# Investigation of a Pressure Sensor with Temperature Compensation Using Mems Circuits for Activity Controlling

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**ABSTRACT:**

*As babies usually start walking between 9 and 16 months, they are at risk of falling from furniture or stairs. As toddlers learn to climb, they are at risk of falling from windows and beds. Falls are a frequent cause of injury in children. Accident and emergency departments and outpatient surveillance systems show that falls are one of the most common mechanisms of injuries that require medical care, and the most common nonfatal injury that at times needs hospitalization. In children younger than four years of age, most fall-related injuries occur at home. Thus, a new safety management method for children is required to prevent child home accidents. Since the major causes of fall-related injuries change as a child grows and develops, fall prevention needs to be addressed. One of the most challenging issues in this context is to classify daily activities of children into safe and dangerous activities. MEMS are the most appropriate devices for motion compensation which is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro-fabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters*

**Key words:**

Accelerometer; activity classification; activity recognition; baby care; child care; wearable device

**Introduction:**

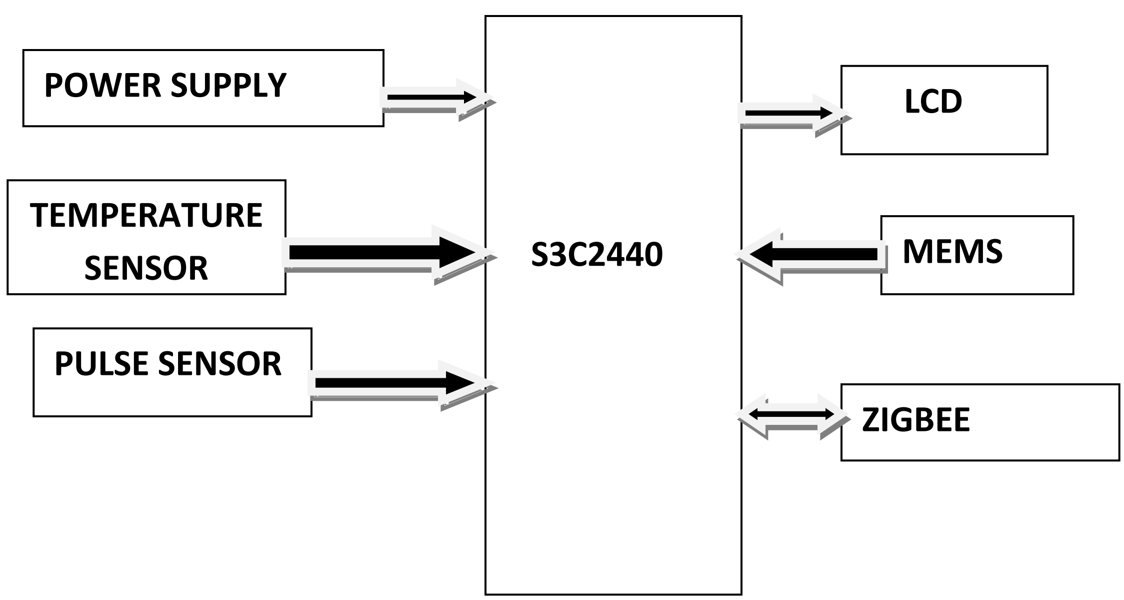
Pressure sensors have been extensively applied in the automobile industries, environmental monitoring systems, process controls and biomedical fields [1-4]. The pres- sure sensor was traditionally manufactured by large-scale mechanical devices, while recently the micro-electro-mechanical systems (MEMS) technologies have the ad- vances and great improvements to fabricate highly-so- phisticated micro-sensors with excellent repeatability characteristics and ultra-low-pressure detection capabili- ties [5-7]. In such devices, the pressure is generally mea- sured by piezoelectric thin films [8,9] or the form of ca- pacitance structures [10]. Since the capacitive-type pres- sure sensors have better sensitivity to the influences of the parasitic capacitance, this pressure sensors do not in- terfere with the test results of pressure by the outer tem- perature. By contrast, the sensitivity, linearity and repeatability characteristics of the piezoresistive-type pres- sure sensors have been greatly improved, and can be eas- ily manufactured by mass production using standard MEMS-based techniques to reduce the cost [11,12]. Most of piezoresistive pressure sensors are easy to produce the error or deformation for test result of pressure when the outer temperature yields variations. In the conventional piezoresistive pressure sensors, the sensing element has four diffused or ion-implanted strain gauges which com- pose a single Wheatstone-bridge circuit on a thin silicon membrane [13]. Such devices have the drawback of zero- pressure offset error due to the temperature [14]. It was shown that the zero-pressure offset error in the single Wheatstone-bridge piezoresistor was primarily caused by the thermal residual stresses due to different thermal ex- pansion coefficients of the monocrystalline silicon sub- strate and the polycrystalline silicon membrane [15,16]. Although numerous approaches have proposed various activity recognition methods, human activity recognition is one of the challenging issues in terms of accurate recognition. In general, a pervasive safety management system aims to reduce risk factors of injuries to prevent accidents by using smart sensors. Multi sensor fusion has been applied to daily life monitoring for elderly people and children at home This approach trained using manually annotated data and applied for activity recognition. Zhu *et al.* also suggested human activity recognition by fusing two wearable inertial sensors attached to one foot and the waist of a human subject, respectively. The use of multiple sensors has been shown to improve the robustness of the classification systems and enhance the reliability of the high-level decision making. On the other hand, a waist worn sensor could fail to detect activities involving head motion, body tilt, and hand motion. In addition to that and for the purpose of minimizing the number of sensors worn, it is important to know the capability of a certain position to classify a set of activities. Recently, Atallah *et al.* [7] investigated the effects of sensor position and feature selection on activity classification tasks using accelerometers. Accelerometers are not only the most broadly used sensors to recognize ambulation activities such as walking and running, but also inexpensive, require relatively low power, and are embedded in most of cellular phones. Their study concluded that optimal sensor positions depend on the activities being performed by the subject. Other important factors to consider, especially if the system is designed for long and continuous use, are how comfortable it is to wear and how easy it is to put on. Frequently, accuracy must be compromised for ease of use and comfort, due to a reduction in number of sensors. The optimal system configuration is, therefore, difficult to evaluate. It depends not only on the accuracy of the system but also on other practical aspects. In our study, for children under three years of age, the waist-worn sensor is put in a diaper to minimize uncomfortableness during physical activity and to measure body motions such as climbing up and climbing down than head, hand, and leg motions. We have developed a wearable sensor device and a monitoring application to collect information and to recognize baby activities. We classified baby activities into 11 daily activities which are wiggling, rolling, standing still, standing up, sitting down,walking, toddling, crawling, climbing up, climbing down, and stopping. Multiple sensors embedded in a wearable device

**Numerical Simulation and Analysis**

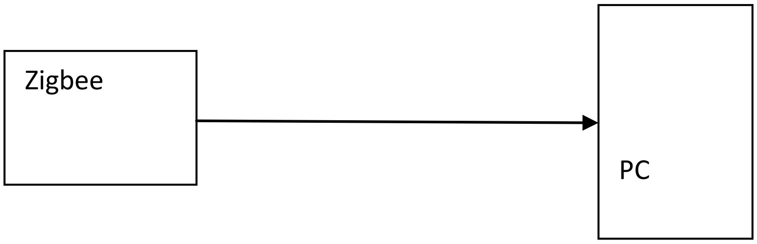
In the practical applications of pressure sensors, the membrane deformations are caused by both the working temperature and pressure. The variations of temperature will affect the measuring result of pressure. The phe- nomena call thermal stress when the variations of pres- sure lead to the membrane deformations. Therefore, the thermal stress is a major pressure course for the mem- brane. And, the different materials have different values of thermal expansions and contractions that will bring about different thermal stress. Similarly, different loca- tions of the piezoresistors will lead to different result of membrane deformations. As a result, by using the simu- lation to analysis the influence of pressure is absolutely to do when establish the model in the initial phase The settings and definitions of the materials are basically monocrystalline and polycrystalline silicon. Recently, the integrated cir- cuit trends to have more and more complex with multi- functions but smaller and smaller in size. It needs much more exact calculation and designation for electrical characteristics. Poor design and process-induced mecha- nical stress effect will cause serious problem during fab- rication stages, especially for the packaging process in the front-end process, which make more variation to electrical characteristics and affect the quality and per- formance of the device in the end. Mechanical stress in- duced unstable and variation of electrical characteristics is one of the major factors to affect the entire perform- ance of a device seriously. And, the different type of silicon has the different direction of etch in the process of fabrication. The different direction of etch will affect the electrical characteristics of sensor. Therefore, in this study, the monocrystalline silicon is design as the sub- strate, where the polycrystalline silicon is the membrane of the pressure sensor.

**System Design:**

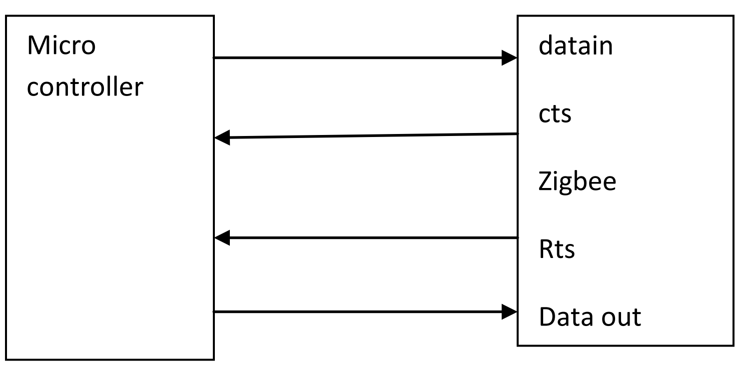
**BLOCK DIAGRAM:**

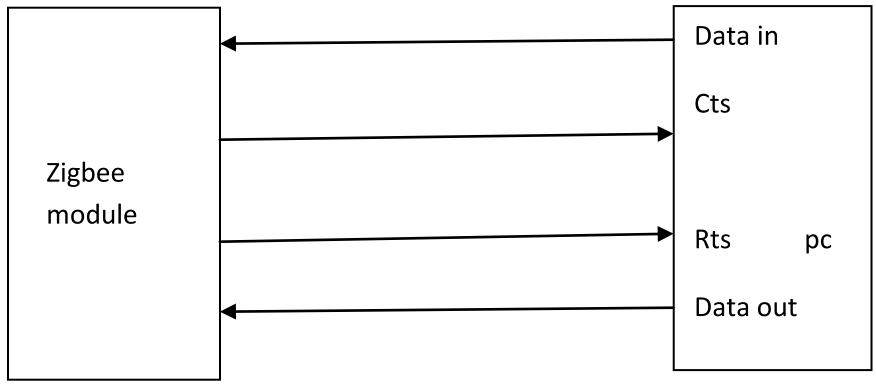


**RECEIVER SECTION:**




The XBee Modules used in the interfacing boards, are engineered to meet IEEE 802.15.4 standards. It is low-cost, low-power, reliable 20 pin device that operates within the ISM 2.4 GHz frequency band. It has 30 to 100 metre data transmission capability with rate of 250,000 bps. XBee modules operate in five modes. When not receiving or transmitting data, the RF module is in Idle Mode. The RF module shifts into the other modes of operation under various conditions. In transmit mode serial data is received in the DI (data in) buffer and the data is stored in the DI
Buffer until it can be processed. When the DI buffer is 17 bytes away from being full, by default, the module de-asserts CTS (high) to signal to the host device to stop sending data CTS is re-asserted after the DI Buffer has 34 bytes of memory available. Smaller size data or low baud rate can be selected to avoid this state of overflow. In receive mode valid RF data is received through the antenna. When RF data is received, the data enters the DO (data out) buffer and is sent out the serial port to a host device. Once the DO buffer reaches capacity, any additional incoming RF
data is lost. If RTS (hardware flow control) is enabled for flow control, data will not be sent out the DO buffer as long as RTS is de-asserted. Sleep Modes enable the RF module to enter states of low- power consumption when not in use i.e. not transmitting/receiving data for the amount of time predefined by the ST (Time before Sleep) parameter. To modify or read RF Module parameters, the module must first enter into Command Mode - a state in which incoming characters are interpreted as commands. The programming requires the installation of X-CTU software and a serial connection to a PC. The detail of the software is given in the next section. When communication occurs between two networked devices, each data packet contains a 'Source Address' and a 'Destination Address' field.






## DATA TRANSMISSION THROUGH ZIGBEE:

The main characteristics of ZigBee network are simple implementation, low power consumption, low cost interface, redundancy of devices, high node density per physical layer (PHY) and medium access control layer (MAC). Besides, they allow the network to work with a great number of active devices. ZigBee is based on IEEE 802.15.4 standard in terms of the PHY and MAC layers [12]. IEEE 802.15.4 defines two kinds of devices: the Full Function Device (FFD) and the Reduced Function Device (RFD). The FFD has the function to coordinate the network and consequently has access to all other devices. The RFD is limited to a star topology configuration, not being able to work as a network coordinator, so it does not have all the protocol services. The FFD and RFD devices can operate in three different ways at the ZigBee standard as the ZigBee coordinator (ZC), ZigBee Router (ZR), or ZigBee End Device (ZED). The network layer supports three topologies: star, cluster tree and mesh as shown in Fig. 3. A star topology consists of a coordinating node and of one or more FFD or RFD which communicates with the ZC. At the cluster tree, the final devices can be associated to the network by the ZC and the ZR helping the increasing of number of nodes and the network scope. At the mesh topology, the FFD can distribute messages directly to other FFD. To enter the network, each device receives an address given by ZC or a ZR. provide a simple-to-use graphical user interface. Each of the four tabs there has a different function. PC Settings tab allows selecting the desired COM port and configuring that port to fit the zigbee settings. As shown in Fig. 4 baud rate, type of flow control and no of bits are required to set before the operation. The Test / Query button is used to test the selected COM port and PC settings. A response is received if the communication between them is correct. The range test tab is used to verify the range of the radio link by sending a user-specified data packet and verifying the response packet is the same, within the time specified (Fig. 5). Terminal tab accesses to the computers COM port with a terminal emulation program. This tab also allows to send and receive predefined assemble packet data or data in Hex and ASCII formats using suitable commands. A complete list of commands is available in the product manual [13]. Terminal tab of the X-CTU software is also used to change the RF module's DL (Destination Address Low) parameter and save the new address to non-volatile memory. Modem Configuration tab is used to program the device firmware settings via a graphical user interface. It is also utilized to restore default parameter values of the RF module.

**CONCLUSION**

This paper has presented the activity recognition method for children using only a triaxial accelerometer and a barometric pressure sensor. Time-domain and frequency-domain features are extracted for categorizing body postures such as standing still and wiggling as well as locomotion such as toddling and crawling. To improve the performance of the child activity recognition method, six features including magnitude, mean, standard deviation, slope, energy, and correlation are extracted from the preprocessed signals. Multiple feature sets are compared to find an optimized classification method, and showed how well they performed on a body.

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