



American International University- Bangladesh (AIUB)

Department of Electrical and Electronic Engineering

EEE 4130: Microprocessor and Embedded Systems Laboratory

Experiment Title: Communication between two Arduino Boards using SPI

Introduction:

A Microcontroller uses many different protocols to communicate with various sensors and modules. There are many different types of communication protocols for wireless and wired communication, and the most commonly used communication technique is Serial Communication. Serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or bus. There are many types of serial communication, like UART, CAN, USB, I2C, and SPI communication.

SPI (Serial Peripheral Interface) is a serial communication protocol. SPI interface was found by Motorola in 1970. SPI has a full-duplex connection, which means that the data is sent and received simultaneously. That is a master can send data to a slave and a slave can send data to the master simultaneously. SPI is synchronous serial communication means the clock is required for communication purposes.

Important Note: A new resolution is underway to improve the terminologies used in SPI communication by removing words like "Master" and "Slave" while discussing SPI. According to this new resolution, people are encouraged to use the word "Controller" in place of "Master" and "Peripheral" in place of "Slave". It is expected that the terms MOSI/MISO and SS will be changed to SDI (Serial Data In)/SDO (Serial Data Out) and CS (Chip Select) respectively. For the sake of avoiding confusion, we have still used the old terminologies in the article, but we encourage our readers to practice the new terms.

Abstract:

In this experiment, we will study about the **SPI protocol and how to use it in Arduino**. We will use **SPI Protocol for communication between two Arduinos**. Here, one Arduino will act as a Master and another one will act as a Slave. Two LEDs and push buttons will be connected to both Arduino. To demonstrate SPI communication, we will control the master side LED by the push button at the slave side and vice versa using the **SPI Serial communication protocol**.

Working Methodology of SPI

A SPI has a master/Slave communication by using four lines. A SPI can have only one master and can have multiple slaves. A master is usually a microcontroller and the slaves can be a microcontroller, sensors, ADC, DAC, LCD etc.

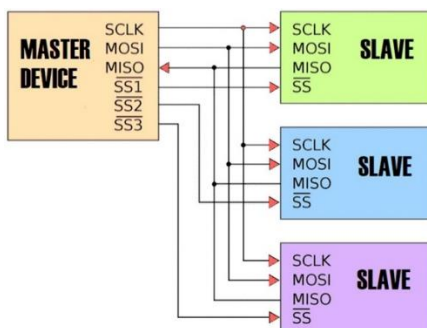


Fig. 1 block diagram representation of SPI Master with several slaves.

SPI has following four lines MISO, MOSI, SS, and CLK

- **MISO (Master in Slave Out)** - The Slave line for sending data to the master.
- **MOSI (Master Out Slave In)** - The Master line for sending data to the peripherals.
- **SCK (Serial Clock)** - The clock pulses which synchronize data transmission generated by the master.
- **SS (Slave Select)** - Master can use this pin to enable and disable specific devices.

To start communication between master and slave we need to set the required device's Slave Select (SS) pin to LOW so that it can communicate with the Master. When it is high, it ignores the Master. This allows you to have multiple SPI devices sharing the same MISO, MOSI, and CLK lines of master. As you can see in Fig. 1, there are 3 slaves in which the SCLK, MISO, MOSI are common connected to the Master and the SS of each slave is connected separately to individual SS pins (SS1, SS2, SS3) of the Master. By setting the required SS pin to LOW, a Master can communicate with that slave.

SPI Pins in Arduino UNO

Fig. 2 shows the SPI pins present Arduino UNO (in the red box).

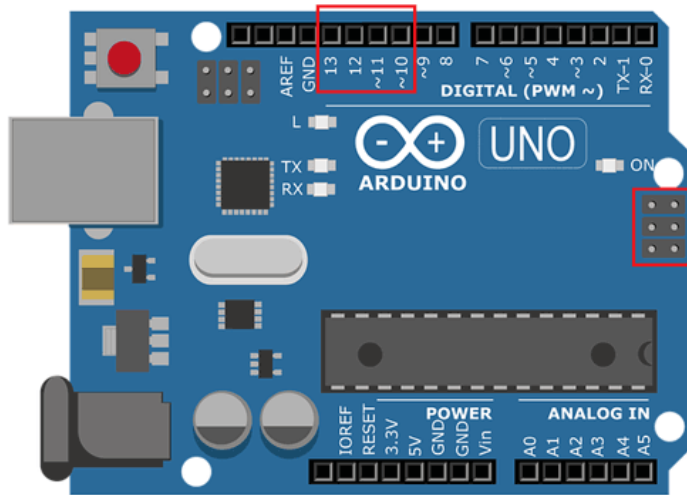


Fig. 2 Arduino board's pins for SPI communication

Table 1: Pin numbers for SPI lines

SPI Line	Pin in Arduino
MOSI	11 or ICSP-4
MISO	12 or ICSP-1
SCK	13 or ICSP-3
SS	10

Using SPI Protocol in Arduino

Before the start of the programming for **SPI communication between two Arduinos**, we need to learn about the **Arduino SPI libraries** used in Arduino IDE.

The header file `<SPI.h>` is included in the main program for using the following functions for the SPI communication.

- 1. SPI.begin():** To Initialize the SPI bus by setting SCK, MOSI, and SS to outputs, pulling SCK and MOSI low, and SS high.
- 2. SPI.setClockDivider(divider):** To Set the SPI clock divider relative to the system clock. The available dividers are 2, 4, 8, 16, 32, 64, or 128. Dividers are `SPI_CLOCK_DIVn`, where $n = 2, 4, 8, 16, 32, 64, \text{ or } 128$.
- 3. SPI.attachInterrupt(handler):** This function is called when a slave device receives data from the Master.
- 4. SPI.transfer(val):** This function is used to simultaneous send and receive the data between Master and slave.

So, now let us start with practical demonstration of SPI protocol in Arduino. In this experiment, we will use two Arduinos- one as the Master and other as a slave. Both Arduinos are attached with a LED and a push button switch separately. Master LED can be controlled by using slave Arduino's push button and vice-versa through SPI communication protocols.

Components Required for Arduino SPI communication

- Arduino UNO (2)
- LED (2)
- Push Button (2)
- Resistors 10 k, 2.2 k (2 + 2)
- Breadboard
- Connecting Wires

Arduino SPI Communication Circuit Diagram

The below circuit diagram shows how to use SPI on Arduino UNO, but you can follow the same procedure for the Arduino Mega or Arduino Nano SPI communications. Almost everything will remain the same except for the pin numbers. You have to check the pinouts of Arduino Nano or Mega.

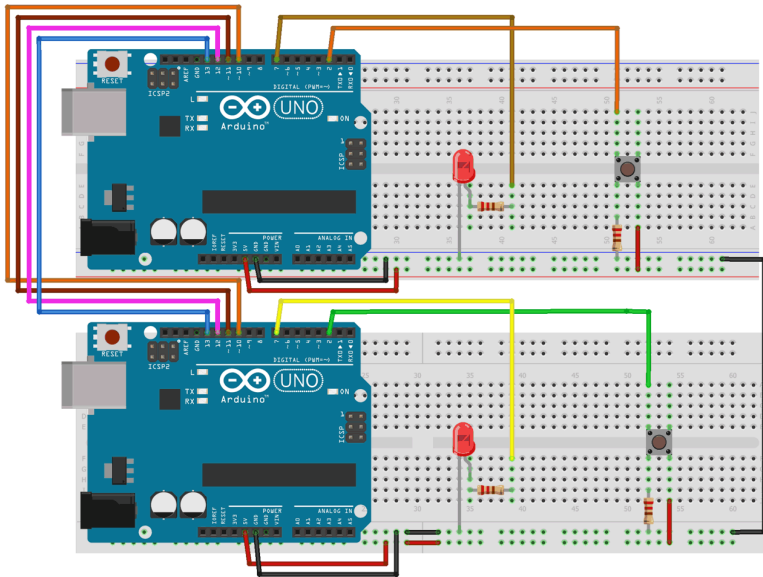


Fig. 3 Two Arduino board's pin connections for SPI communications (schematic diagram)

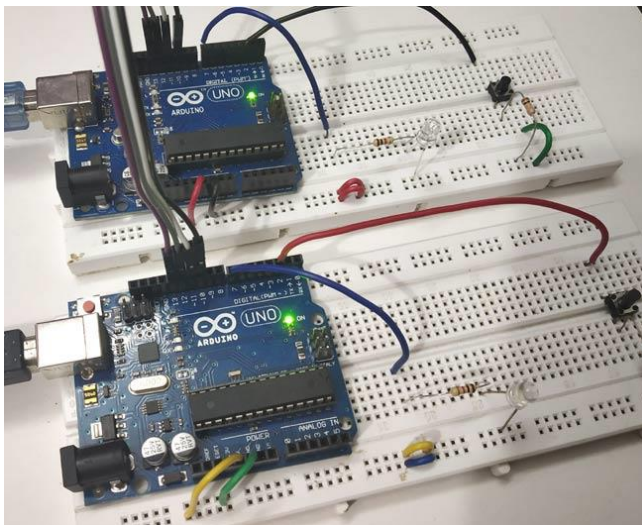


Fig. 4 Two Arduino board's pin connections for SPI communications (breadboard diagram)

How to Program Arduino for SPI Communication:

This experiment has two programs- one for the Master Arduino and the other for the slave Arduino.

Arduino SPI Master Programming Explanation:

1. First of all we need to include the SPI library for using SPI communication functions.

```
#include<SPI.h>
```

2. In void setup()

We Start Serial Communication at a Baud Rate of 1,15,200.

```
Serial.begin(115200);
```

Attach LED to pin 7 and Push button to pin 2 and set those pins as OUTPUT and INPUT respectively.

```
pinMode(ipbutton, INPUT);
```

```
pinMode(LED, OUTPUT);
```

Next, we begin the SPI communication

```
SPI.begin();
```

Next, we set the Clockdivider for SPI communication. Here, we have set divider 8.

```
SPI.setClockDivider(SPI_CLOCK_DIV8);
```

Then we set the SS pin HIGH since we did not start any transfer from the Master to slave Arduino.

```
digitalWrite(SS, HIGH);
```

3. In void loop():

We read the status of the push button pin connected to pin2 (Master Arduino) for sending those value to the slave.

```
buttonvalue = digitalRead(ipbutton);
```

Set Logic for setting x value (to be sent to the slave) depending upon input from pin 2

```
if(buttonvalue == HIGH)
```

```
{
```

```
    x = 1;
```

```
}
```

```
else
```

```
{
```

```
    x = 0;
```

```
}
```

Before sending the value, we need to send LOW to the slave select value to begin the transfer to slave from Master.

```
digitalWrite(SS, LOW);
```

Then we send the push button value stored in *Mastersend* variable to the slave Arduino and also receive value from the slave that will be stored in *Mastereceive* variable.

```
Mastereceive=SPI.transfer(Mastersend);
```

After that, depending upon the *Mastereceive* value, we will turn the Master Arduino LED ON or OFF.

```
if(Mastereceive == 1)
```

```
{
```

```
    digitalWrite(LED, HIGH);          //Sets pin 7 HIGH
```

```
    Serial.println("Master LED ON");
```

```
}
```

```
else
```

```
{
```

```
    digitalWrite(LED, LOW);          //Sets pin 7 LOW
```

```
    Serial.println("Master LED OFF");
```

```
}
```

Note: We use *serial.println()* to view the results in a new line in Serial Monitor of Arduino IDE.

Arduino SPI Slave Programming Explanation:

1. First of all we need to include the SPI library for using SPI communication functions.

```
#include<SPI.h>
```

2. In void setup()

We Start Serial Communication at Baud Rate 1,15,200.

```
Serial.begin(115200);
```

Attach LED to pin 7 and Push button to pin2 and set those pins OUTPUT and INPUT respectively.

```
pinMode(ipbutton,INPUT);
```

```
pinMode(LED,OUTPUT);
```

We set MISO as OUTPUT (to send data to Master IN). So, data is sent via MISO of Slave Arduino.

```
pinMode(MISO,OUTPUT);
```

Now, turn on or enable the SPI in Slave Mode by using SPI Control Register (bit 6 of SPCR).

```
SPCR |= _BV(SPE);
```

Then turn ON interrupt for SPI communication. If a data is received from the Master, the Interrupt Service Routine (ISR) is called and the received value is taken from SPDR (SPI Data Register)

```
SPI.attachInterrupt();
```

The value from master is taken from SPDR and stored in *Slavereceived* variable. This takes place in following Interrupt Routine function.

```
ISR (SPI_STC_vect)
{
    Slavereceived = SPDR;
    received = true;
}
```

3. Next in void loop(), we set the Slave Arduino LED to turn ON or OFF depending upon the Slavereceived value.

```
if (Slavereceived==1)
{
    digitalWrite(LEDpin,HIGH); //Sets pin 7 as HIGH LED ON
    Serial.println("Slave LED ON");
}
else
{
    digitalWrite(LEDpin,LOW); //Sets pin 7 as LOW LED OFF
    Serial.println("Slave LED OFF");
}
```

Next, we read the status of the Slave Arduino Push button and store the value in *Slavesend* to send the value to Master Arduino by giving value to SPDR register.

```
buttonvalue = digitalRead(buttonpin);
if (buttonvalue == HIGH)
{
    x=1;
}
else
{
    x=0;
}
```

```
Slavesend = x;
SPDR = Slavesend;
```

To check how SPI works on Arduino, let us test the program in hardware.

When push button at Master side is pressed, the LED at slave side turns ON and when the push button at Slave side is pressed, the LED at Master side turns ON.

Codes:

Master/Controller Arduino Code:

```
//SPI MASTER (ARDUINO)
//SPI COMMUNICATION BETWEEN TWO ARDUINO CIRCUIT DIGEST

#include<SPI.h>           //Library for SPI

#define LED 7
#define ipbutton 2

int buttonvalue;

int x;

void setup (void){

    Serial.begin(115200); //Starts Serial Communication at Baud Rate 115200
    pinMode(ipbutton,INPUT); //Sets pin 2 as input
    pinMode(LED,OUTPUT); //Sets pin 7 as Output
    SPI.begin(); //Begins the SPI communication
    SPI.setClockDivider(SPI_CLOCK_DIV8); //Sets clock for SPI communication at
                                           // 8 (16/8 = 2 MHz)
    digitalWrite(SS,HIGH); //Setting SS to HIGH do disconnect master from slave
}

void loop(void){

    byte Mastersend, Mastereceive;
    buttonvalue = digitalRead(ipbutton); //Reads the status of the pin 2

    if(buttonvalue == HIGH) //Setting x for the slave based on input at pin 2
    {
        x = 1;
    }
    else
    {
        x = 0;
    }

    digitalWrite(SS, LOW); //Starts communication with Slave from the Master
    Mastersend = x;
    Mastereceive = SPI.transfer(Mastersend); //Sends the Mastersend value to
                                           //the slave and also receives value from the slave
```

```

if(Mastereceive == 1) //To set the LED based on value received from slaveu
{
    digitalWrite(LED,HIGH); //Sets pin 7 HIGH
    Serial.println("Master LED is ON");
}

else
{
    digitalWrite(LED,LOW); //Sets pin 7 LOW
    Serial.println("Master LED is OFF");
}
delay(1000);
}

```

Slave/Peripheral Arduino Code:

```

//SPI SLAVE (ARDUINO)
//SPI COMMUNICATION BETWEEN TWO ARDUINO

#include<SPI.h>

#define LEDpin 7
#define buttonpin 2

volatile boolean received;
volatile byte Slavereceived, Slavesend;

int buttonvalue;
int x;

void setup(){
    Serial.begin(115200);
    pinMode(buttonpin,INPUT);    // Setting pin 2 as INPUT
    pinMode(LEDpin,OUTPUT);      // Setting pin 7 as OUTPUT
    pinMode(MISO,OUTPUT);        //Sets MISO as OUTPUT to send data to Master In
    SPCR |= _BV(SPE);            //Turn on SPI in Slave Mode
    received = false;
    SPI.attachInterrupt();    //Interrupt ON is set for SPI communication
}

ISR(SPI_STC_vect)                //Interrupt routine function
{
    Slavereceived = SPDR; // Value received from Master stored in Slavereceived
    received = true;      //Sets received as True
}

void loop() {
    if(received) //To set LED ON/OFF based on the value received from Master
    {
        if (Slavereceived == 1)
        {
            digitalWrite(LEDpin, HIGH);    //Sets pin 7 as HIGH to turn on LED

```

```
        Serial.println("Slave LED is ON");
    }
    else
    {
        digitalWrite(LEDpin,LOW);    //Sets pin 7 as LOW to turn off LED
        Serial.println("Slave LED is OFF");
    }

    buttonvalue = digitalRead(buttonpin);    //Reads the status of the pin 2

    if (buttonvalue == HIGH)    //To set the value of x to send to Master
    {
        x = 1;
    }

    else
    {
        x=0;
    }

    Slavesend = x;
    SPDR = Slavesend;    //Sends the x value to the Master via SPDR
    delay(1000);
}
```