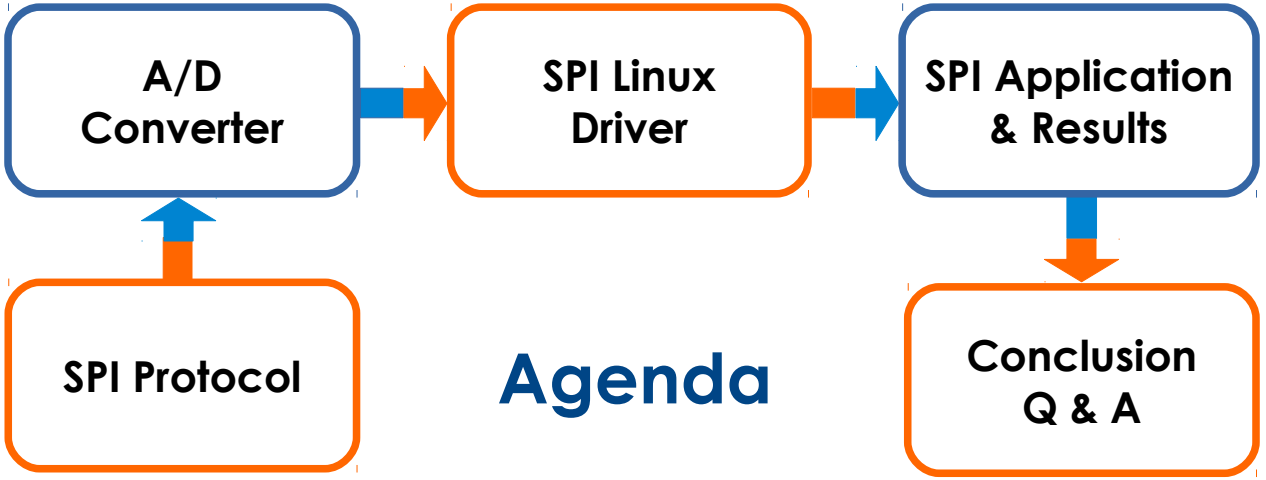
GLOBAL EDGE
Intelligence Of Things

Linux SPI Driver

Interfacing ADC with Raspberry Pi

Presented By-
Aditya Hambar

Agenda


A/D Converter
SPI Linux Driver
SPI Application & Results
SPI Protocol
Agenda
Conclusion Q & A

SPI Protocol

A/D Converter

Linux SPI Driver

SPI...???

Serial Peripheral Interface

- Serial Communication Protocol
- Developed by Motorola in 1979
- 4 – wire Serial Bus Protocol
- Simple & Efficient Interface
- Widely used with Embedded Systems

Why SPI...???

Asynchronous Communication

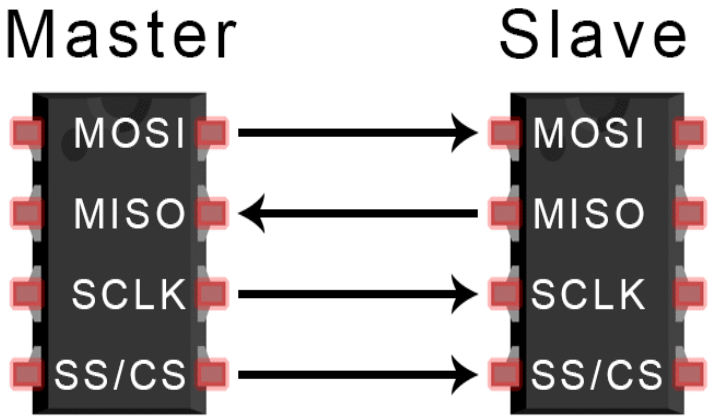
- No control over data.
- No any guarrantee that both sides are running precisely at the same rate.
- Can arise a problem due to different speeds.
- Start and Stop bits are required.
- Lot of overhead due to extra bits.

Vs

Synchronous Communication

- Separate lines for Data & Clock.
- Keeps both sides in perfect sync.
- Clock helps in sampling the data at exact time.
- Receiving hardware is much simpler.
- Useful in small distance communication.

SPI Protocol



MOSI – Master Out Slave In

MISO – Master In Slave Out

SCLK – Serial Clock

SS/CS – Slave Select/Chip Select

SPI Protocol

SCLK

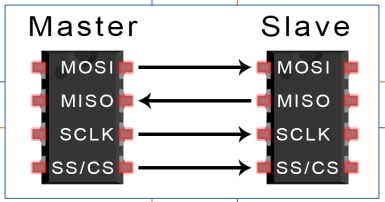
Master generates serial clock and sends to slave with SCLK pin.

Direction : Master -> Slave

MOSI

Data out pin for sending data bits to Slave.

Direction : Master -> Slave



MISO

Data in pin for receiving data bits from Slave.

Direction : Slave -> Master

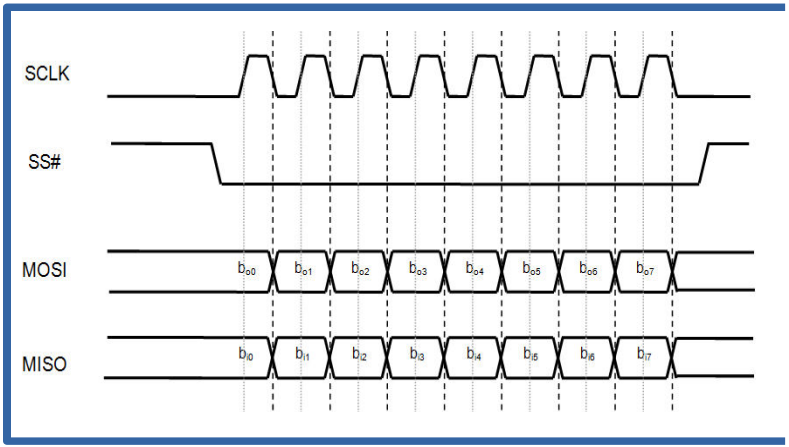
SS/CS

Slave select pin for selecting particular slave device.

Direction : Master -> Slave

Simple SPI Communication

- Master generates the serial clock on SCLK pin.
- Master pulls SS/CS pin low in order to select a particular slave device.
- Data bits are sent through MOSI pin and received through MISO pin.



- Data bits are sampled at one edge of SCLk & toggeled at other edge (depending upon SPI mode).

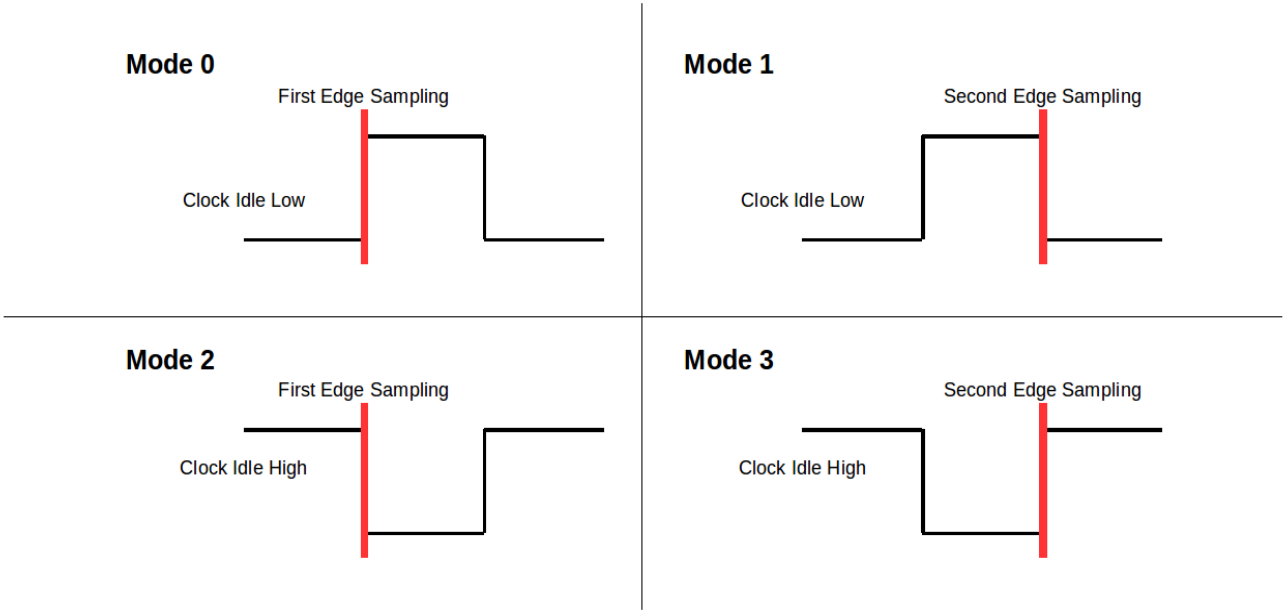
SPI Modes

Mode	CPOL	CPHA
0	0	0
1	0	1
2	1	0
3	1	1

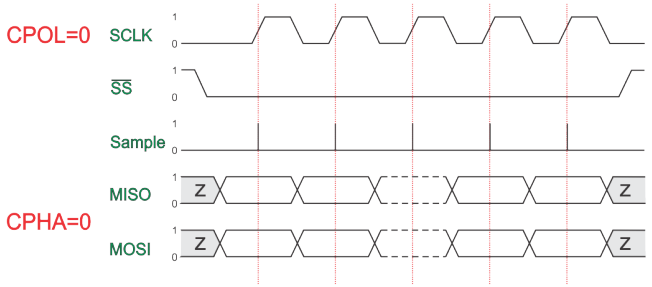
CPOL – Clock Polarity

CPHA – Clock Phase

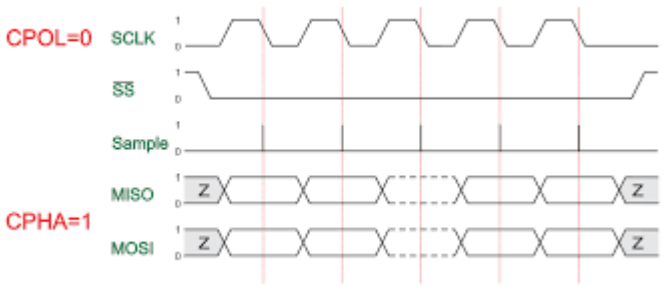
SPI Modes


Mode 0
First Edge Sampling
Clock Idle Low
Mode 1
Second Edge Sampling
Clock Idle Low
Mode 2
First Edge Sampling
Clock Idle High
Mode 3
Second Edge Sampling
Clock Idle High

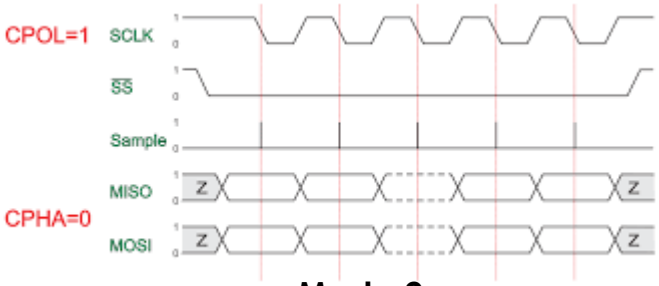
SPI Modes



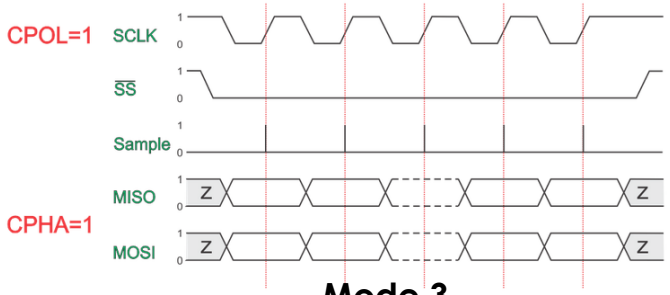
Mode 0



Mode 1

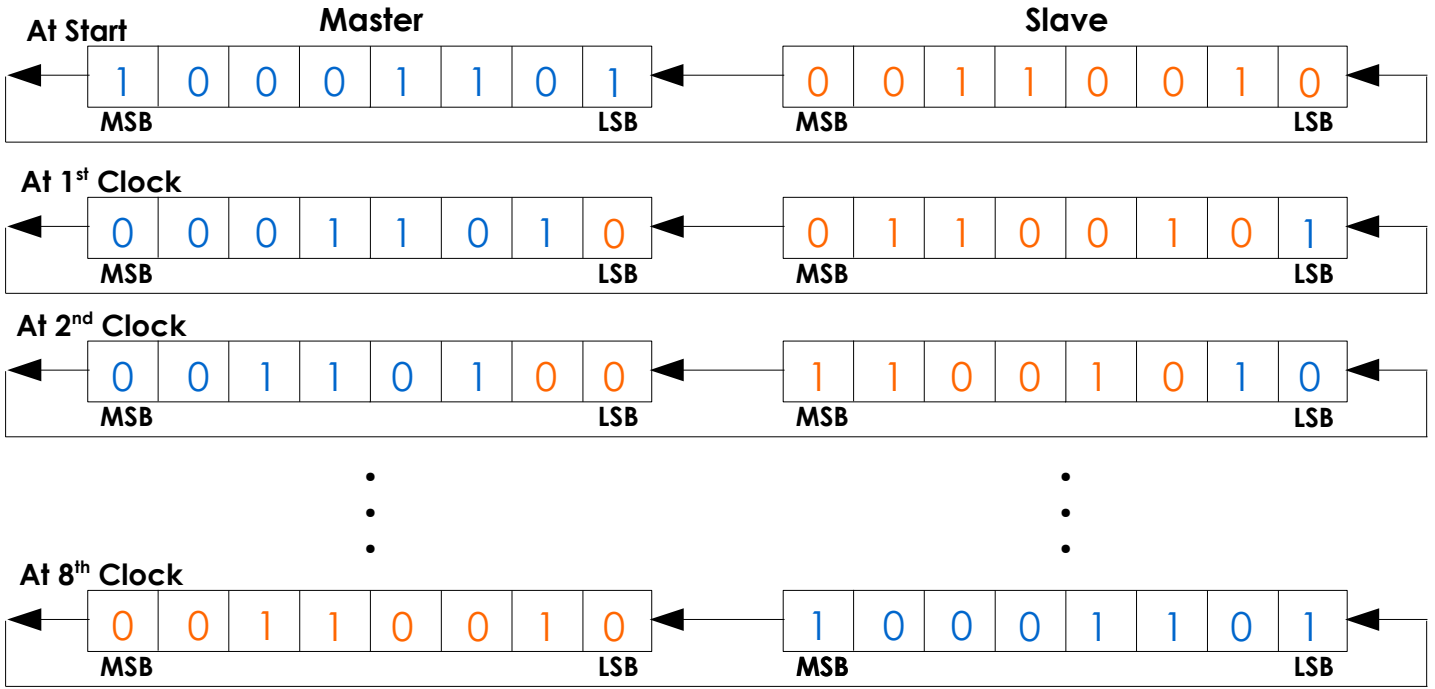


Mode 2

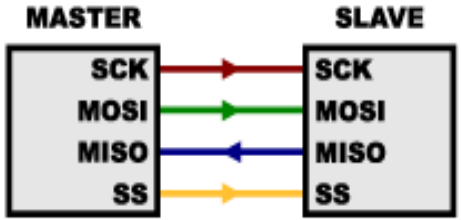


Mode 3

Shift Registers

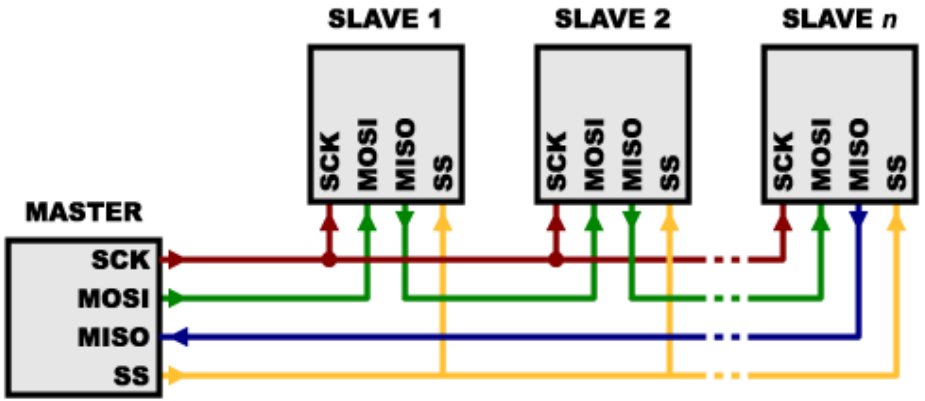


SPI Interfacing



Single Slave Interface

Multi Slave Interface



Positives & Negatives

POSITIVES

- Simple hardware interfacing.
- Faster than asynchronous serial communication.
- Flexibility for the bits transfer.
- Supports multiple slaves.
- No need for individual addresses.
- Full duplex communication.
- Does not require processing overheads.
- High speed of data transfer.

NEGATIVES

- Requires more pins on IC.
- Supports only one master device.
- Separate SS lines to each slave.
- Master must control all communications.
- No acknowledgment mechanism.
- No flow control.

SPI Protocol

A/D Converter

Linux SPI Driver

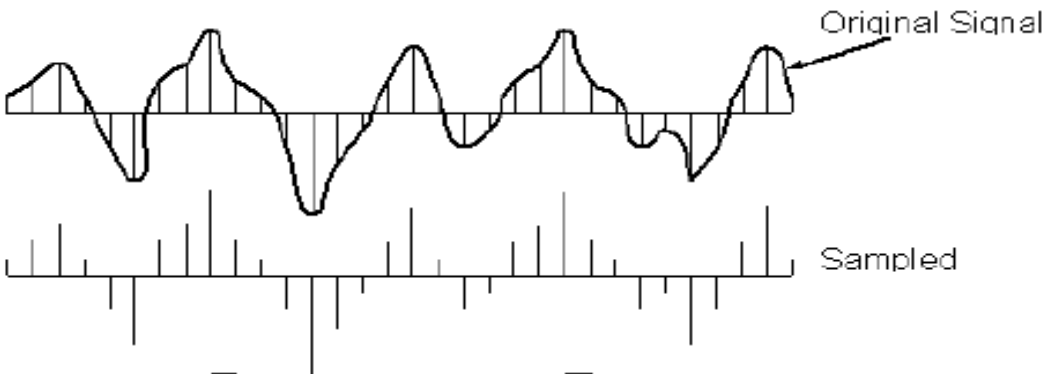
A/D Converter...???

Analog to Digital Converter

Electronic Integrated Circuit which converts Analog Signal into Digital Signals.

Continuous Time & Continuous Amplitude Into Discrete Time & Discrete Amplitude

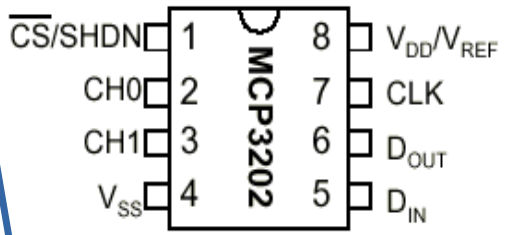
Analog to Digital Conversion



- Analog input signal is sampled at discrete time.
- Sampled discrete amplitude levels are then converted into digital format i.e. sequence of 1's and 0's.

ADC - “MCP 3202”

- 8 – Pin Package.
- High performance and low power consumption
- 12 bit ADC Capability.
- Works on Successive Approximation principle.
- An industry-standard SPI serial interface.



Working of ADC - “MCP 3202”

Initialization of ADC -

- Communication is done by pulling CS pin low.
- DIN will constitute a start bit.
- SGL/DIFF bit and ODD/SIGN bit follow the start bit.
- Then MSBF bit is transmitted.

SGL/DIFF – For selecting Single-Ended mode or Pseudo-differntial mode.

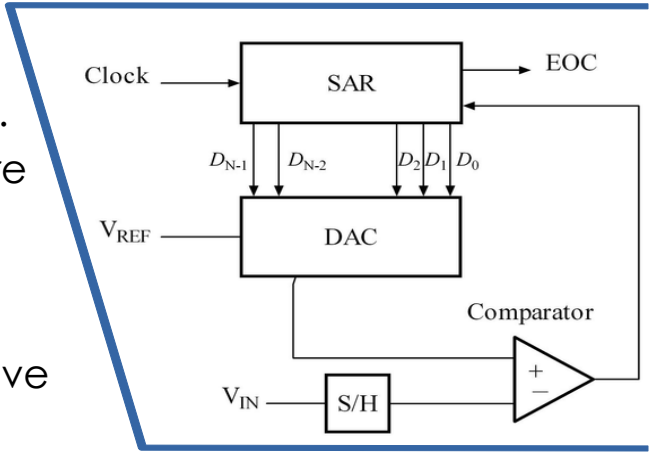
ODD/SIGN – For selecting one of the Channels in Single-Ended mode & Polarity in Pseudo-differntial mode.

MSBF – For selecting MSB first or LSB first data format.

Working of ADC - “MCP 3202”

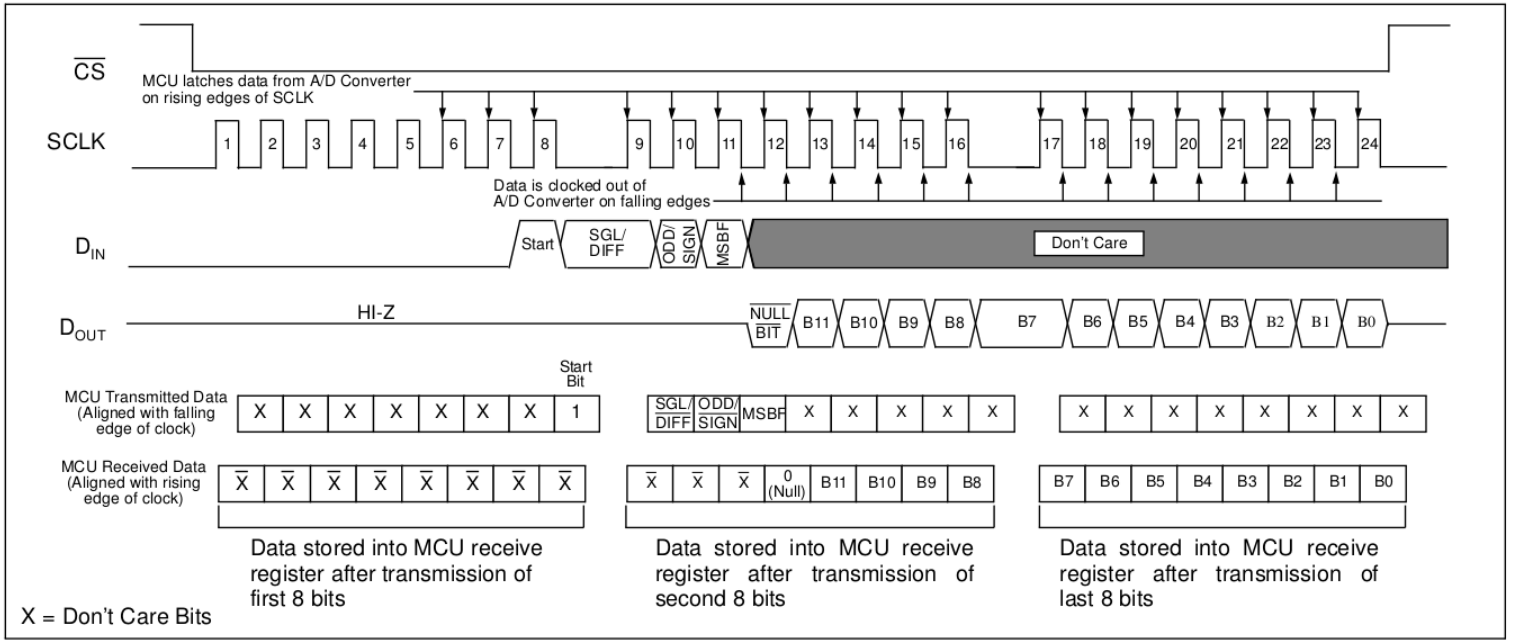
Conversion of A to D -

- Successive Approximation Principle.
- A sample and hold circuit to acquire the input voltage (Vin).
- Comparator compares Vin to the output of the internal DAC & gives result of the comparison to successive approximation register (SAR).



- SAR supplies an approximate digital code of Vin to the internal DAC.
- DAC supplies an analog voltage equal to the digital code output of the SAR to Comparator.

Timing Diagram of “MCP 3202”



SPI Protocol

A/D Converter

Linux SPI Driver

Linux SPI Driver API...???

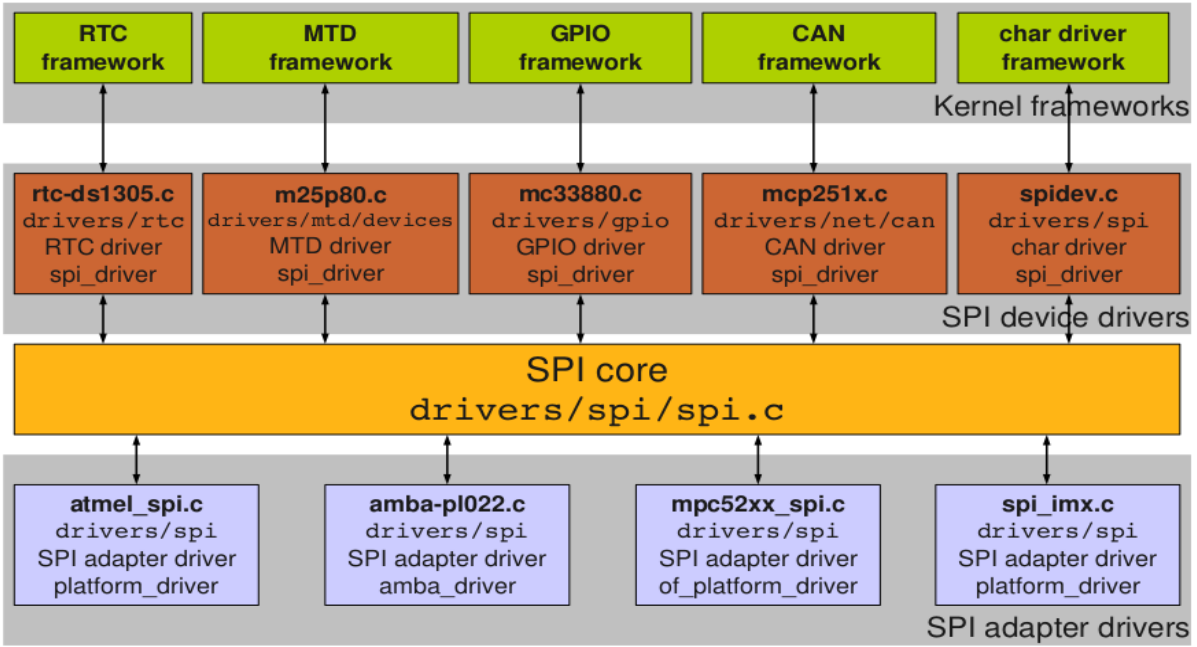
Linux SPI Driver API

Linux talks to SPI peripherals...

A generalized interface to declare SPI buses and devices.

Manage them according to the standard Linux driver model, and perform input/output operations...!!!

Linux SPI Components



Programming with SPI

SPI Driver

Controller Driver

- Abstracts controller hardware (GPIO/FIFOs/SPI shift register).
- Represented as a *struct spi_master*
- SPI devices are children of master, represented as a *struct spi_device*

Protocol Driver

- Represented as *struct spi_driver*
- Bound to a *spi_device* using normal driver model calls.

Programming with SPI - Structures

struct spi_master

```
{
        struct device dev;
        u16 num_chipselect;
        size_t (*)(struct spi_device *spi)
                max_transfer_size;
        int (*)(struct spi_device *spi,
                struct spi_message *mesg)transfer;
        void (*)(struct spi_device *spi) cleanup;
        ...
};
```

- SPI Controller Driver
- Allows easy communication with SPI slave devices.
- Takes care of multiplexing between different SPI slaves on the same master.

Programming with SPI - Structures

struct spi_device

```
{
        struct device dev;
        struct spi_controller *master;
        u8 chip_select;
        void *controller_state;
        void *controller_data;
        ...
        ...
};
```

- Controller side proxy for an SPI slave device.
- Used to interchange data between an SPI slave & CPU memory.
- Device specific template.

Programming with SPI - Structures

struct spi_board_info

```
{
        const void * platform_data;
        void * controller_data;
        u16 chip_select;
        u16 mode;
        ...
        ...
};
```

- Board-specific template for a SPI device.
- Useful when adding new SPI devices to the device tree.
- Hold information which can't always be determined by drivers.

Programming with SPI - Structures

struct spi_driver

```
{
        const struct spi_device_id * id_table;
        int (*probe) (struct spi_device *spi);
        int (*remove) (struct spi_device *spi);
        void (*shutdown) (struct spi_device *spi);
        struct device_driver driver;
};
```

- Host side "protocol" driver.
- Represents the kind of device driver that uses SPI messages.
- Works through messages rather than talking directly to SPI hardware.

Programming with SPI - Structures

struct spi_message

```
{
        struct spi_device * spi;
        unsigned frame_length;
        unsigned actual_length;
        int status;
        ...
        ...
};
```

- One multi-segment SPI transaction.
- Used to execute an atomic sequence of data transfers.
- Messages sent to a given spi_device are always executed in FIFO order.

Programming with SPI - Structures

struct spi_transfer

```
{
        const void *tx_buf;
        void *rx_buf;
        unsigned tx_nbits:3;
        unsigned rx_nbits:3;
        u8 bits_per_word;
        u32 speed_hz;
        ...
        ...
};
```

- A read/write buffer pair.
- SPI transfers always write the same number of bytes as they read.
- Protocol drivers should always provide rx_buf and/or tx_buf.

SPI Driver Implementation

Character Device & Character Driver -

A character device is one that can be accessed as a stream of bytes.

A char driver is in charge of implementing this behavior. Such a driver usually implements at least the open, close, read, and write system calls.

SPI Devices can be accessed as a character devices.

SPI Driver Implementation

File Operation structure -

```
struct file_operations fops = {
    .owner = THIS_MODULE,
    .open = mySpiOpen,
    .release = mySpiRelease,
    .read = mySpiRead,
};
```

File Operation Function Definitions -

```
static int mySpiInit(void);
static void mySpiExit(void);
int mySpiOpen(struct inode *, struct file *);
int mySpiRelease(struct inode *, struct file *);
ssize_t mySpiRead(struct file *, char __user *, size_t, loff_t *);
```

SPI Driver Implementation

Function - module_init()

Module initialization function.

- Setting up a char device - *alloc_chrdev_region()*
- Allocate and register structure of type struct cdev - *cdev_alloc()*
- Tell the kernel about it - *cdev_add()*
- Create the class of character device - *class_create()*
- Create the device of the class - *device_create()*
- Register spi driver to the Kernel - *spi_register_driver()*

SPI Driver Implementation

Function - *probe()*

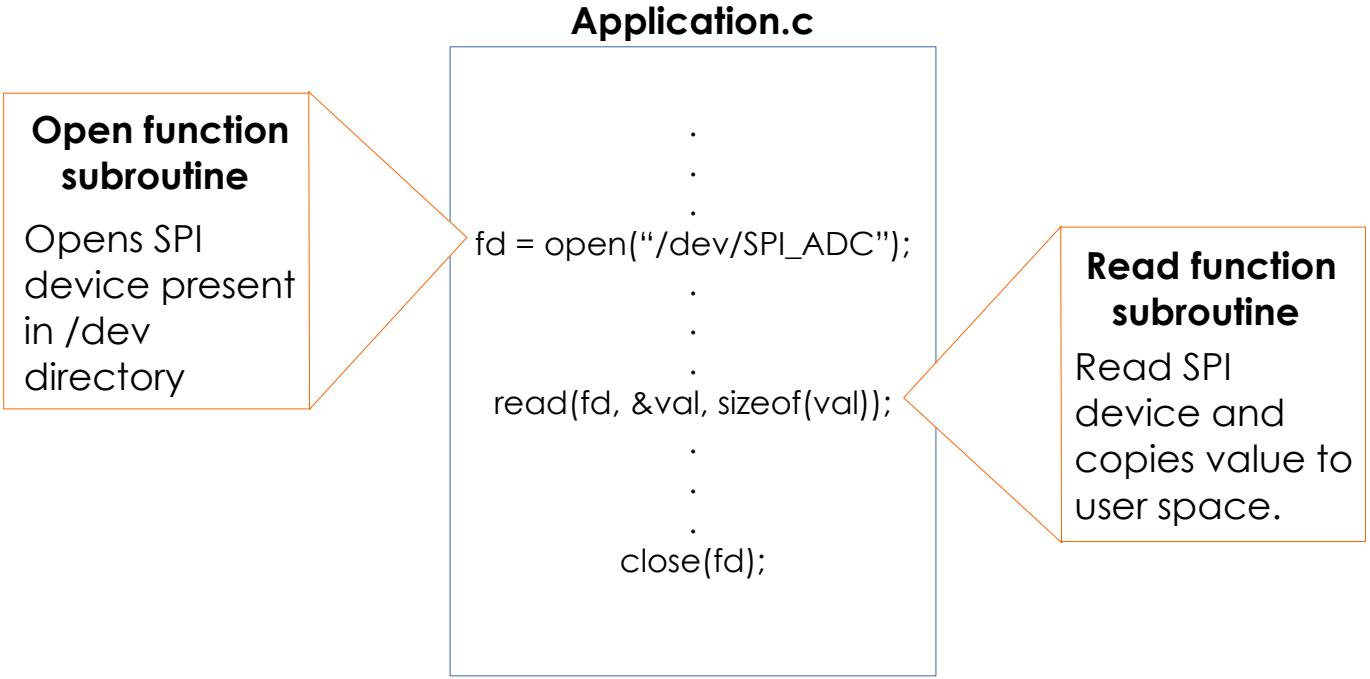
- Purpose is to detect devices residing on the bus & to create device nodes corresponding to these devices.
- The kernel calls the driver's probe() function once for each device.
- Probe function starts the per-device initialization: initializing hardware, allocating resources, and registering the device with the kernel.

SPI Driver Implementation

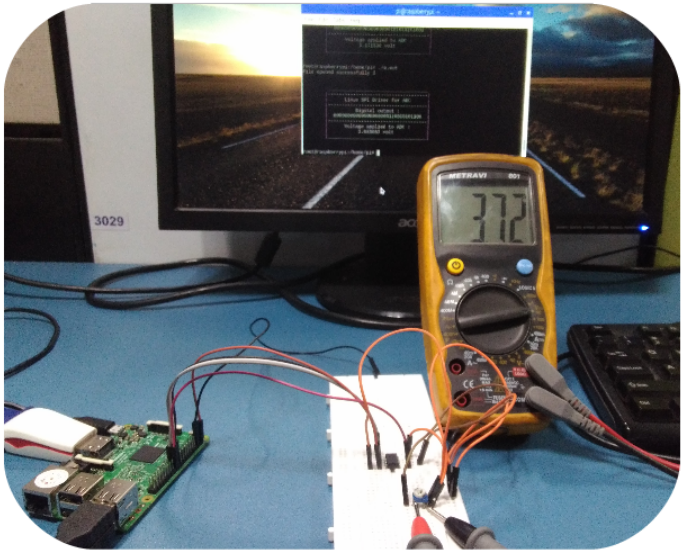
Function - read()

- Purpose is to read data from slave device i.e ADC.
- This function sends command to initialize ADC and simultaneously reads the conversion data from ADC, in its receiver buffer.
- Functions & structures used by read -
  - *struct spi_transfer*
  - *struct spi_message*
  - *spi_message_init()*
  - *spi_message_add_tail()*
  - *spi_sync()*

SPI Application Implementation

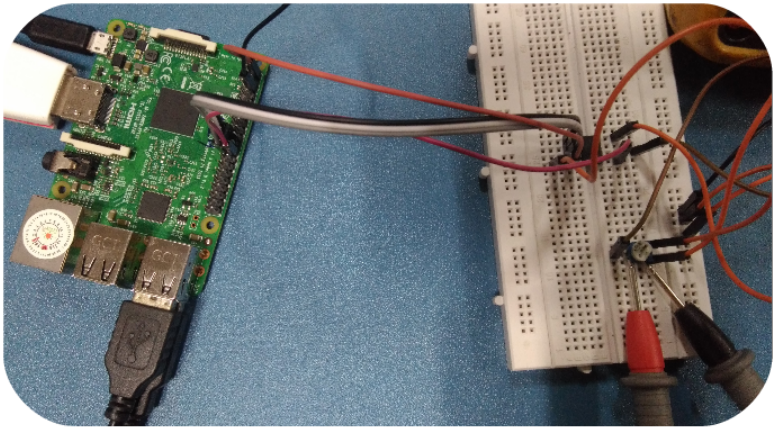


Snapshots



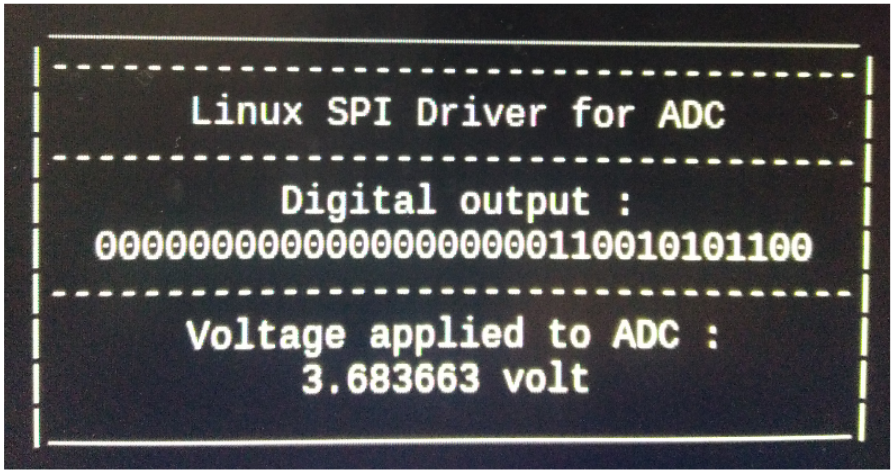
Whole Setup

Connection of ADC with Raspberry-Pi



Results

Voltage applied to ADC's input



Voltage obtained by SPI Application using Linux SPI Driver

Conclusion

SPI – A simple & easy protocol for Embedded Systems.

SPI have 4 modes depending on CPOL & CPHA.

Outcomes

A/D conversion using MCP3202.

Linux SPI Driver has 2 types – Protocol & Controller.

It is easy to write your own SPI driver using Linux's spi.c core.

References

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QUESTIONS?

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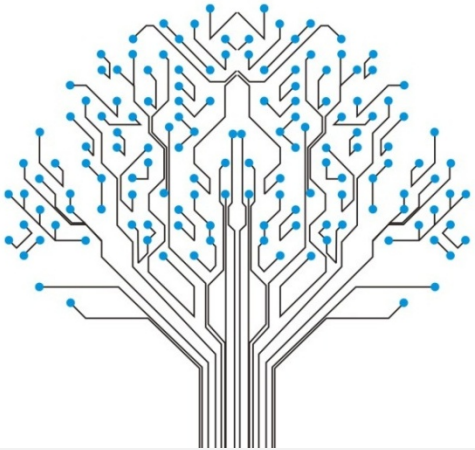

Fairness
Learning
Responsibility
Innovation
Respect