

# LifeMonitor

## GROUP II



### CpE - 424: Engineering Design 8

**Final Report**

By

Niraj Manglani

Shakib Shayegh

Hugo Lima

James Burkle

Farhad Etemadipour

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Faculty Advisor: Haibo He

“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.

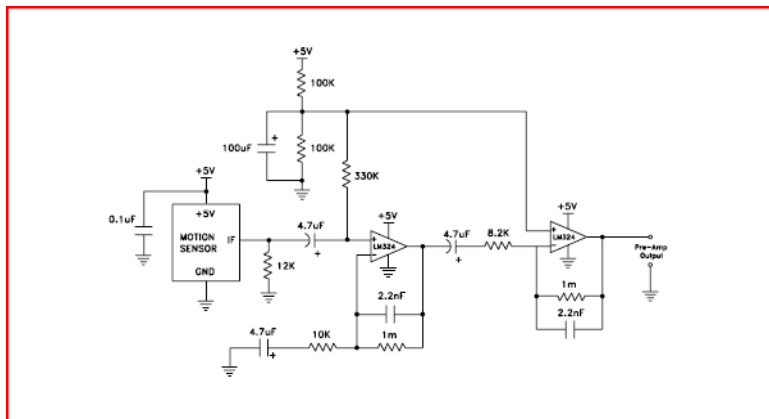
There are two methods of monitoring breathing that are currently available commercially. The RespiSense monitor that attaches to the infant's diaper and detects movement in the abdomen due to respiration. It weighs about 32 grams, has no wires or plug connections. The second device is the Angelcare monitor. 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 obstruction or perform CPR.

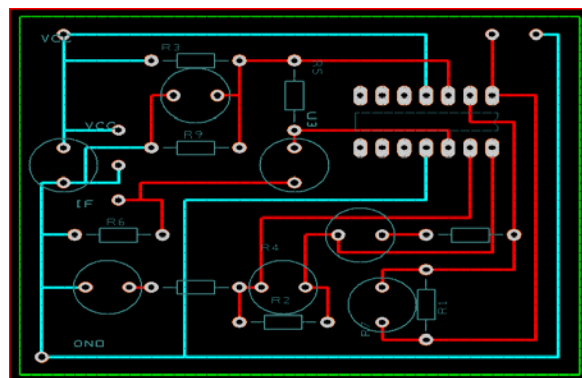
## II. Implemented Prototype

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.

<b>Categories</b>	<b>Sub-categories</b>	<b>Quantity</b>
<b>Amplifier</b>	LM324	2
<b>Microwave Motion Sensor</b>	MDU 1100	1
<b>Resistors:</b>		
	12 K $\Omega$	1
	10 K $\Omega$	1
	1 M $\Omega$	2
	330 K $\Omega$	1
	100 K $\Omega$	2
	8.2 K $\Omega$	1
<b>Capacitors:</b>		
	0.1 $\mu$ f	1
	100 $\mu$ f	1
	4.7 $\mu$ f	3
	2.2 nf	2
<b>DAQ board</b>		1
<b>Power Supply (alternately batteries)</b>	5V Input	1
<b>Microprocessor and controller</b>		1
<b>LED</b>	Multicolor LED	1
<b>Speaker</b>		1
<b>PCB Board</b>		1
<b>Signal Analyzer software</b>	Coded in C	1

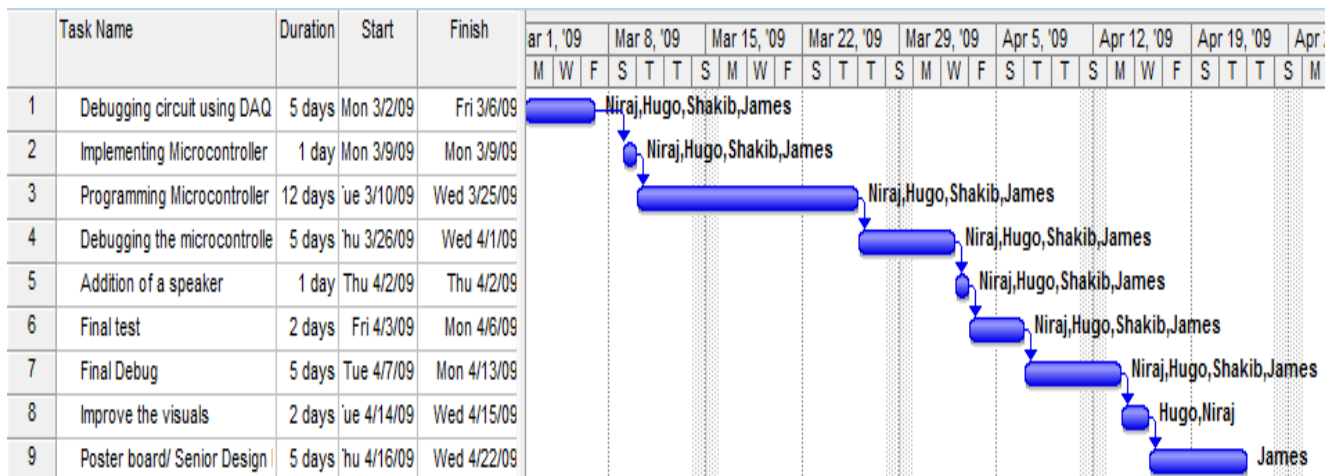
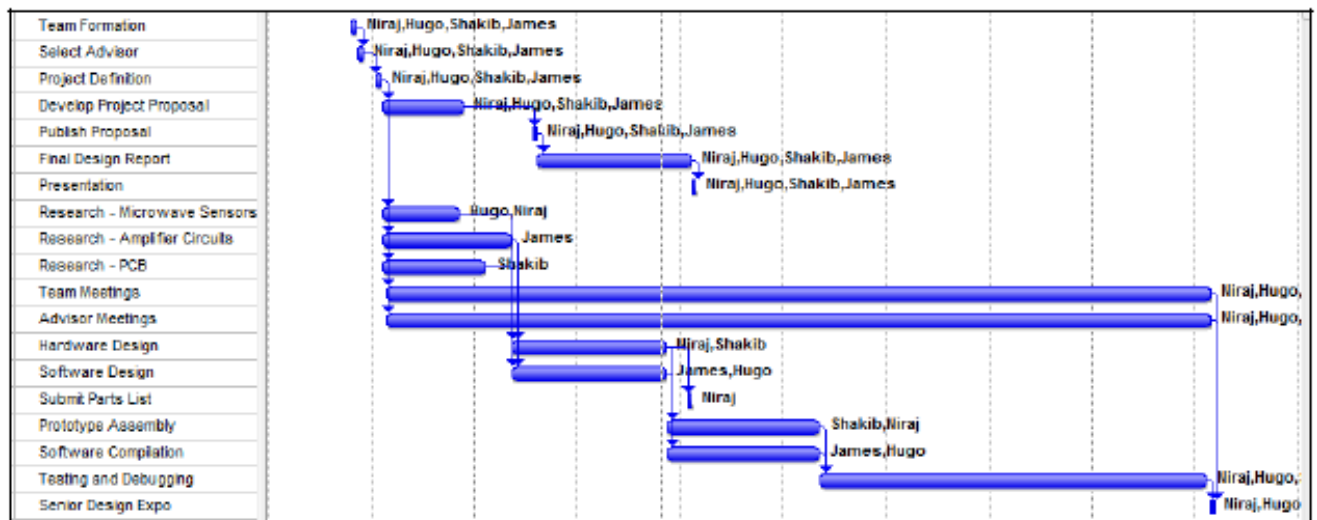
## II.2 Financial Budget

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 K $\Omega$	1	\$1
	10 K $\Omega$	1	\$1
	1 M $\Omega$	2	\$2
	330 K $\Omega$	1	\$1
	100 K $\Omega$	2	\$2
	8.2 K $\Omega$	1	\$1
Capacitors:			
	0.1 $\mu$ f	1	\$1
	100 $\mu$ f	1	\$1
	4.7 $\mu$ f	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 Analyzer software	Coded in C	1	\$0
<b>TOTAL</b>			<b>\$242</b>

### 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.



### **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 its preliminary design and testing the first prototype. Due to the 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 use 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. The 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 the team could relate the problem to. Also, all the power and signal wires seemed to be wired next to one another, at which resulted in the noise. The final goal was to come up with a way to reduce noise, and that is where the final design of the PCB came through.

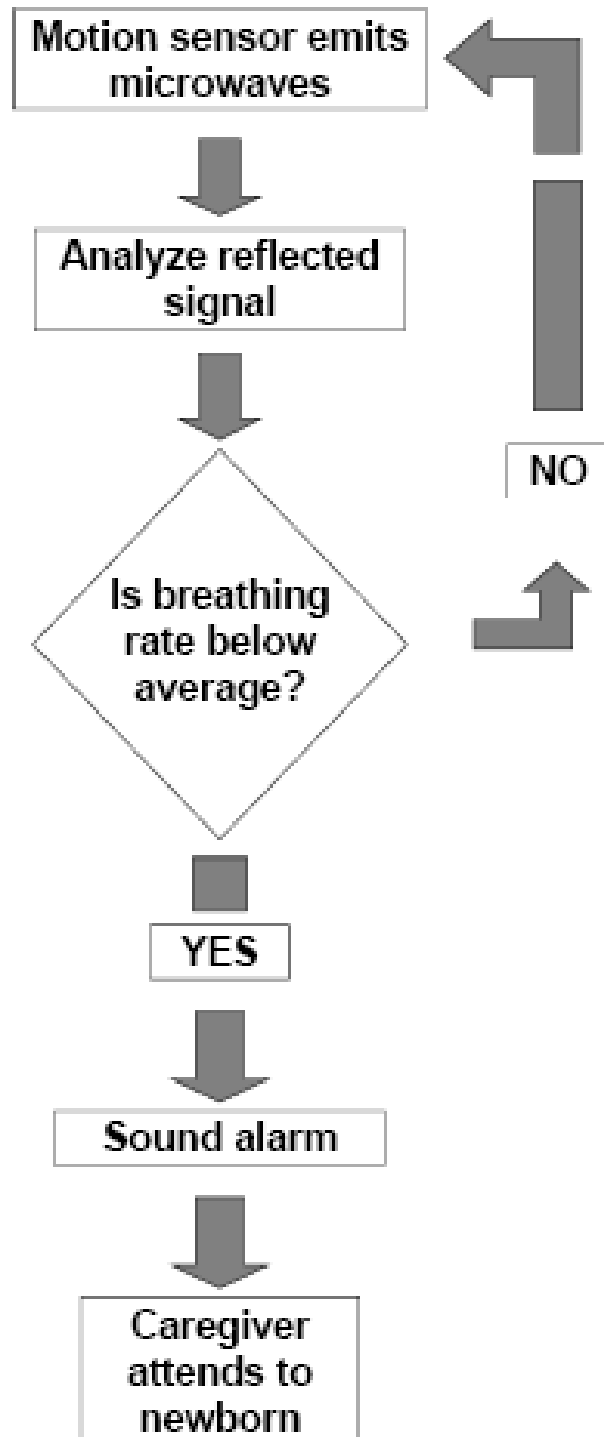
The team decided to order a custom-made PCB to be manufactured by an outsourced company. This allowed the team to reduce the amount of wired jumpers and connectors. A two-layer board was picked out to do the work on. To reduce noise, all power signals were drawn on the bottom layer of the board, and 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 shielded 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>

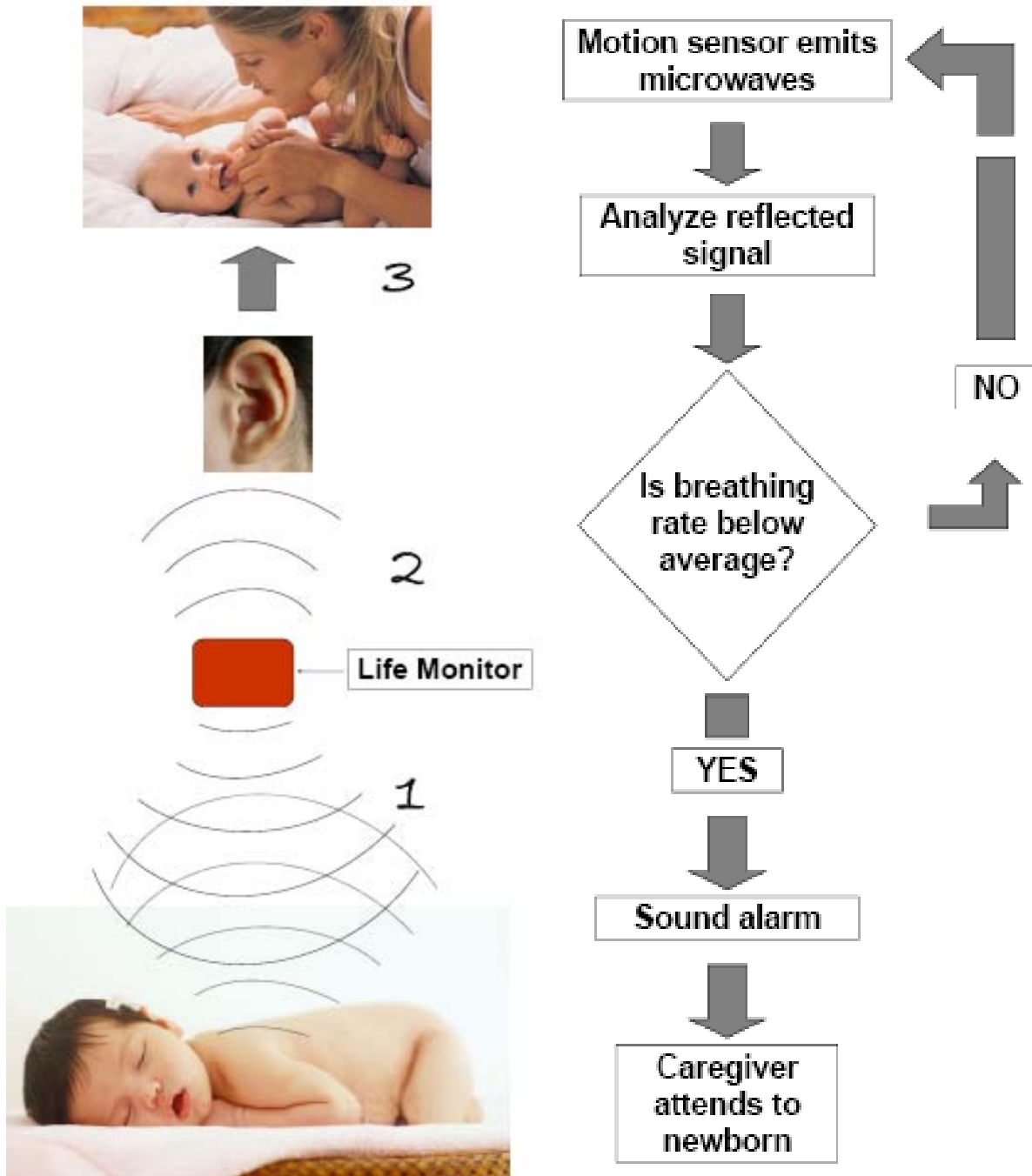
[3] O. Boric Lubecke, P.-W. Ong, V.M. Lubecke, "10 GHz Doppler Radar Sensing of Respiration and Heart Movement," IEEE 2002.

[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



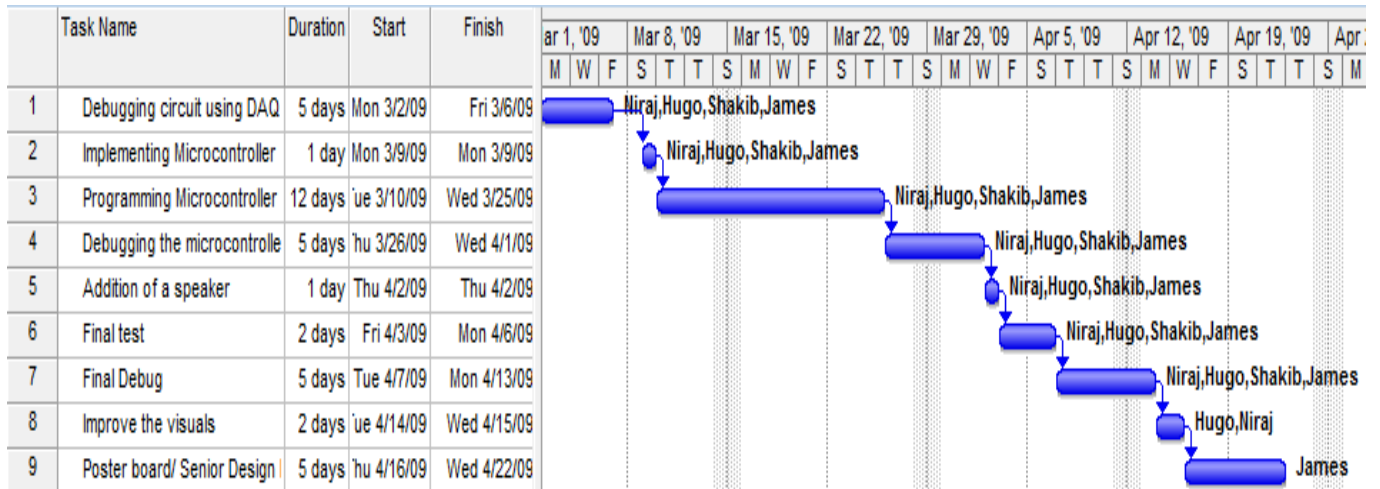
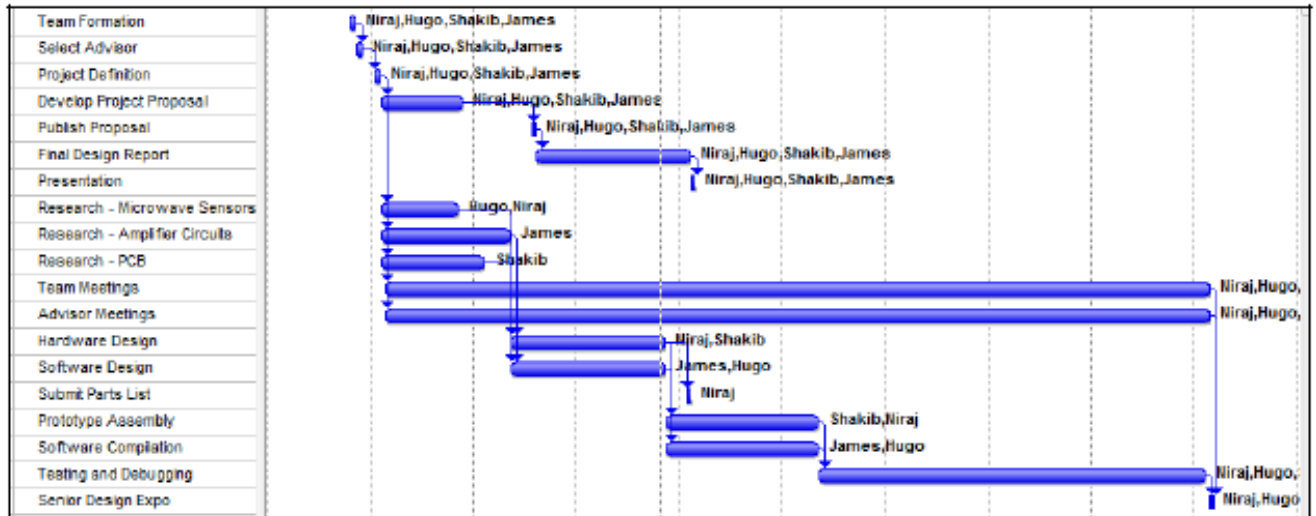
# Appendix 1: Block Diagram



## Appendix 2: Cost/Parts Table

Categories	Sub-categories	Quantity	Price
Amplifier	LM324	2	\$20
Microwave Motion Sensor	MDU 1100	1	\$80
<b>Resistors:</b>			
	12 K $\Omega$	1	\$1
	10 K $\Omega$	1	\$1
	1 M $\Omega$	2	\$2
	330 K $\Omega$	1	\$1
	100 K $\Omega$	2	\$2
	8.2 K $\Omega$	1	\$1
<b>Capacitors:</b>			
	0.1 $\mu$ f	1	\$1
	100 $\mu$ f	1	\$1
	4.7 $\mu$ f	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 Analyzer software	Coded in C	1	\$0
<b>TOTAL</b>			<b>\$242</b>

### Appendix 3: Original & Updated Gantt chart



## Appendix 4: Brochure

### Visit Us Online

<http://tiger.ece.stevens-tech.edu/08-09/grp2/index.htm>

### Special Thanks

We 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 our success.



We 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.



**Niraj Manglani**

[nmanglan@stevens.edu](mailto:nmanglan@stevens.edu)

BE Electrical Engineering  
ME Network Information Systems

Project Lead  
Technical Lead



**Shakib Shayegh**

[sshayegh@stevens.edu](mailto:sshayegh@stevens.edu)

BE Computer Engineering  
ME Systems Engineering

Project Manager



**James Burkle**

[jburkle@stevens.edu](mailto:jburkle@stevens.edu)

BE Computer Engineering  
ME Security and Privacy

Lead Software Architect



**Hugo Lima**

[hlima@stevens.edu](mailto:hlima@stevens.edu)

BE Computer Engineering  
ME Network Information Systems

Lead Hardware Designer



**Farhad Mahouti**

[fetemadi@stevens.edu](mailto:fetemadi@stevens.edu)

BE Electrical Engineering  
ME Systems Engineering

Lead System Engineer and Tester



**LifeMonitor™**  
Wireless Vital Sign Monitor

**Senior Design  
Spring 2009**

## 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

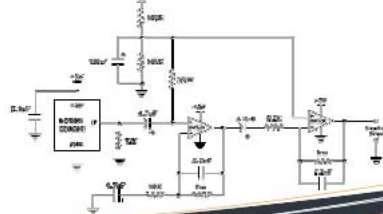


## OUR GOAL

- 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.



## COMPONENTS

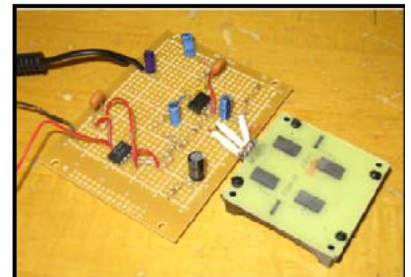
- MD1100 Microwave Sensor
- Amplifier circuit
- NI6008 USB DAQ Card
- Custom C code

## 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








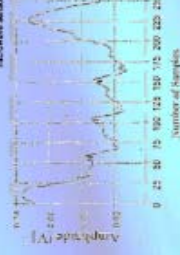


Providing peace of mind and saving lives

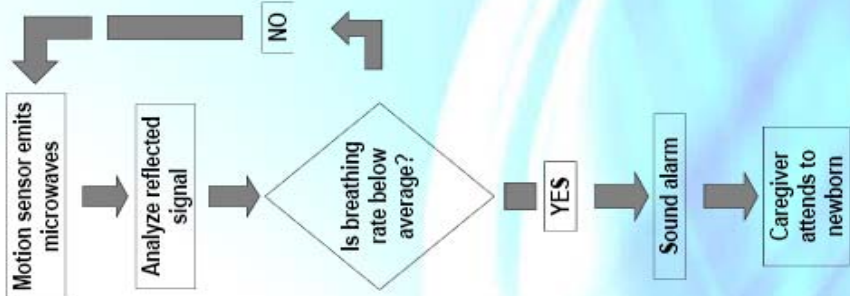
Side B

# Appendix 5: Senior Poster Display

## LifeMonitor



### Our Mission

- Reduce the risk of SIDS
- Develop a monitor to detect and measure respiration rate
- Auto-sound alarm if breathing rate drops below threshold
- Completely unintrusive - no physical contact to the infant!
- User friendly design

### Sudden Infant Death Syndrome

- Claims the lives of over 2500 infants per year
- These deaths remain unexplained even after thorough investigation
- Some possible causes include suffocation, sleep apnea, and minor infections
- Typical scenario involves a parent who gets up to check on a sleeping baby and finds that the infant is no longer breathing

### Reducing the Risk

- Ultimately the best way to prevent harm is to attend to the child as soon as something happens.
- Below are some other helpful tips by the American SIDS Institute:
  1. Place infants to sleep on their backs, even though they may sleep more soundly on their stomachs. Infants who sleep on their stomachs and sides have a much higher rate of SIDS than infants who sleep on their backs.
  2. Place infants to sleep in a baby bed with a firm mattress. There should be nothing in the bed but the baby - no covers, no bumpers, pads, no positioning devices and no toys. Soft mattresses and heavy covers are associated with the risk for SIDS.
  3. Keep your baby's crib in the parents' room until the infant is at least 6 months of age. Studies clearly show that infants are safest when their beds are close to their mothers.
  4. Do not place your baby to sleep in an adult bed. Typical adult beds are not safe for babies. Do not fall asleep with your baby on a couch or in a chair.
  5. Do not over-occlude the infant while she sleeps. Just use enough clothes to keep the baby warm without having to use cover. Keep the room at a temperature that is comfortable for you. Overheating an infant may increase the risk for SIDS.
  6. Avoid exposing the infant to tobacco smoke. Don't have your infant in the same house or car with someone who is smoking. The greater the exposure to tobacco smoke, the greater the risk of SIDS.
  7. Breast-feed babies whenever possible. Breast milk decreases the occurrence of respiratory and gastrointestinal infections. Studies show that breast-fed babies have a lower SIDS rate than formula-fed babies do.
  8. Avoid exposing the infant to people with respiratory infections. Avoid crowds. Carefully clean anything that comes in contact with the baby. Have people wash their hands before holding or playing with your baby.
  9. SIDS often occurs in association with relatively minor respiratory (rhino cold) and gastrointestinal infections (vomiting and diarrhea).
  10. Offer your baby a pacifier. Some studies have shown a lower rate of SIDS among babies who use pacifiers.
  11. If your baby has periods of not breathing, going limp or turning blue, tell your pediatrician at once.
  12. If your baby stops breathing or gags excessively after spitting up, discuss this with your pediatrician immediately.
  13. Thoroughly discuss each of the above points with all caregivers. If you take your baby to daycare or leave him with a sitter, provide a copy of this list to them. Make sure they follow all recommendations.

<http://www.sids.institute>  
 American SIDS Institute

### Components

- MDU 1100 Microwave Sensor
- Amplifier Circuit
- USB NI6008 DAQ
- Mandriva Linux 10.1
- Custom C code

### Accomplishments

- Accurate detection of respiration
- Working prototype that sounds alarm when breathing ceases

### Future Potential

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

(Note) These experiments depicting mechanical breathing and heart rate using a 10 GHz microwave sensor (Bell Labs)

### Group 2 Members

Advisor: [rajg@stevens.edu](mailto:rajg@stevens.edu)  
 Irshaj Bhattarai: [irshajb@stevens.edu](mailto:irshajb@stevens.edu)  
 Iqbal Hussain: [iqbalh@stevens.edu](mailto:iqbalh@stevens.edu)  
 Anshu Kulkarni: [anshu@stevens.edu](mailto:anshu@stevens.edu)  
 James Saha: [jaha@stevens.edu](mailto:jaha@stevens.edu)  
 Farid Chatterjee: [faridc@stevens.edu](mailto:faridc@stevens.edu)

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