A Smart Wearable System for Sudden Infant Death Syndrome Monitoring

M.Tech. Embedded Systems

16ES603 Embedded System Programming

Mini Project Report

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ABSTRACT

Sudden Infant Death Syndrome (SIDS) is one of the major causes of death among infants during their sleep. Our project is a sensor node integrated in a Chest Belt, and it has the capacity to monitor the following parameters: body temperature, heart and breathing rates and body position. After a minimal data processing, this set of information is sent to the receiver, via ZigBee technology. If a critical event occurs, the device will trigger an alarm, visible and audible in the proximity, and sends a distress message to a mobile application. The Baby Night Watch is an important tool for medical studies, since it allows the visualization of previous physiological data and export it to different types of datasets. Experimental tests have proven that this device has the potential to identify situations that could be potentially life-threatening for an infant.

INTRODUCTION

In recent years, a wide range of wearable devices and sensors including accelerometers and gyroscopes, smart fabrics and actuators, wireless communication networks and power supplies, and data capture technology for processing and decision support, have been developed for clinical research and health monitoring. Various kinds of wearable sensors have emerged for different purposes with the development of sensing technologies. For instance, wearable devices, instrumented with variable resistance bend sensors, enable applications for human posture recognition and motion capture by recovering human joint bend angles. A wearable wrap-around sensor composed of multiple electrodes (antennas, excited at a single low frequency), was proposed for continuous measurement of the permittivity of biological tissues deep into the torso (specifically the lungs and heart).

Health monitoring is an essential application of wearable sensor systems, especially for infants. Recently, together with advances in sensor techniques, wireless communication and power supply technologies, wearable sensor systems have enabled the creation of a new generation of constant health monitoring for infants. For example, a developed sensory baby vest including fully-integrated sensors for measuring electrocardiography (ECG), respiration, temperature and humidity (to detect excessive sweating), which allow the early detection of potential life-threatening events.

Since these tiny, vulnerable infants can hardly articulate pain and uncomfortableness in Neonatal Intensive Care Units (NICU) or at home, continuous monitoring of their vital signs and physiological parameters is crucial for clinicians and parents to know their exact health conditions. Preterm infants or critically ill infants admitted into the NICU need sustained monitoring in case of various dangerous conditions, which may include apnea, hypoglycaemia, sepsis or sepsis-like infection, seizure, arterial hypotonia, bradycardia, hypoxia, hypothermia, acidosis, and even problems of Sudden Infant Death Syndrome (SIDS). In addition, the apparent life-threatening events of 1- to 4-year-old infants, such as drowning in the bathrooms or head injuries occurring from falls or shaking, motivate clinicians and parents to search for an inexpensive and non-invasive way to effectively monitor the health status of infants and send alarm information whenever the infant's health condition is bad or whether the infant comes into contact with any other threatens from outside word. The primary purpose of the project is to review the current status of infant monitoring technology based on wearable sensor systems.

During sleep, doctors state that the infants should sleep on their back and they must not sleep on their stomach, as the infants are particularly vulnerable to SIDS due the risk of asphyxiation. Thus, we have developed an algorithm for the continuous monitoring of the position of the infant during the sleep. This algorithm is based on the data retrieved from an accelerometer and it is able to identify all four possible positions of the infant during the sleep: lying on his back; lying on his side; lying on his stomach. Moreover, the two of the major signs that SIDS may be about to happen is abnormal breathing pattern and heart rate. For the new borns the typically breathing rate is between 30 to 60 breaths per minute, 40 breaths per minute for infants, and it decreases to 24 to 30 breaths per minute after the first year. For the detection of the breathing rate, we used the same 3D accelerometer, and we have developed a low complexity algorithm with low overhead. Through the use of textile electrodes, knitted in the chest belt and with dedicated electronic, the heart rate is measured by our system. The textiles revealed to be an excellent interface for bio-signal sensing, as they are flexible, stretchable and conform to the body (increasing the physical comfort of the infant), rendering them an interesting solution for ubiquitous, continuous health monitoring. For the infants the normal heart rate is above 100 beats per minute. For the body temperature monitoring we use a small contactless infrared temperature sensor.

BLOCK DIAGRAM

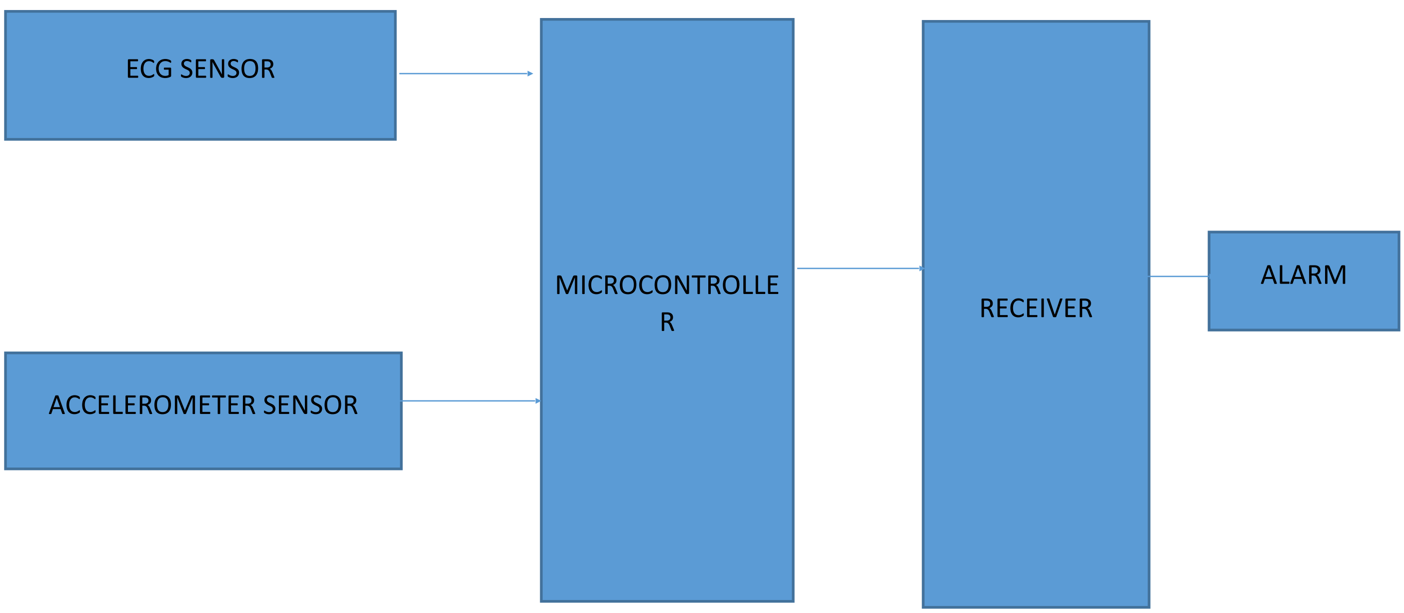
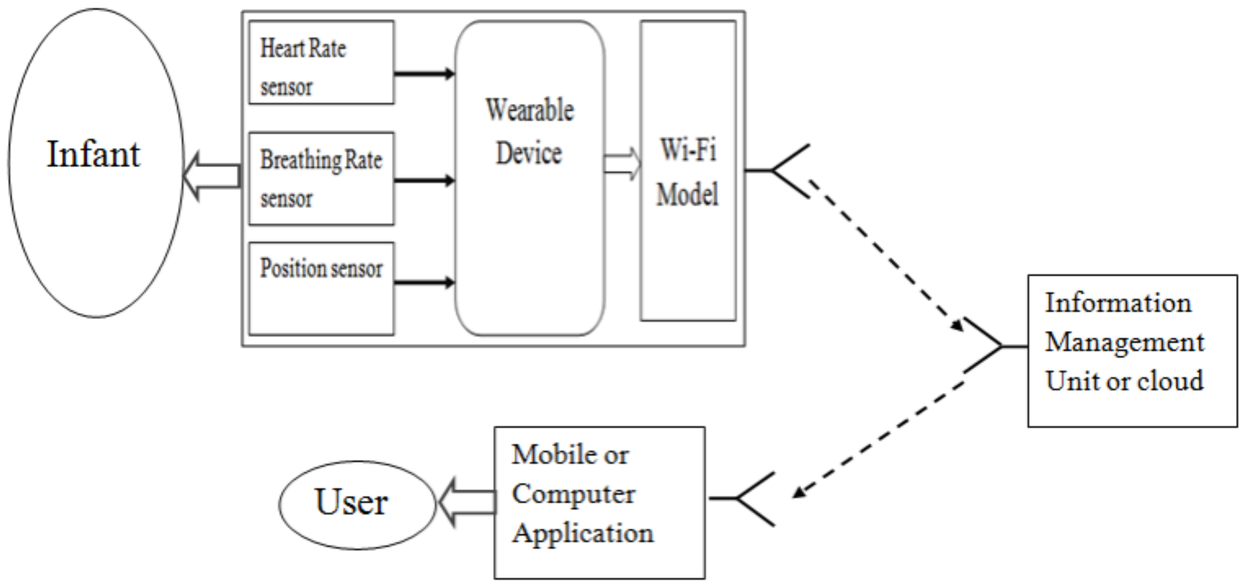


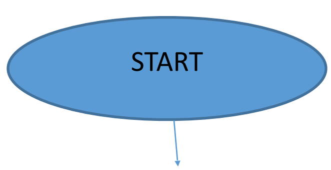
Fig1: Block Diagram



Block Diagram

The microcontroller used in this project is PIC16F877. The analog signals of the ECG sensor and the accelerometer is interfaced through the ADC pins of the microcontroller. ADXL335, the accelerometer interfaced has three axes values and these three values are checked at regular intervals to detect the critical position of the baby. AD8232, the ECG sensor interfaced has only one output which is used to calculate the heart rate of the infant. The receiver module receives all these values and checks for the critical condition and turns on the alarm if a critical condition has occurred.

FLOWCHART



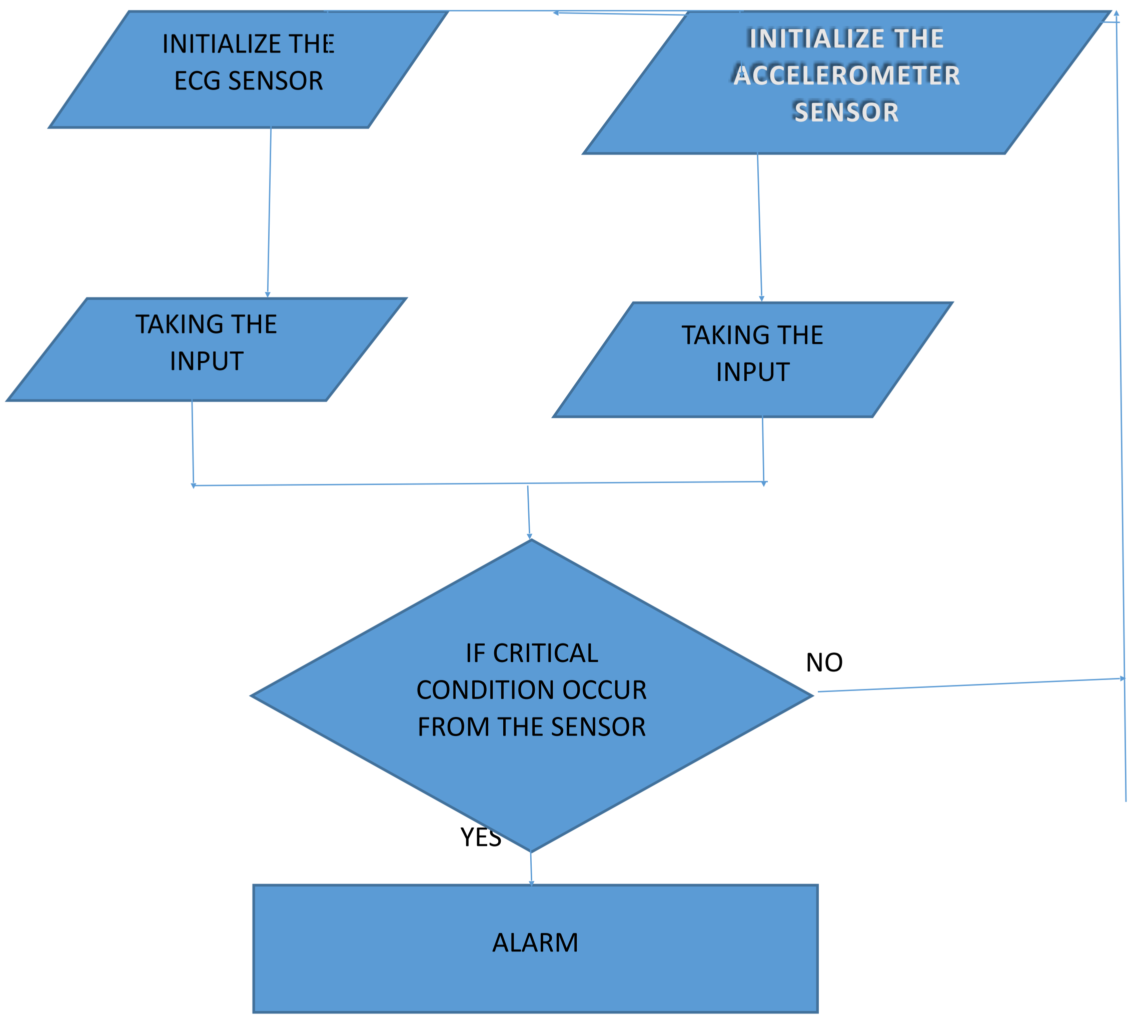


Fig2: Flow Chart

HARDWARE DESCRIPTION AND INTERFACING

1. PIC16F877

It is a powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC architecture into a 40- or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

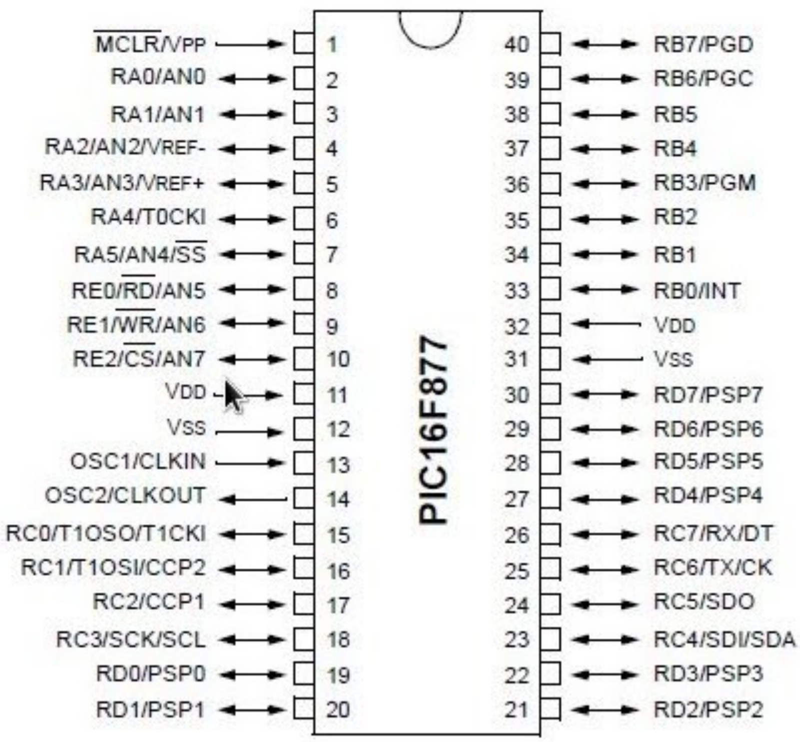


Fig3: Pinout of 16F877

2. ACCELEROMETER - ADXL335

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. The ADXL335 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ).

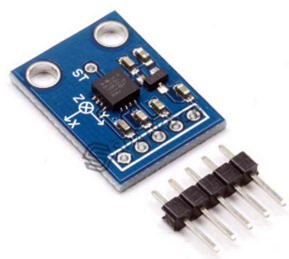


Fig 4: ADXL335

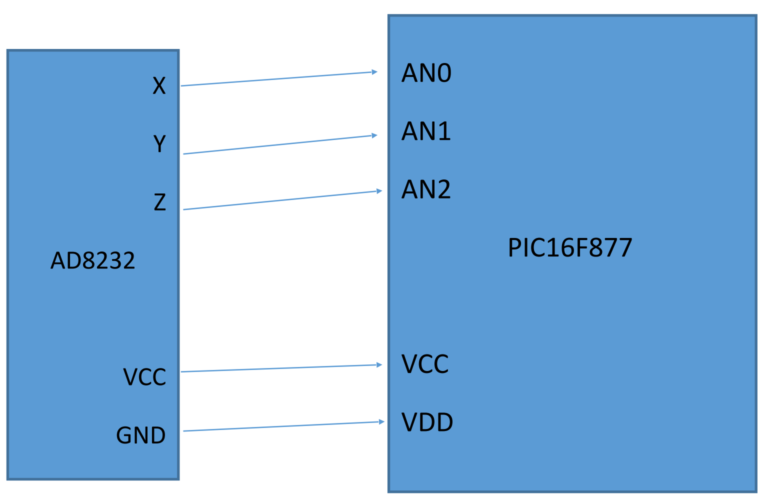


Fig 5: Interfacing XL335 with PIC16F877

To detect the position of the infants during the sleep, the ADXL335 inertial sensor from STMicroelectronics was used. In this project we did not use the built-in gyroscope. The ADXL335 has 3 independent acceleration channels, a dynamically user-selectable full-scale range and, a SPI/I2C serial interface. From Fig. 6 the different positions of the infants are easily recognised by the force that the earth gravity (±g or ±9.81m/s2) applies to each axis. Fig. 6 also shows that the gravity force on the YY's axis is almost zero for all of the four possible positions and, therefore, YY is not used to determine the infant's position. When the infant is lying on his backs (scenario A), in the ZZ's axis we will have ≈1g and on the XX's axis ≈0g. In scenarios B and D, the infant is lying on his side, in the ZZ's axis we have ≈0g and in the XX's axis ≈−1g when the infant is lying over his left arm (scenario B) and ≈lg when the infant is lying over his right arm (scenario D). In scenario C the infant is lying on his stomach and, in the ZZ's axis we have ≈−1g and in the XX's ≈0g. Also in Fig. 3 the gray bars represent the transient stages between each position. Based on the information we have developed an algorithm for position recognition. To minimize the small fluctuations that can occur between accelerometer readings, a threshold value was defined that allows to control the tilt angle in which a position is defined. So, the working principle of the proposed algorithm is: if the accelerometer reading in one axis is higher than the threshold value and the reading of the other axis is lower than the defined threshold, the position is set according to the values read (i.e. if the value in the ZZ's axis is +1 g and the value in the XX's axis is 0, then the position of the infant is defined as lying on his back). To prevent unnecessary energy consumption, the position updates will only be send to the Gateway when a valid position change is detected.

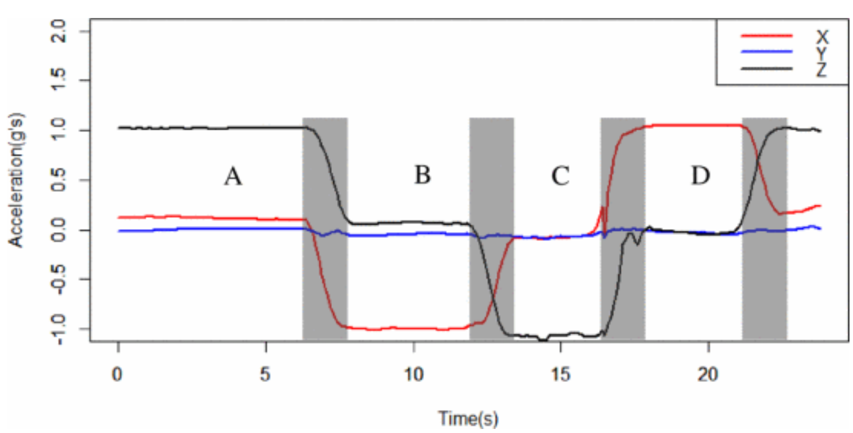


Fig 6: Acceleration variation on each axis over positions changes.

2. ECG SENSOR - AD8232

The AD8232 is an integrated signal conditioning block for ECG and other bio potential measurement applications. It is designed to extract, amplify, and filter small bio potential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. This design allows for an ultralow power analog-to-digital converter (ADC) or an embedded microcontroller to acquire the output signal easily. The AD8232 can implement a two-pole high-pass filter for eliminating motion artefacts and the electrode half-cell potential. This filter is tightly coupled with the instrumentation architecture of the amplifier to allow both large gain and high-pass filtering in a single stage, thereby saving space and cost. An uncommitted operational amplifier enables the AD8232 to create a three-pole low-pass filter to remove additional noise. The user can select the frequency cut-off of all filters to suit different types of applications.

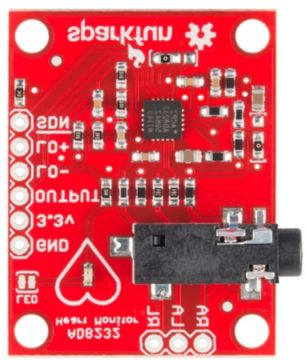


Fig 6: AD8232

To implement the heart rate measurement conditioning circuitry, an AD8232 was used and the heart rate monitor was designed to measure small bio potential signals in noisy conditions. The Instrumentation Amplifier has a gain of 100 V/V. Regarding the cut-off frequencies, the implemented block of the two-pole high-pass filter eliminates motion artefacts and drift caused by varying electrode-skin polarization and contact noise whilst the additional two-pole low-pass, using a Sallen Key configuration, attenuates the line noise and other interference. To compute the heart rate value, a PIC16F877 microcontroller was used in combination with the AD8232. Using its ultra-low power internal analog comparator, it is possible to compare the filtered ECG wave with an external voltage level. The analog comparator solution compares the voltage reference with the level of the ECG signal and the output changes when the ECG signal drops below the voltage divider value (voltage reference set to 300 mV). To calculate the infants heart rate, a timer of the PIC16F877 is used to measure the time between two heart rate pulses.

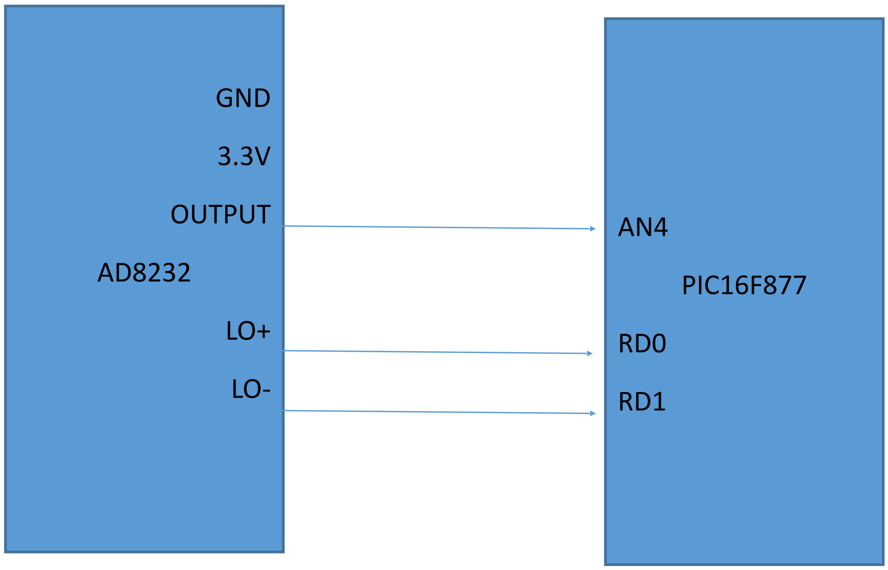
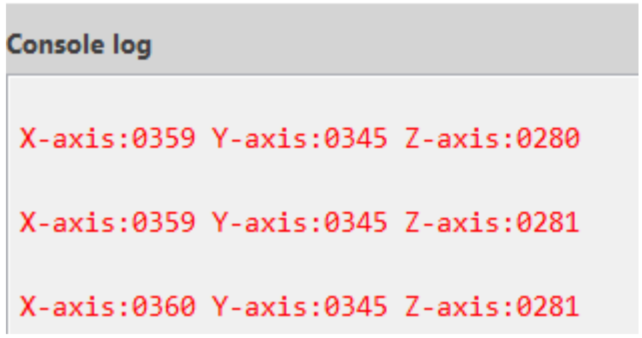


Fig 7: Interfacing AD8232 with PIC16F877

RESULTS AND DISCUSSION



CONCLUSION

Experimental tests have proven that this device has the potential to identify situations that could be potentially life-threatening for an infant.