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ISM Band Radio for Wireless Monitoring and Control

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Abstract - *"ISM Band Radio for Wireless M&C" is targeted for wireless monitoring and control applications and this radio is operational in license-free ISM(Industrial Scientific and Medical) band of 2.4 -2.4835 GHz. The Transceiver IC of ISM Band Radio module facilitates for replacing the wired media with wireless link, enabled with Zigbee protocol (IEEE802.15.4) between two nodes. An ISM Transceiver IC of Microchip maker, which supports Zigbee protocol (IEEE802.15.4 standard) is used for wireless transmission and reception. The Zigbee technology is a low data rate, low power consumption; low cost wireless networking protocol targeted towards automation and remote control applications. ARM7 controller is used for programming (i) initialization of Transceiver IC, (ii) implementation of Tx and Rx frame formats as per Zigbee protocol and (iii) providing user data interfaces RS-232, RS-485/RS-422 and Ethernet and (iv) Key board and LCD interface.*

The applications of ISM Band Radio are Home and Industrial automation, scientific measuring and observation, wireless remote monitoring and control in medical field and SCADA systems. It finds applications in Wireless data transfer from PC to PC (Chat mode, SMS & file transfer) at lower data rates.

***Key Words*: Arm controller (LPC2378), RFIC MRF24J40, ISM Transceiver, Zig Bee and IEEE 802.15.4**

1. INTRODUCTION

ISM Band Radio for wireless monitoring and control application replaces the wire line media between two operating ends i.e., between (i) Process being monitored and (ii) Monitoring & Controlling end. Presently wire line media with data transfer interface standards like RS-232, RS-485/RS-422 are being used for M&C applications. But the limitations here are cable length, access and coverage.

The ISM Band Radio operates in license free band of 2.4-2.4835GHz. ISM Band Radio module consists of User interface card and RF interface card. The main component of User interface card is ARM7 controller IC, which supports varied data interfaces and that of RF interface card is RF Transceiver IC, which supports Zigbee protocol. ARM7 controller is preferred for the fast access control and management of data transmission using RS-232, RS-485/RS-422, RJ-45(Ethernet) and USB. RF Transceiver IC supports OQPSK modulation and data rate up to 250 kbps with Zigbee protocol. So, ISM Band Radio's wireless transmission is based on Zigbee protocol (IEEE802.15.4). It supports both indoor (up to 1 km) and outdoor (up to 10km) applications. It operates with a DC supply voltage of +5 V and RF output power is 0dBm to+28dBm.

2. SYSTEM OVERVIEW

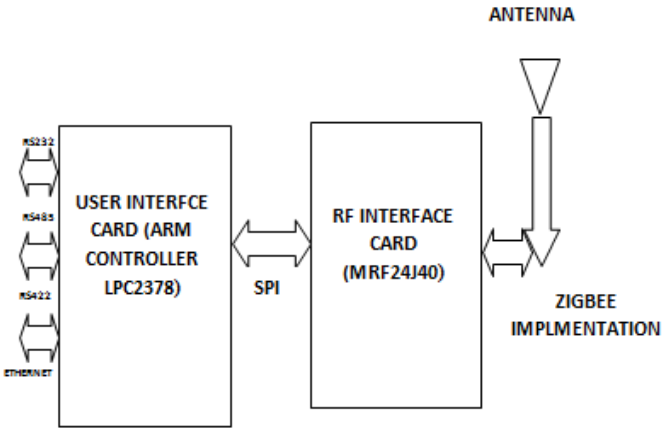

Fig-1: ISM Transceiver

ISM Band Radio is mainly based on ARM controller and RF Transceiver IC. The ARM or Controller supports the interfaces like RS232, RS485 and Ethernet. ISM Band Radio supports RFIC MRF24J40 and ZigBee Protocol IEEE802.15.4 for wireless transmission.

2.1 Implementation of ISM Transceiver

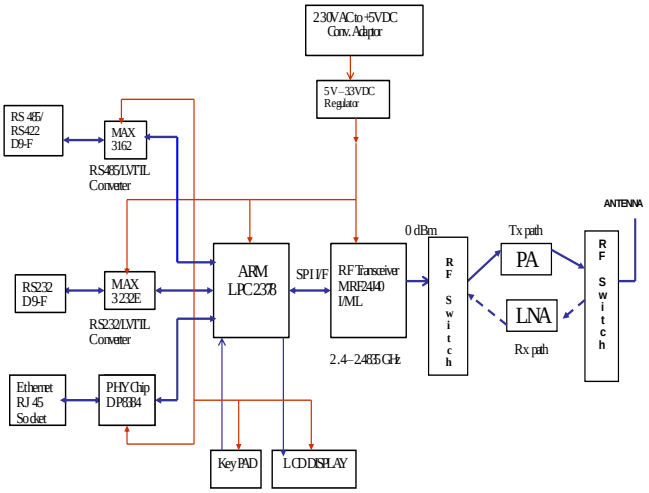

Fig-2: Block diagram of ISM transceiver

ISM Band Radio is mainly based on ARM controller and RF Transceiver IC. ARM controller is the heart of the ISM Band Radio and is used for programming (i) initialization of RF Transceiver IC, (ii) implementation of Tx and Rx frame formats as per Zigbee protocol and (iii) providing user data interfaces RS-232, RS-485/RS-422 and Ethernet and (iv) Key board and LCD interface.

It takes data/message form one of the operating ends through interfaces like RS232, RS485 and Ethernet and it initialize the RFIC and place the data to RFIC through SPI interface, and implementing Tx and Rx frame formats as per Zigbee protocol (IEEE802.15.4.Std.).

RS232 is the one of the interface for wireless data transfer, this is a RS232 to LVTTL / LVTTL to RS232 level converter, coverts RS232 level(about -11V, available at the cable output) to LVTTL level(about 3.3V) required on the ISM Band Radio module) and vice-versa. RS232 has two signal lines RXD0 and TXD0 for reception and transmission. RS232 is interfacing with ARM controller through MAX3232E IC. ARM controller takes data from one of the operating end through RS232 and place the data to receive buffer of UART0 port of ARM controller through UnRSR and UnRBR registers and ARM controller place the data to RFIC TXnFIFO for wireless transmission through SPI port of ARM controller through SOSPDR registers.

RS485 also used for data line one for transmission and reception. RS485 uses differential signals for minimizing noise presents during transmission. RS485 is interfacing with ARM controller through MAX3162 IC.

Ethernet interface provide higher data rate of 10/100mbps, uses two pairs of data line for transmission and reception (TXD0, TXD1 andRXD0, RXD1), it interfaces with ARM controller through DP83848i IC.

Required power supply is provided by 230V AC to +5VDC conversion adaptor and 5V DC to +3.3V DC voltage regulator is provided on the Radio module. Zigbee protocol supports transmission range up to 80 Km.

To extend the communication range, external Power Amplifier and Low Noise Amplifier will be added after RF Transceiver IC. For wireless data transmission and interfaces, code is developed using embedded C language and using Kiel tool.

Data transfer for wireless monitoring and control application we are using wire line media ISM transceiver replaces the wired media with wireless media. For wireless transmission, transmission and reception ends having ISM Band transceiver. Using wire line media we can transmit only 20meter distance, while using ISM Band radio distances increase up to 500 meter.

ISM Transceiver mainly consist of

- ARM controller LPC2378
- Microchip's RFIC
- Power supply
- Interfaces RS232, RS485,Ethernet and their interfacing ICs
- Keyboard and LCD Display
- Power amplifier and LNA

2.2 ARM Controller

LPC2378 microcontroller is based on 16bit/32bit ARM7TDMI-S CPU with real time emulation that combines microcontroller with 512KB of embedded flash memory.

ARM7TDMI-S processor, running at up to 72 MHz

Up to 512kB on-chip flash program memory with In-System Programming (ISP) and In-Application Programming (IAP) capabilities., 32kB for ARM local bus for high performance CPU access, 16kB SRAM for Ethernet interface, 8kB SRAM for general purpose DMA use also accessible by the USB

The LPC2378 implements two AHB buses in order to allow the Ethernet block to operate without interference caused by other system activity The ARM7TDMI-S processor is a general purpose 32-bit microprocessor, which offers high performance and very low power consumption. The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of micro programmed complex instruction set computers. This simplicity results in a high instruction throughput and impressive real-time interrupt response from a small and cost-effective processor core. Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously

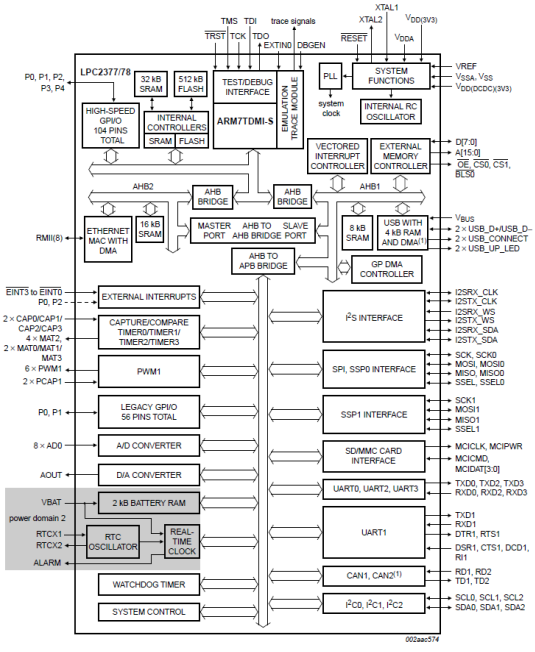

Fig-3 block diagram of LPC 2378

The ARM7TDMI-S processor also employs a unique architectural strategy known as Thumb, which makes it ideally suited to high-volume applications with memory restrictions, or applications where code density is an issue. The key idea behind Thumb is that of a super-reduced instruction set. Essentially, the

ARM7TDMI-S processor has two instruction sets:

- The standard 32-bit ARM set
- A 16-bit Thumb set

The Thumb set's 16-bit instruction length allows it to approach twice the density of standard ARM code while retaining most of the ARM's performance advantage over a traditional 16-bit processor using 16-bit registers. This is possible because Thumb code operates on the same 32-bit register set as ARM code.

2.3 Wireless Data Transmission

The MRF24J40 is compliant with the IEEE 802.15.4™-2003 Standard.

Table-1: General MAC Format

Octets:2	1	0/2	0/2/8	0/2	0/2/8	Variable	2
Frame control	Sequence number	Destination PAN identifier	Destination Address	Source PAN identifier	Source Address	Frame payload	FCS
		Addressing Fields					

The Standard specifies the physical (PHY) and Media Access Controller (MAC) functions that form the basis for a wireless network device

The wireless ISM Transceiver has been tested for different ranges for the indoor application in terms of power level of transmit and receive signal strength in dBm. It has been tested by programming the ARM7 controller IC with a loop of continuous data transmission. It has been tested data communication (chat mode, file transfer) between two PCs with RS232 interface and ZigBee protocol for wireless transmission.

The frame type subfield is 3 bits in length

Table 5.3 Frame Type subfield format

Frame Type Value			Description
B2	B1	B0	
0	0	0	Beacon
0	0	1	Data
0	1	0	Acknowledgment
0	1	1	MAC command
*1 - 1	*0 - 1	*0 - 1	Reserved bits *[100(b2b1b0) – 111(b2b1b0)]

- Frame pending subfield

The frame pending subfield is 1 bit in length and shall be set to 1 if the device sending the frame has additional data to send to the recipient following the current transfer. If more data are pending, the recipient shall retrieve them by sending another data request command to the device. If the device sending the frame does not have any more data for the recipient, this subfield shall be set to 0. The frame pending subfield shall be used only in frames transmitted either during the CAP by devices operating on a beacon-enabled PAN or at any time by devices operating on a no beacon-enabled PAN. At all other times it shall be set to 0 on transmission and ignored on reception.

- Acknowledgment request subfield

The acknowledgment request subfield is 1 bit in length and specifies whether an acknowledgment is required from the recipient device on receipt of a data or MAC command frame. If this subfield is set to 1, the recipient device shall send an acknowledgment frame after determining that the frame is valid. If this subfield is set to 0, the recipient device shall not send an acknowledgment frame after determining that the frame is valid.

- Intra-PAN subfield

The intra-PAN subfield is 1 bit in length and specifies whether the MAC frame is to be sent within the same PAN (intra-PAN) or to another PAN (inter-PAN). If this subfield is set to 1 and both destination and source addresses are present, the frame shall not contain the source PAN identifier field. If this subfield is set to 0 and both destination and source addresses are present, the frame shall contain both destination and source PAN identifier fields.

- Destination addressing mode subfield

The destination addressing mode subfield is 2 bits in length If this subfield is equal to 0 and the frame type subfield does not specify that this frame is an acknowledgment or beacon frame, the source addressing mode subfield shall be nonzero, implying that the frame is directed to the PAN coordinator with the PAN identifier as specified in the source PAN identifier field.

- Source addressing mode subfield

The source addressing mode subfield is 2 bits in length and shall be set to one .If this subfield is equal to 0 and the frame type subfield does not specify that this frame is an acknowledgment frame, the destination addressing mode subfield shall be nonzero, implying that the frame has originated from the PAN coordinator with the PAN identifier as specified in the destination PAN identifier field.

Table- 5.4 Source addressing mode sub field format

Addressing mode value b1 b0	Description
0 0	PAN identifier and addressing field are not present
0 1	r
1 0	Addressing field contains a 16 bit short address
1 1	Addressing field contains 64 bit extended address

The sequence number field is 8 bits in length and specifies a unique sequence identifier for the frame.

- Destination PAN identifier field

The destination PAN identifier field is 16 bits in length and specifies the unique PAN identifier of the intended recipient of the frame. A value of 0xffff in this field shall represent the broadcast PAN identifier, which shall be accepted as a valid PAN identifier by all devices currently listening to the channel. This field shall be included in the MAC frame only if the destination addressing mode subfield of the frame control field is nonzero.

- Destination address field

The destination address field is either 16 bits or 64 bits in length, according to the value specified in the destination addressing mode subfield of the frame control field, and specifies the address of the intended recipient of the frame. A 16 bit value of 0xffff in this field shall represent the broadcast short address, which shall be accepted as a valid short address by all devices currently listening to the channel. This field shall be included in the MAC frame only if the destination addressing mode subfield of the frame control field is nonzero.

- Source PAN identifier field

The source PAN identifier field is 16 bits in length and specifies the unique PAN identifier of the originator of the frame. This field shall be included in the MAC frame only if the source addressing mode and intra-PAN subfields of the frame control field are nonzero and equal to zero, respectively.

- Source address field

The source address field is either 16 bits or 64 bits in length, according to the value specified in the destination addressing mode subfield of the frame control field and specifies the address of the originator of the frame. This field shall be included in the MAC frame only if the source addressing mode subfield of the frame control field is nonzero.

- Frame payload field

The frame payload field has a variable length and contains information specific to individual frame types. If the security enabled subfield is set to 1 in the frame control field, the frame payload is protected as defined by the security suite selected for that relationship.

- FCS field

The FCS field is 16 bits in length and contains a 16 bit ITU-T CRC. The FCS is calculated over the MHR and MAC payload parts of the frame.

2.4 RFIC IC MRF24J40

The MRF24J40 is an IEEE 802.15.4 Standard compliant 2.4 GHz RF transceiver. It integrates the PHY and MAC functionality in a single chip solution .The Features of MRF24J40 are it is a IEEE 802.15.4™ Standard Compliant RF Transceiver, Supports Zig Bee®, Simple, 4-Wire Serial Peripheral Interface (SPI),Integrated 20 MHz and 32.768 kHz Crystal Oscillator Circuitry

A frequency synthesizer is clocked by an external 20 MHz crystal and generates a 2.4 GHz RF frequency. The receiver is a low-IF architecture consisting of a Low Noise Amplifier (LNA), down conversion mixers, poly phase channel filters and base band limiting amplifiers with a Receiver Signal Strength Indicator (RSSI). The transmitter is direct conversion architecture with a 0dBm maximum output (typical) and 36 dB power control range.

An internal Transmit/Receive (TR) switch combines the transmitter and receiver circuits into differential RFP and RFN pins. These pins are connected to impedance matching circuitry (balun) and antenna. An external Power Amplifier (PA) and/or LNA can be controlled via Six General Purpose Input/output (GPIO) pins can be configured for control or monitoring purposes. They can also be configured to control external PA/LNA RF switches.

The power management circuitry consists of an integrated Low Dropout (LDO) voltage regulator. The MRF24J40 can be placed into a very low-current (2μA typical) Sleep mode. An internal 100 kHz oscillator or 32 kHz external crystal oscillator can be used for Sleep mode timing.

The Media Access Controller (MAC) circuitry verifies reception and formats for transmission IEEE 802.15.4 Standard compliant packets. Data is buffered in Transmit and Receive FIFOs. Carrier Sense Multiple Access-Collision Avoidance (CSMA-CA), super frame constructor, receive frame filter and security engine functionality are implemented in hardware. The security engine provides hardware circuitry for AES-128 with CTR, CCM and MAC modes.

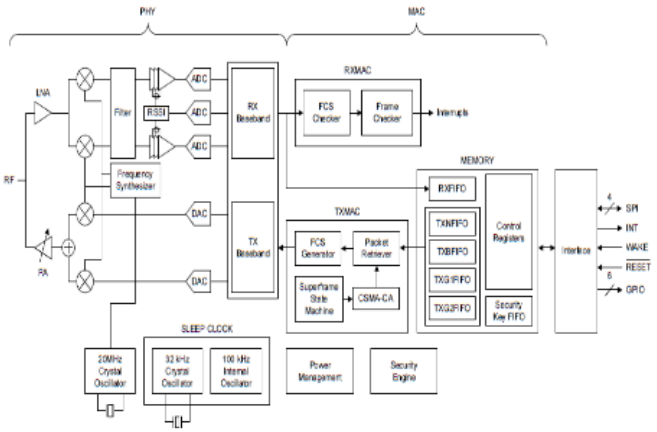

Fig-4 Block diagram of RFIC IC MRF24J40

2.3 Zigbee and IEEE 802.15.4

ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology. ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth.

IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol (physical and data link layer). On the other hand, ZigBee Alliance aims to provide the upper layers of the protocol stack (from network to the application layer) for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability compliance testing, marketing of the standard, advanced engineering for the evolution of the standard. This will assure consumers to buy products from different manufacturers with confidence that the products will work together.

IEEE 802.15.4 is now detailing the specification of PHY and MAC by offering building blocks for different types of networking known as "star, mesh, and cluster tree". Network routing schemes are designed to ensure power conservation, and low latency through guaranteed time slots. A unique feature of ZigBee network layer is communication redundancy eliminating "single point of failure" in mesh networks. Key features of PHY include energy and link quality detection, clear channel assessment for improved coexistence with other wireless networks.

3. GENERAL APPLICATIONS

The following are the some of the application of RF Transceivers.

Wireless remote monitoring and control, home automation and SCADA system.

Wireless data transfer from PC to PC(chat mode, SMS & File transfer)

Point to Point Wireless Link For ZigBee std.

4. TEST RESULTS AND DISCUSSION

Following are the test results observed on the spectrum analyser

Table-2: Result analysis

Sl.No	Mod. Signal freq.	Distance	RF Tx o/p (PA o/p)	Received Signal Level
01.	2.45 GHz	10 m	18 dBm	-44 dBm
02.	2.45 GHz	20 m	18 dBm	-39dBm
03.	2.45 GHz	40 m	18 dBm	-57 dBm
04	2.45 GHz	60 m	18 dBm	-63dBm
05	2.45 GHz	80 m	18 dBm	-78dBm
06	2.45 GHz	2000 m	18 dBm	-77dBm
07	2.45 GHz	400 m	18 dBm	-78dBm

The above measurements are observed in the practical environment i.e., different departments of R&D building of ITI Ltd,

LAN interface of PC interface with PHY Chip of module is established and link status is observed as per the requirement (auto-negotiation).

Tested raw data communication between two PCs through ZigBee enabled wireless link using packet eth and wire shark test case tool.

5. CONCLUSION

The wireless ISM Transceiver has been tested for different ranges for the indoor application in terms of power level of transmit and receive signal strength in dBm. It has been tested by programming the ARM7 controller IC with a loop of continuous data transmission. It has been tested data communication (chat mode, file transfer) between two PCs with RS232 interface and ZigBee protocol for wireless transmission.

REFERENCE

1. S.P. Bhumkar, V.V. Deotare, R.V.Babar —"Intelligent Car System for Accident Prevention Using ARM-7"||, International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 4, Pp: 56-78, 2012

2. National SemiconductorDP83848I PHYTER® - Industrial Temperature Single Port 10/100 Mb/s Ethernet Physical Layer Transceiver

3. MICROCHIP-MRF24J40 Data sheet, IEEE802.15.4 2.4GHzRF Transceiver.

4. GAO Bo,YANG Jin-yan;Wireless Monitoring Network Based on JN5121 Chip[J];Ordnance Industry Automation;2008-12

5. D. Tseles, D. Piromaiis, I. Melides, RISC Technology Microcontroller-based Sman Measurement and Control Device, IEEE, M ELECON '96 (M editerranean ELEctrotechnical CONference), Bari, Italy, 13-16 May 1996

6. MICROCHIP-MRF24J40 Data sheet, IEEE802.15.4 2.4GHzRF Transceiver