

# Implementation of Wireless Sensor Network for monitoring physical parameters of a moving object using 16-bit Microcontroller

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**Abstract**—In this paper, efforts have been made to develop a Wireless Sensor Network based system to monitor physical parameters of a moving object or geographically distributed sensor array. Using this system one can monitor the parameters of the moving object to ensure its optimal movement. Such objects include automobiles, aircraft etc, while the parameters may be acceleration, rate of change of  $g$  (acceleration due to gravity), or inclination. Whenever any of these parameters crosses the set limits, the system will give suitable indications. The sensors to monitor these parameters would be part of the wirelessly connected nodes on-board the moving object. These nodes (termed End Device) will remain connected to a central master unit (termed Access Point) and will in turn be connected to a PC where all the sensor data will be collected, processed and displayed through the GUI of the PC.

**Keywords**—*wireless sensor network; acceleration due to gravity; inclination; End Device; Access Point*

## I. INTRODUCTION

Wireless Sensor Networks (WSNs), as they are named, are self organizing, infrastructure-less, wireless networks made of small, battery-powered devices equipped with specialized sensors and wireless transceivers [1].

Wireless sensor networks have gained considerable popularity given their flexibility in solving numerous problems in different application domains. Some of such domains include agriculture, military, manufacturing, transportation, medical, environmental and engineering [1].

In paper [3], a novel hardware and software architecture of a working wireless sensor network system to monitor body movement and heart activity of a patient has been proposed. The software developed also includes an Activity Sensor (ActiS) which samples three-axis accelerometers to determine orientation, type of activity (walking, sitting, etc.)

In paper [4], an integrated hardware and software system for a scalable wireless sensor network (WSN) has been designed and developed for structural health monitoring. The prototype WSN was also successfully deployed on a long-span bridge with 64 nodes.

In paper [5], a wireless accelerometer sensor module (ADXL202) and algorithm has been implemented to determine the wearer's posture, activity and fall.

In this paper, an important application of Wireless Sensor Networks has been demonstrated. This research implements a wireless accelerometer sensor module, MMA7260  $g$  sensor ( $g$  = acceleration due to gravity) from Freescale Semiconductor [7]. This  $g$  sensor will be used to derive Acceleration, Rate of change of  $g$  and Inclination of the object. The toolkit eZ430-RF2500 [6] from Texas Instruments Inc has been used for the setup and realization of a wireless sensor network.

## II. BACKGROUND CONCEPTS

### A. Access Point Device

Access Point forms an all important part of the communication system. Usually this Access Point Device [2] is also a sensory node with a physical interface to the PC where all the data is collected for monitoring and analysis purposes. All participating nodes (i.e. End Devices [2]) must connect themselves to this Access Point Device before being able to establish communication. The Access Point provides each node with an address unique to it for ease of identification and re-induction in the network in case of any system reset. All the End Devices send their data in packets to the Access Point where from those data are communicated to the PC. This Access Point may contain an analog sensor module but must have a RF transceiver, microcontroller and energy source.

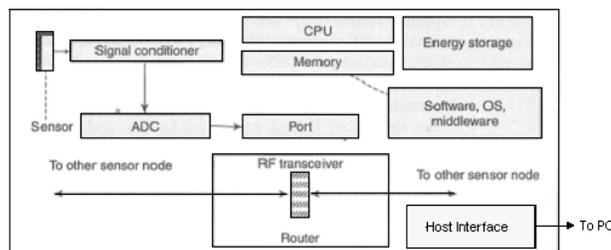


Figure 1. Access Point Device of the network

### B. End Device

The sensory nodes forming the wireless sensor network are the End Devices of the network. These devices consist of analog sensor module along with RF transceiver, microcontroller and energy source, usually battery. The End Devices communicate among themselves and the Access Point using the RF transceiver by transmitting and receiving data packets across the network.

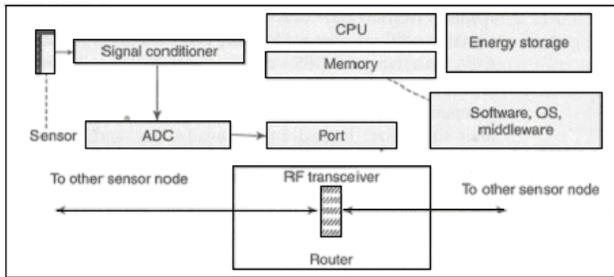


Figure 2. End Device i.e. smart sensor

### C. *g* Sensor

This is actually a 3-axis linear accelerometer which provides output based on change in capacitance due to change in *g* in 3 directions, *x*, *y*, *z*. The change in *g* is caused by change in orientation of the object with respect to surface of earth. In this sensor a *g* cell is formed using 3 sets of combination of moving and fixed beams in which change in *g* in their normal direction will change the differential capacitance of the *g* cell. This change of capacitance is in turn converted to an analog voltage and further to digital output from the cell. There are 3 independent outputs corresponding to 3 axes of *g*.

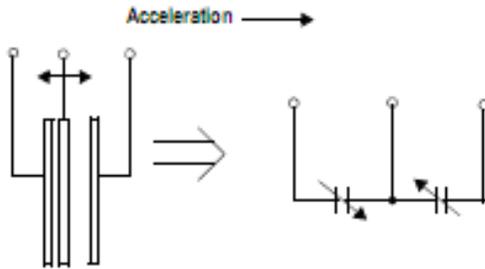


Figure 3. *g*-cell

## III. IMPLEMENTATION DETAILS

Functionally this project has the following two major components:

### A. Development tool eZ430-RF2500 from Texas Instruments Inc

The hardware and software descriptions of this component will be discussed separately:

- **Hardware Description:**  
The eZ430-RF2500 [6] is a complete USB-based MSP430 wireless development tool providing all the hardware and software to evaluate the MSP430F2274 [6] microcontroller and CC2500 [9] 2.4GHz wireless transceiver, which is used to find out the temperature of the environment in which the End Device is currently placed. It has several features like USB debugging and programming interface featuring a

driverless installation and application backchannel, 21 available development pins, highly integrated, ultra-low-power MSP430 MCU with 16MHz performance, two general-purpose digital I/O pins connected to green and red LEDs for visual feedback, interruptible push button for user feedback and a range up to 450ft at 10kbps and up to 300ft at 250kbps.

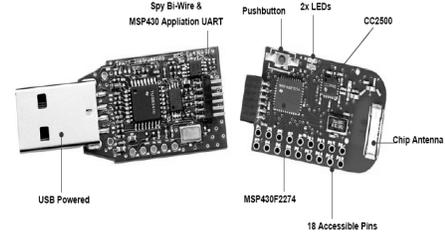


Figure 1. eZ430-RF2500

Figure 4. Access Point Module: eZ430-RF2500

Each module consists of the following hardware modules along with basic driver software.

1. MSP430F2274 microcontroller
2. CC2500 low frequency RF transceiver

In addition to these parts the Access Point also contains an interface module for interfacing with the PC as well as for downloading the kernel or developed object files for the microcontroller. This interface is a standard 2.0 USB interface driven by its own driver.

Similarly, the End Device is interfaced with the *g* sensor MMA7260 [7] through the ports of MSP430F2274 microcontroller. The power to this unit is provided by batteries comprising of two AAA type cells.

- **Software Description:**

The software developed for the End Device is an additional driver primarily meant for acquiring data in real-time from the *g* sensor MMA7260, and processing this data for the corresponding engineering units for obtaining Inclination of the object, Dynamic Acceleration, Orientation. This driver software is integrated into the in-built backbone software based on SimpliciTI™ [8] provided by the manufacturer of the tool. During operation the End Device will acquire data related to Inclination of the object, Dynamic Acceleration, Orientation and transmitted these through the low-power RF transmission over the wireless network. Through this network these data will be received by the Access Point, processed and in turn transmitted to PC.

### B. MMA7260 'g' sensor

MMA7260 'g' Sensor by Freescale Semiconductor [7] is basically a 3-axis linear accelerometer device [7] which consists of two surface micro-machined capacitive sensing cells (g-cell) and a signal conditioning system called ASIC[7], contained in a single integrated circuit package. The g-cell is a mechanical structure formed from semiconductor materials and internally, is modeled as a set of beams attached to a movable central mass that move between fixed beams [7]. When subjected to change in acceleration, the movable beams are deflected from their rest position, causing change in distance from fixed beams. This change in distance is a measure of acceleration [7]. The g-cell beams form two back-to-back capacitors. As the center beam moves with acceleration, the distance between the beams change causing change in capacitance [7]. This varying capacitance is ratio-metric and proportional to acceleration. Using this basic acceleration, information like Inclination, Orientation of the body and rate of change of Acceleration are derived in 3 dimensions. It has features like 1.71 V to 1.89 V supply voltage, 12-bit digital output, Embedded 4 channels of motion detection, Freefall detection (2 channels), Pulse Detection (1 channel), Transient (Jolt) Detection (1 channel), Orientation (Portrait/Landscape) detection with hysteresis compensation as well as 10,000g high shock survivability.

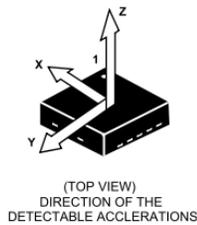


Figure 5. Detectable directions of accelerometer MMA7260

The 'g' sensor is a ratiometric device. Ratiometricity simply means the output offset voltage and sensitivity will scale linearly with applied supply voltage. Sensitivity describes the gain of the sensor and can be determined by applying a 'g' acceleration to it, such as the earth's gravitational field. The sensitivity of the sensor can be determined by subtracting the -1g acceleration value from the +1g acceleration value and dividing by two. The g-Select feature allows for the selection among 4 sensitivities present in the device.

g-Select2	g-Select1	g-Range	Sensitivity
0	0	1.5g	800 mV/g
0	1	2g	600 mV/g
1	0	4g	300 mV/g
1	1	6g	200 mV/g

Figure 5. 'g' select pin descriptions

A sensor in a steady state on a horizontal surface will measure 0g in X-axis and 0g in Y-axis whereas the Z-axis will measure 1g.

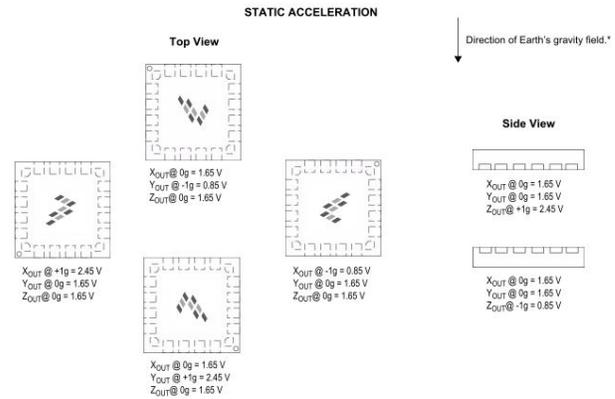


Figure 6. Device configuration in 6 different orientation modes and ideal outputs

## IV. EXPERIMENTATION AND RESULTS

### A. Derivation of mathematical relation between Accelerometer output and inclination of End Device

An important component of the accelerometer is the 10-bit ADC. Considering its specifications, we derive the following formula:

$$10\text{-bit ADC} \rightarrow \text{Number of steps} = 2^{10} = 1024$$

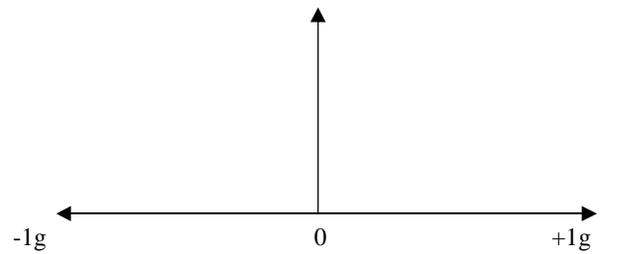
$$\text{Reference voltage of ADC}_{10} = 2.5\text{V} = 2500\text{mV}$$

So, relating these two, we have,

2500mV is calibrated in 1024 steps.

Therefore, 1 mV is calibrated in  $(1024/2500)$  steps, which implies  $(1024/2500)$  steps/mV or  $(2500/1024)$  mV/step... (1)

Now, we consider the following figure showing the accelerometer output on a particular detectable axis, while equal and opposite gravitational forces are acting on it:



Therefore, 180 degree shift generates a difference voltage of  $(1.708 - 1.092)\text{V} = 0.626\text{V}$

So,

$$1 \text{ degree shift generates } (0.626/180) \text{ V} = 3.477 \text{ mV/degree} \dots (2)$$

At 0g, the ADC output is 1400 mV (offset).

Let, temp = Number of steps corresponding to this value.

From (1), we get, temp =  $((1400 * 1024) / 2500)$  steps = 573.4 steps

So, we modify (2) and get the following:

$$1 \text{ degree inclination generates } ((F - 1400) / 3.477) \text{ mV}$$

Where,  $F = (573 * 2500) / 1024$

Taking the mod value of the above, we get 0.308 degree

For our convenience, while showing our results on the GUI

we will take 30.8 degree~30 degree as our offset value. This means that while the actual inclination of the object is 30 degrees, on our GUI, this value will show as 60 degree. Such a manipulation is necessary in order to compensate for the inherent errors in manual handling of the nodes.

### B. Results as displayed on GUI

A graphical user interface, named as ADS Star Inclination Monitor, developed for the project using Visual Basic 6.0 framework is shown below:

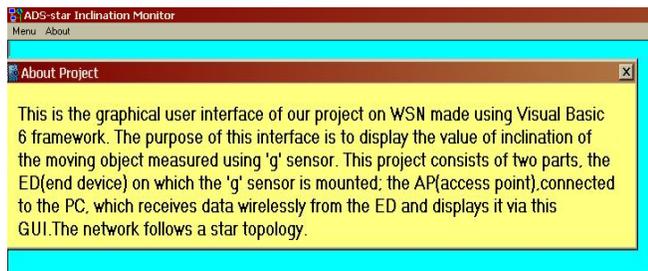


Figure 7. ADS Star Inclination Monitor

### CONCLUSION

The goal of this project has been to document the variation of the physical parameters of an object as it changes its location with time.

Our primary descriptive question has been: How these mobile objects communicate with each other in the wireless environment? In this regard we have used a Wireless Sensor Network development tool eZ430-RF2500, a product of the Texas Instruments.

We have organized our analysis across our studies according to the topics that correspond to a wireless sensor network:

sensors, microcontrollers and transceivers. In this way, we have mapped an architecture of different components of a wireless sensor network, while remaining attentive to the dynamics of a MANET, seeking to understand it from an Information Technology point of view. We have focused our discussion on the MANET based on the tool from Texas Instruments and some additional sensors. Although we see our work as essentially exploratory, we have tried to identify some initial landmarks and boundaries that define this area of ethnographic inquiry.

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