SPI (Serial Peripheral Interface)

1. Introduction

SPI is a common communication protocol used by many devices – for example SD card reader modules, RFID card reader modules and 2.4 GHz wireless transmitter/receivers all use SPI to communicate with microcontrollers.

- Devices are in a **master–slave** relationship: the master is the controlling device (usually a microcontroller) and the slave (usually a sensor, display or memory chip) takes instructions from the master.
- The simplest configuration is single master, single slave; one master can also control more than one slave.

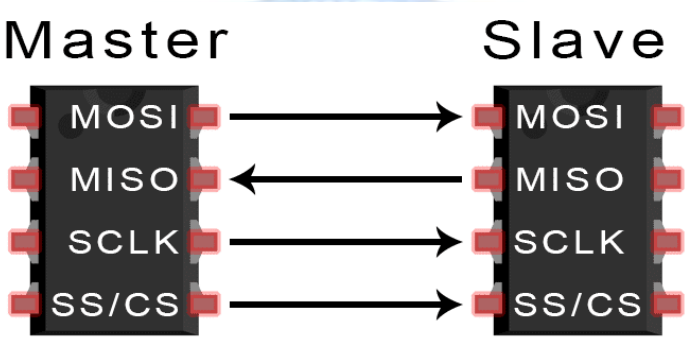


Figure 2.15 SPI master–slave connection

2. SPI Signals

Signal	Full name	Function
MOSI	Master Output / Slave Input	Line for the master to send data to the slave
MISO	Master Input / Slave Output	Line for the slave to send data to the master
SCLK	Clock	Line for the clock signal
SS/CS	Slave Select / Chip Select	Line for the master to select which slave to send data to

3. How SPI Works

3.1 The Clock

- The clock synchronises the output of data bits from the master with the sampling of bits by the slave; one bit is transferred per clock cycle, so speed is set by the clock frequency.
- SPI is always initiated by the master, since the master configures and generates the clock.
- SPI is **synchronous** (devices share a clock). Asynchronous methods such as UART use no clock; both sides use a pre-configured baud rate.

3.2 Clock Polarity and Phase

- **Clock polarity** (set by the master): bits are output and sampled on either the rising or the falling edge.
- **Clock phase:** output and sampling occur on the first or the second edge of the clock cycle, regardless of rising or falling.

3.3 Slave Select

- The master selects a slave by pulling that slave's CS/SS line **low**; in the idle (non-transmitting) state the line is kept high.
- Multiple CS/SS pins on the master allow multiple slaves wired in parallel; with only one CS/SS pin, slaves can be daisy-chained.

4. Multiple Slaves

Method	When used
Parallel wiring	Master has multiple slave-select pins (one per slave)
Daisy chain	Only one slave-select pin is available

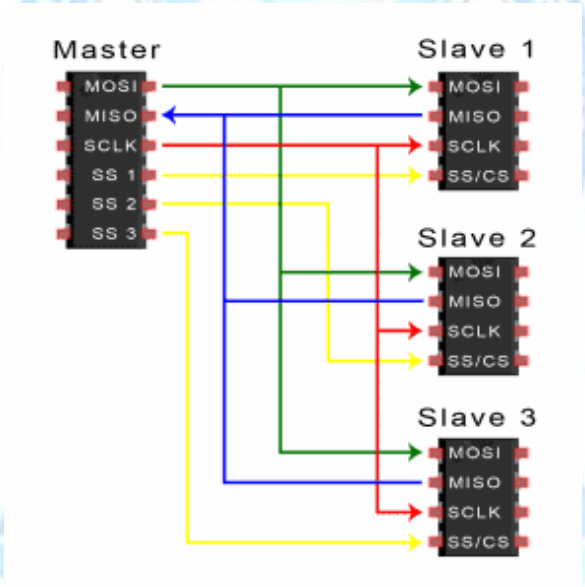


Figure 2.16 Slaves wired in parallel (one SS line per slave)

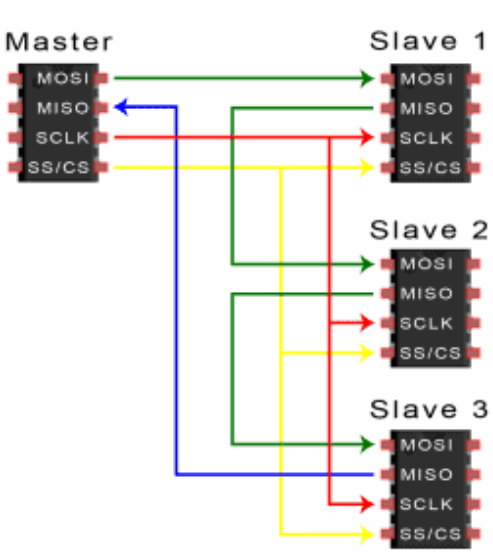


Figure 2.17 Slaves daisy-chained (single SS line)

5. MOSI and MISO

- The master sends data bit by bit, serially, on MOSI – usually **most significant bit first**.
- The slave returns data serially on MISO – usually **least significant bit first**.

6. Steps of SPI Data Transmission

1. The master outputs the clock signal.
2. The master switches the SS/CS pin low, which activates the slave.
3. The master sends data one bit at a time along MOSI; the slave reads the bits as they arrive.
4. If a response is needed, the slave returns data one bit at a time along MISO; the master reads the bits as they arrive.



Figure 2.18 Step 1 – master outputs the clock



Figure 2.19 Step 2 – SS/CS pulled low

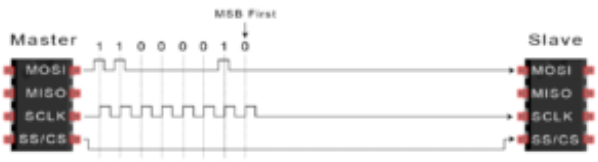


Figure 2.20 Step 3 – master sends data on MOSI (MSB first)

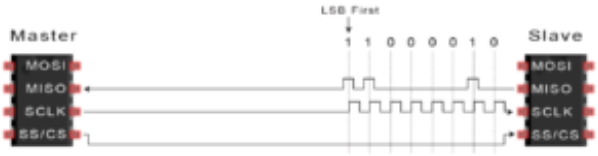


Figure 2.21 Step 4 – slave replies on MISO (LSB first)