CHAPTER 1 : INTRODUCTION

In mobile communication, when we make a call, the signal first goes to the nearest Base Transceiver Station(BTS) where the processing of the signal is done and then it is forwarded. In this process, heat is generated at the cabin side at BTS. The heat generated is not normal and hence to cool the cabin an air conditioner is installed at every cabin.

Now, there are many BTS in a city and that many numbers of ACs installed at every cabin. So to operate each AC a man is required at each of them or else there will be loss of energy as during day time the calls made are mode than during night time resulting into more heat generation during day time. Hence, if the AC maintains less temperature during night time even if it is not required then loss of energy and if energy is to be saved then one man is required at each cabin. And then think of the man at BTS forgetting to close the door of cabin!

Think of a situation where only a single person sitting at a remote location can control the all the BTS station without requiring a man at the cabin. The remote person can set the temperature of the cabin wirelessly as per the requirement. He can also get the information whether the door of the cabin is open or closed. Even when there is a power cut then he may come to know the time at which the generator started and stopped. He can also know the back up battery bank voltage at the BTS.

All of the above conditions can be fulfilled by the device procell which has to be installed at every cabin and then just sit at one place and monitor all the BTS.

CHAPTER 2 : FUNCTIONAL UNITS

2.1) Different units:

Procell can be broadly classified as two functional units:

1)Remote Controller Station (RCS)

2)Procell device cabin

REMOTE CONTROLLER STATION:

It consists of kit with a wireless module and a keypad. The kit consists of a pic32 bit controller which does all the operation and also selects the mode of operation at the procell device cabin. There are two modes of operation which include:

1)Automatic mode: when the device procell operates.

2)Manual: when the functioning of the cabin is handled manually.

RCS defines the temperature range of the AC by signaling to the device remotely using wireless module. It also creates a database of all the events as per instructed by the device.

It uses a keypad to enter the temperature needed to be set by interfacing it with the controller.

DEVICE CABIN (BTS STATION) :

The BTS cabin has a processing unit of BTS which generates heat and hence cooling is required.For cooling purpose an Air Conditioner is already there at the device cabin whose temperature is to be set as per the requirement. Now, during daytime phone calls are made in more numbers than the night time and hence more cooling is to be required during day time and during night time the temperature of the surrounding is also low. Hence different temperatures should be set ideally to save power during different times but it is not done as a person is required at the BTS for every change.

Furthermore, the BTS cabin has a door which should be sensed so that the cooling of A.C doesn't get wasted away. And we should also monitor the battery bank voltage for allowing it to charge only when it has reached below cut off level. All these functionalities are achieved by the device procell which results in energy conservation.

Here also there is a pic32 microcontroller which is interfaced to temperature sensor(LM35) for sensing the temperature so that it can on or off the A.C according to the temperature set from the R.C.S side.

2.2) Block Diagram of Procell device:

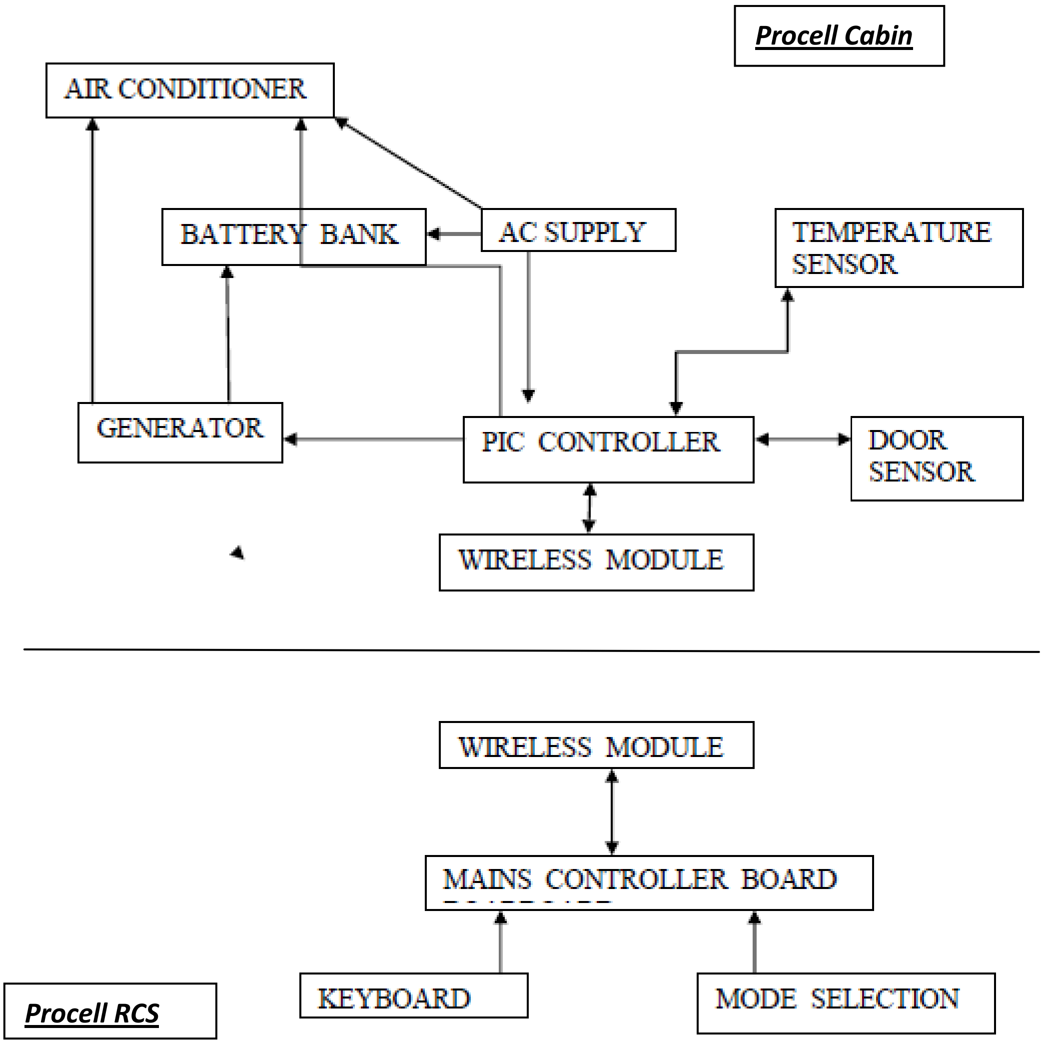


Figure 2.1 Block diagram of rocell device

CHAPTER 3 : FUNCTION SPECIFICATIONS

Different units that are functional in the device procell are as under:

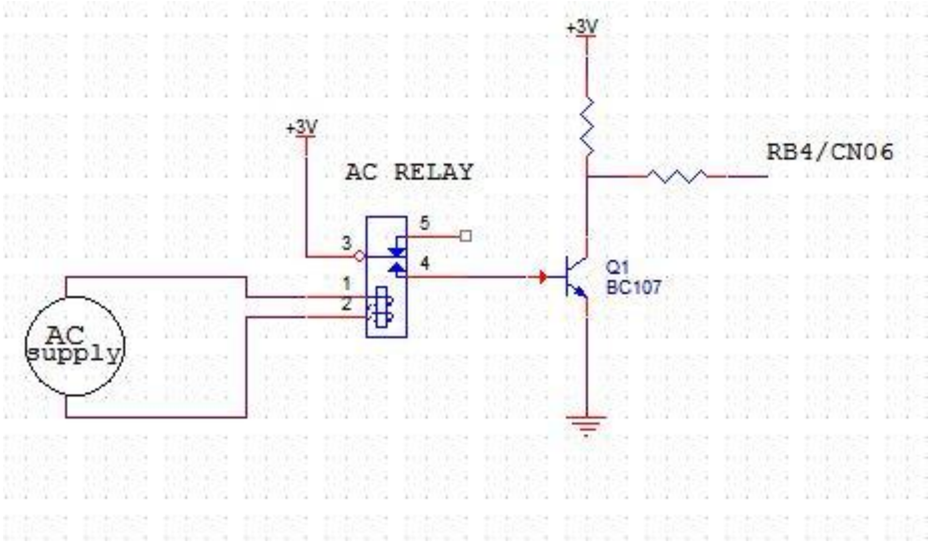
1) AC mains sensing
2) Battery bank sensing
3) Temperature sensing and AC(Air Conditioner) controlling
4) Door sensing
5) Generator controlling
6) wireless module
7) Mode selection unit

Taking each of this one by one and beginning with

<u>3.1) AC Mains Sensing :</u>

- The device has a unit that comprises of AC RELAY that energizes the coil when 230V AC supply is provided.
- To sense the AC mains, the input pin of the controller is pulled up with 220ohm resistor as shown in the figure below.
- If AC mains is there then the 3V is provided at the base of the transistoe and if AC mains is not there then the pulled up 3 volts is provided as input to the controller.
- For sensing this PIC controller has change notification pins which generate an interrupt when there is a change of state to that pin from '1' to '0' or '0' to '1'.

- If AC supply is there then LCD will display “supply on” and if not then it will display “generator on”.



(prepared in orcad) figure 3.1 AC relay circuit diagram

3.2) Battery Bank Sensing:

- The device continuously senses the voltage of the battery bank which is 48 volts and it switches on the battery when there is no AC supply.
- In the project the device senses dc voltage on the pin of a port which is connected through a potentiometer for varying the voltage.
- If the voltage at the pin drops below 1 volts i.e the cutoff level then the the controller shows indication by glowing the LEDs.

3.3) Temperature Sensing And AC Controlling:

- The temperature sensor LM35 senses continuously the temperature of the cabin.
- RCS has two temperature range one during day and another during night. Setting different temperature range during day and night is due to the fact that

during day the use of cell tower will be more than during night as at night people sleep except few.

- Durnig night time the heat generated by the BTS will be low and hence cooling required will be less so power consumption can be controlled.
- RCS wirelessly sends the temperature range to the device and the device switches off the air conditioner accordingly with the help of the DC relay.
- Hence setting two temp. ranges allows us to efficiently use the power by switching off the air conditioner when there is sufficient temperature in the ambience.

<u>3.4) Door Sensing :</u>

- Sensing whether the door is open or not is very essential since AC is cooling the cabin.
- A switch is used to sense whether the door is open or not. The controller sends the information regarding it to the RCS wirelessly.
- It also notes down the time when the door is opened so that the RCS can know the time for which it was open.

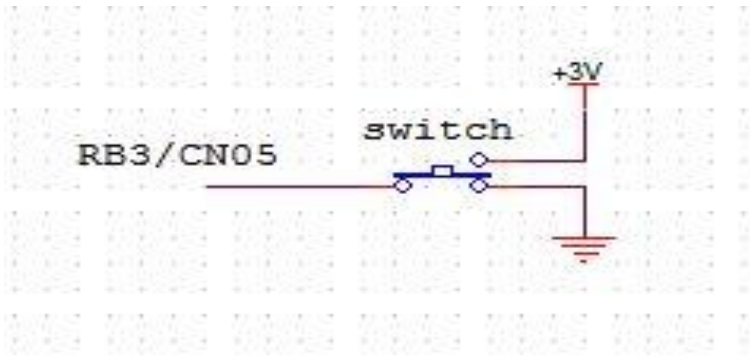


Figure 3.2 (Prepared in orcad) Switch for door

<u>3.5) Generator Controlling :</u>

- When the AC mains supply goes off and the AC needs to be on then generator has to be switched on.

- Hence at that time the controller checks the battery bank whether it is charged or not. If not then it immediately starts the generator but if the battery is charged then it will on the DG only when AC is on.

3.6) Wireless Module :

- Wireless module rfm-73 is used for wireless communication between the RCS and the procell device.
- The controller in the device monitors all the events and sends its information to the RCS through this module.
- The RCS sends the control information through this module to the device and the device sets itself accordingly.

3.7) Mode selection unit :

- The two modes in which the device operates are :

  1) Auto mode

  2) Manual mode

- The device normally operates in auto mode where everything is controlled automatically only the person sitting in the RCS has to give few commands if required to the device.
- Whereas in manual mode a person is present at the cabin who does each and everything manually with his hands like starting generator, controlling AC,etc
- The controller at the RCS sends the information to the device that whether it has to operate in auto mode or manual mode.
- The temp. range is set with the help of push button switches, one for increasing, one for decreasing and one to select menu.

CHAPTER 4 : DEVICES AND PERIPHERALS SPECIFICATIONS

4.1) Explorer 16 Development Board :

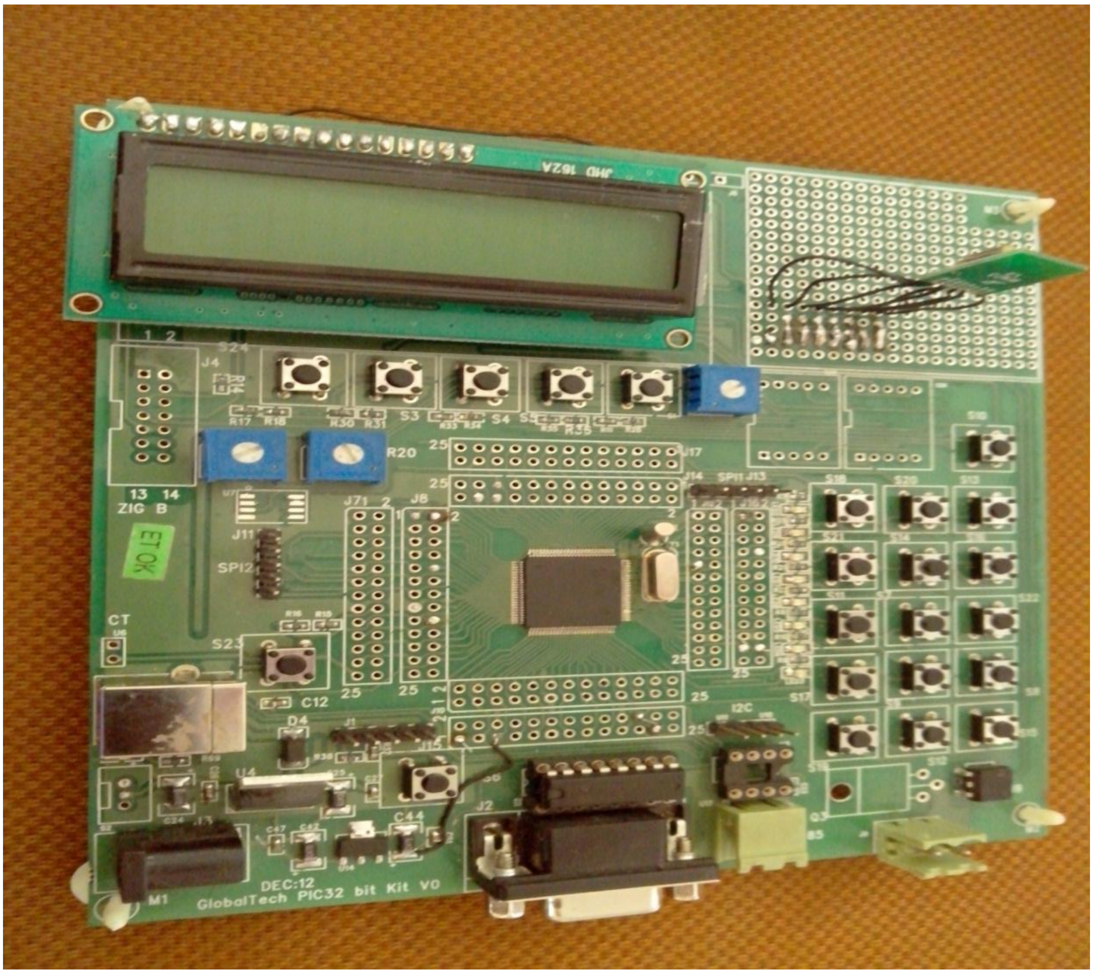


Figure 4.1 Explorer 16 board

1.10-pin PIMriser, compatible with the PIMversions of all Microchip PIC24F/24H/PIC32F/dsPIC33F devices

2. Direct 9 VDC power input that provides +3.3V and +5V (regulated) to the entire board

3. Power indicator LED

4. RS-232 serial port and associated hardware

5. On-board analog thermal sensor

6. USB connectivity for communications and device programming/debugging

7. Standard 6-wire In-Circuit Debugger (ICD) connector for connections to an MPLAB ICD 2 programmer/debugger module

8. Hardware selection of PIM or soldered on-board microcontroller (in future versions)

9. 2-line by 16-character LCD

10. Provisioning on PCB for add on graphic LCD

11. Push button switches for device Reset and user-defined inputs

12. Potentiometer for analog input

13. Eight indicator LEDs

14. 74HCT4053 multiplexers for selectable crossover configuration on serial communication lines

15. Serial EEPROM

16. Independent crystals for precision microcontroller clocking (8 MHz) and RTCC
operation (32.768 kHz)

17. Prototype area for developing custom applications

18. Socket and edge connector for PICtail™ Plus card compatibility

19. Six-pin interface for PICkit 2 Programmer

20. JTAG connector pad for optional boundary scan functionality

4.2) PIC32 Microcontroller:

The PIC32 controller used is PIC32MX575F256L of microchip family which is a 32 bit microcontroller with 256k flash memory having following features :

4.2.1) High-Performance 32-bit RISC CPU:

- MIPS32® M4K® 32-bit core with 5-stage pipeline
- 80 MHz maximum frequency
- 1.56 DMIPS/MHz (Dhrystone 2.1) performance at zero Wait state Flash access

• Single-cycle multiply and high-performance divide unit
• MIPS16e® mode for up to 40% smaller code size
• Two sets of 32 core register files (32-bit) to reduce interrupt latency
• Prefetch Cache module to speed execution from Flash

4.2.2) Microcontroller Features:

• Operating voltage range of 2.3V to 3.6V
• 64K to 512K Flash memory (plus an additional 12 KB of Boot Flash)
• 16K to 128K SRAM memory
• Pin-compatible with most PIC24/dsPIC® DSC devices
• Multiple power management modes
• Multiple interrupt vectors with individually programmable priority
• Fail-Safe Clock Monitor mode
• Configurable Watchdog Timer with on-chip Low-Power RC oscillator for reliable operation

4.2.3) Peripheral Features:

• Atomic SET, CLEAR and INVERT operation on select peripheral registers
• Up to 8-channels of hardware DMA with automatic data size detection
• USB 2.0-compliant full-speed device and On-The-Go (OTG) controller:
  - Dedicated DMA channels
• 10/100 Mbps Ethernet MAC with MII and RMII interface:
  - Dedicated DMA channels
• CAN module:
  - 2.0B Active with DeviceNet™ addressing support
  - Dedicated DMA channels
• 3 MHz to 25 MHz crystal oscillator
• Internal 8 MHz and 32 kHz oscillators
• Six UART modules with:
  - RS-232, RS-485 and LIN support
  - IrDA® with on-chip hardware encoder and decoder
• Up to four SPI modules

- Up to five I2C™ modules
- Separate PLLs for CPU and USB clocks
- Parallel Master and Slave Port (PMP/PSP) with 8-bit and 16-bit data, and up to 16 address lines
- Hardware Real-Time Clock and Calendar (RTCC)
- Five 16-bit Timers/Counters (two 16-bit pairs combine to create two 32-bit timers)
- Five Capture inputs
- Five Compare/PWM outputs
- Five external interrupt pins
- High-speed I/O pins capable of toggling at up to 80 MHz
- High-current sink/source (18 mA/18 mA) on all I/O pins
- Configurable open-drain output on digital I/O pins

4.2.4) Debug Features:

- Two programming and debugging Interfaces:
  - 2-wire interface with unintrusive access and real-time data exchange with application
  - 4-wire MIPS® standard enhanced Joint Test Action Group (JTAG) interface
- Unintrusive hardware-based instruction trace
- IEEE Standard 1149.2 compatible (JTAG) boundary scan

4.2.5) Analog Features:

- Up to 16-channel, 10-bit Analog-to-Digital Converter:
  - 1 Msps conversion rate
  - Conversion available during Sleep and Idle
- Two Analog Comparators

PIC32MX575F256L Microcontroller

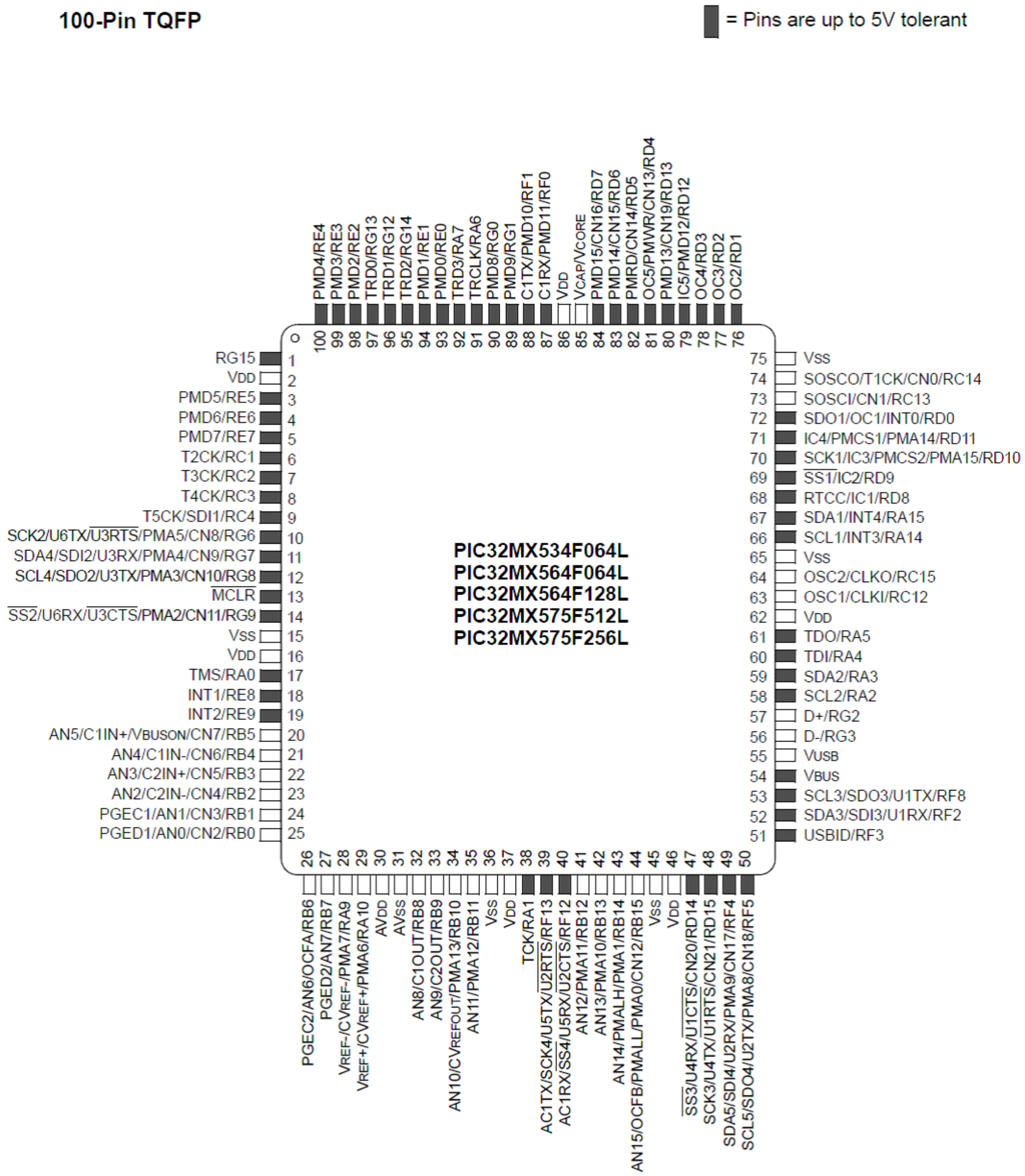


Figure 4.2   PIC32 Microcontroller

4.3) 2*16 Character LCD :

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- N.V. optional for + 3V power supply

4.4) Keypad:

- It is a 4*4 hex keypad which is connected to the pins of pic microcontroller on development board as :

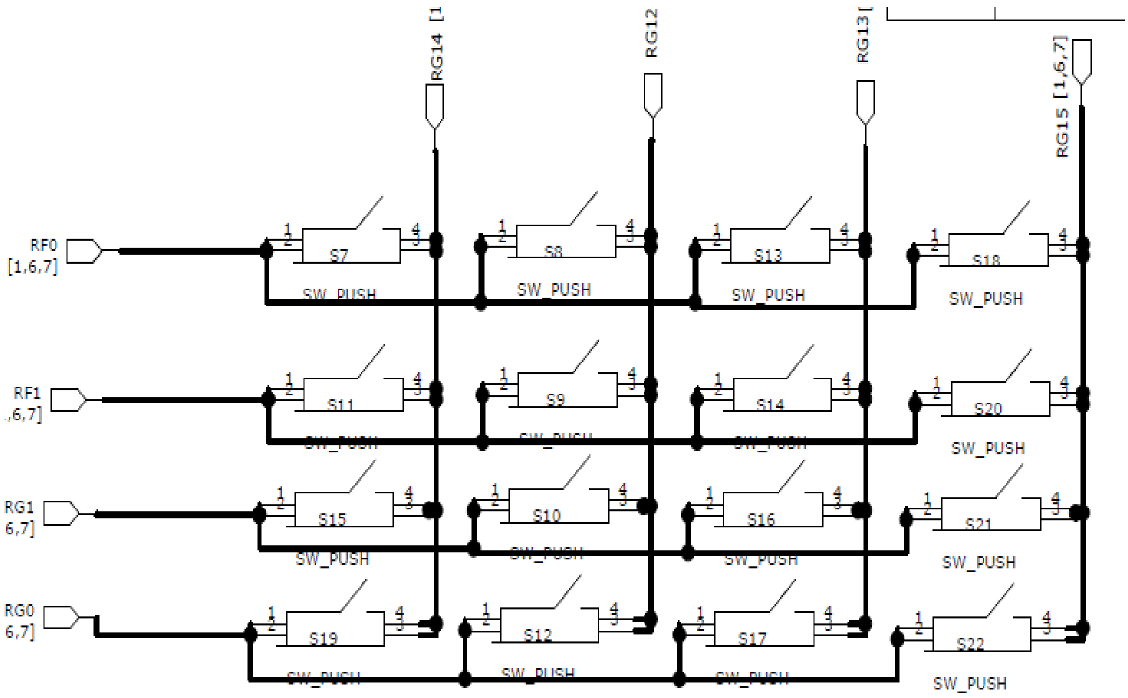


Figure 4.3 keypad in explorer 16 board

- In keypad, all columns are pull down. One row is given a logic high('1’) at a time and all other rows zero and then all the columns are checked whether any one is high or not. And then the next row is given a high and all other rows zero and then all the columns are checked again and likewise.
- Now, if any key is pressed then the corresponding column is set high and accordingly we can determine which key is pressed.

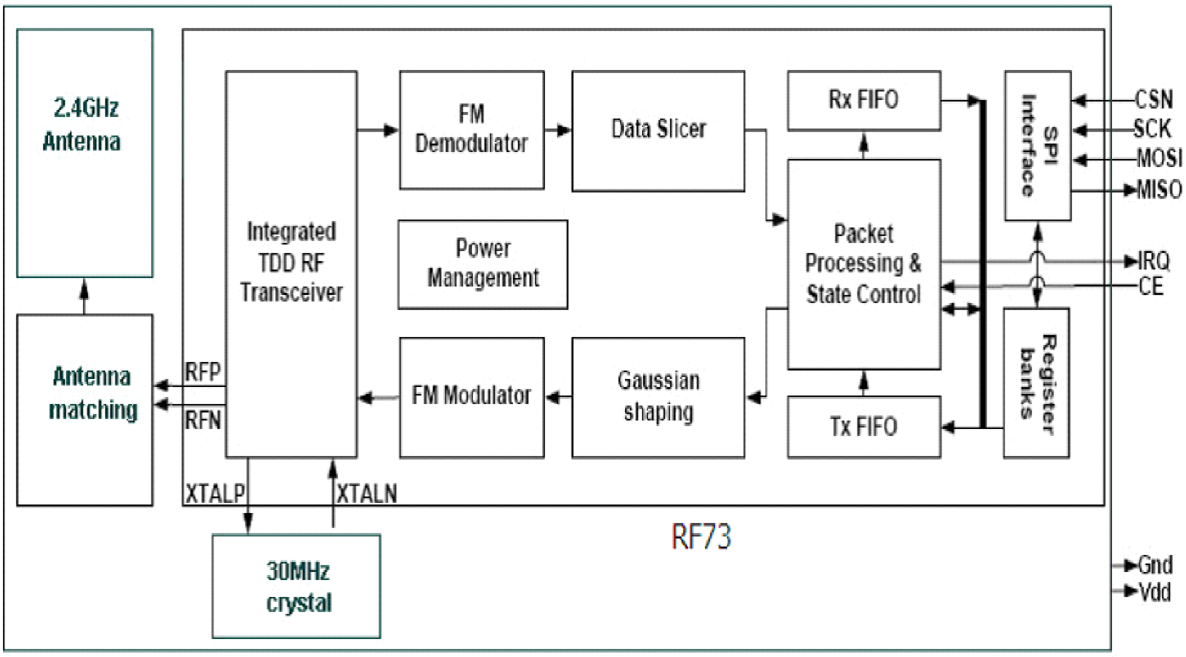
4.5) Wireless Module :

It is a transceiver module which is used for communication between the RCS and procell cabin wirelessly.

Features :

- 2400-2483.5 MHz ISM band operation
- Support 250Kbps, 1Mbps and 2 Mbps air data rate
- Programmable output power
- Low power consumption
- Tolerate +/- 60ppm 16 MHz crystal
- Variable payload length from 1 to32bytes
- Automatic packet processing
- 6 data pipes for 1:6 star networks
- 1.9V to 3.6V power supply
- 4-pin SPI interface with maximum 8MHz
- clock rate
- Compact 20-pin 3x3 or

Block Diagram



RFM73 Block Diagram

Figure 4.4 Block Diagram of RFM73

General Description

RFM73 is a GFSK transceiver operating in the world wide ISM frequency band at 2400- 2483.5 MHz. Burst mode transmission and up to 2Mbps air data rate make them suitable for applications requiring ultra low power consumption. Auto re-transmission and auto acknowledge give reliable link without any MCU interference. RFM73 operates in TDD mode, either as a transmitter or as a receiver. The RF channel frequency determines the center of the channel used by RFM73. The frequency is set by the RF_CH register in register bank 0 according to the following formula: F0= 2400 + RF_CH (MHz). The resolution of the RF channel frequency is 1MHz. A transmitter and a receiver must be programmed with the same RF channel frequency to be able to communicate with each other. The output power of RFM73 is set by the RF_PWR bits in the RF_SETUP register. Demodulation is done with embedded data slicer and bit recovery logic. The air data rate can be programmed to 250Kbps, 1Mbps or 2Mbps by RF_DR_HIGH and RF_DR_LOW register. A transmitter and a receiver must be programmed with the same setting.

3 Pin Information

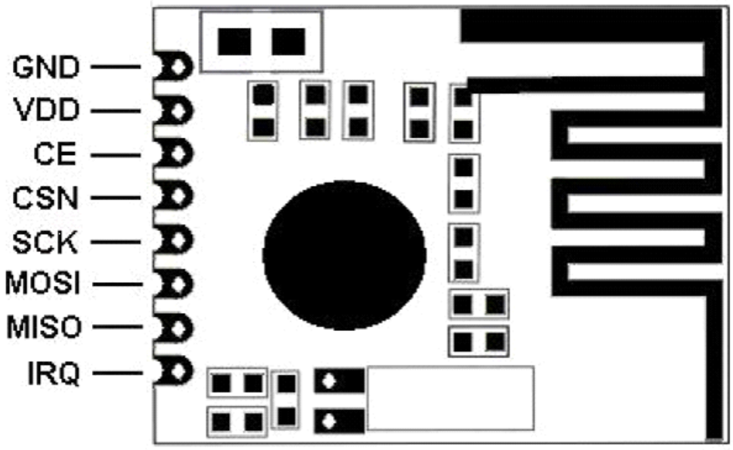


Figure 4.5 Pin Information of RFM 73

Name	Pin Function	Description
GND	Ground	Ground (0 V)
VDD	Power	Power Supply (1.9 V to 3.6 V DC)
CE	Digital Input	Chip Enable Activates RX or TX mode
CSN	Digital Input	SPI Chip Select, Active low
SCK	Digital Input	SPI Clock
MOSI	Digital Input	SPI Slave Data Input
MISO	Digital Output	SPI Slave Data Output with tri-state option
IRQ	Digital Output	Maskable interrupt pin, Active low

Table 4.1 Pin function of RFM 73

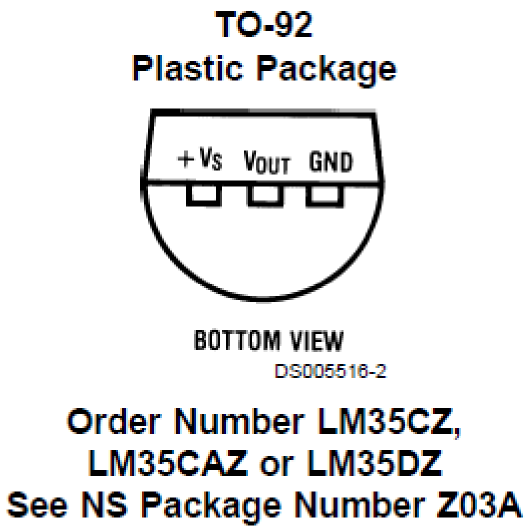
<u>4.6) Temperature Sensor :</u>

The LM35 series are precision integrated-circuit temperaturesensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a largeconstant voltage from its output to obtain convenient Centigrade scaling.

Feature Of LM35 :

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±1⁄4°C typical
- Low impedance output, 0.1 W for 1 mA load

LM35 is a 3 pin IC as shown in the figure below :



TO-92 Package, −60°C to +150°C

Figure 4.6 LM35

4.7) EXTERNAL MEMORY :

- The 25XX256 is a 32,768-byte Serial EEPROM designed to interface directly with the Serial Peripheral Interface (SPI) port of many of today's popular microcontroller families, including Microchip's PIC micro® microcontrollers.

- The 25XX256 contains an 8-bit instruction register. Thedevice is accessed via the SI pin, with data being clocked in on the rising edge of SCK. The CS pin must be low and the HOLD pin must be high for the entire operation. All instructions, addresses, and data are transferred MSB first, LSB last.

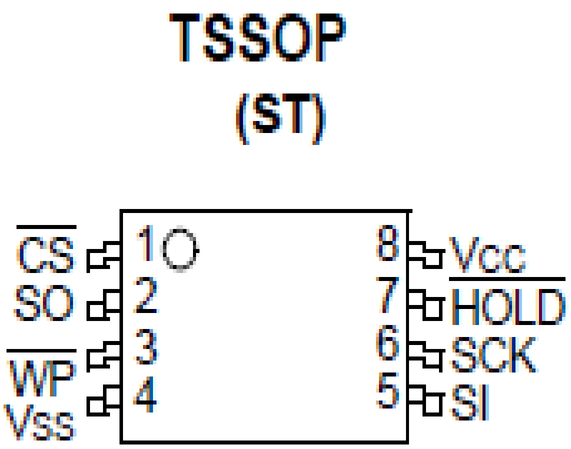


Figure 4.7 EEPROM pin diagram

Features:

• Max. clock 10 MHz

• Low-power CMOS technology:

- Max. Write Current: 5 mA at 5.5V, 10 MHz
- Read Current: 6 mA at 5.5V, 10 MHz
- Standby Current: 1 µA at 5.5V

• 32,768 x 8-bit organization

• 64 byte page

• Self-timed erase and write cycles (5 ms max.)

• Block write protection:

- Protect none, 1/4, 1/2 or all of array

• Built-in write protection:

- Power-on/off data protection circuitry

- Write enable latch

- Write-protect pin

• Sequential read

• High reliability:

- Endurance: 1,000,000 erase/write cycles

- Data retention: > 200 years

- ESD protection: > 4000V

• Temperature ranges supported:

• Pb-free packages available

Pin Function Table

Name	Function
$\overline{CS}$	Chip Select Input
SO	Serial Data Output
$\overline{WP}$	Write-Protect
Vss	Ground
SI	Serial Data Input
SCK	Serial Clock Input
$\overline{HOLD}$	Hold Input
Vcc	Supply Voltage

Table 4.2 Pin Function Table of EEPROM

4.8) Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact(s) either makes or breaks (depending upon construction) a connection with a fixed contact**.**

Normally-open (NO) contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.

Normally-closed (NC) contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.

<u>SPST</u> – Single Pole Single Throw. These have two terminals which can be connected or disconnected. Including two for the coil, such a relay has four terminals in total. It is ambiguous whether the pole is normally open or normally closed. The terminology "SPNO" and "SPNC" is sometimes used to resolve the ambiguity.
<u>SPDT</u> – Single Pole Double Throw. A common terminal connects to either of two others. Including two for the coil, such a relay has five terminals in total.
<u>DPST</u> – Double Pole Single Throw. These have two pairs of terminals. Equivalent to two SPST switches or relays actuated by a single coil. Including two for the coil, such a relay has six terminals in total. The poles may be Form A or Form B (or one of each).
<u>DPDT</u> – Double Pole Double Throw. These have two rows of change-over terminals. Equivalent to two SPDT switches or relays actuated by a single coil. Such a relay has eight terminals, including the coil.

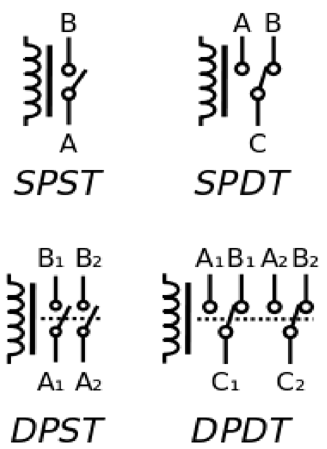
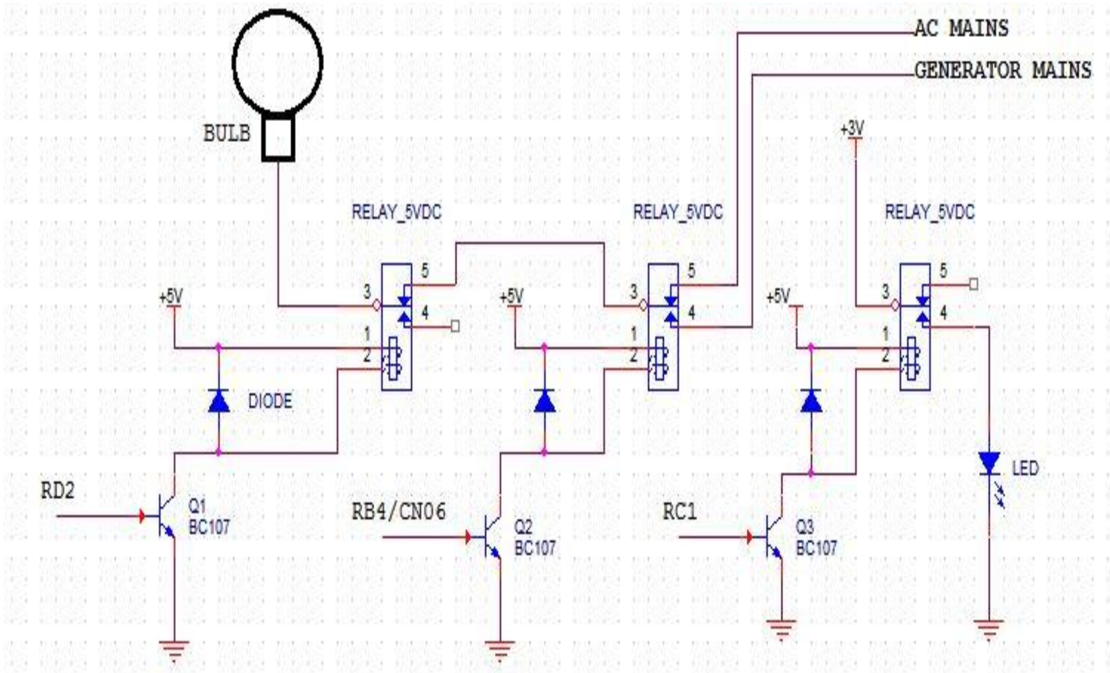


Figure 4.8 Different types of Relay

4.8.1) Types of Relay :

8.1.1) AC Relay : In AC relay, the coil is energized with the 230V AC supply. The use of AC relay in the roject in described earlier in the topic AC mains sensing.

8.1.2) DC Relay: In DC relay, the coil is energized with the DC voltage applied to its control pin.



(prepared in ORCAD) Figure 4.9 DC relay circuit diagram

As, shown in the figure, when the controller senses that there is no AC mains as described earlier then it will provide the control signal at pin RB4 to switch it on. It can be seen that the output of the central relay goes to the input of the relay with a bulb. The bulb is considered the air conditioner which has to be on if AC mains is there or it operates on generator. For controlling the air conditioner it is switched off when it reaches sufficient temperature by providing control signal ‘0’ at RD2 pin.

Now, the third relay on the right side is of charging the battery bank. When the controller senses that the battery voltage is below cut-off level then it signals the relay of battery bank by providing the control signal from the pin RC1 of the controller.

To drive a 6V DC relay, we need to give atleast 5V DC voltage. For this purpose, transistor is used whose collector is given a constant DC voltage of 5V from the power supply and the emitter is grounded. So, when the control signal is provided at the base of the transistor then the circuit gets complete and hence the relay is energized.

CHAPTER 5 : SCHEMATICS

SCHEMATICS

Schematics of the RCS and procell cabin are made in ORCAD 9.2 software.

5.1) PROCELL CABIN SIDE:

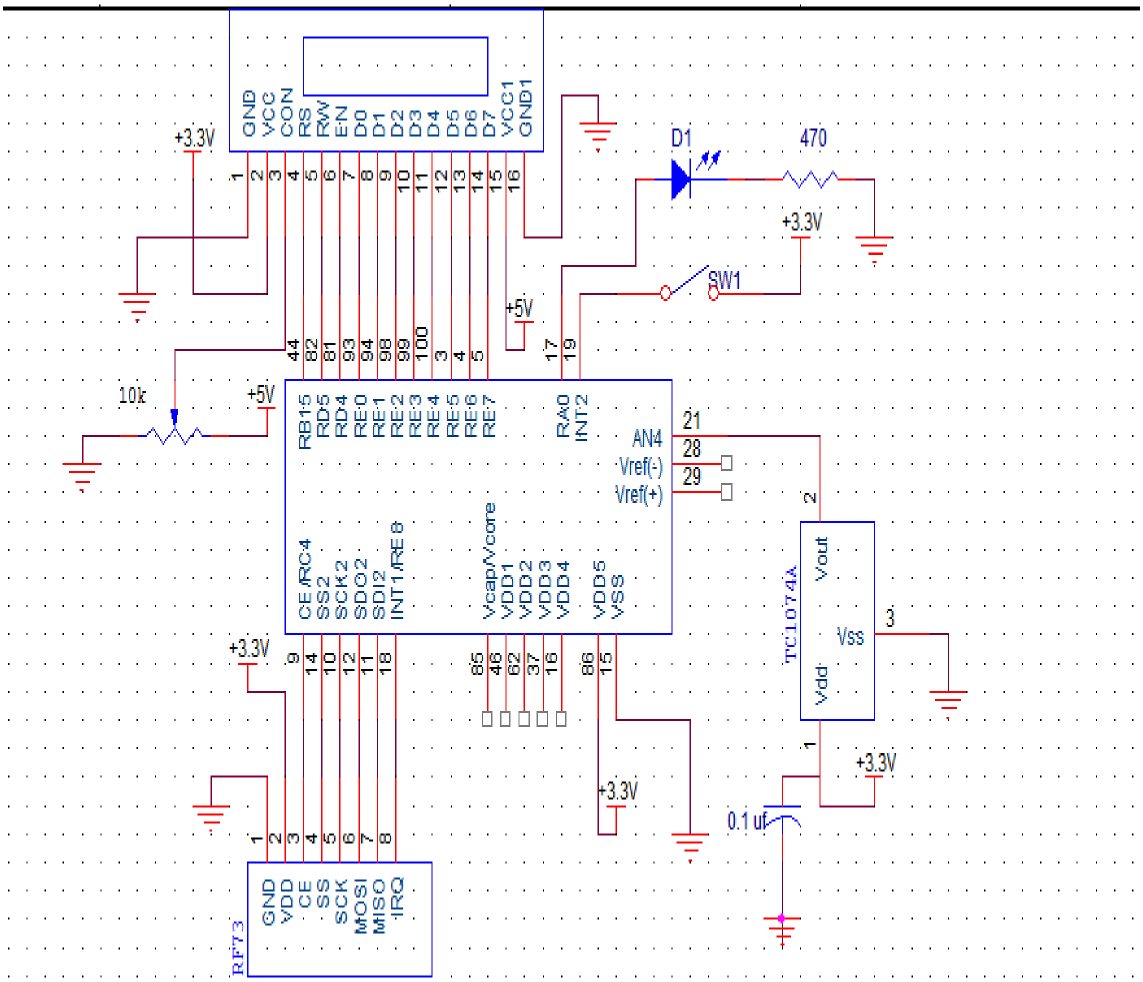


Figure 5.1 Procell device cabin side circuit diagram

5.2) PROCELL REMOTE CONTROL STATION (RCS) :

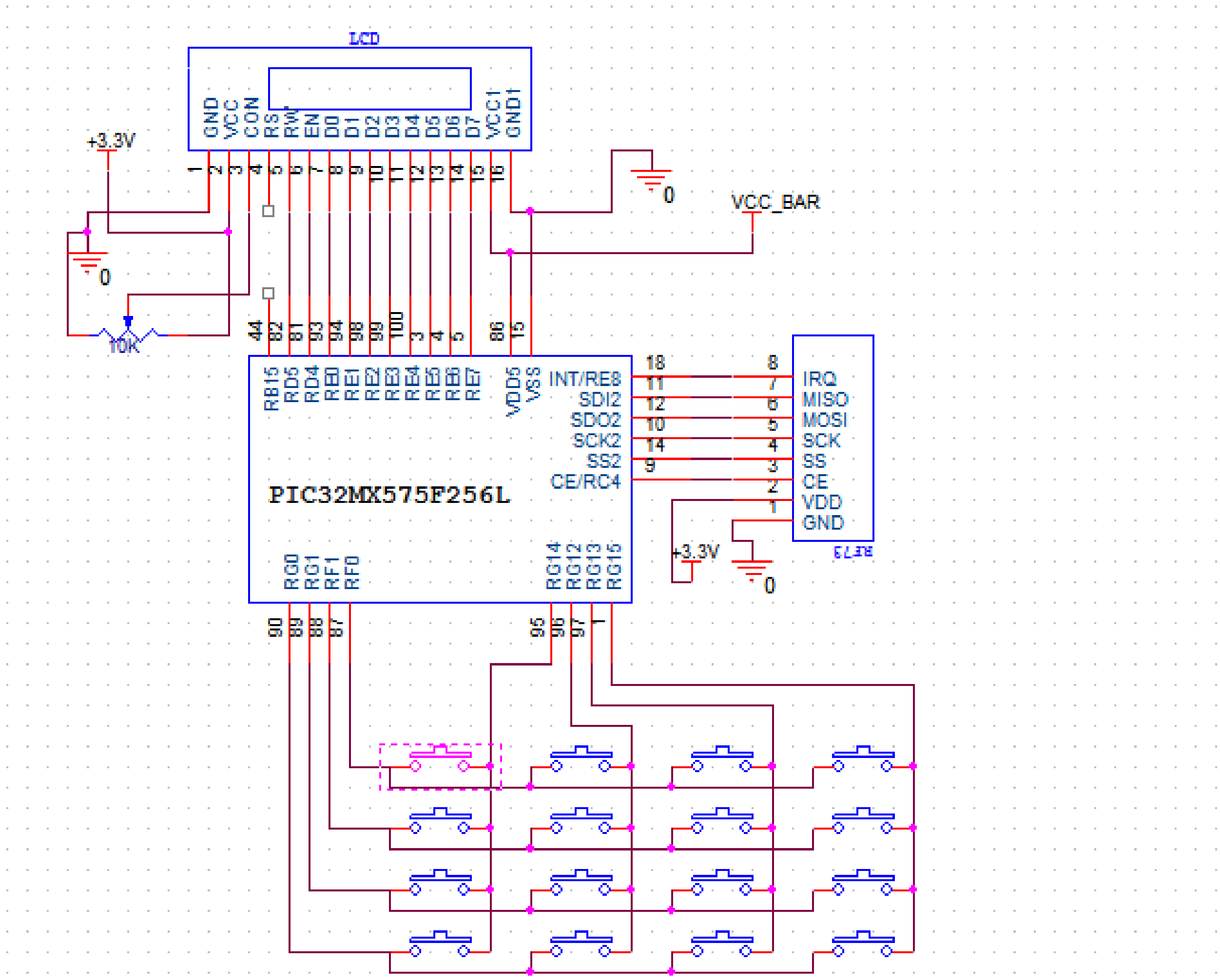


Figure 5.2 Procell device RCS side circuit diagram

CHAPTER 6 : BOOT LOADER AND SPI

6.1) INTRODUCTION

- ***Boot loader is used for what?***
  - The boot loader for PIC32 devices is used to upgrade firmware on a target device without the need for an external programmer or debugger.
- ***Boot loader applications:***
  - Five boot loader firmware implementations:

    - Universal Asynchronous Receiver Transmitter (UART)
    - Universal Serial Bus (USB) device based on the Human Interface Device (HID) class
    - USB host based on the Mass Storage Device (MSD) class
    - Ethernet
    - Secure Digital (SD) card
  - A demonstration application, which can be Downloaded into the target PIC32 device using the Boot loader
  - A PC host application (required for UART, USB HID and Ethernet boot loaders only) to communicate with The boot loader firmware running inside the PIC32

    Device. This application is used to perform erase and programming operations.

- ***Prerequisites:***
  - A PC with MPLAB® IDE version 8.60 or later, or MPLAB X Beta version 7.12 or later installed, and the C32 compiler version 2.01 or later installed.
  - A USB-to-serial port converter for the UART boots loader.

- A USB Flash drive for use with the USB mass storage boot loader.
- A SD card for use with the SD card boot loader.
- An Ethernet (RJ-45) crossover cable for use with the Ethernet boot loader.
- A traditional programming tool for initially writing the boot loader firmware into the PIC32 device (such as MPLAB® REAL ICE™ In-Circuit Emulator or the
- MPLAB ICD 3 In-Circuit Debugger). PIC32 starter kits do not require any programming tools
- Before using the PIC32 Boot loader, the user should be familiar with the following concepts:
  - PIC32 device Configuration registers
  - Compiling and programming a PIC32 device
  - PIC32 linker scripts

6.2) BASIC FLOW OF THE BOOTLOADER

- The flowchart in Fig. 1 illustrates the operation of the boot loader appli-cation. The boot loader code starts executing on a device Reset. If there are no conditions to enter the firmware upgrade mode, the boot loader starts executing the user application. The boot loader performs Flash erase/ prog-ram operations while in the firmware upgrade mode.

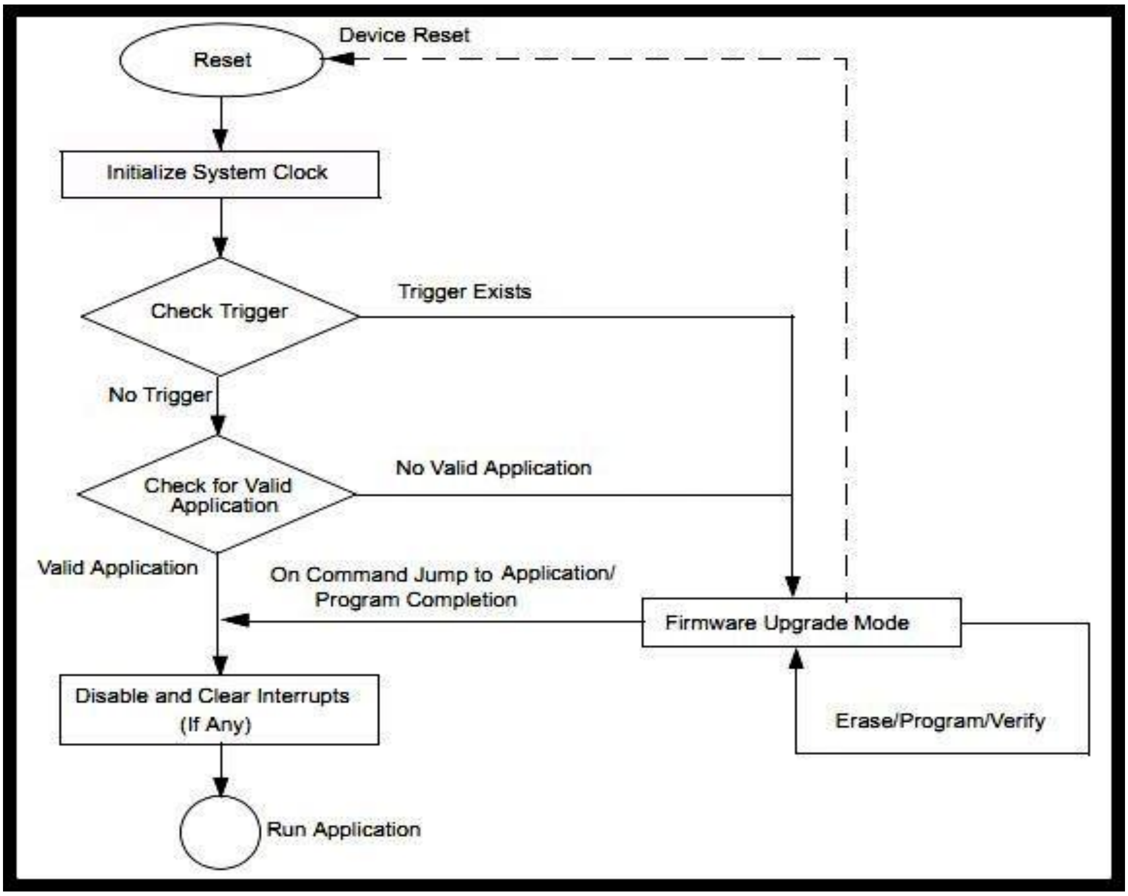


Figure 6.1 Basic flow of bootloader

➢ *Entering the Firmware Upgrade Mode:*

- On a device Reset, the boot loader forces itself into the firmware upgrade mode if the content of the user application's reset vector address is erased. To manually force the boot loader into the firmware upgrade mode, press and hold the switch, S3, on the Explorer 16 Development Board during power-up. On PIC32 starter kits, press and hold the switch, SW3, during power-up. While in firmware upgrade mode, the LED labeled D5 on the Explorer 16 Development Board and the LED labeled LED3 on the PIC32 starter kit will blink.

➢ ***IMPLEMENTATION OVERVIEW (UART, USB HID, AND ETHERNET)***

- The boot loader application is implemented using a framework. The boot loader firmware communicates with the PC host application by using a predefined communication protocol. The boot loader framework provides Application Programming Interface (API) functions to handle the protocol related frames from the PC application. For more information on the communication protocol.

➢ ***FRAMEWORK (UART, USB HID, AND ETHERNET)***

- Fig. 2 illustrates the boot loader architecture. The boot loader framework provides several API functions, which can be called by the boot loader application and the transport layer. The boot loader framework assists
  the user to easily modify the boot loader application to adapt to different requirements.

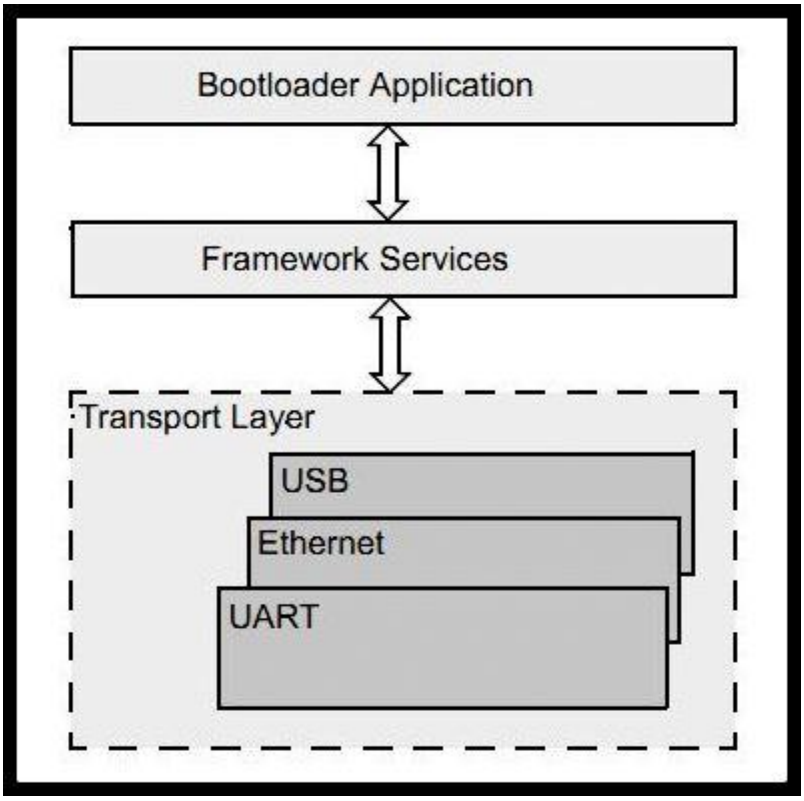


Figure 6.2 Framework

The `Bootloader.c` file contains the boot loader application code. This file includes the boot loader functionality, and is illustrated in Fig.1

6.3) SPI

6.3.1Introduction

The Serial Peripheral Interface (SPI) module is a synchronous serial interface useful for communicating with external peripherals and other microcontroller devices. These peripheral devices may be a serial EEPROM, shift register, display driver, Analog -to-Digital Converter (ADC), or an audio codec. The PIC32 family SPI module is compatible with Motorola SPI and SIOP interfaces.

6.3.2Key Features of SPI

Master and Slave modes support

Four different clock formats

Framed SPI protocol support

Standard and Enhanced Buffering modes (Enhanced buffering mode is not available on all devices)

User-configurable 8-bit, 16-bit, and 32-bit data width

SPI receive and transmit buffers are FIFO buffers, which are 4/8/16 deep in Enhanced Buffering mode

Programmable interrupt event on every 8-bit, 16-bit, and 32-bit data transfer

Audio Protocol Interface mode

Some PIC32 devices support audio codec serial protocols such as Inter-IC Sound (I2S),Left-Justified, Right-Justified, and PCM/DSP modes for 16, 24, and 32-bit audio data.

6.3.3SPI Specifications

The SPIx serial interface consists of four pins:

SDIx: Serial Data Input

SDOx: Serial Data Output

SCKx: Shift Clock Input or Output

SSx: Active-Low Slave Select or Frame Synchronization I/O Pulse

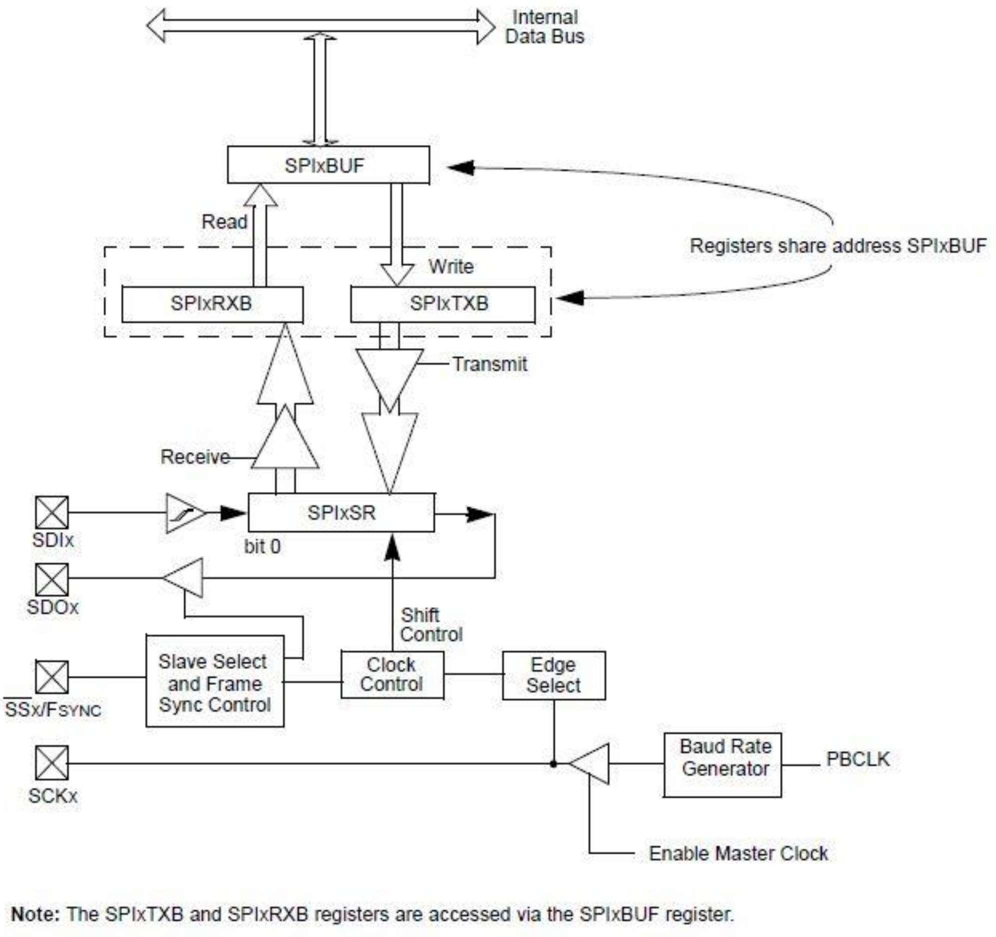


Fig. 6.3 Block diagram of the SPI module

6.3.4) Some Notes for SPI:

The SPIx Receive Buffer (SPIxRXB) and SPIx Transmit Buffer (SPIxTXB) registers are accessed via theSPIxBUF register and are multi-element FIFO buffers in Enhanced Buffer mode (pointer arithmetic is circular for these buffers). Enhanced Buffer mode is not available on all devices. Refer to the specific device data sheet for availability.

The SPIx Shift Register (SPIxSR) is not directly accessible by application software.

When the CPU Read Pointer (CRPTR) is less than or equal to the SPI Write Pointer (SWPTR). The CRPTR is incremented when the application reads a data element from the SPIxRXB register, and the SWPTR is incremented when a data element is moved from the SPIxSR register to the SPIxRXB register.

The SPI Read Pointer (SRPTR) is less than or equal to the CPU Write Pointer (CWPTR). The CWPTR is incremented when the application writes a new data element to the SPIxBUF register, and the SRPTR is incremented when data is moved from the SPIxTXB register to the SPIxSR register

6.3.5) Normal Mode SPI operation :

In Normal mode operation, the SPI Master controls the generation of the serial clock. The number of output clock pulses corresponds to the transfer data width: 8, 16, or 32 bits. Figure 1-2 and Figure 1-3 illustrate SPI Master-to-Slave and Slave-to-Master device connections.

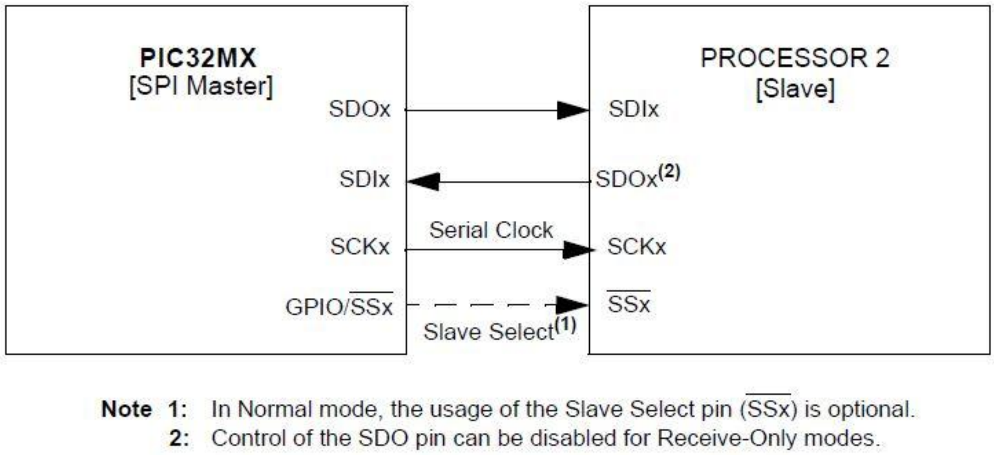


Fig 6.4 Typical SPI Master-to-slave Device Connection Diagram

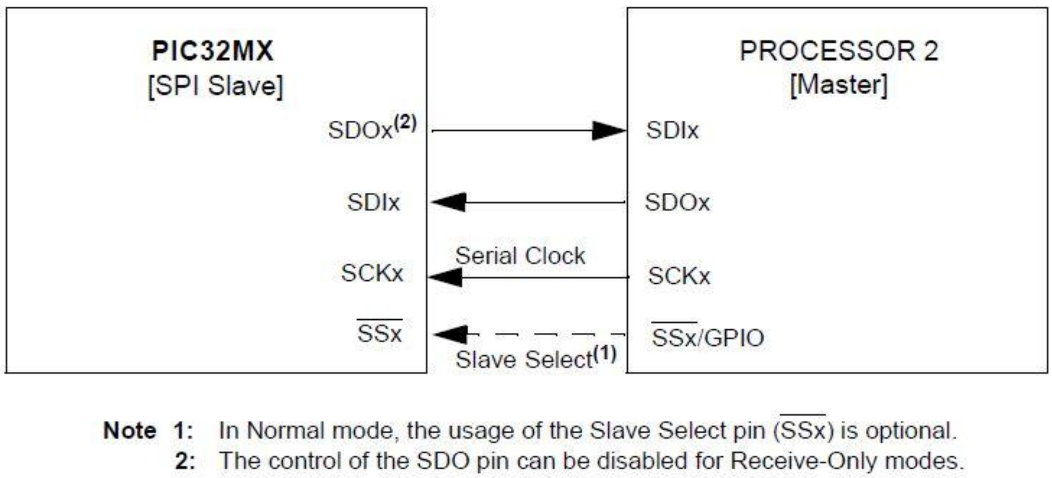


Fig 6.5 Typical SPI slave-to-Master Device Connection Diagram

6.3.6) Framed Mode SPI Operation :

In Framed mode operation, the Frame Master controls the generation of the frame synchronization pulse. The SPI clock is still generated by the SPI Master and is continuously running. Figure 1.4 and Figure 1.5 illustrate SPI Frame Master and Frame Slave device connections.

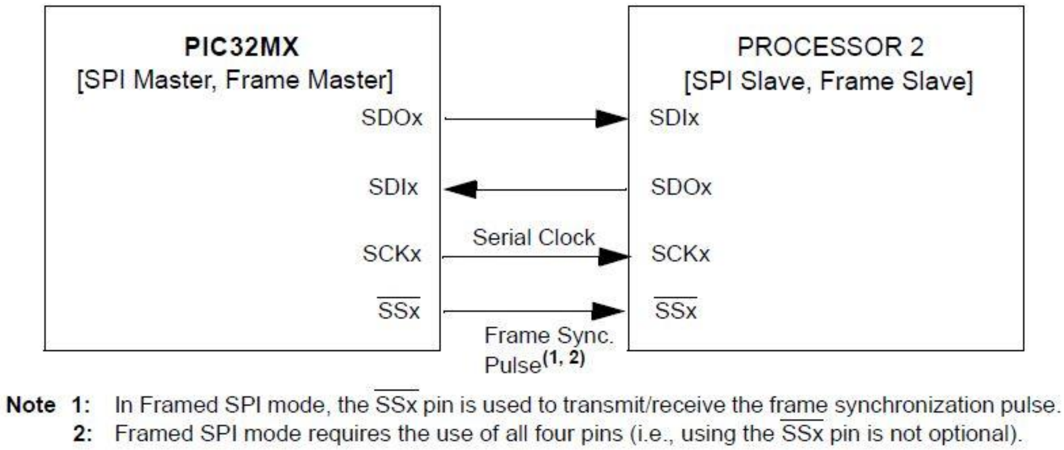


Fig 6.6 Typical SPI Master, Frame Master Connection Diagram

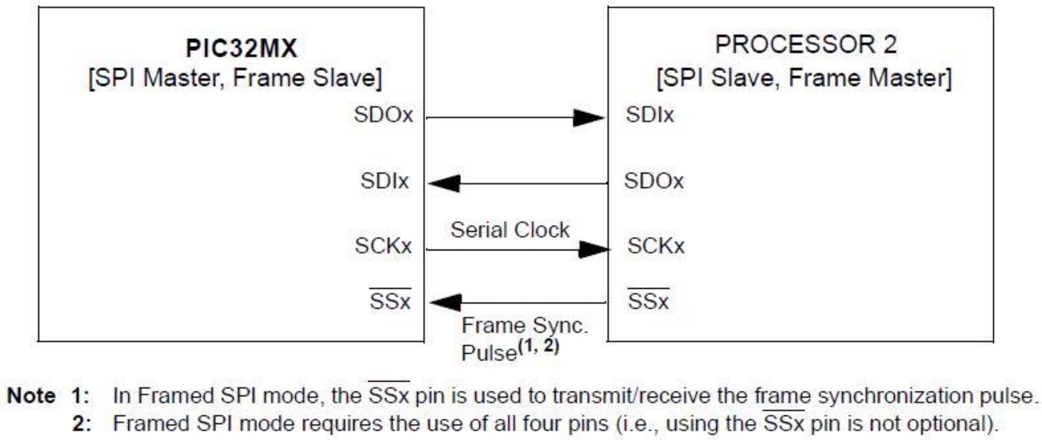


Fig 6.7 Typical SPI Slave, Frame Slave Connection Diagram

6.3.7) Status and Control Registers :

The SPI module consists of the following Special Function Registers (SFRs):

SPIxCON: SPI Control Register

SPIxCON2: SPI Control Register 2

SPIxSTAT: SPI Status Register

SPIxBUF: SPI Buffer Register

SPIxBRG: SPI Baud Rate Register

6.3.8) SPIxCON Register :

R/W-0	R/W-0	R/W-0	r-x	r-x	r-x	r-x	r-x
FRMEN	FRMSYNC	FRMPOL	—	—	—	—	—
bit 31							bit 24

r-x	r-x	r-x	r-x	r-x	r-x	R/W-0	r-x
—	—	—	—	—	—	SPIFE	—
bit 23							bit 16

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
ON	FRZ	SIDL	DISSDO	MODE32	MODE16	SMP	CKE
bit 15							bit 8

R/W-0	R/W-0	R/W-0	r-x	r-x	r-x	r-x	r-x
SSEN	CKP	MSTEN	—	—	—	—	—
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	P = Programmable bit	r = Reserved bit
U = Unimplemented bit	-n = Bit Value at POR: ('0', '1', x = Unknown)		

Figure 6.8 SPIxCON register

6.3.8) SPI Master Mode Clock Frequency :

The SPI module allows flexibility in baud rate generation through the 9-bit SPIxBRG register. SPIxBRG is readable and writable, and determines the baud rate. The peripheral clock PBCLK provided to the SPI module is a divider function of the CPU core clock. This clock is divided based on the value loaded into SPIxBRG. The SCKx clock obtained by dividing PBCLK is of 50% duty cycle and it is provided to the external devices via the SCKx pin.

$$F_{SCK} = \frac{F_{PB}}{2 * (SPIxBRG+1)}$$

CHAPTER 7

INTRODUCTION TO THE WIRELESS MODULE RFM73

Low Power High Performance 2.4 GHz GFSK Transceiver

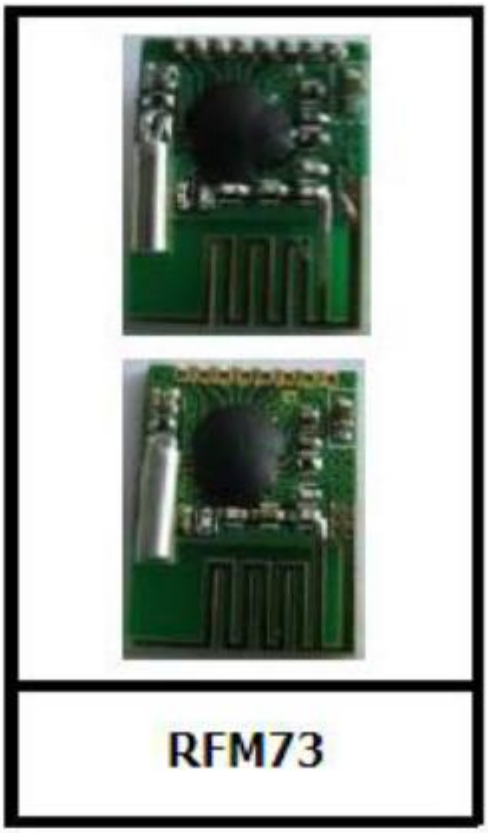


Fig 7.1:real figure of RFM73

<u>7.1 Features :</u>

2400-2483.5 MHz ISM band operation.

Support 250Kbps, 1Mbps and 2 Mbps air data rate.

Programmable output power.

Low power consumption.

Tolerate +/- 60ppm 16 MHz crystal.

Variable payload length from 1 to32bytes.

Automatic packet processing.

6 data pipes for 1:6 star networks.

1.9V to 3.6V power supply.

4-pin SPI interface with maximum 8MHz clock rate.

Compact 20-pin 3x3 or 4x4mm QFN.

7.2 block diagram :

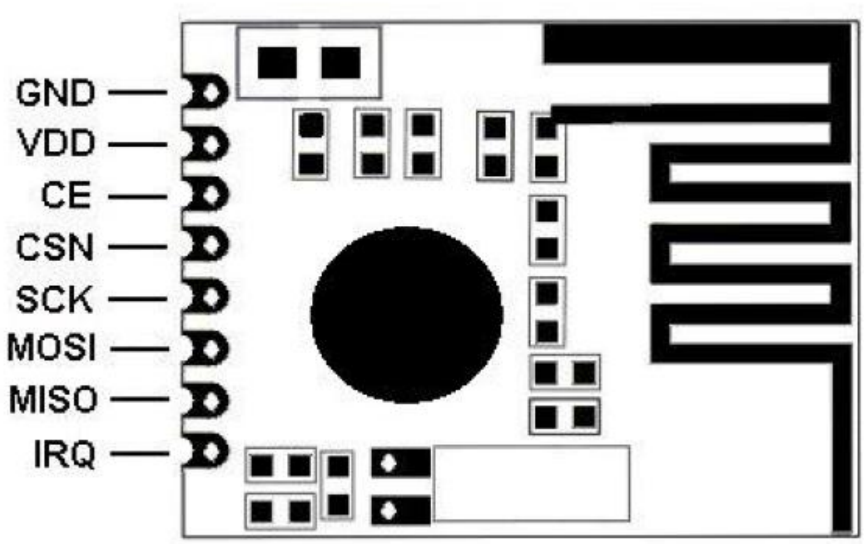


Fig 7.2:pin description of RFM73.

7.3 PTX control state diagram :

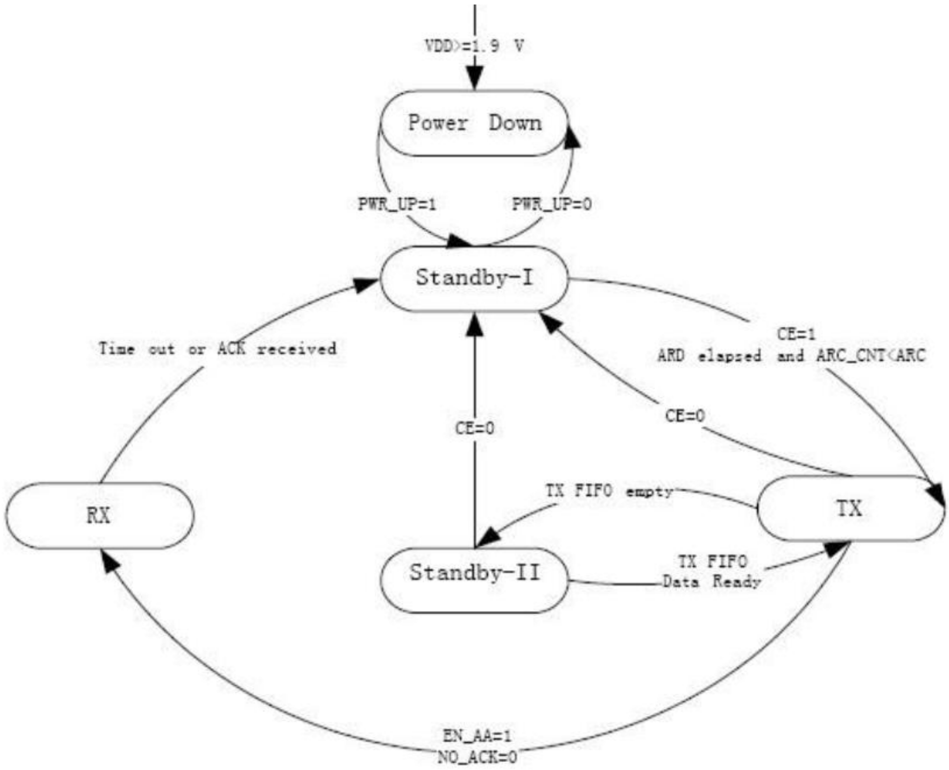


Figure 7.3 : PTX control state diagram

7.4 PRX control state diagram :

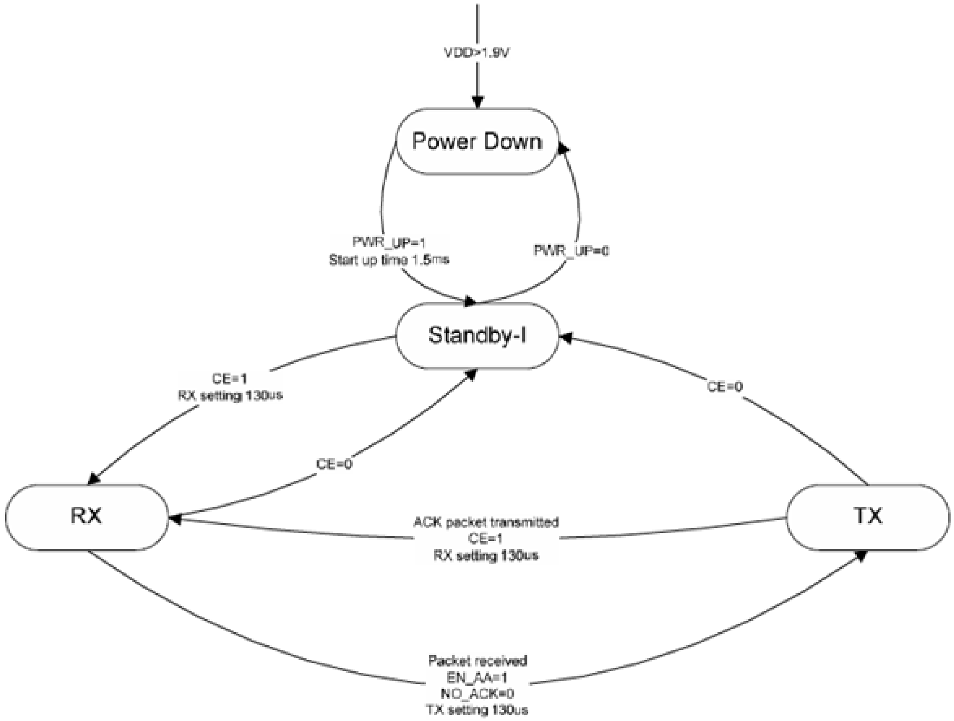


Fig 7.4:PRX state control diagram.

7.5 modes for rfm73:

7.5.1 Power Down Mode

In power down mode RFM73 is in sleep mode with minimal current consumption. SPI interface is still active in this mode, and all register values are available by SPI. Power down mode is entered by setting the PWR_UP bit in the CONFIG register to low.

7.5.2 Standby-I Mode

By setting the PWR_UP bit in the CONFIG register to 1 and de-asserting CE to 0, the device enters standby-I mode. Standby-I mode is used to minimize average current consumption while maintaining short start-up time. In this mode, part of the crystal oscillator is active. This is also the mode which the RFM73 returns to from TX or RX mode when CE is set low.

7.5.3 Standby-II Mode

In standby-II mode more clock buffers are active than in standby-I mode and much more current is used. Standby-II occurs when CE is held high on a PTX device with empty TX FIFO. If a new packet is uploaded to the TX FIFO in this mode, the device 0will automatically enter TX mode and the packet is transmitted.

7.6 Detail analysis

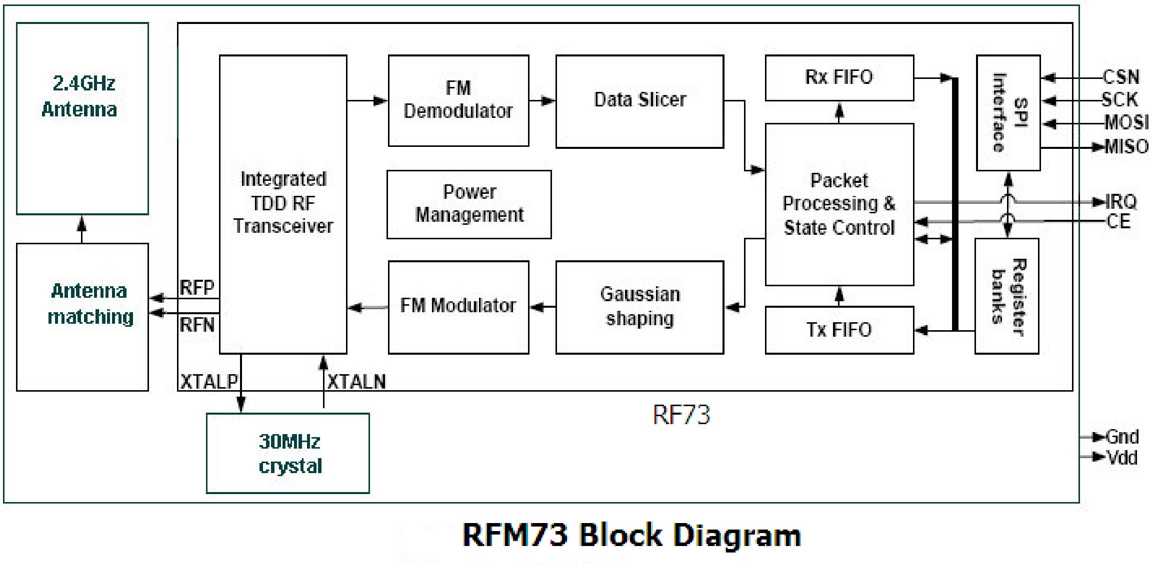


Fig 7.5 RFM BLOCK DIAGRAM

7.6.1 spi commands:

Command name	**Command word (binary)**	**# Data bytes**	Operation
R_REGISTER	000A AAAA	1 to 5 LSB byte first	Read command and status registers. AAAAA = 5 bit Register Map Address
W_REGISTER	001A AAAA	1 to 5 LSB byte first	Write command and status registers. AAAAA = 5 bit Register Map Address Executable in power down or standby modes only.
R_RX_PAYLOAD	0110 0001	1 to 32 LSB byte first	Read RX-payload: 1 – 32 bytes. A read operation always starts at byte 0. Payload is deleted from FIFO after it is

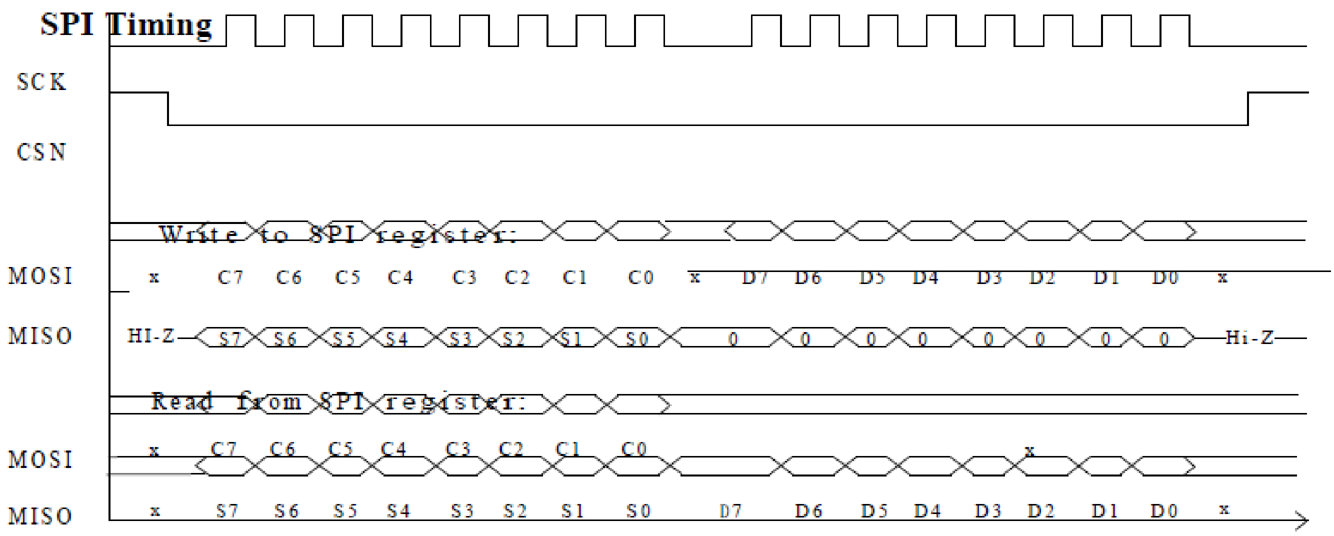
			read. Used in RX mode.
W_TX_PAYLOAD	1010 0000	1 to 32 LSB byte first	Write TX-payload: 1 – 32 bytes. A write operation always starts at byte 0 used in TX payload.
FLUSH_TX	1110 0001	0	Flush TX FIFO, used in TX mode
FLUSH_RX	1110 0010	0	Flush RX FIFO, used in RX mode Should not be executed during transmission of acknowledge, that is, acknowledge package will not be completed.
REUSE_TX_PL	1110 0011	0	Used for a PTX device Reuse last transmitted payload. Packets are repeatedly retransmitted as long as CE is high. TX payload reuse is active until W_TX_PAYLOAD or FLUSH TX is executed. TX payload reuse must not be activated or deactivated during package transmission
ACTIVATE	0101 0000	1	This write command followed by data 0x73 activates the following features: • R_RX_PL_WID • W_ACK_PAYLOAD • W_TX_PAYLOAD_NOACK A new ACTIVATE command with the same data deactivates them again. This is executable

			in power down or stand by modes only. The R_RX_PL_WID, W_ACK_PAYLOAD, and W_TX_PAYLOAD_NOACK features registers are initially in a deactivated state; a write has no effect, a read only results in zeros on MISO. To activate these registers, use the ACTIVATE command followed by data 0x73. Then they can be accessed as any other register. Use the same command and data to deactivate the registers again. This write command followed by data 0x53 toggles the register bank, and the current register bank number can be read out from REG7 [7]
R_RX_PL_WID	0110 0000		
W_ACK_PAYLOAD	1010 1PPP	1 to 32 LSB byte first	Used in RX mode. Write Payload to be transmitted together with ACK packet on PIPE PPP. (PPP valid in the range from 000 to 101). Maximum three ACK packet payloads can be pending. Payloads with same PPP are handled using first in - first out principle. Write payload: 1– 32 bytes. A write operation

			always starts at byte 0.
W_TX_PAYLOAD_NO ACK	1011 0000	1 to 32 LSB byte first	Used in TX mode. Disables AUTOACK on this specific packet.
NOP	1111 1111	0	No Operation. Might be used to read the STATUS

Table 7.1: RFM command register details

7.6.2 SPI timing diagram :



Cn: SPI command bit
Sn: STATUS register bit
Dn: Data Bit (LSB byte to MSB byte, MSB bit in each byte first)

Note: The SPI timing is for bank 0 and register 9 to 14 at bank 1. For register 0 to 8 at bank 1, the byte order is inversed that the MSB byte is R/W before LSB byte.

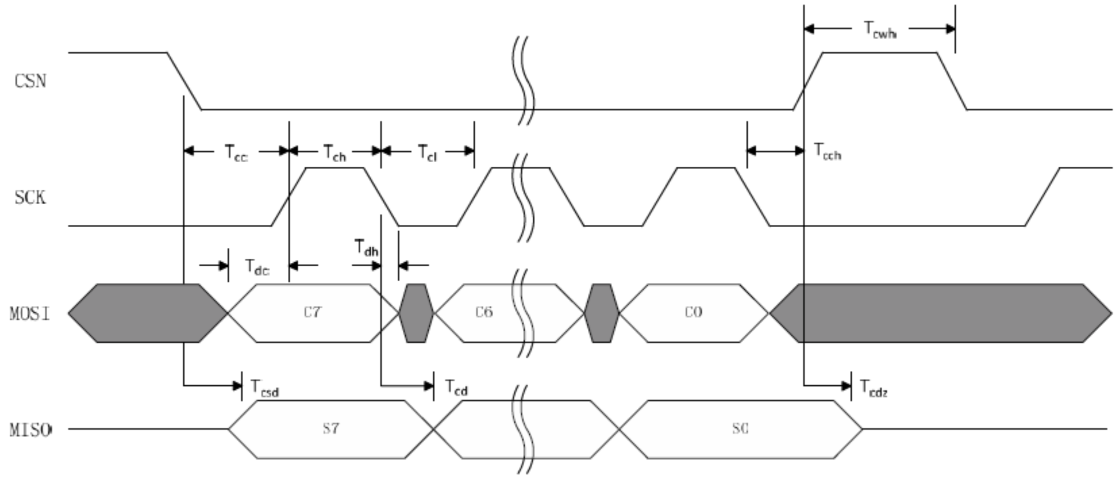


Fig 7.6: SPI timing diagram

Symbol	Parameters	Min	Max	Units
Tdc	Data to SCK Setup	10		ns
Tdh	SCK to Data Hold	20		ns
Tcsd	CSN to Data Valid		38	ns
Tcd	SCK to Data Valid		55	ns
Tcl	SCK Low Time	40		ns
Tch	SCK High Time	40		ns
Fsck	SCK Frequency	0	8	MHz
Tr,Tf	SCK Rise and Fall		100	ns
Tcc	CSN to SCK Setup	2		ns
Tcch	SCK to CSN Hold	2		ns
Tcwh	CSN Inactive time	50		ns
Tcdz	CSN to Output High Z		38	ns

Table 3 SPI timing parameter

Table 7.2 SPI timing parameter

The packet format has a preamble, address, packet control, payload and CRC field.

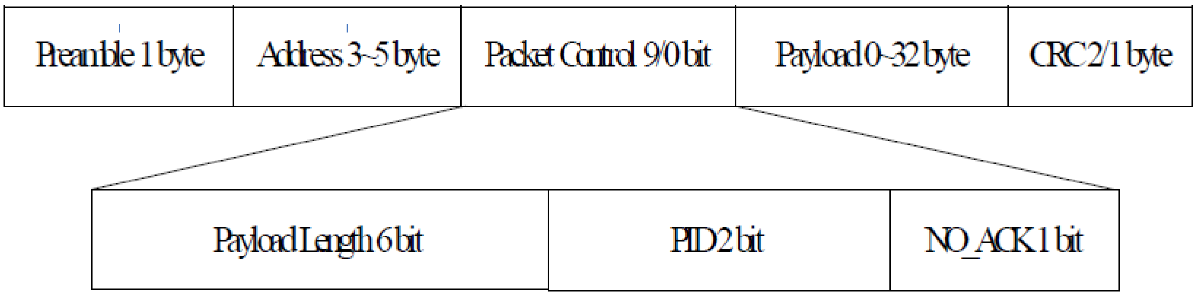


Figure 5 Packet Format

Fig 7.7 packet format of RFM73.

We used a 32 byte data for transmission.

And here also we used two register banks 1)bank0 and 2)bank1.

Now we will see how it works using SPI interface with PIC32MX.

Here in RFM, we have four pins of SPI :

1) SCK

2) CSN.

3) MOSI.

4) MISO.

first of all we will see the details of the operation (how it works).

We have to interface it with the SPI because here we have to use the SPI mode of communication.

Here we have made two types of functions

1) for transmission mode and

2) for reception mode.

Now for the transmission and reception mode we have to set various parameters and once we have set required parameters then only we are able to communicate with pic32mx.

After setting required parameters in the rfm73 we have to set the required parameters in the pic32mx for the serial transmission with the rfm73.

Now our devices are ready to communicate with each other.

So then we have to set whether rfm73 is in transmission mode or in reception mode and thus this way effective communication occurs.

7.7 Applications :

Wireless PC peripherals.

Wireless mice and keyboards.

Wireless gamepads.

Wireless audio.

VOIP and wireless headsets.

Remote controls.

Consumer electronics.

Home automation.

Toys.

Personal health and entertainment.

REFERENCES

- Datasheets :

  - PIC32ReferenceManual
  - LM35 (Temperature sensor)
  - RFM73-module-transreceiver (wireless module)
  - EEPROM 25LC256
  - Explorer 16

- 32-bit-Peripheral-Library-Guide
- Wikipedia
- Books :

  - ANSI C (C programming)
  - Let_Us_C_YashwantKanetkar (C programming)
  - The 8051 Microcontroller and Embedded Systems Using Assembly and C-2nd-ed- Full Book
  - Electronic Principles by Albert Paul Malvino
  - Op-Amps and Linear Integrated Circuits by Ramakant A. Gayakwad.