LifeMonitor

GROUP II

CpE - 424: Engineering Design 8

Final Report By

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"I pledge my honor that I have abided by the Stevens Honor System"

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I. Abstract

The group is designing a non-intrusive vital sign monitoring system for monitor respiration patterns of an infant while they are asleep. The monitor will be mounted above the crib without any physical attachment to the body and will detect vital signs through the use of a microwave Doppler motion sensor. If the sensor fails to detect respiration for a set period of time, it will indicate that the baby is no longer breathing and will trigger an alarm in a separate device. This “notification device” will emit an audible noise upon receiving the signal from the sensor. The notification device will be battery operated and will be equipped with a belt clip for convenient portability for the parents within range of the sensor. The group hopes to finalize the design and production of the notification device in the near future. The LifeMonitor system is both easy to implement and inexpensive, while providing parents with peace of mind. In the fight against Sudden Infant Death Syndrome (SIDS), a home monitoring system is long overdue.

I.1 Acknowledgement

The group would first like to thank our advisor, Dr. Haibo He. His enthusiasm for the project and willingness to advise and assist the group has been a major factor in the product's success thus far. The group would also like to thank John Hallatt of Microwave Solutions for his dedication to higher education. He was able to send the group several microwave sensors for our tests.

I.2 Introduction

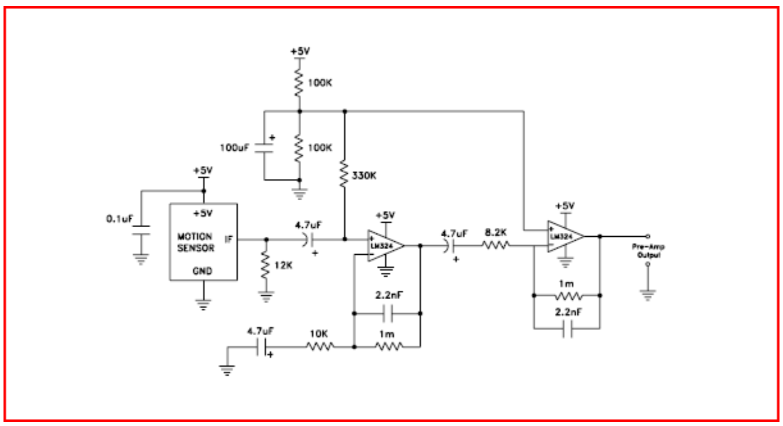
Each year there are over 2500 infant deaths in the United States attributed to SIDS. Current baby monitors are not capable of warning the parents if the infant suffers from fatal health issues as they only transmit sound. The next generation of baby monitors will naturally progress to provide vital sign information that, as of now, is only provided by hospital equipment. A crucial first step in this progression is the monitoring of the baby's breathing. The first indication of there being cause for concern is often discontinued respiration, as in severe cases of sleep apnea and suffocation. The second step would be to integrate heart rate monitoring systems into these next generation baby monitors. There are no non-intrusive heart rate monitors currently on the market. Our main objective is to design and develop this next generation baby monitor.

There are two methods of monitoring breathing that are currently available commercially. The Respisense monitor that attaches to the infant's diaper and detects movement in the abdomen due to respiration. It weighs about 32 grams, has no wires or plug connections. The second device is the Angelcare monitor. It comes with a small and extremely sensitive mat that is placed under the infant's mattress and it then can detect vibrations through the mattress from the infant's breathing. Respisense monitors are inexpensive, while Angelcare monitors are very expensive, as they are capable of making temperature readings of the environment in which the baby is sleeping. Both monitors sound an alarm when movement ceases for 20 seconds so the caregiver has sufficient time to respond. The technology is currently available to monitor the breathing and heart rate of an infant without physical contact to the body. The group's goal is to develop a small, lightweight baby monitor that will be able to wirelessly monitor an infant's vital signs. This product will be hung above a crib, car seat, or stroller and will alert caregivers if the heart or respiration rate falls below normal levels. In order to accomplish this, the baby monitor will be equipped with a microwave sensor that uses the principles of the Doppler Effect to detect motion. The sensor is extremely sensitive and will output a voltage based on the motion of the chest cavity (from respiration) and vibrations on the chest's surface (from heart beat). A microcontroller will analyze these signals and calculate the frequency at which the infant is breathing and its heart is beating. At this point the program will continue to monitor and update these frequencies until an unsafe drop in either of these values is detected. The triggered alarm will sound on an attached speaker and flash an LED, enabling caregivers to take swift action as necessary. If a baby stops breathing as a result of sleep apnea, sometimes simply waking the baby up is enough for it to begin breathing again. If an infant is suffocating from rolling into a pillow or a blanket, the parents will be alerted and can remove the obstruc tion or perform CPR.

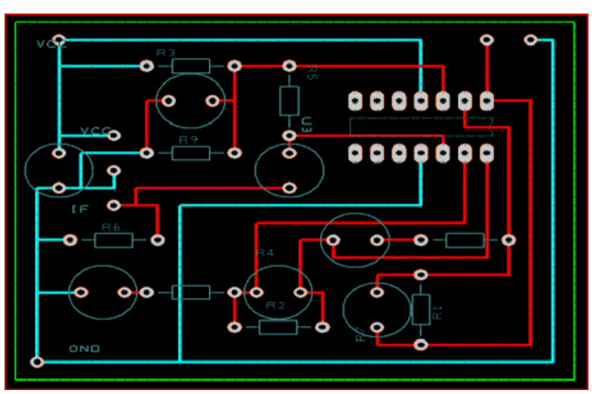
II. Implemented Prototype

The team took two distinctive approaches to finish off the project. First approach focused on the design and fabrication of the Op-Amp circuit which is used to amplify the readings from the sensor. The second approach focused on manipulation of readings off the sensor and cleansing the reading from any unwanted noise.

The need for the Op-Amp circuit is to protect the sensor and provide it with a safe voltage and current (5.000 V DC @ Less than 0.050 A) and also amplify the readings which come out of the sensor.



The completed design was then translated back onto a PCB, Printed Circuit Board and was ordered through 4pcb.com website to be fabricated. After completion of a prototype of the circuit, the outputs levels for the sensor are at a safe level (5.000 V DC @ 0.046 A)



Simultaneous to the process of fabrication of the Op-Amp, the team worked on analyzing the reading from the microwave sensor. The team then successfully hooked up the sensor through a DAQ card to a pc and acquired some readings. Through this process, the DAQ card returns a series of output voltages that range around 2.5V when the sensor is not being triggered. When there is motion in front of the sensor, the output values form a wave that ranges from 1.4 to almost 3.4 volts. Consequently, the team successfully worked on gathering readings when the Op-Amp is connected with the sensor to the DAQ card. Following this step, the readings need to be adjusted and cleansed from any unwanted noise with the help of some low-pass/high-pass filters. The last phase of the project which has yet to be completed is implementing a microcontroller board within the device. This microcontroller will have the ability to manipulate and analyze the readings coming from the sensor through the op-amp circuit. Based on the voltage changes, the board will output a safe or not safe level for breathing and heart beat patterns.

II.1 Prototype Specification (Part List)

Based on the chosen design, the following is the list of the parts that are needed in order to produce one prototype of LifeMonitor baby monitor. As a side note, the team produced more than one working and functional prototype for testing purposes. In this case, we will need to double the quantity of some components that get soldered on the PCB board.

Categories	Sub-categories	Quantity
Amplifier	LM324	2
Microwave Motion Sensor	MDU 1100	1
Resistors:		
	12 KΩ	1
	10 KΩ	1
	1 MΩ	2
	330 KΩ	1
	100 KΩ	2
	8.2 KΩ	1
Capacitors:		
	0.1 μf	1
	100 μf	1
	4.7 μf	3
	2.2 nf	2
DAQ board		1
Power Supply (alternately batteries)	5V Input	1
Microprocessor and controller		1
LED	Multicolor LED	1
Speaker		1
PCB Board		1
Signal Analyzer software	Coded in C	1

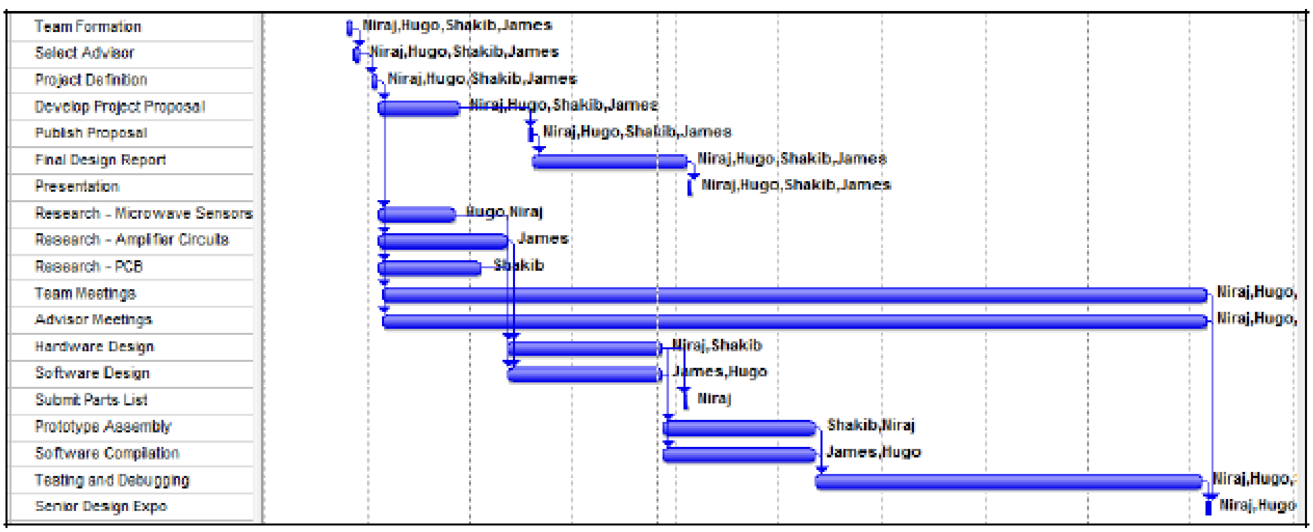
II.2 Financial Budget

As it was discussed earlier, the team requires the following components in order to build a functional prototype of the baby monitor. Also added to the table is the component price and total price for the whole project. Note that all prices include the tax and shipping paid for by the team. The important note is that for software development, the team will accomplish the whole task within the house and will not spend any money to purchase it. Another note would be of the price of the PCB, we obtained the price of $5 dollars if we mass produce this device, but in actuality, it is about $55 dollars for one PCB .

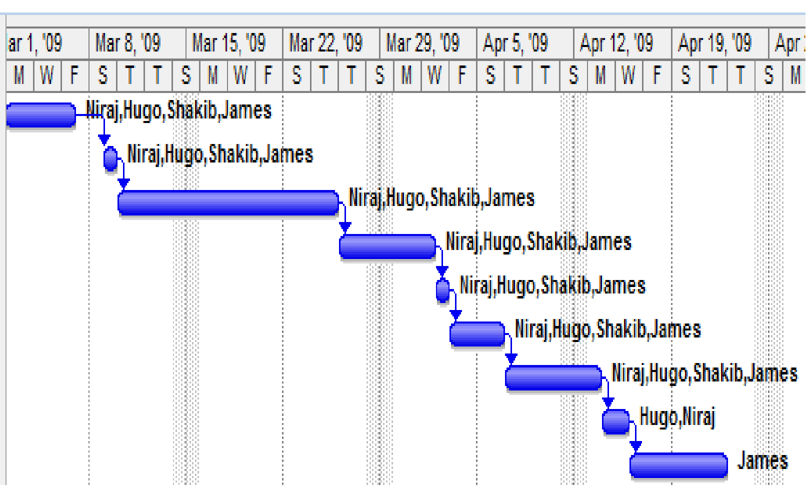
Categories	Sub-categories	Quantity	Price
Amplifier	LM324	2	$20
Microwave Motion Sensor	MDU 1100	1	$80
Resistors:			
	12 KΩ	1	$1
	10 KΩ	1	$1
	1 MΩ	2	$2
	330 KΩ	1	$1
	100 KΩ	2	$2
	8.2 KΩ	1	$1
Capacitors:			
	0.1 μf	1	$1
	100 μf	1	$1
	4.7 μf	3	$3
	2.2 nf	2	$2
DAQ board		1	$45
Power Supply (alternately batteries)	5V Input	1	$5
Microprocessor and controller		1	$60
LED	Multicolor LED	1	$2
Speaker		1	$10
PCB Board		1	$5
Signal Analyz-er software	Coded in C	1	$0
TOTAL			$242

II.3 Project Schedule

The following charts show the complete life cycle of the project from group formation to Senior Design Expo Day. As can be seen from these charts, each task is given a specific duration and resources assigned to it. Most of the time, the entire team works together to accomplish a task, but in the case of parallel tasks, such as research in specific fields, the team is broken up to maximize efficiency and reduce the length of project. Also, after a semester of working together, we updated the Gantt chart to show our status in terms of the deadline.



	Task Name	Duration	Start	Finish
1	Debugging circuit using DAQ	5 days	Mon 3/2/09	Fri 3/6/09
2	Implementing Microcontroller	1 day	Mon 3/9/09	Mon 3/9/09
3	Programming Microcontroller	12 days	ue 3/10/09	Wed 3/25/09
4	Debugging the microcontrolle	5 days	'hu 3/26/09	Wed 4/1/09
5	Addition of a speaker	1 day	Thu 4/2/09	Thu 4/2/09
6	Final test	2 days	Fri 4/3/09	Mon 4/6/09
7	Final Debug	5 days	Tue 4/7/09	Mon 4/13/09
8	Improve the visuals	2 days	ue 4/14/09	Wed 4/15/09
9	Poster board/ Senior Design	5 days	'hu 4/16/09	Wed 4/22/09



III Prototype Performance and Evaluation

III.1 Hardware

From the hardware aspects of this system, eliminating noise seemed to be the greatest challenge that the team was facing during it preliminarily design and testing the first prototype. Due to sensitivity of the microwave sensor, the smallest degree of noise would trigger off a false reading or a measurement. It would have been perfect if the team would just the sensor in the embedded system only. However, due to the very small range of output provided by the sensor, the output data provided by the sensor could not be used effectively. Solution to this problem was to amplify the output signal. The team did its research to find the most effective op-amp circuit that could be used. This matter was resolved during the beginning of this semester; however the problem was yet to be solved.

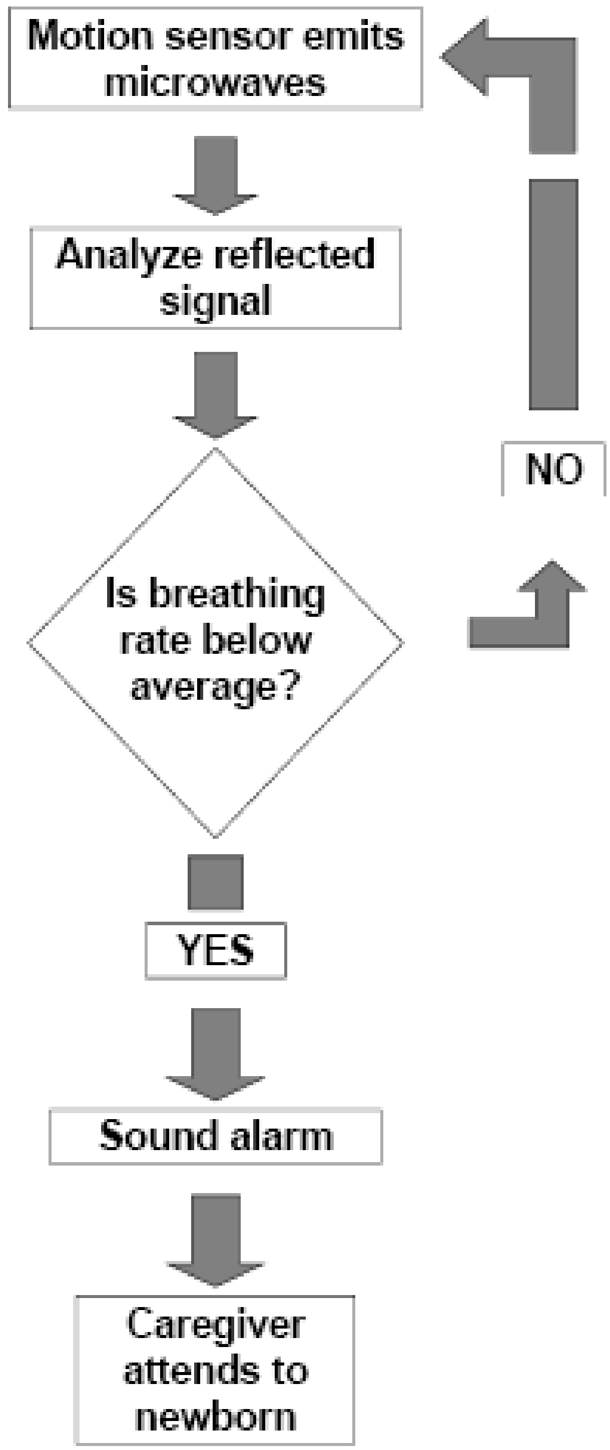
The first designed circuit generated a great amount of unwanted noise, causing the output signal to be very unsatisfactory. The poor idea of using a PCB that was bought from radio shack was the first thought that team could relate the problem to. Also, all the power and signal wires seemed to be wired next to one another, at which resulted the noise. The final goal was to come up with a way to reduce noise, and that is where the final design of the PC board came through.

The team decided to order a custom made PC board to be manufactured by an outsourced company. This allowed the team to reduce the amount of wired jumpers and connectors. A two layer board was picked out to do the arm work on. To reduce noise, all power signals were drawn on the bottom layer of the board, and all signal wires that had to be amplified were drawn on the top layer. Since the amount of heat generated by the system is negotiable, a 10 mill pitch thickness and 1 ounce copper seemed to be the most useful concept to be used in creating the art work on the PCB. This gave enough room for the system to be operated at room temperature with 10 degree C rising.

To reduce noise furthermore, a shilled twisted pair of wire was used to connect between the sensor and the Data Acquisition and Control board (DAC). Also, a very limited amount of wire was used to connect the sensor to the PCB as well. This idea also allowed the team to be able to package the entire system into a very small embedded box made out of Plexiglas. Using through hole components for the PCB allowed for much easier method of soldering the resistors and capacitors. Once completed the team was able to limit noise to a great degree. Once the software was implemented, the success was measured based on how the team was able to record the movement of the chest at every breath.

III.2 Software

The main program that drives the LifeMonitor system is written in C. It utilizes an API provided by National Instruments for their Data Acquisition Boards (DAQ). The sensor is connected and the program takes readings from the DAQ board. I then takes this samples are runs them through a carefully designed logic mechanism in order to determine whether or not the sensor has detected a breathe. If the program decides it has not detected a breath for a period of 5 to 7 second, it sounds an alarm. This program's source code was developed and copyrighted by the LifeMonitor team and is available only in binary form.



IV Conclusion

The Life Monitor Project aimed and succeeded to bring a much needed tool quickly and effectively to the market. Parents will be attracted to it due to its low cost, non-obtrusiveness and ease of use, as well as the incredible value it brings into their home. The decision to go with the Doppler radar sensors will greatly reduced the cost involved in prototyping, testing and, ultimately, manufacturing costs. The projected sales and scope of this tool makes it a very exciting project to further work on. The short range goal of the team at the conclusion of Senior Design Expo is to patent the idea and continue to further develop this device so that one day it can reach homes nationwide.

V References

[1] http://www.sids.org/index.htm

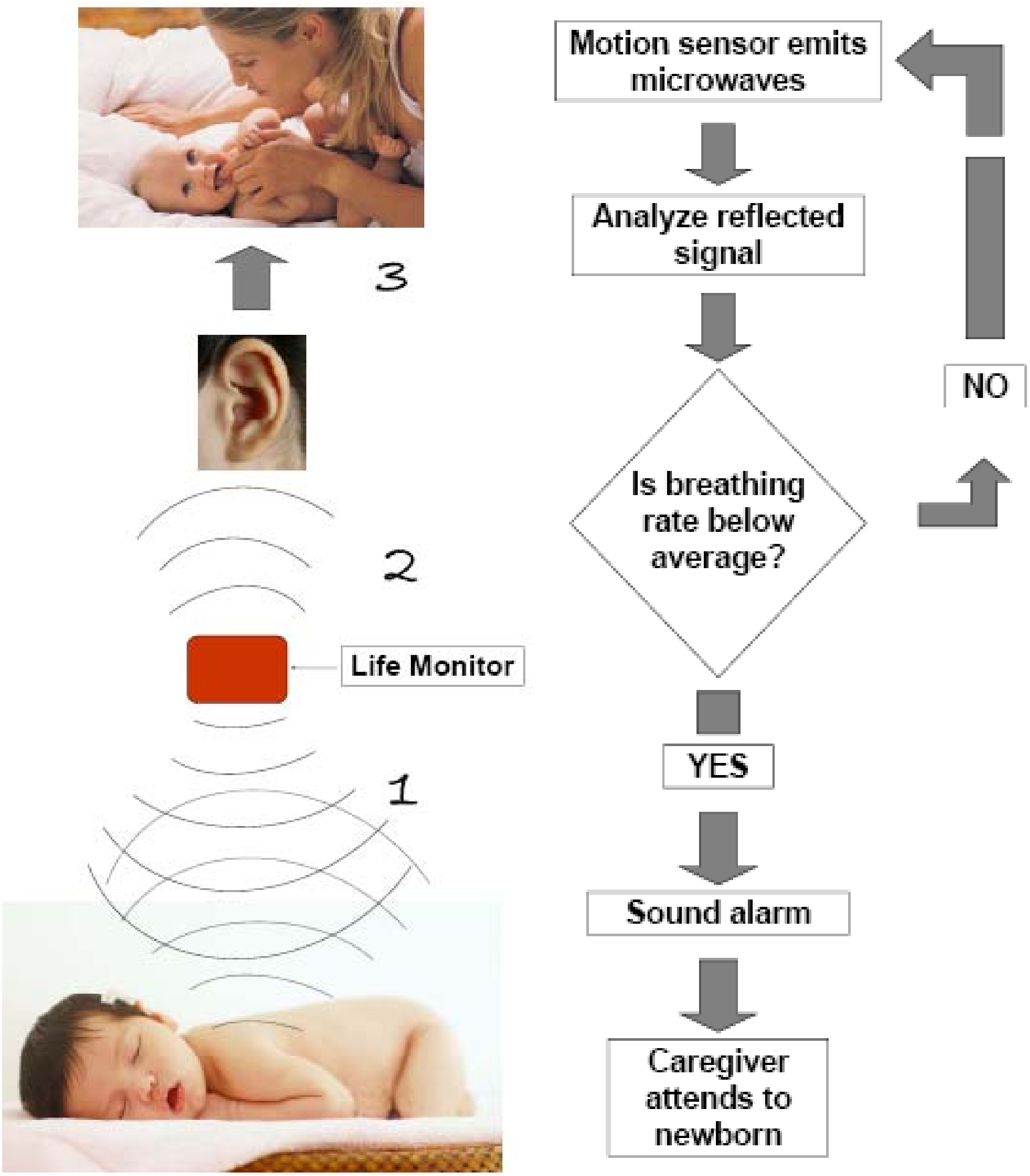
[2] http://www.sids.org/nprevent.htm

[3] O. Boric Lubecke, P.-W. Ong, V.M. Lubecke, "10 GHz Doppler Radar Sensing of Respiration and Heart Movement," IEEE 2002.

[4] M. Y. W. Chia, S. W. Leong, C. K. Sim, K. M. Chan, "Through-wall UWB radar operating within FCC's mask for sensing heart beat and breathing rate," IEEE 2002

[5] Ramya Murthy & Ioannis Pavlidis, "Noncontact Measurements of Breathing Function."
IEEE 2006

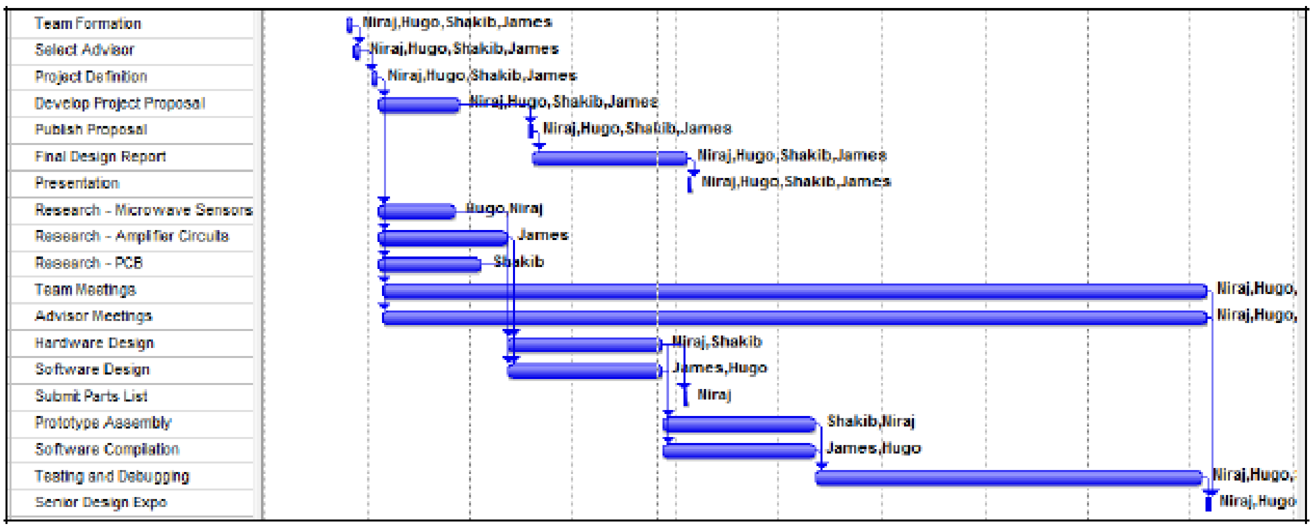
Appendix 1: Block Diagram

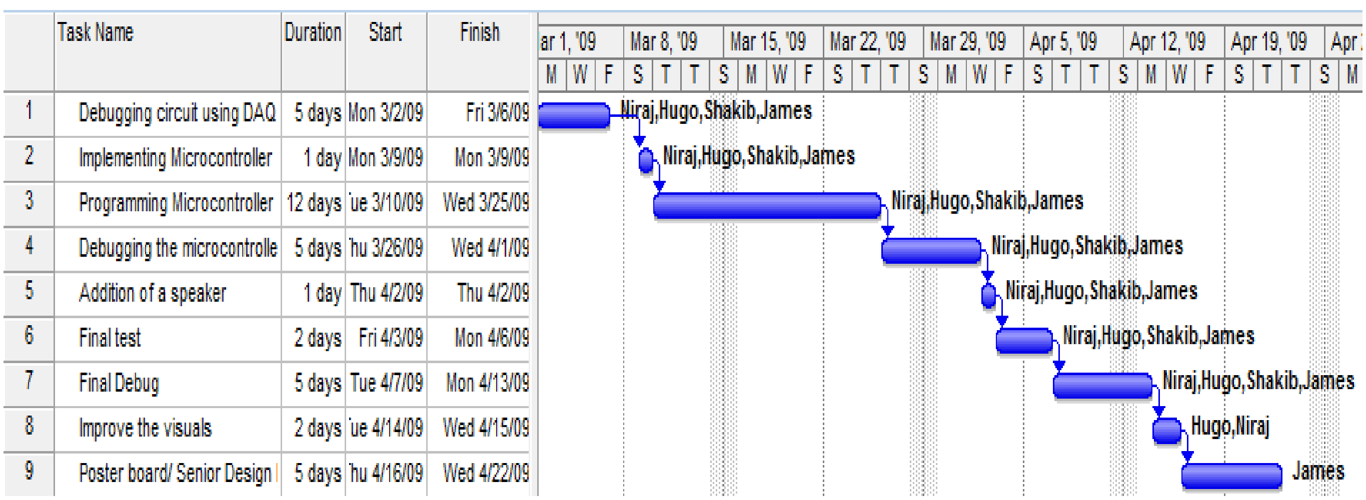


Appendix 2: Cost/Parts Table

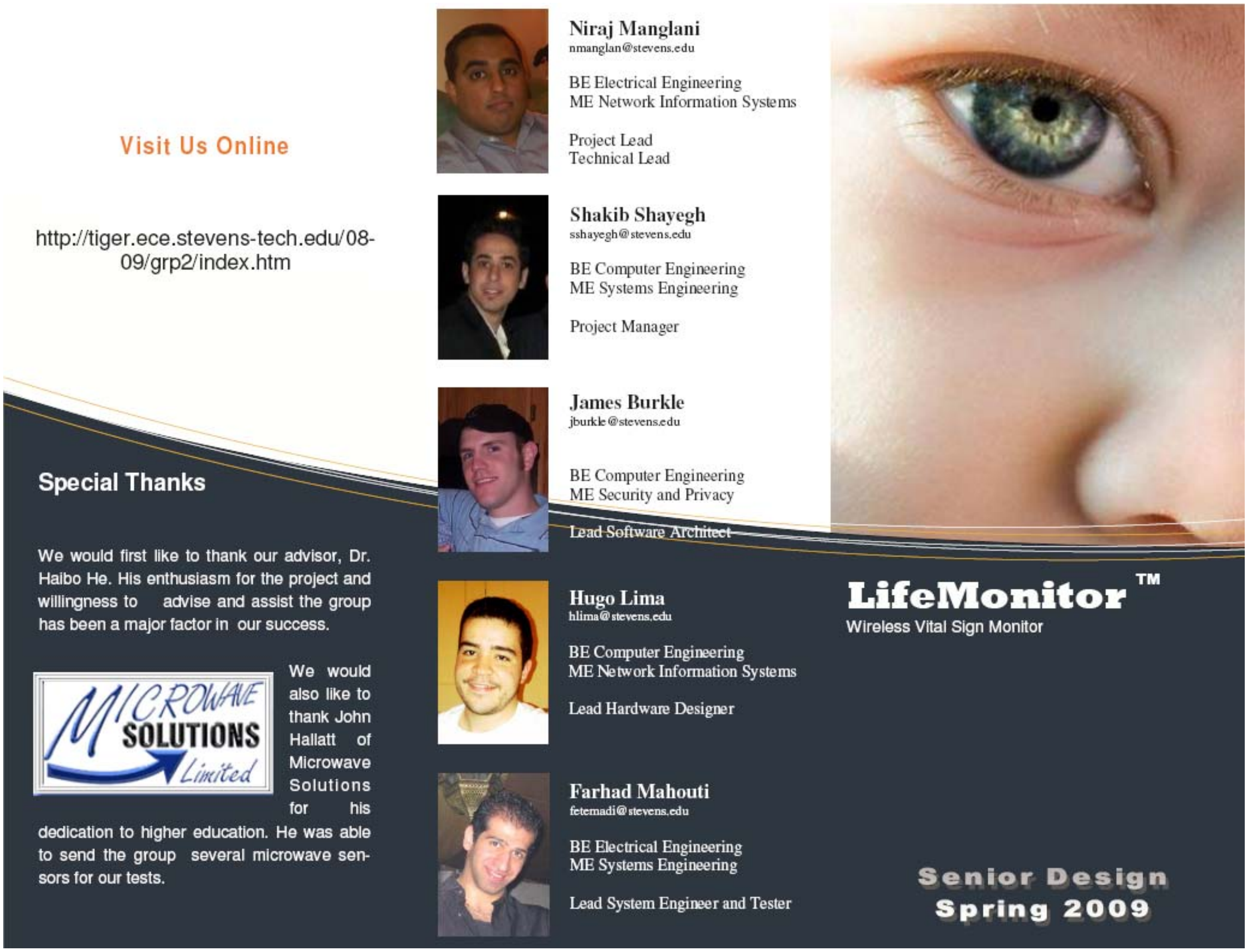
Categories	Sub-categories	Quantity	Price
Amplifier	LM324	2	$20
Microwave Motion Sensor	MDU 1100	1	$80
Resistors:			
	12 KΩ	1	$1
	10 KΩ	1	$1
	1 MΩ	2	$2
	330 KΩ	1	$1
	100 KΩ	2	$2
	8.2 KΩ	1	$1
Capacitors:			
	0.1 µf	1	$1
	100 µf	1	$1
	4.7 µf	3	$3
	2.2 nf	2	$2
DAQ board		1	$45
Power Supply (alternately batteries)	5V Input	1	$5
Microprocessor and controller		1	$60
LED	Multicolor LED	1	$2
Speaker		1	$10
PCB Board		1	$5
Signal Analyz-er software	Coded in C	1	$0
TOTAL			$242

Appendix 3: Original & Updated Gantt chart





Appendix 4: Brochure



Side A

LifeMonitor

Wireless vital sign monitor for the purpose of reducing the risk of SIDS

THE PROBLEM

- **SIDS** is the sudden death of an infant under one year of age that remains unexplained even after autopsy.
- 7,000 deaths per year worldwide
- 1 death every hour of every day

Possible causes of SIDS:

- Stress caused by infection or other factors
- Birth Defects
- Failure to fully develop
- Sleep apnea

OUR GOAL

- Reduce the risk of SIDS
- Eliminate physical attachments to the body
- Reliability
- Cost effectiveness
- Simplicity

THE SOLUTION

The LifeMonitor consists of a MD1100 microwave sensor which is used to detect motion in the chest cavity of an infant due to respiration. This reading then gets amplified through the circuit below and gets passed on to the logic gates through the DAQ card. If the breathing pattern is acceptable, this cycle gets repeated. At any point if this pattern gets disrupted, a signal is sent and a warning tone is played through the speaker.

Providing peace of mind and saving lives

COMPONENTS

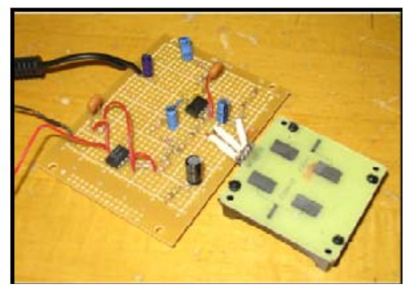
- MD1100 Microwave Sensor
- Amplifier circuit
- NI6008 USB DAQ Card
- Custom C code

CHALLENGES

- Presence of unwanted noise
- Difficulty detecting distinguished heart beats
- Health concerns in regards to usage of microwave sensors

FUTURE Advances

- Ability to detect heart rate
- Alarm sounds on beeper
- Daily reports of breathing patterns
- Automatic uploads of data to pediatrician
- Nationwide data collected to better understand sleeping patterns of infants



Side B

Appendix 5: Senior Poster Display