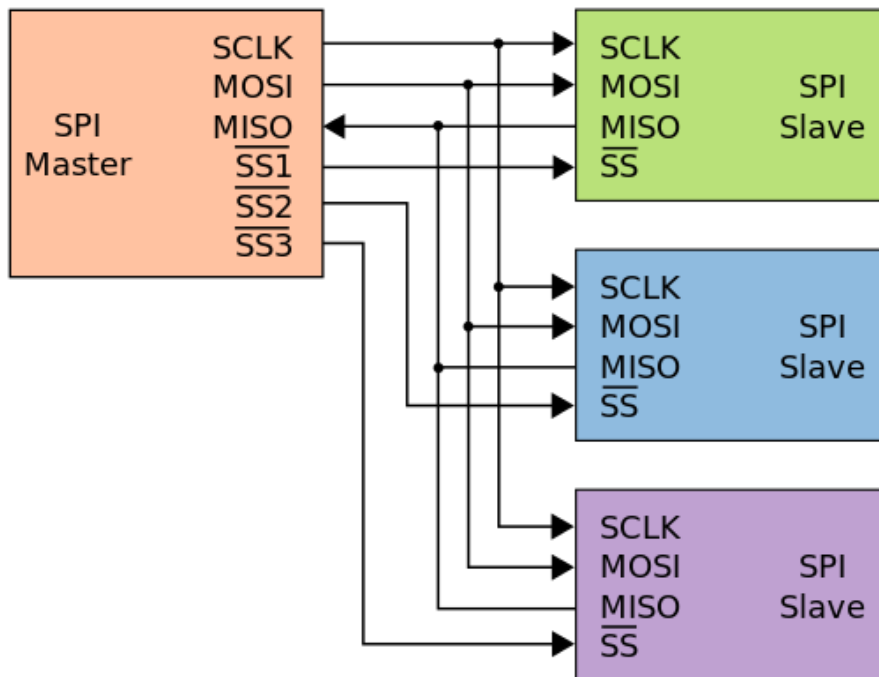


Synchronous Data Transmission



Serial Peripheral Interface (SPI)

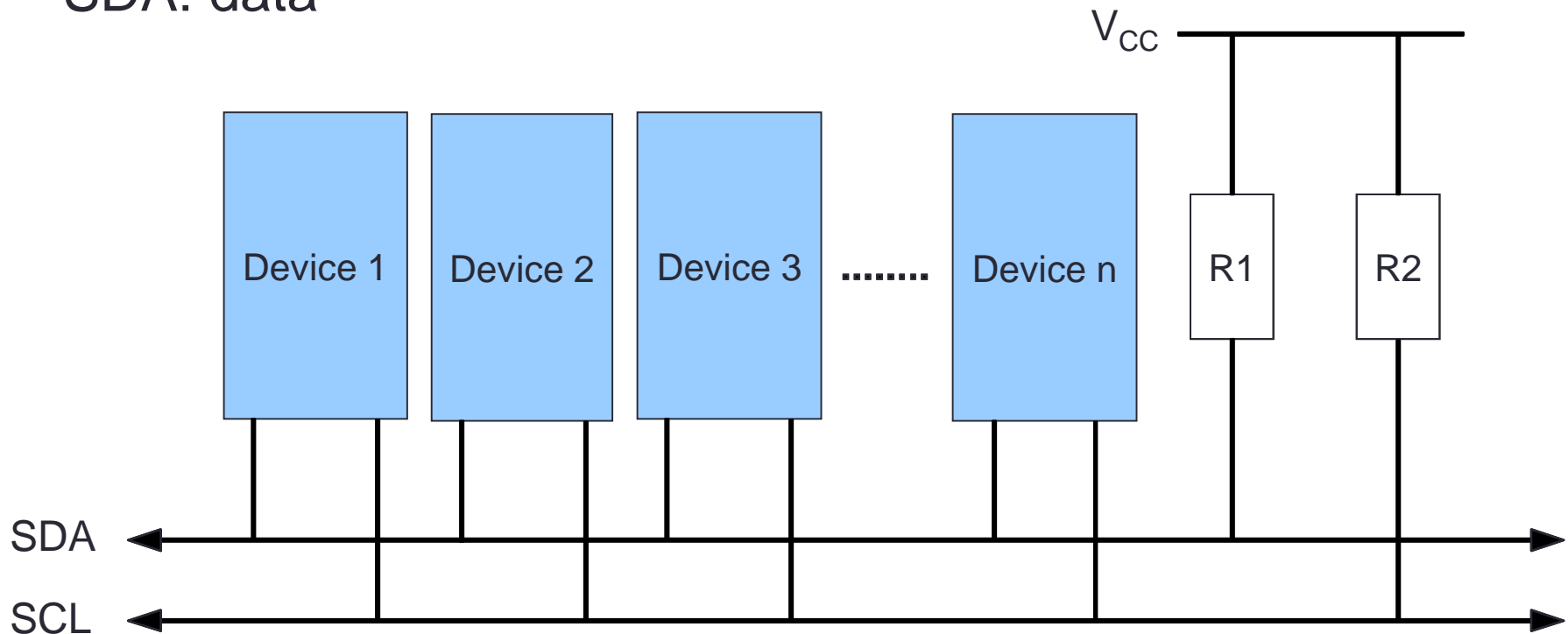
- Synchronous serial data link
- Devices communicate in master/slave mode



Pin	Description
SCLK	Serial Clock
MOSI	Master Output, Slave Input
MISO	Master Input, Slave Output
SS	Slave Select

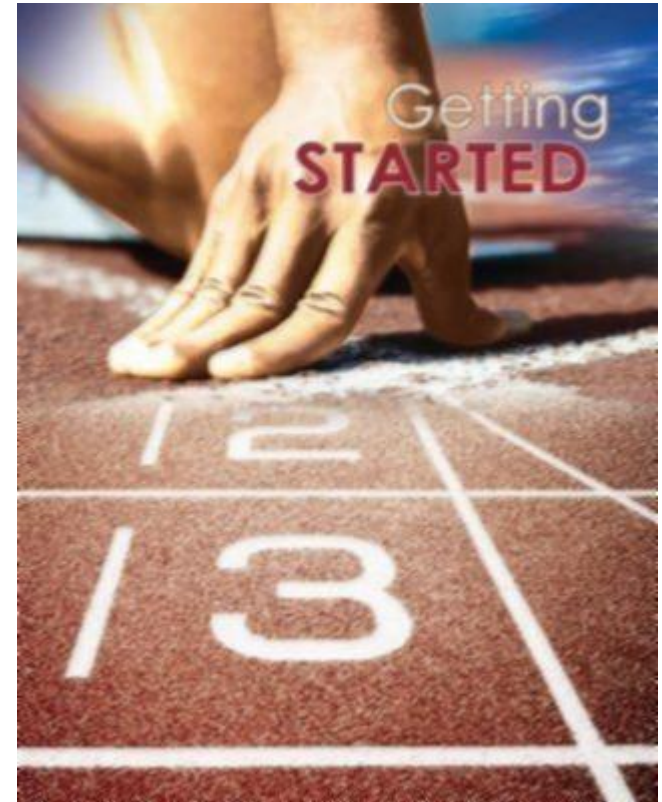
I²C

- Up to 127 devices – combining address and data packets into a transmission
- SCL: clock
- SDA: data



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Reference

- ATmega328P data sheet
- AVR 8-bit instruction set
- Atmel AVR307: Half Duplex UART Using the USI Module
- M. A. Mazidi, S. Naimi, and S. Naimi, *The AVR Microcontroller and Embedded Systems: Using Assembly and C*, Prentice Hall, 2010