A general purpose Wireless Sensor Network node design, based on IEE 802.15.4 and ZigBee compliant standards, intended to experimentation, testbed, educational and commercial OEM prototypes.

E.C. Araújo[1], A.C. Seabra[1]
[1]Laboratório de Sistemas Integráveis (LSI), University of São Paulo, São Paulo, Brazil
*Corresponding author: Edriano Carlos de Araújo tel. +55 1176996291, Edriano@lsi.usp.br

Abstract

Over the last years Wireless Sensor Network has become a very important and challenging research field, generating a wide set of constraints for both hardware and software developments. Discuss hardware issues and software development is a difficult task due the vastness of applications and characteristics implied on this project. In order to maintain the focus, this work will be based on hardware design and its applications.

Keywords: Microcontroller, ZigBee, IEE802.15.4, Transceivers, Wireless Sensor Network. .

1. Introduction

As every new technology there have been a large number of proprietary protocols proposed for sensor network, each one eager to become the new standard. The current effort made by IEE 802.15.4, ZigBee alliance [5] and Industrial constantly products launching, it becomes plausible to say that this architecture has a great potential to become a standard. In December 2004 ZigBee alliance released its first specification based on physical layer (PHY) and (MAC) layer of IEE 802.15.4 protocol. Since then ZigBee application is getting more and more developed.

With increasing use of ZigBee, more and more students and companies will get interested in, develop products or simply test the technology, and in order to accomplish they will need a tool for testbed, which is the main focus of this work.

2. Hardware design

In order to attend educational and professional applications, some constraints must be taken into consideration when developing the Node, such as low cost, low power consuming, small form factor, easy to program and learn, a good signal-to-noise ratio and most important modularity.

2.1. Modularity

Modularity is a very important feature regarding WSN, as they have been used for solving many different problems and the ideal configuration which include software, sensing, power supply and communication are completely ambient dependent. This make Nodes versatile reducing redesign cost. Once application or environment changes, there is no need to start from scratch. In this development kit we propose three modules.

- Mother board (Figure 2_2)
- Sensor board (Figure 2_3)
- Power supply board (Figure 2_1)

Power supply module

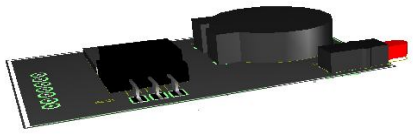


Figure 2_1

Mother board module

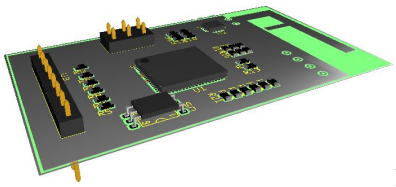


Figure 2_2

Sensor board

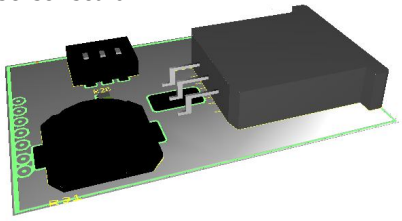


Figure 2_3

Device construction

A first, mother board prototype has been constructed to test some IEE 802.15.4 and ZigBee concepts as well as modularity (Figure 2_4).
The system core is the MC1321 a ZigBee™ platform which incorporates a low Power 2.4 GHz radio frequency transceiver and an 8-bit microcontroller into a single 9x9x1 mm QFN package. [4]
A three axes accelerometer MMA7260 was included to facilitate didactic use and fast concepts tests. The power supply and other peripherals can be plugged through expansion connector.

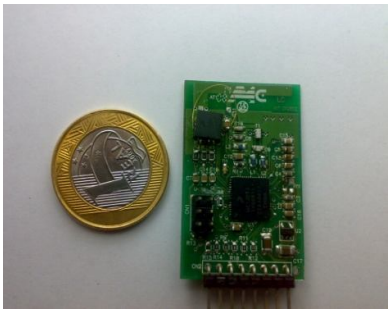


Figure 2_4

2.2. **Connectivity among modules**

Trhough Expansion connector the mother board can communicate with one or more peripherals using I²C, RS232 like or ADC converter. As we have communication both ways even the power supply module can be smart and informe mother board aboult some possibles failures.

2.3. Considerations regarding the constraints and chosen components

Low cost system:

- The combination of the radio and a microcontroller in a small footprint package allows for a cost-effective solution.
- The transceiver includes integrated transmit/receive switch on-board.
- The MC1321x also contains a microcontroller based on the HCS08 Family of Microcontroller Units (MCU) and can provide up to 60KB of flash memory and 4KB of RAM.
- The onboard MCU allows the communications stack and also the application to reside on the same system-in-package (SiP).
- Freescale provide free of charge the Simple Media Access Controller (SMAC) which is a simple ANSI C based code stack available as sample source code and CodeWarrior special edition limited to 32 Kbytes of C code.

Low power consuming:

- The microcontroller has four low power modes (Wait plus three Stop modes).
- The transceiver has programmable output power - 0 dBm nominal output power, programmable from -27 dBm to +4dBm typical and sleep mode.
- The accelerometer has an enable input that turns it completely off.
- When the three components are sleeping it is possible to achieve less than 1uA.

Easy to program:

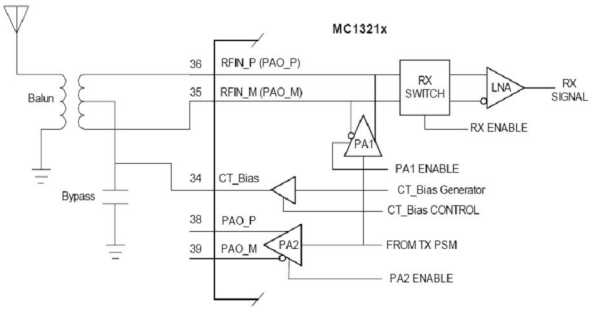
- All MCUs in the HCS08 Family contain a single-wire background debug interface that supports in-circuit programming of on-chip nonvolatile memory and sophisticated non-intrusive debug capabilities.

3.0. Challengers

After decide the circuit platform and main components, some tradeoff s have to be dealt.

3.1. Do we have to use Internal or external transmitter receiver switch? [3]

Using the internal TX/RX switch allows for the simplest, lowest cost design with the lowest parts count, the internal on-chip switching circuitry results in a design that is slightly lower in performance than a design with multiple baluns and an external low-loss switch. For this work in order to keep the small form factor and low cost effectiveness was used the internal TX/RX switch.



3.2. Do I have to use single port or dual port configuration?

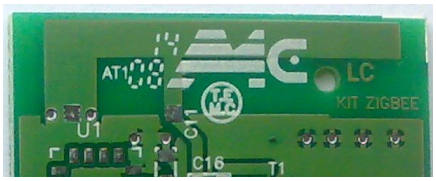
As it was decided to use the internal PA and LNA, single port with one antenna has to be used instead of dual port.

3.3. What kind of antenna would be used?

Good antenna design is a critical factor in obtaining good range in the application it is especially true in low power and compact designs where antenna space is less than optimal. [1][2]

When searching for antenna literature a great variety of antennas can be found, some of them are listed here Dipole Antenna, Monopole Antennas, F-Antenna, Meander Antenna Loop Antennas, Chip Antennas. But which one would be the best choice?

- Dipole any materials close to the antenna (metal or dielectric) can distort the radiation pattern. Generally they are big.
- Mender the radiation resistance, bandwidth, and efficiency drops off as size decreased, and tuning becomes increasingly critical.
- Chip antenna If a slightly larger PCB area is available than is required by the chip antenna and the "keep out" area can be allocated to a PCB antenna, it is possible to implement a PCB antenna with the same or better performance than a chip antenna.
- The F-antenna can be thought of as a tilted whip, where impedance matching is accomplished by tapping the antenna at the appropriate impedance point along its width. This antenna is used extensively because it is reasonably compact, has a fairly omnidirectional radiation pattern, good efficiency, and is very simple. For this work the F-Antenna was chosen. [1][2]



The F-Antenna.

4.0. Applications

Due to modularity this kit can be used in a vastness of applications even the ones intended for business such as remote temperature sensors, PH meters, lighting etc.

4.1. First step

Before starting thinking winch application design, it is very important to know how to set-up the kit, and what tools should be used. It is very important to keep in mind that reducing development time and cost are preponderant when choosing a development tool environment. In order to accomplish the previous requirements we have decided to use BeeKit and codewarrior special edition provided by Freescale, and USB multilink as a programmer/debugger.

- **BeeKit** is a standalone software intend to create, modify and save wireless network applications easily and quickly, through its graphical user interface it is possible to configure parameters before creating the project. All files created with BeeKit can be imported in to an integrated development environment for continued developing and debug. (Figure 4_1 shows BeeKit Components).

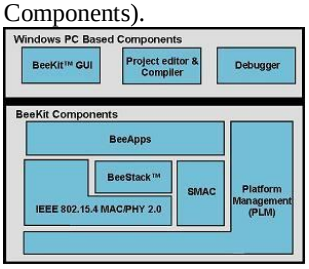


Figure 4_1

- **CodeWarrior special edition** is the IDE provided by Freescale was the chosen on, although another IDE could be used, Codewarrior allows infinite assembler compiling and until 32KB of C code and it is highly integrated with BeeKit. With this tool it is possible to compile, program and debug the application generated with BeeKit.
- **USB BDM Multilink programmer** it is a cheap and easy to use tool provided by P&E microcomputer [6], one of the best features of this microcontroller is the Background debug mode, this interface provides in-circuit debugging functionality in microcontrollers and only requires a single wire to communicate.
- **Protocol** Once decided which development tool environment will be used, a communication protocol has to be determined. BeeKit provides a complete set of protocols such as Simple MAC (SMAC) IEE 802.15.4 PHY/MAC and BeeStack ZigBee Protocol Stack.

  Simple MAC: (SMAC) has small memory requirement about 3Kbytes, supports proprietary networks, point-to-point and star network.

  802.15.4 Standard-compliant: MAC Supports Star, mesh and cluster tree topologies. Supports GTS for low latency and provides multiple power saving modes.

  ZigBee compliant network stack: Supports ZigBee 1.0 specification, star, mesh, tree networks and advanced encryption standards (AES) 128 bits.

  AS we stated before cost is a concern and BeeKit only provides SMAC free of charge. SMAC incorporated into BeeKit is easy to use and can be totally customized for user application.

4.2. Using the Kit

With **T**he three axes accelerometer within the mother board is possible to create many applications such as:

- Falling detector
- HDD protection
- Image stabilization
- Games
- Seismograph
- Pedometer

Figure 4_2 shows the accelerometer orientation

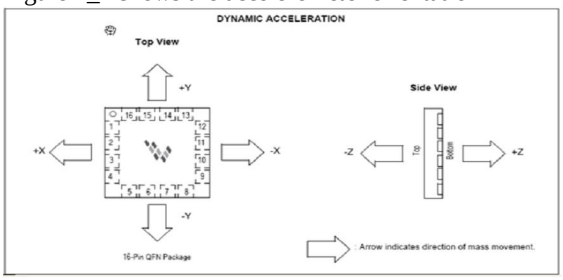


Figure 4_2

The three axes accelerometer outputs are connected to the ZigBee transceiver through their analog inputs. In figure 4_3 it s possible to see the raw data being sent from accelerometer.

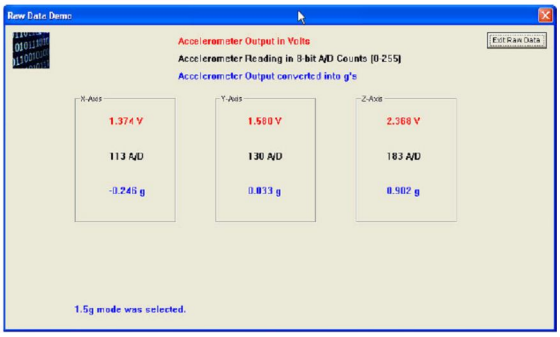


Figure 4_4 shows a 3D example that can be used for gaming board application joystick, or a relative mouse based on relative locations.

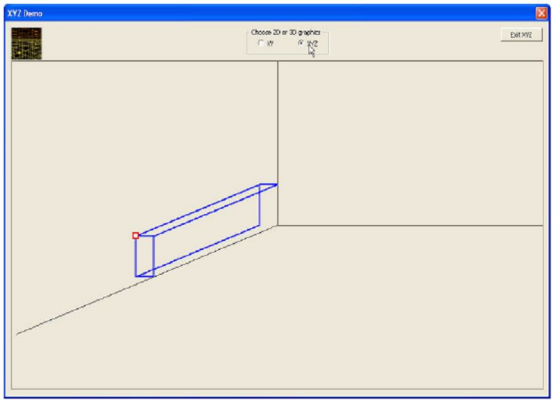


Figure 4_5 shows how the readings from the accelerometer can be translated from the g readings to angle of rotation.

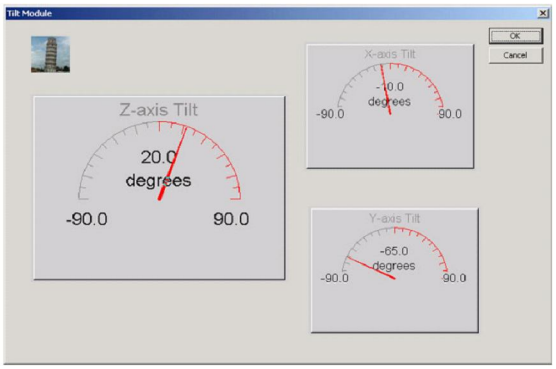
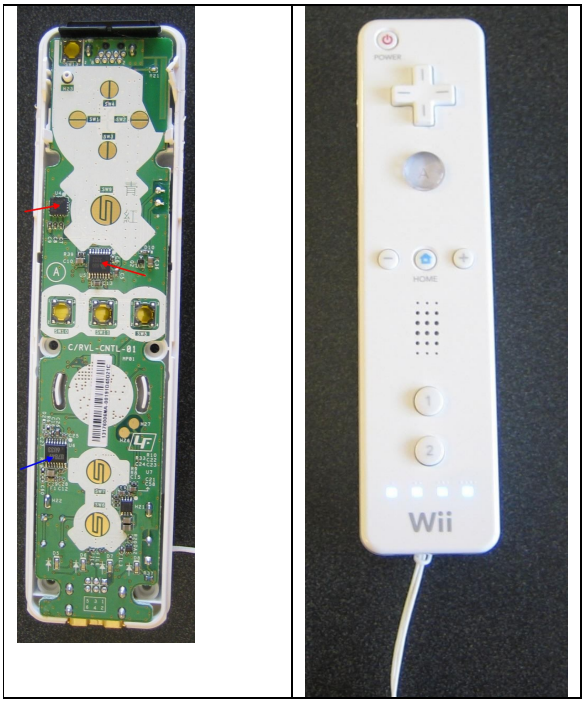
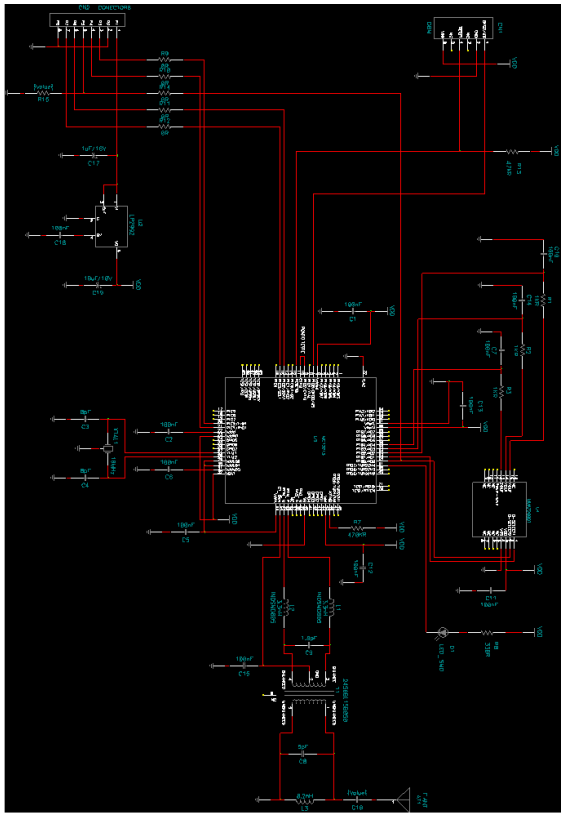


Figure 4_6 shows a professional application of wireless and sensor control.

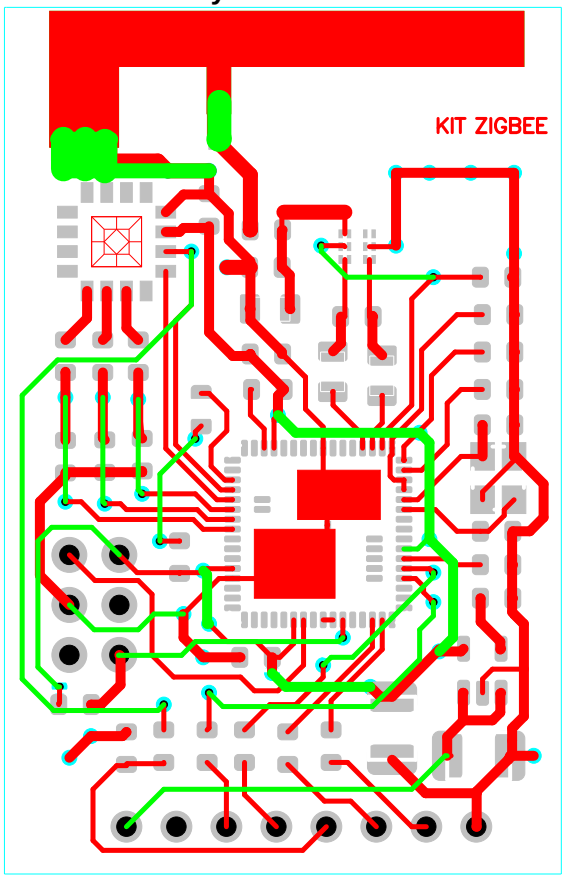


On this picture we can see a wii mote joystick based on a Bluetooth radio and a three axes accelerometer, wich is considered the primary reason for the success of the video game.

Electrical schematic do Kit



Mother board layout



5.0. Conclusion

In this paper we propose a general purpose ZigBee compliant wireless network sensor kit. Most of our effort was focused on Hardware development, always chasing for low cost and easiness of use.
Wireless sensor network and also ZigBee technology are new and need more accurate research in many areas.
This work can be helpful for students wants to test this technology and do not have access expensive tools.

Acknowledgments

E.C Araújo would like to acknowledge STP Tecnologia for technical and financial support and A. C. Seabra for the opportunity given.

References

[1] AN2731 Freescale Semiconductors Compact Integrated Antennas Designs and Applications for the MC1319x, MC1320x, and MC1321x

[2] C. Soras, M. Karabolkis, G. Tsachtsiris, and V. Makios. Analysis and Design of an Inverted-F Antenna Printed on a PCMCIA Card for the 2.4 GHz ISM Band.

[3] Freescale Semiconductors Using the MC1321x Internal Transmit/Receive Switch in a Low-Cost, Single-Port, Two-Layer Design.

[4] Freescale Semiconductors **MC13211/212/213/214** ZigBee™- Compliant Platform 2.4 GHz Low Power Transceiver for the IEEE® 802.15.4 Standard plus Microcontroller Reference manual.

[5] ZigBee Alliance, ZigBee Specification 1.0 December 14th, 2004. http://www.zigbee.org

[6] P&E Microcomputer system www.pemicro.com

[7] Microchip www.microchip.com

[8] Nec www.nec.com