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April 12, 1999

Dr. Andrew Rawicz
School of Engineering Science
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Re: ENSC 370 Process Report Concerning the ZenTech Infant Monitoring System

Dear Dr. Rawicz,

The attached document, *Process Report Concerning the ZenTech Infant Monitoring System*, discusses our development of the *Infant Monitoring System*.

The Process Report discusses the evolution of the Infant Monitoring System from its conceptual model to its current state. The future of the project is then discussed, detailing the enhancements the ZenTech team wishes to pursue. The document also examines the time line and budget deviations.

Should you have any questions or concerns, please feel free to contact me via e-mail at skulchyc@sfu.ca.

Sincerely,

Scott D. Kulchycki
ZenTech Canada

Enclosure: *Proposal for the Development of an Infant Monitoring System*

ZenTech Infant Monitoring System Process Report

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Submitted to:	Andrew Rawicz School of Engineering Science Simon Fraser University Steve Whitmore School of Engineering Science Simon Fraser University

Submission Date:	April 12, 1999

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1 Introduction

Sudden Infant Death Syndrome (SIDS) quietly claims the lives of thousands of children around the world each year. The parents of the child are left in a state of shock, confusion, and helplessness. Currently, there are monitors available to detect the onset of SIDS in children. However, many of these systems require direct connections to the baby, which many parents feel stigmatise the child as “sick” or “abnormal”. In addition, the systems presently available are expensive and complex.

The ZenTech team was formed for the ENSC370 engineering project course. Our mission was to create a non-intrusive infant monitoring system to help prevent or at least detect SIDS. After approximately thirteen weeks of continuous hard work, we are realising the completion of a working prototype. This document, the process report, will explain the various aspects of the project. We will discuss the product evolution, the current status of the system and its differences from the original design, and what the future holds for the ZenTech Infant Monitoring System (IMS). By developing the report in this order, we hope to give the reader a sense of the chronology of the project development. In addition, this document includes a discussion of the ZenTech group dynamics, as well as individual reports from the team members outlining what they have gained from the project.

2 Product Evolution

From the beginning, the project goal was to monitor the breathing of the infant in a non-invasive manner. The original specifications for the IMS broke the project into the 4 main stages of signal acquisition, signal processing, signal analysis, and user interface. After some consideration, we decided to integrate the signal processing and anaylsis into one stage and introduce a new stage after the signal aqcuisition, that of signal conditioning.

Since initiation of the project development, the system composition has undergone several major changes, not the least of which was the conceptual reorganization described in the previous paragraph. We will briefly outline the major design changes that the various stages of the IMS underwent over its four month development cycle.

2.1 Signal Acquisition

At the outset of the project, the ZenTech team chose to monitor the breathing of the infant via the acoustic signature we believed was present in the action of breathing. We thought that the sound generated by breathing would be strong enough that we would be able to easily record it for signal analysis.

Initially, we chose to develop a special mattress composed of a number of air chambers that would be contained within a standard infant mattress (an air-composite mattress). It was our hope that the air chambers would provide physical amplification of the breathing signal. Sensitive microphones mounted beneath the chambers would record the sounds for analysis.

Though theoretically promising, this idea failed to produce a breathing signal of any recognisable form and the idea was quickly discarded.

After the failure of the air-composite mattress, we were still convinced that the acoustic signature of breathing would provide the signal we needed. However, after noting the extremely low signals gathered via the air chambers, we felt a better approach would be to place sensors similar to stethoscopes on the child to acquire the sound. After much testing, we found that even when pressed firmly against the body, the sound of breathing, as heard through the chest, was too quiet. Additionally, mounting a sensor on the subject violated the original system goal of non-intrusiveness.

It was rapidly becoming obvious that the acoustic signature of breathing, as heard through the body, was not going to easily provide us with the signal we needed to analyse, thus we began exploring other indicators of breathing, especially motion.

Our first concept for monitoring breathing via chest movements involved ultrasound sensors. We felt that by mounting ultrasound sensors in and around the crib, we would be able to detect the slight movements of the chest that accompany breathing. However, we soon realised that if the child were to be covered by a blanket or other object, the ultrasound sensors would not be able to detect motion beneath these obstructions, and thus no signal would be noted.

We then explored the possibility of motion detection by infrared sensors. It was our hope that the infrared sensors would be able to detect the motion of a body of heat (the chest of the infant) even through several layers of blankets and other obstructions. After consulting with the TA's for this course, however, we discovered that the required signal processing for such an endeavour would be extremely difficult. Thus, we chose to explore simpler approaches.

The next big step in monitoring the breathing through motion detection was seen when we acquired a simple piezoelectric sensor which responded to changes in the sensor position with a voltage signal. Our first attempt to utilize this sensor was to place the sensor on top of the mattress, such that the child would lay on the sensor (or, possibly, array of sensors) and the breathing would distort the sensors, creating a recognizable breathing signal. This configuration is shown in Figure 1.

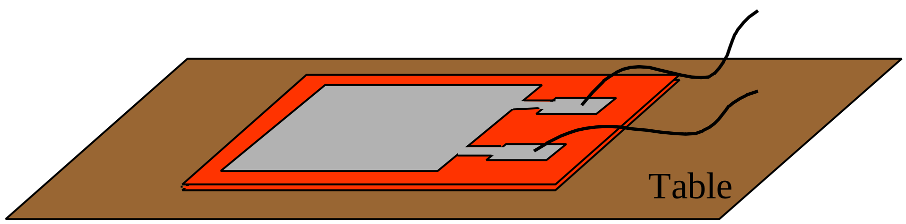

Figure 1 – Flat Piezoelectric Sensor

However, we soon found that once the weight of a subject was on the flat sensor, the response to the breathing motion was almost none (as explained in our design specifications, the sensor would saturate with constant force). Our next attempt at sensor configuration was to elevate the two sides of the sensor and to bend the sensor upwards, such that the sensor would be able to bend up and down, providing a stronger signal. These configurations are shown in Figure 2 and Figure 3.

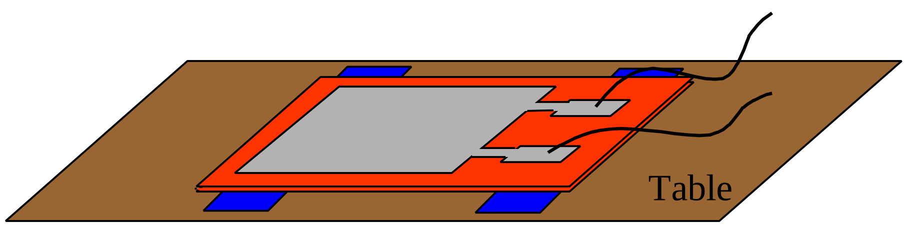

Figure 2 – Modified Piezoelectric Sensor

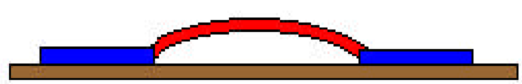

Figure 3 – Modified Piezoelectric Sensor

Although we found these configurations *did* produce a stronger signal, the sensor would still saturate with constant force and thus the idea was rejected.

Noting the continued failure we seemed to be having with detecting the breathing through body motion, we decided to again explore the possibility of monitoring the acoustic signature of the breathing. However, this time, we chose to monitor the sound of the breathing external to the body. To this end, we elected to mount a sensitive microphone on a soft plexiglass sheet that would then be placed beneath the head of the subject, such that the sound would be physically conducted by the plexiglass. Oddly enough, it turned out that this configuration was *too* sensitive. In the laboratory, we found that the microphone was able to pick up normal conversation from several meters away. Although the eavesdropping potential of such a system was inviting, we chose to abandon the idea and return to motion detection.

In one final effort at breathing monitoring through motion detection, we came upon the idea of mounting the piezoelectric sensors *within* the mattress. To that end, we devised three separate configurations. The first configuration placed a sensor vertically between the adjacent coils of a mattress spring. Though the signal acquired from this setup was weak, we were excited to see that we could get a recognisable breathing signal.

At the same time as the vertical sensor configuration was being developed, we were working on a setup that saw us affix a sensor on a block to the top of the inside of the mattress. The sensor was taped to the block on one end, while the free end of the sensor was attached to the coil of a nearby spring. This configuration is shown in Figure 4.

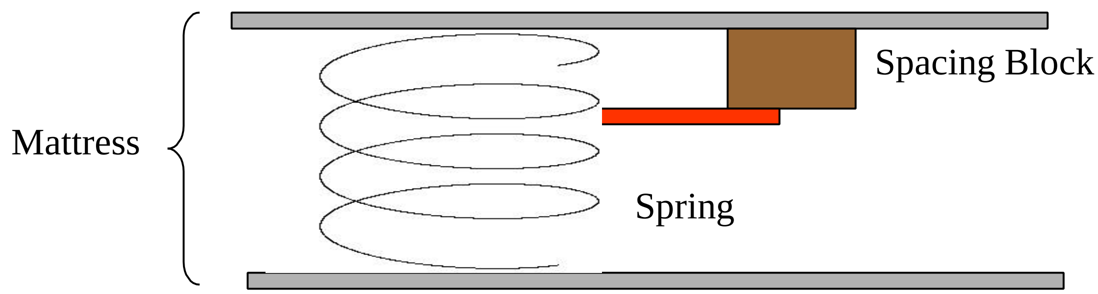

Figure 4 – Block Sensor Configuration

With this setup, we were able to acquire an easily recognisable breathing signal due to the bending of the springs while breathing. We had finally hit upon a workable sensor configuration.

Building on our success with the piezoelectric sensor mounted on a block, we began working on a much more elaborate configuration This configuration, shown in Figure 5, used the same concept as the block sensor configuration.

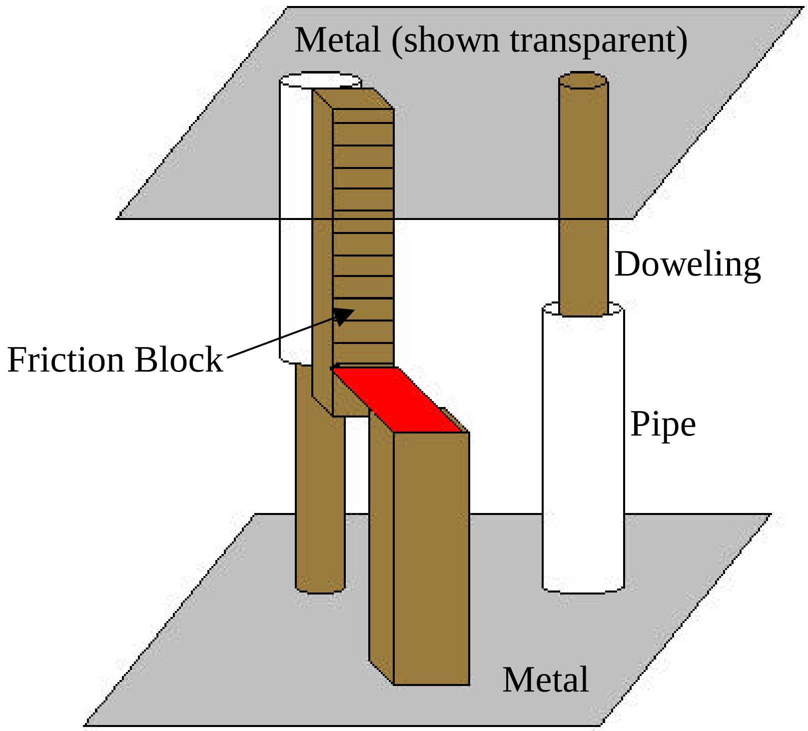

Figure 5 – Parallel Shaft Sensor Configuration

The sensor is able to move down so as not to become saturated when a weight is applied. The top and bottom metal sheets are attached to the mattress, and the two parallel shafts keep the sensor aligned with the friction block. The friction block is simply a piece of wood with small notches cut into one face. These notches provide enough friction for the sensor to move when there is a breathing related movement. However, the friction still allows the sensor to move freely downward when a weight is applied.

Much to our surprise (and disappointment), this particular piezoelectric sensor configuration turned out to be too sensitive to movements in the areas surrounding the mattress. That is, we were able to detect the motion of walking from several meters away.

Thus, we finally decided that the signal acquisition would be accomplished through the use of the block sensor configuration. (Note that we are still working on the parallel shaft concept in the hopes of reducing its sensitivity to noise.)

2.2 Signal Conditioning

As has been discussed, the ZenTech team did not originally view the signal conditioning stage as a distinct stage. In fact, we felt that the signal generated by the breathing would be of sufficient quality that we could apply it directly to the signal processing and analysis stage. However, once we began to research and try different signal acquisition configurations, we found that any signal we were able to gather would be, at best, noisy and extremely weak.

Thus, we quickly realised that the signal noise was going to be a formidable barrier to proper signal interpretation. Thus, even before discarding the attempts at air chamber acoustics, we began developing various filters. Initially, we felt that we would be able to filter out noise with a simple low-pass filter. Unfortunately, our first RC circuits failed to provide a large enough roll-off slope and we began researching notch (band reject) filters. Eventually, we were able to develop a band reject filter that was adjustable in the 60Hz region (where the majority of our noise was located).

Once we began working with the piezoelectric sensors within the mattress, we realised that in order to gather the mainly low-frequency breathing signal, we would have to improve the low frequency operation of the sensors. The sensors themselves are essentially voltage sources in series with a capacitor of extremely low value. Thus, to lengthen the time constant of the circuit (and thus lower the operating frequency), we needed to place a large resistance across the sensor terminals. We were able to accomplish this by feeding the sensor outputs into a simple current buffer, with an extremely large, but finite, resistance between input and ground.

We then fed this signal into the band reject filter and found that the magnitude of the output from the circuit was too low to be easily recognized. Thus, we decided to integrate a simple negative feedback amplifier into the circuit. Unfortunately, the impedance matching between the filter and the amplifier was such that the signal was greatly attenuated at the interface of the two circuits. Thus, we again found it necessary to introduce a simple current buffer.

Once we had finally created a clean, strong signal from the sensors, we next had to interface the signal to the processing stage of the project which, by this time, had been defined as a 68HC11 microprocessor. To input the signal to the processor, we needed to introduce a level shift to the signal (such that the DC level of the signal was 2.5V) and we needed to introduce a limiter in the form of a negative feedback amplifier to limit the signal applied to the processor to 0 and 5V.

After the addition of the level shifter and the limiter, we had completed the signal conditioning stage of the project.

2.3 Signal Processing

From the beginning of the project, we felt that the signal processing functions would be implemented utilizing a Motorola 68HC11 microprocessor. Additionally, from out initial research, we found that sleeping infants can experience delays between breaths of up to 20 seconds. Thus, to properly watch for a cessation of breathing, we decided to look for a time between breathing of greater than 20 seconds.

The bulk of our signal processing stage approach did not change much over the course of the product development except for two main items. First, we decided that the power loss signal could not possibly be taken care of by the processing stage (as originally planned in our functional specifications) because to operate the processing stage, we needed system power.

The second change in the processing stage came about due to the unexpected success of our signal acquisition stage earlier in the term. Until that time, we had planned to simply use one of the SFU Engineering HC11 EVB units to perform the signal processing. However, once we realised a successful signal acquisition stage, we were able to turn our attention to the system packaging. We felt that since the real product would be a stand alone unit, we would not be able to use an EVB unit. Thus, we decided to modify our prototype to better reflect the future product by implementing our own single chip system.

2.4 User Interface

Even before we began seriously researching the signal acquisition possibilities for our project, we were formulating the shape the user interface would eventually take. Our most fundamental requirement for the user interface was that the system provide feedback to the user that was intuitively obvious. Initially, we felt that a simple power switch, an array of LEDs, an audible alarm, and an LCD would allow us to fully develop such a useful interface.

We felt that the system would utilise two LEDs: one green LED to indicate system power, another red LED to indicate a system alarm. In addition to the LED in the event of a system alarm, an audible alarm (buzzer) would sound. The system would be activated with a simple on/off switch, and an LCD would relay to the user the amount of time which had elapsed since the infant's last breath.

As we developed the product and considered safety concerns in greater detail, we soon recognised that we required some means of informing the user of a power failure. Thus, we decided to add a third orange LED to the user interface that would light when the system power failed.

Once we had decided on a signal acquisition configuration, we recognised that the system would possibly generate false alarms. Thus, we felt that the user interface should also include a reset button that would shut off the alarm and restart the system in the event of a false alarm.

Once we had succeeded in acquiring and recognising the breathing signal, we turned our attention to the product packaging. We decided that instead of simply displaying the time since the last baby breath, the LCD should provide another form of feedback that would convey a sense of calm to the user. Specifically, we chose to animate a crawling baby on the screen. Our reasoning behind this was the result of careful consideration, whereby we felt that the image of a crawling baby would be indicative of a healthy (breathing) baby.

Finally, we decided to add a logo animation to the system start up for two reasons. First, we felt that it looked pretty cool and we were aiming for a marketable product. Second, and more seriously, the start up screen creates a delay during which the system input (sensor outputs) can settle to their quiescent levels before signal monitoring begins.

The previous discussion has outlined, in detail, the steps taken during the evolution of the product that resulted in the prototype system we were able to successfully demonstrate on April 12th, 1999. It is obvious from this discussion that the signal acqusition was the most challenging and time consuming portion of the project, requiring complete conceptual overhauls and different approaches several times. Also, the evolution involved the merging of two stages and the introduction of an entirely new stage to the system.

3 Current System Status

The power supply in the current system is not the circuit outlined in the design specifications, but a pre- made circuit obtained from the lab. This change was as a matter of convenience; the part required for the original power supply was difficult to find and the pre- made power supply was readily available. The power supply used provides ±12V, +5V, and ground connections, spawning only slight modifications to the circuitry.

3.1 Signal Acquisition Stage

In the signal acquisition stage, the sensors are in the spring block configuration outlined in the design specifications (see Figure 4). This configuration has the piezoelectric sensor mounted inside the mattress on a spacing block so that the end of the sensor barely touches a spring of the mattress. The sensor is attached to the spring to offer a semi-stable fulcrum point to allow the sensor to bend while the spacing block moves with the surface of the mattress. Currently, six sensors are mounted within the mattress in a rectangular array. This array allows monitoring of the abdominal and chest area of the test subject. These sensors are connected in parallel to improve the frequency response of the system and to reduce signal noise.

As shown in Figure 6, the signal conditioning stage is composed of two buffers, a 60 Hz noise filter, a inverting amplifier, a low pass filter, an adjustable level shifter, and a 5 V limiter.

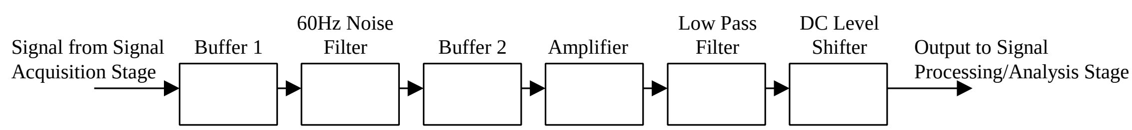

Figure 6- Signal Conditioning Stage Flowchart

As outlined in the design specifications, the buffers are placed at both the input and output of the 60 Hz noise filter to prevent impedance loading between the filter and the rest of the circuit. The filter used is adjustable to allow attenuation at exactly 60Hz given the deviations in the electronic devices used. The inverting amplifier allows utilization of the entire operating range of the op- amp (-12 to +12), instead of just the small range of the sensor outputs. The low pass filter removes any signal above 40 Hz, which simply cleans any high frequency noise that still may be present. In order to use both the positive and negative signals provided by the sensors, a DC offset was added to center the conditioned signal in the input range recognised by the micro controller. The level shifter was made adjustable to allow for precise placement of the center of the signal and to compensate for different supply voltages. The limiter was added to protect the micro- controller from over-voltage inputs, thus preventing any damage to the analog-to-digital converter. The circuit diagram for the voltage limiter is shown in Figure 7.

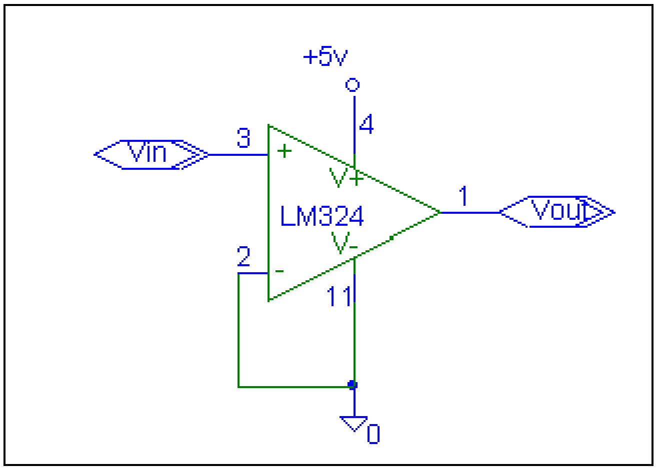

Figure 7: Schematic of Voltage Limiter

3.2 Signal Processing

The signal processing stage is completed by a Motorola 68HC11 micro controller configured for single chip operation. The single chip configuration required the addition of an RS232 driver to allow us to program the 68HC11. The conditioned signal is sampled using the micro- controller's 8-bit analog-to-digital converter. These sampled values are tested against hard-coded threshold values (upper and lower) which are programmed into the micro-controller. Any signal received above the upper threshold or below the lower threshold represents a breathing signal or movement by the baby and will reset a built in timer. If no such signal is received within 20 seconds, the micro-controller sends an alarm signal to the user interface.

3.3 User Interface

The user interface is the last stage of the system. Once the power is turned on, the LCD displays the ZenTech name, allowing time for the system to stabilize. After the system has stabilized, a crawling baby appears on the LCD signifying that the baby is being monitored. As long as the crawling baby is displayed on the screen, the baby is alive and healthy. If there is no breathing signal received for 20 seconds, the alarm signal from the micro-controller triggers a buzzer alarm along with a red warning light (the alarm and power fail circuit is shown in Figure 8).

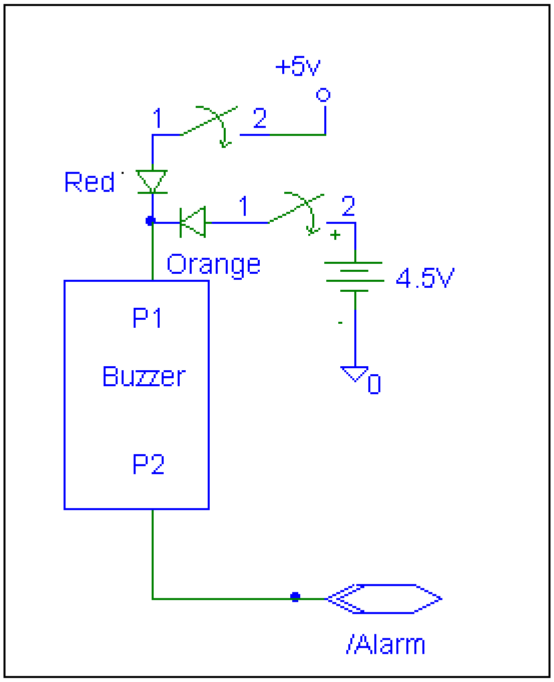

Figure 8 - Alarm and Power Fail Circuitry

If a false alarm occurs, the system is easily reset by pressing the reset button mounted on the top of the unit.

4 The Future of the IMS

Although ENSC 370 is coming to a conclusion, we are very interested and eager to keep working on the IMS. We are confident that through more hard work we will be able to attain a fully functional product that will be marketable. Although we are still in the development stages of the product, we have already been contacted by a research organisation. This organisation, Inforex, was conducting market research with regards to SIDS monitors. The ZenTech team is very excited about this interest because it reinforces our claim that there is a large market for such monitoring systems. As we progress in our development we are increasingly realising that we will need to patent our ideas to protect our work. We have already had a meeting with Teri Lydiard from the University/Industry Liaison Office to discuss the various aspects of the patent application process.

We at ZenTech realize that although we have worked long hours to accomplish the current version of the IMS, there are numerous enhancements and processes which we must go through. Before bringing the product to market, there are many improvements to the system that must be made.

4.1 Signal Acquisition

The signal acquisition stage of the IMS proved to be the most problem solving intensive. As stated in the evolution section of this report, many possible design solutions were discussed and analysed. We eventually decided to use the piezoelectric sensors to monitor the breathing. Currently, we are able to acquire a breathing signal as discussed earlier. However, we realise that for marketability purposes we will need to improve upon the current design. Our goal is to create a self-contained sensor unit. This unit will be much like a spring coil that the mattress already has in it. The fact that it will be able to be mounted inside the mattress at the time of production will improve marketability of the IMS. While we are working on the new sensor unit we will also be increasing the signal to noise ratio.

Another aspect that we must consider with regards to the sensors is their reliability. Obviously, the IMS will have to be durable for an extended period of time. We will achieve this durability by experimenting with various sensor array configurations within the mattress. We will also improve the reliability by introducing redundant sensors.

4.2 Signal Conditioning

The signal conditioning stage requires the least amount of enhancements. However, one improvement that we are going to implement is to introduce a higher order low pass filter.

4.3 Signal Processing

There are several improvements and enhancements that we can make to the signal processing stage. One of the most important improvements will be to introduce dynamic thresholds. Our goal is to have these dynamic thresholds self adjust for varying signal intensities. These variations in signal intensities may result from a weight variation of the child on the mattress or different strengths in the breathing signal.

A very useful enhancement for the IMS will be to add a recording function that logs the child's breathing pattern. We feel that this enhancement will greatly benefit medical research regarding the possible causes of SIDS. If a child does have difficulty breathing, patterns in the breathing will be present in order to establish a possible trend.

4.4 User Interface

Currently the user interface displays a crawling baby and the time of the last breath. For our final IMS product only the baby will be present. The reason for removing the time count of the last breath is that we feel that this information would serve no purpose but to alarm the parent or caregiver. Our research investigation has shown that it is quite normal for an infant to have pauses in their breathing pattern. We feel that if the time is displayed that the parent would feel uncomfortable because they would be anticipating the next breath. If an alarm does sound because of a cessation in breathing then the time of the last breath will still be displayed. This information will be very useful for medical aid.

For the current prototype, if the baby does stop breathing, a buzzer sounds. This buzzer is in the actual IMS base unit. The buzzer will eventually be removed from the child's room and will be wireless so that it can be placed in another room. Clearly, this change will have to be made for the final product because it will allow the baby to be monitored even if the parent is in another part of the house where they normally would not be able to hear the audible warning.

4.5 General Improvements

The power supply for the IMS will be reduced in size in order to decrease the IMS base unit size. We chose to use a larger power supply for the demonstration because we were having difficulty in acquiring the desired components to implement it ourselves. When we came across the current power supply we discovered that it had all the voltages that we needed. Because the power supply had all the requirements we needed, we decided that we would use it. When we replace the power supply the size of the IMS base unit will be dramatically reduced. This reduction in size will make the IMS more aesthetically pleasing and will allow for easier positioning in the infant's room.

Clearly, there is an abundance of work that still needs to be accomplished on the IMS. We at ZenTech look forward to working on the project in the months ahead. We strongly believe that we are developing a product that has great market potential. As we proceed to the marketability stage of the project, we look forward to learning the business side of the development process.

5 Project Time-Line

Our project milestones, as outlined in the project proposal, were almost all met on time with the exception of the design specification, research, and the process report. The design specifications were finished late because the class deadline was extended and we needed further work to write them properly. The research portion of the project extended over the length of the term because we were continuously searching for ways to improve the project. The process report was finished late because we needed to demo our project before writing this document. Shown in Figure 9 is a Gantt chart displaying the original project milestones and timeline along with extended time factors and additional milestones we felt better reflected the progress of the project throughout the term. Note that the original times to completion are shown as black bars while the extended times are shown as gray bars.

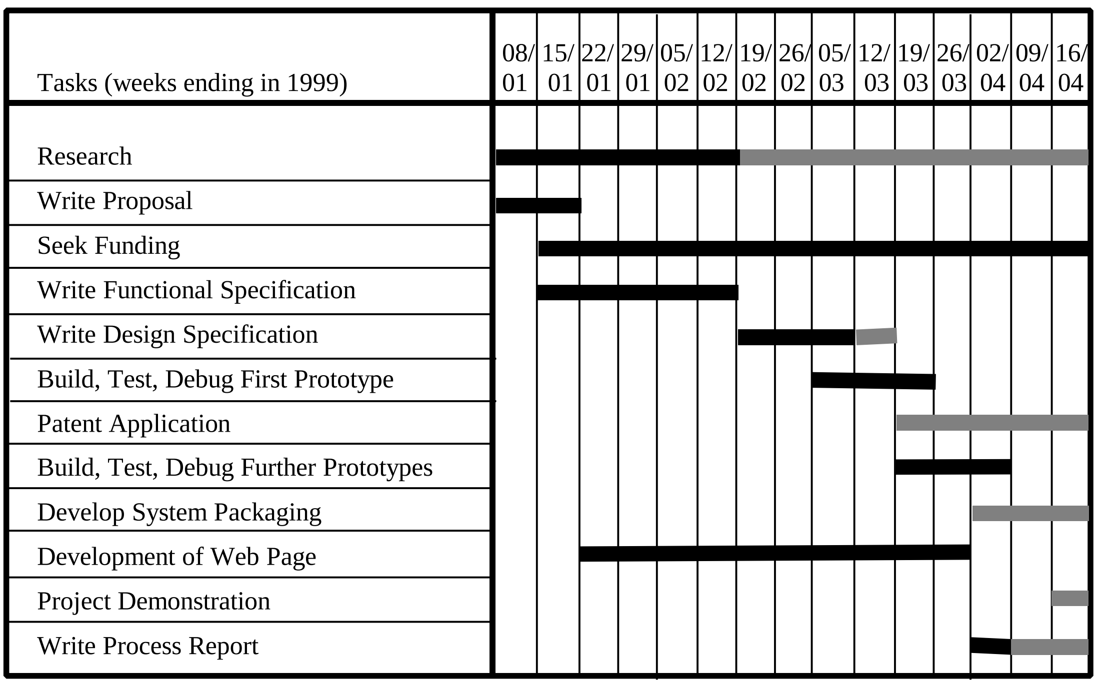

Figure 9 - Modified Project Gantt Chart

We will now provide a brief chronology of the project.

January 19, 1999	Completed project proposal
February 2, 1999	Submitted first progress report
February 10, 1999	Acquired a baby mattress and began working with a variety of sensors such as microphones and piezoelectric sensors to obtain a signal representative of an infant's breathing
February 16, 1999	Completed functional specification
February 27, 1999	Decided piezoelectric sensors were best to detect motion of breathing
March 8, 1999	Assembled the first prototype board containing analog circuitry for signal

	conditioning
March 12, 1999	Completed design specifications
March 14, 1999	Acquired a Motorola 68HC11 micro controller EVB to begin software development for the user interface and DSP
March 18, 1999	Began the patent process for our new sensor technology
March 20, 1999	Constructed the second system prototype
March 29, 1999	Changed from EVB to single chip processor operation
March 31, 1999	Constructed system package
April 12, 1999	Successfully demonstrated product operation and completed process report

As we have mentioned previously, we fully intend to further develop this product for market. We have begun the patent application process for our sensor configuration. By the end of August, 1999, we hope to have decided on a final sensor implementation that will allow for construction of single, independent mattress coil replacements. Then, by the end of October, 1999, we hope to have completed our patent application. Once we have applied for the patent, we will begin shopping the technology around to potential manufacturers. We hope to find a manufacturer by May, 2000 so that we may begin product production and sales by August, 2000.

6 Budget

In our project proposal, we predicted that our first prototype system would cost approximately $900. After all development costs were accounted for, we found that the actual cost of the first working system prototype was approximately $650. A cost breakdown and comparison of actual and predicted costs is summarised in Table 1.

Table 1 - Project Cost Breakdown

Item	Predicted Cost ($)	Actual Cost ($)
Mattress	200.00	51.29
Microphones/Sensors	130.00	128.00*
System Box	20.00	30.63
Microprocessor and EVB	200.00	30.00
Components	150.00	218.91
Project Enhancements	200	9.00
Soldering Iron	**	159.57
Misc.***	**	60.00
TOTAL	*900.00*	*648.40*

* - Note that this cost is for 100 sensors, while our prototype used only 6
** - Note that we did not foresee these costs in the proposal
*** - Note that miscellaneous costs include parts delivery costs and packaging costs

From Table 1, we see that we came in well under our expected costs. This is due in part to the system simplifications we made during the course of the project and is also due to acquiring some components (such as the power supply and several board components) for free.

Unfortunately, though we had originally planned to acquire funding for our project through various medical institutions and SIDS organizations, our repeated efforts to contact anyone from these places bore no results. However, we have applied for the Wighton fund and hope to recover almost all costs involved with the project.

7 Individual Perspectives

7.1 Scott D. Kulchycki

I feel that this ENSC370 course was an extremely valuable experience, as I was able to develop several engineering skills I already had and learn new ones. Working on this project taught me about analog design, as I was heavily involved with the signal conditioning stage of the system. I was able to hone my circuit debugging skills on the signal conditioning and signal processing boards. Working with these boards and the piezoelectric sensors also helped develop my soldering skills, especially since the sensors could not be exposed to heat for any length of time. I was able to learn about the Motorola 68HC11 processor and the associated assembler language. Most importantly, I learnt the importance of imagination in problem solving. Had we not been able to look at our problem from multiple angles, we would have been stuck with our original acoustic approach and may not have completed the project. However, our diverse thinking processes generated multiple implementation possibilities, allowing us to decide on a final, elegant solution.

In addition to these engineering skills, I take from this course, industry experience. This project relied heavily on team relations and the ability to work with and trust fellow group members. Thus, we quickly learnt how to best interact with each other in order to accomplish the team goal. As well, our research efforts helped develop communication skills, especially when contacting various experts and consultants in the field.

Finally, but certainly not of least importance, I learned and am continuing to learn entrepreneurial skills. As has been discussed, we will be taking the technology we have developed through patenting and will hopefully be able to license the technology to mattress manufacturers. We have already begun the patent application process and have had interest in the product. Thus, though the lesson has just begun, this course is responsible for introducing me to the world of running a business.

Sadly, because we worked hard in the beginning of the term and throughout the course, we were never able to 'live' in the lab. This is part of the 370 course that we were warned would happen and thus were somewhat disappointed when we missed out on it, but not really.

Tim Wilder, Rob Trost, Mike Sjoerdsma, and myself found that we worked extremely well together. I had worked with Mike on previous lab courses but I had never had the pleasure of working with Rob or Tim. I found that we all quickly became friends and learnt how best to work together. I was easily able to trust my group mates with the progress of the project, which was important to me. In fact, there never was a tense moment among the four of us over the course of the four month course. Rob brought with him volumes of experience in signal processing and user interface aspects. Tim was our debugging and circuit/sensor installation expert. Mike was our resident mechanical wizard. I tried to get my fingers into all parts of the project, but concentrated mainly on the signal conditioning and system testing. All members of the group were involved in the overall design of the system and everyone provided valuable suggestions and insights into all stages of the project.

Unfortunately, we did not complete the project with the same number of persons in the team as we began with. In the beginning, Rhiannon Coppin was an integral member of the ZenTech team. However, because we felt that she later did not contribute her share of the work to the project, she regrettably withdrew from the group.

If we were to repeat the course, I can honestly say that I would not change the approach we took. Knowing exactly how to solve the problem from the beginning would have been nice but it may have defeated the purpose of the course. I believe that all the decisions made during this course were the correct decisions and that we would not change anything given the chance to do it again. With respect to group dynamics, I regret that Rhiannon left the group, however I feel that we could not have done anything more to include her in the project than what we did.

I am truly proud of what we have accomplished in this course. I began the term scared that we would not be able to complete the project but have now developed a working prototype. That we will be taking this to the next step of patenting and, hopefully, licensing shows our commitment to this product. I feel that this was an extraordinary course and though I am glad we are finished, I know that the skills we have learned here will be applicable throughout my career as an engineer.

7.2 Michael Sjoerdsma

In my opinion, ENSC 370 was a very valuable and enjoyable course. Although there was a lot of work required, I felt the knowledge and experience gained was well worth it. I feel that ENSC 370 produces a student that is capable of dealing with a complex problem on many different levels. This course teaches engineering aspects of a project as well as the more social/human interaction side of a project.

I learnt a great deal about the different sensors available. Because we did not know the exact way of implementing the solution for our IMS system, we had to explore several different techniques. Through this process of elimination, I learnt a great deal about strain gauges and piezoelectric sensors. I also found it very valuable to help with some of the signal conditioning phases in the project. Although I was not responsible for the processing stage of the IMS, I was present when the development was being done and feel that I have a better understanding of how a micro-controller works. I also really enjoyed working with the piezoelectric sensors and trying to create new sensor configurations. Experimenting with the mechanical side of things helped refresh many skills I had previously learnt.

I believe that one of the most valuable components of this course is the amount of freedom given to the students to explore various project ideas. Our team spent many hours brainstorming to come up with possible projects for the course. Once we had decided upon a project idea, we brainstormed on how to implement the system. With many courses the answers are "textbook" and do not require creative thinking. This course requires students to experiment with several ideas and find out which is the most feasible. You could say that ENSC 370 helps cultivate one's imagination.

The ZenTech team, Scott, Rob, Tim, and myself worked very well together. I always felt very comfortable working with them. I cannot recall one negative incident between the four of us. I feel that our various talents complemented each other.

Unfortunately during the course of this semester, the ZenTech team was reduced from five people to four. At the beginning, Rhiannon Coppin was also a member of our team. Although, at the beginning of the course Rhiannon was contributing regularly we felt that her participation was less than acceptable after a while. Rhiannon decided to leave the group. It is unfortunate that such a problem occurred. However, I feel that the group could not have done much more to encourage her participation. Although, this unfortunate incident occurred the group and Rhiannon are still on good terms. I believe that this shows the maturity of all parties involved.

ENSC 370 has given valuable experience in producing a product from start to a working prototype. I am looking forward to continuing the project and bringing to a marketable state.

7.3 Robert Trost

This project was a most interesting experience for me. Seeing as how I was supposed to take ENSC 370 in the Spring 1998 semester, I entered the course only knowing a few people in the course, and none of them particularly well. Understanding that a project course is highly dependent on group work I was quite concerned about finding a group I could work with, or in finding any group at all. I noticed that most groups had already been formed before the semester had even started. Luckily, after a small amount of begging, Scott, Mike, Tim, and Rhiannon accepted me as a member of 'their' group. Our brainstorming sessions went well, and I found that I got on quite well with the rest of the group. Although at first I didn't feel very welcome in the group, as the project progressed, I felt like less and less of an outsider, and more like a full-fledged group member.

I learned a lot about group-work in the process of assembling the project, and I especially learned about the individual group members, who I barely knew before the semester. Scott is an extremely hard worker, and I felt that he was always pushing to achieve the best results possible. I found Mike and Tim to have much more relaxed attitudes towards the project. Though we all worked extremely hard, I felt it was always Scott's push that was keeping us moving forward. I felt that I was able to contribute most to the project through my experience and knowledge. As a group we had problems with one member, Rhiannon. I believe that this resulted from personal issues on Rhiannon's part, and as a group we did as much as was possible to be accommodating.

I found that our group worked quite efficiently in terms of problem solving. When we were stumped by a problem, one or two individual group members would attempt to overcome that hurdle on their own, though still accepting help from the rest of the group. For example when we had 60Hz noise problems from our sensors, we initially built a cookbook notch filter to eliminate the problem, but this filter did not seem to operate as it was supposed to, so I volunteered to take on the problem. With a little bit of reading and few MATLAB simulations, I was able to build a very effective 60Hz notch filter. Another example comes during the development of our sensing setup. We were looking for effective methods of mounting the sensors inside the mattress to get the strongest signal possible. Mike took on this challenge and produced a variety of innovative solutions to the problem, and he is still developing even better methods.

As well as improving my group-work skills, I feel that I have also gained invaluable technical experience through this project. I gained an understanding of the capabilities of the various sensors we attempted to use. And the multitude of technologies that are available to solve almost any problem. Though I had some experience with micro-controllers before, it was the first time assembling a single chip system. And of course we faced many problems during the design process which we had to troubleshoot and debug. I feel that this experience has augmented my skills and knowledge in the area of the engineering design process.

7.4 Tim Wilder

Overall, I found ENSC370 very valuable in teaching and understanding the entire design process. As each step of the design process was completed, the amount of work required to transform an idea to a working design became much clearer. Every step of the process, from the proposal, the functional specs, the design specs, all the way to the finished product provided a new and different challenge usually requiring modifications to an earlier step.

I learned the need for proper design layout for prototypes. A proper design layout allowed for easier debugging of the circuit, and simply looked more professional. I also learned the importance of organizational skills, especially when working in a group environment.

Research for this project exposed me to the various types of the sensors available for motion sensing and acoustic sensing. The analog circuitry design that accompanied these various sensors offered examples of different amplifier/filter circuits. The research into SIDS has proven valuable for this course and will continue to do so for the duration of the project.

From a group perspective, I've learned the importance of working with people you feel comfortable working with. I found the group meetings to be a useful forum for voicing any concerns or questions that I had. I believe that by having the majority of the group working at any one time, we were able to resolve most problems quickly and efficiently by utilizing the various experiences of the entire group. I enjoyed working in the group and witnessing the different work habits and thought processes of the other members of the group, and simply learning from their experiences.

I can now truly acknowledge the need to ask questions, not only to resolve doubts, but also to open other possible avenues of thought, to offer a new perspective. Questions cause discussion and promote understanding and confidence in the work you've already accomplished. I have come to believe that completed projects are not produced, but rather evolve from many attempts to answer the numerous questions that have to be asked to successfully complete the project.

8 Gratuities

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