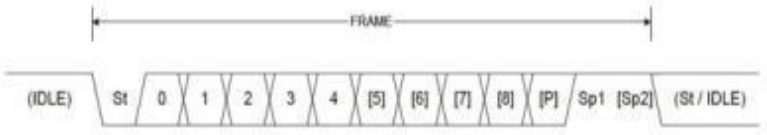
CI - Lab 002 - PC Bridge

Lab Target:

Using UART (Universal Asynchronous Receiver/Transmitter) to create a communication bridge between PC and µC. In this lab, we will explain how to use the USART module from AVR Atmega16 to send/receive data.

Theory:

A frame refers to the entire data packet which is being sent/received during a communication. Depending upon the communication protocol, the formats of the frame might vary. For example, TCP/IP has a particular frame format, whereas UDP has another frame format. Similarly in our case, RS232 has a typical frame format as well. A frame starts with the start bit followed by the least significant data bit. Then the next data bits, up to a total of nine, are succeeding, ending with the most significant bit. If enabled, the parity bit is inserted after the data bits, before the stop bits. When a complete frame is transmitted, a new frame can directly follow it, or the communication line can be set to an idle (high) state. Here is the frame format as mentioned in the AVR datasheet:



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 (RxD or TxD). An IDLE line must be high.

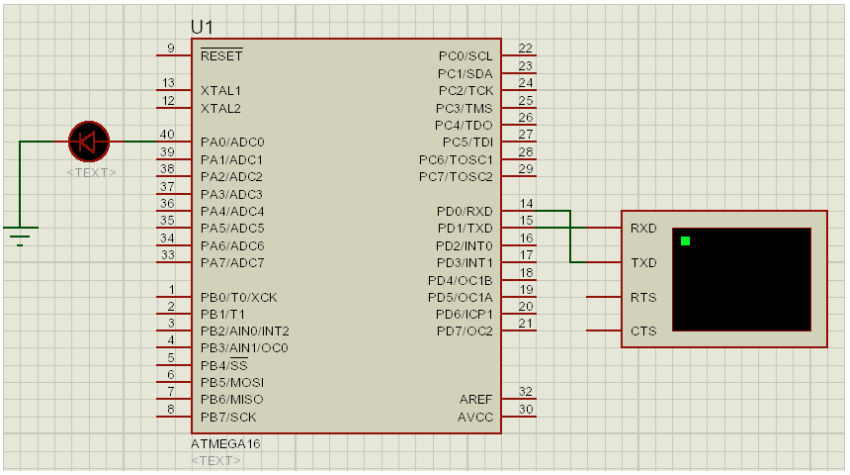
Required Registers with Values:

```
#define BAUD_RATE_VALUE (((F_CPU)/(BAUD_RATE*16UL))-1)
// Set Baud rate value.
UBRRL = (BAUD_RATE_VALUE)&0x00FF;
UBRRH = (((BAUD_RATE_VALUE)&0xFF00)>>8);
// Enable TX and RX.
UCSRB = (1<<RXEN)  | (1<<TXEN) | (1<<TXCIE) | (1<<RXCIE)
// Set frame to be 8-bit with 1 stop bit.
UCSRA = 0.
UCSRC = (1<<URSEL) | (3<<UCSZ0);
```

Experiment:

Using proteus simulator connect LED on **PIN A0**, using **terminal** module found in the instruments tab. The goal here is to turn on and off the LED by sending 0 or 1.

Circuit Diagram:



Code:

```
int main(void)
{

   static volatile uint8_t cmd_buffer[1];

   /* Init UART driver. */
   UART_cfg my_uart_cfg;

   /* Set USART mode. */
   my_uart_cfg.UBRRL_cfg = (BAUD_RATE_VALUE)&0x00FF;
   my_uart_cfg.UBRRH_cfg = (((BAUD_RATE_VALUE)&0xFF00)>>8);

   my_uart_cfg.UCSRA_cfg = 0;
   my_uart_cfg.UCSRB_cfg = (1<<RXEN)  | (1<<TXEN) | (1<<TXCIE) | (1<<RXCIE);
   my_uart_cfg.UCSRC_cfg = (1<<URSEL) | (3<<UCSZ0);

   UART_Init(&my_uart_cfg);

   sei();

   while(1)
   {

      /* Send terminal prompt. */
      UART_SendPayload((uint8_t *)">", 1);
      while (0 == UART_IsTxComplete());

      /* Receive the full buffer command. */
      UART_ReceivePayload(cmd_buffer, 1);
      /* Pull unitl reception is complete. */
      while(0 == UART_IsRxComplete());

      /* Parse command buffer. */
      switch(cmd_buffer[0])
      {
         case '0':
         {
            // turn on LED.
            DDRA  = 255;
            PORTA = 0;
            break;
         }
         case '1':
         {
            // turn off LED.
            DDRA  = 255;
            PORTA = 1;
            break;
         }
         default: {/* Do nothing. */}
      }

      UART_SendPayload((uint8_t *)"\r", 1);
      while (0 == UART_IsTxComplete());
   }
   return 0;
}
```

```
#ifndef _UART_H_
#define _UART_H_

#define BAUD_RATE_VALUE (((F_CPU)/(BAUD_RATE*16UL))-1)

typedef struct {

   /* Place here module configuration registers. */
   uint8_t UBRRH_cfg;
   uint8_t UBRRL_cfg;
   uint8_t UCSRA_cfg;
   uint8_t UCSRB_cfg;
   uint8_t UCSRC_cfg;

}UART_cfg;

extern void          UART_Init(UART_cfg *my_cfg);
extern void          UART_SendPayload(uint8_t *tx_data, uint16_t len);
extern void     UART_ReceivePayload(uint8_t *rx_data, uint16_t len);
extern uint8_t       UART_IsDataAvaiable(void);
extern uint8_t       UART_IsTxComplete(void);
extern uint8_t       UART_IsRxComplete(void);

#endif
```

```
#include <avr/io.h>
#include <avr/interrupt.h>

static volatile uint8_t  *tx_buffer;
static volatile uint16_t tx_len;
static volatile uint16_t tx_cnt;

static volatile uint8_t *rx_buffer;
static volatile uint16_t rx_len;
static volatile uint16_t rx_cnt;

ISR(USART_RXC_vect)
{
   uint8_t rx_data;

   cli();

   /* Read rx_data. */
   rx_data = UDR;

   /* Ignore spaces */
   if((rx_cnt < rx_len) && (rx_data != ' '))
   {
      rx_buffer[rx_cnt] = rx_data;
      rx_cnt++;
   }
   else
   {
      /* Do nothing. */
   }

   sei();
}
```

```
ISR(USART_TXC_vect)
{
   cli();

   tx_cnt++;

   if(tx_cnt < tx_len)
   {
      /* Send next byte. */
      UDR = tx_buffer[tx_cnt];
   }
   sei();
}


void UART_Init(UART_cfg *my_cfg)
{
   /* Set baud rate */
   UBRRH = my_cfg->UBRRH_cfg;
   UBRRL = my_cfg->UBRRL_cfg;

   UCSRA = my_cfg->UCSRA_cfg;
   UCSRB = my_cfg->UCSRB_cfg;
   UCSRC = my_cfg->UCSRC_cfg;

}

void UART_SendPayload(uint8_t *tx_data, uint16_t len)
{
   tx_buffer = tx_data;
   tx_len    = len;
   tx_cnt    = 0;

   /* Wait for UDR is empty. */
   while(0 == (UCSRA & (1 << UDRE)));

   /* Send the first byte to trigger the TxC interrupt. */
   UDR = tx_buffer[0];

}

void UART_ReceivePayload(uint8_t *rx_data, uint16_t len)
{
   rx_buffer = rx_data;
   rx_len    = len;
   rx_cnt    = 0;
}

uint8_t UART_IsTxComplete(void)
{
   return ( (tx_cnt >= tx_len) ? 1 : 0 );
}

uint8_t UART_IsRxComplete(void)
{
   return ( (rx_cnt >= rx_len) ? 1 : 0 );
}
```

Lab Deliverables:

GUI based LED control system:

Build a GUI based PC application that controls the serial/USB port communicating with the AVR MCU. The application should show the text incoming (whenever it is received by the PC from the AVR MCU). MCU will have 2 buttons connected to it, buttons will ignite a serial transmission process. One button will send character ‘A’ while the other button will send character ‘Z’. GUI also has 2 buttons, one "Turn ON" that sends the MCU a command to turn on the LED connected to it. And a "Turn OFF" button that sends a command to the MCU to turn off the LED connected to it.

Students will receive a base score of ‘5’ on finishing the above task.

Extended Features:

#	Feature Description	Score
1	Build a simple incubator including a temperature meter and a fan control. Temperature is displayed on the PC GUI. GUI has Control buttons to set the fan speed.	+5
2	Build a complete multimeter which measures: volts, current and resistor values. Values must be displayed on the PC GUI application.	+5