Deceleration-X Systems

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Burnaby, BC
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April 20, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
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RE: ENSC 370 Project Process Report

Dear Dr. Rawicz:

We have enclosed a copy of our process report for ENSC 370. Our process report outlines the process of development of our automobile deceleration indicator. The goal of the project is to provide drivers with a concrete means to determine the rate of deceleration of surrounding cars which ultimately translates to fewer motor vehicle accidents.

Our process report discusses the current state of our project, how is deviated from the functional and design specifications and our future plans for the project. We also examine how closely we were able to follow our budget and time constraints.

Our group consists of four engineering students with experience and expertise in the hardware design. If you have questions or concerns regarding the process report, please do not hesitate to contact me by phone at 461-6981 or by email at scwong@sfu.ca.

Sincerely,

Steven Wong
President, Deceleration-X Systems
Enclosure: Process Report for the Automobile Deceleration Indication System.

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Introduction

Deceleration-X Systems has worked diligently and rigorously on the Automobile Deceleration Indication System over the past 3.5 months. Our intense labours have resulted in the creation of a superior project. This process report reviews the growth of the ADI System from conception to maturity. Along this journey, the entire group has also grown from the experience.

System Development Status

Signal Acquisition Stage

The implemented signal acquisition stage closely approximates the design specified in the design specification document. An Analog Devices ADXL250 dual-axis accelerometer was used to detect vehicle deceleration in directions parallel to the vehicle's direction of travel and orthogonal to the direction of travel and road surface. The accelerometer signal from the orthogonal axis is used to determine the component of gravity orthogonal to the vehicle's direction of travel, from which the force of gravity projecting parallel to the vehicle's direction of travel and corresponding deceleration error signal may be determined. The ADXL250 accelerometer provides a nominal dynamic range of ±50g with a nominal 38mV/g scale, which proves sufficient for the implemented functionality and for planned data-logging applications. The accelerometer is conveniently mounted such that the signal corresponding to the acceleration parallel to the vehicle's direction of travel increases as the vehicle decelerates, while the signal corresponding to the component of gravity orthogonal to the vehicle's direction of travel increases as the component increases in magnitude.

Signal Conditioning Stage

The implemented signal conditioning stage deviated slightly from the design specified in the design specification document. The accelerometer signal describing the acceleration parallel to the vehicle's direction of travel is conditioned by passing the signal through a second order low-pass Butterworth filter followed by a post filter amplification stage. The filter is implemented using a single second order Sallen-Key low-pass filter circuit designed to provide a 20 Hz bandwidth. The filtered signal was then amplified using a variable high gain, non-inverting amplifier providing a dynamic range of approximately $15m/s^2$. The variable gain was incorporated into the prototype to assist debugging and tweaking the system.

The amplification stage additionally incorporated summing circuitry allowing a variable dc voltage to be added to or subtracted from the filtered signal. The variable dc offset voltage is used to adjust the zero acceleration output voltage, allowing the zero acceleration voltage to be varied across the entire 0-5V output voltages range. The variable offset adjust is adjusted to provide a nominal zero acceleration output voltage of 1.5V. The nominal zero acceleration output voltage was selected to provide sufficient swing in the increasing direction to detect the desired range of decelerations, while simultaneously providing sufficient swing in the decreasing direction to detect small decelerations in conjunction with relatively large negative error signals.

The accelerometer signal corresponding to the acceleration orthogonal to the vehicle's direction of travel is conditioned by passing the signal through a sixth-order low-pass Butterworth filter followed by a post amplification stage. The filter was implemented using three cascaded Sallen-Key low-pass filter stages designed to provide a bandwidth below 1Hz. The high filter order was chosen to approximate the "brick wall" response for which the maximum nominal accelerometer resolutions are quoted in the ADXL250 data sheets. Achieving a very large signal-to-noise ratio was critical for achieving the resolution required to detect the relatively small changes in the vehicle's orientation necessary for providing adequate error compensation.

The significant reduction in the bandwidth of the filter from the design specification to implementation was required to accommodate the high gain of the amplification stage. The original design's 10 Hz bandwidth resulted in the conditioned and amplified output being much too sensitive to minute accelerations for the system to operate acceptably. Prior to decreasing the bandwidth, small relatively rapid accelerations, such as those associated with the vibration of the table on which the device sat, translated into significant output signal components. Had the bandwidth not been reduced, the device would have been much too sensitive to vehicle vibrations or accelerations due to bumps in the road surface to serve any practical purpose. Reducing the bandwidth significantly improved the conditioning stage's performance. The modified filter stage rejects almost all short lived signal fluctuations, passing only the gradual signal changes resulting from changes in the force of gravity acting upon the accelerometer as the vehicle travels along an incline. Some additional phase-lag is incurred as a result of the reduced bandwidth, though the effects of the additional phase-lag seems to improve device performance as detecting whether the vehicle is traveling up and incline or down a decline becomes easier.

As with the parallel signal conditioning stage, the orthogonal filter stage is followed by a variable gain amplification stage which additionally incorporates summing circuitry to allow the zero acceleration output level to be adjusted. The zero acceleration output level is adjusted such that the output is 4.5V when the axis of sensitivity is parallel to the force of gravity, while the gain was adjusted to ensure the output was reduced to 0.5V as the axis of sensitivity is rotated through thirty degrees. The dynamic range of the conditioned signal proves sufficient to determine angles up to approximately thirty degrees, which is sufficient for most every driving situation, while the resolution is sufficient to determine orientation changes as below one degree.

In both conditioning circuits, a Butterworth low-pass filter was chosen because the Butterworth filter response is maximally flat approaching unity though lower frequencies in the pass-band. These lower frequencies are of primary interest for the intended applications.

Signal Processing Stage

The signal processing stage does not deviate much from the specifications identified in the functional and design specifications. The signal-processing unit is composed of a two channel analog-to-digital converter (ADC) with analog multiplexing abilities and a PIC microcontroller. A 10-bit ADC is used instead of an 8-bit ADC as originally designed for. The 10-bit ADC proves a greater number of quantization levels, therefore greater sensitivity to variations in deceleration. Since the microcontroller is intended to process 8-bit numbers, we only used the highest 8-bits of the ADC. The data-logger will use all 10-bits of accuracy because it must accommodate a greater dynamic range of decelerations while maintaining similar resolution. Instead of using separate ADCs for each axis, we used a two-channel ADC with an internal analog mutliplexer. The resulting circuit is significantly more compact, as one ADC and the digital multiplexer may be eliminated.

The ADC takes the conditioned 0-5V analog signal from the Signal Conditioning Stage and maps it into a 10-bit digital number. Currently, only the 8 most significant bits are fed into a PIC16F84 microcontroller for further processing. Since the PIC only has one 8-bit port, an output bit was used to control the multiplexer in the ADC to alternately retrieve the digitized parallel and orthogonal signals. A 10-bit ADC was used to provide greater resolution for data logging.

The grade compensation algorithm was implemented as described in the design specifications. However, the formula in the design specifications did not accurately predict the actual errors we measured. Therefore, we decided to experimentally measure the actual errors through. We tilted our unit at various angles and recorded the parallel-axis and orthogonal-axis voltages that resulted from the Signal Conditioning Stage. Since the unit is not physically accelerating or decelerating, any signal appearing was a result of gravity. These voltages are then converted into their equivalent binary representation as produced by the ADC. The resulting digital representations for the errors at various angles can be coded into a lookup table allowing the corresponding parallel-axis error for a specific orthogonal-axis voltage to be looked up.

The Signal Processing Stage operates as follows. Once the digitized orthogonal signal value is available in the PIC, the difference between the value and the value resulting from gravity fully projecting onto the axis is computed. The result allows us to use a lookup table to determine the corresponding parallel signal error component due to gravity. Depending if the vehicle is travelling uphill or downhill, the error is subtracted or added from or to the parallel signal value. The lookup table implementation eliminates complex trigonometric and mathematical computations that would have strained the microcontroller’s computational capabilities.

The algorithm used for the signal processing is the same as the one shown below in Figure 1.

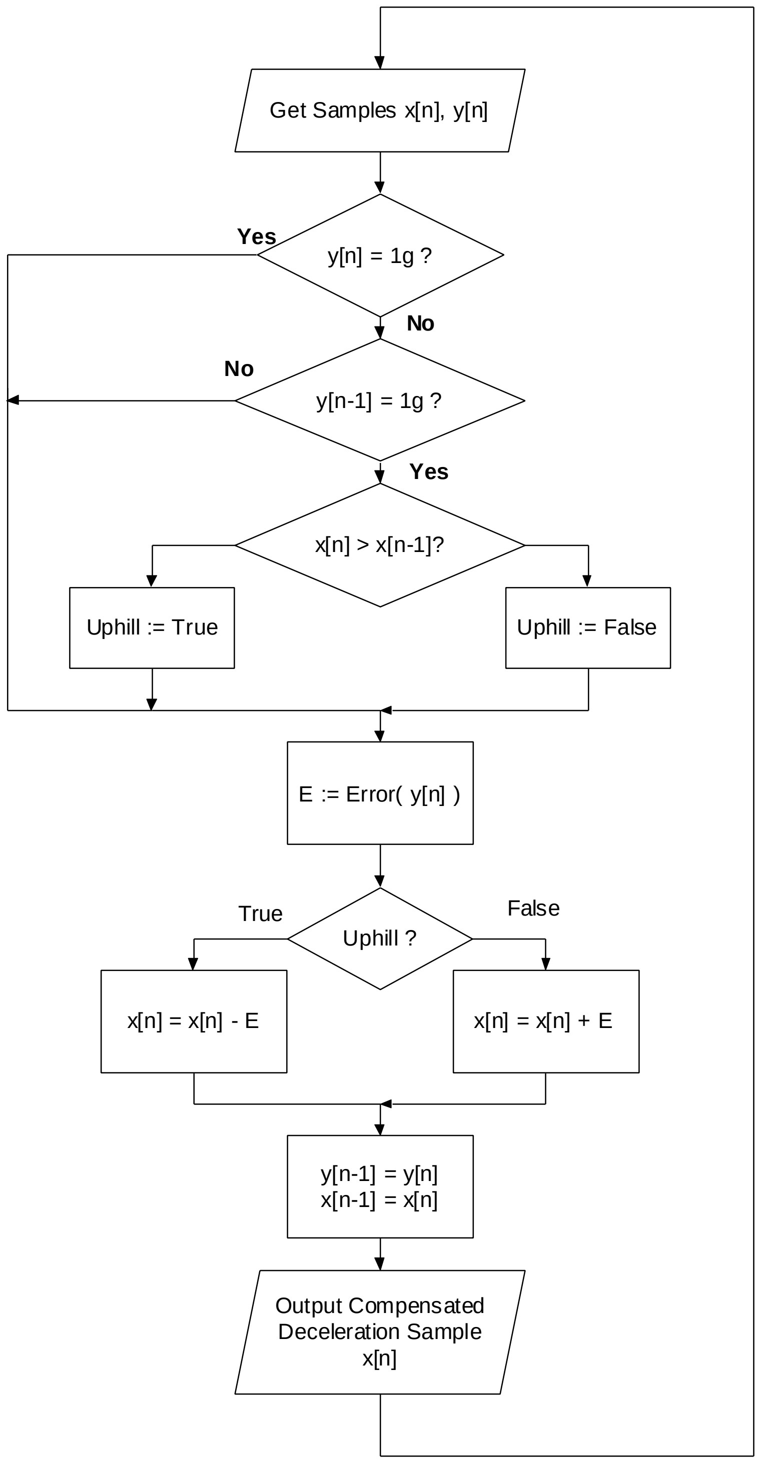

Figure 1: Signal Processing Algorithm

Once the compensated deceleration is determined, it is compared to the 8 output threshold deceleration levels and the deceleration ranges they define. Depending on which range the compensated deceleration falls within, the corresponding encoded output will be sent to the display unit via the output port. These threshold levels and ranges they define can be set accordingly to our judgement and allow flexibility to configurations due to different vehicles and environments.

Output Generation Stage

The output display stage was implemented as described by the design specifications. An AMD PALCE22V10Q generic array logic (GAL) was used to implement the logic required to translate the 3-bit digital input into 7 binary signals; each corresponding to one displayed light level. Each of these digital signals controls an electronic switch which turns a light level on or off.

The actual display unit consists of two identical banks of lights (left and right sides), each encased in its own Plexiglas enclosure. All circuitry related to the output stage is contained within these enclosures and communication with the main sensor and processing unit is achieved through a CAT5 network cable. The lighting system uses high intensity LED's, projecting through a coloured dispersion lens to scatter the focused light.

In addition to the functions described by the design specifications, we have implemented a hazard indicator feature. Using a 3-position switch in the main unit to generate simple TTL digital signals, the user can select a *normal* mode of operation, or *hazard left* and *hazard right* modes. The purpose of this feature is to inform other drivers approaching from a distance, whether they should pass to the left or to the right of your vehicle, if you are stopped on the side of a road. The light levels are sequentially activated in either the left or right banks of lights, as selected by the 3-postion switch. Signals to generate this sequential light pattern are produced by the GAL.

Plans for Continued Development

The following sections outline modifications and improvements we plan to make our Advanced Deceleration Indication System as we move closer to a hopefully marketable and viable product.

Signal Conditioning Stage

It will be necessary to expand the dynamic range of the conditioned parallel axis signal in order to support data logging functionality. The dynamic range should ideally be expanded to correspond to the dynamic range of the accelerometer, which is nominally ±50g. One possible configuration providing the expanded dynamic range while maintaining the existing resolution at lower decelerations would use the pre-amplification signal for data logging, and the post-amplification signal for deceleration indication. Such a configuration would minimize the additionally complexity required to support data logging. Alternately, a separate amplification stage for the data logging signal could be incorporated to provide improved resolution or buffering. The additional parallel axis signal may be digitized using the existing ADC by incorporating an additional analog multiplexer. Note that the dynamic range and resolution of the orthogonal axis when digitized using the 10 bit ADC is adequate for data logging purposes.

Signal Processing Stage

Future development will include the incorporation of the data-logging unit using a RAM unit. In addition, a clock/timer may be used to record date and time of events. However, if an economical microcontroller with 10-bit or more wide input ports with large memory is available, data logging may be incorporated into a microcontroller which would replace the existing. For example, the 10-bit or more data can be written in spare memory or EEPROM/RAM of the microcontroller. Such a device may require us to upgrade our ADC to higher resolutions. There is also a possibility that a more powerful microcontroller with built-in ADC can implement the entire processing stage on a single IC. Either of these case, the more economical and reliable method will be opted for.

Output Generation

The light enclosures will be reduced in size, to accommodate easier installation, and will possibly house the sensor and processing units, if the system is to be marketed as an automotive after-market product. If the intention for the system shifts to a system that is integrated into vehicles during design and manufacturing, then it will be necessary to allow vehicle manufacturers to integrate variations of the Output Generation Stage into future vehicle designs.

Production Model Modifications

It is desirable to remove the variable used to control the variable gain and zero acceleration offset adjustments from a production model. The variable resistors are more expensive than their counterpart fixed resistors, prone to changing their value over the course of the device's life, and require manual tweaking during the assembly process. A production system would ideally account for differences in the zero acceleration output voltage and scale factors across devices resulting from component value variations without incorporating components such as variable resistors which require manual adjustment.

One possible means of removing the variable resistors while maintaining highly accurate devices is to tailor each device's error value lookup table according to characteristics obtained for the device during assembly. The device characteristics of importance are the conditioned parallel and orthogonal signal level values and the changes in the values as the device's orientation is varied. By rotating the device through a series of known angles and noting the changes in the signal levels it is possible to determine the zero acceleration output levels for both signals and the signal scale levels. Furthermore, the parallel error signal and corresponding orthogonal signal level generated at a particular angle may be directly determined through such measurements. The measured error signal levels may then be used to readily derive the entries for the error lookup table. Thus, each device's error lookup table may be tailored to the characteristics of that device. A small block of E^2PROM external to the microprocessor may be employed to store the error lookup table and facilitate easy programming. Constructing the error lookup table through the procedure outlined above carries the additional advantage of inherently compensating for any misalignment in the mounting of the accelerometer.

If this product is to go into full production, a metal case will be used to further shield the system from noise and static charges. The circuit will most likely be fabricated as a PCM board to speed assembly and facilitate inexpensive mass production. All external wiring will be done such that they are hidden under the inner lining of the car. An improved user interface will be developed to allow the user to know if the system is in hazard mode and signaling in a certain direction. Furthermore, all components would most likely be replaced with SMT parts to achieve a smaller and more compact unit so it can be placed within the car taking up even less room.

Budgetary and Time Constraints

Budget

Table 1 contains the projected and actual cost of the project as of April 19th, 1999.

Table 1: Revised Development Budget

Required Materials	Estimated Cost	Actual Cost
Sensors (accelerometers)	100	38
Light Sources (& lenses)	50	45
Discrete Components	100	90
Prototype Boards	70	10
Cables, Wiring & Connectors	20	30
Enclosure	60	20
Total	**400**	**233**

As indicated by the table, our estimate was almost double our actual cost. We obtained our accelerometer as a sample, but the price stated in the table is the cost of the sensor if purchased in volume. The prototyping was done on simple vector boards as opposed to having a PCB fabricated; therefore our estimate for this category is significantly higher. We were also able to obtain some free, custom enclosure work, resulting in additional savings to our actual cost. Note that the Actual Costs do not necessary reflect the cost of producing a production model ADI system because the quoted costs include discrete components which were purchased at a premium as single units. A significant reduction in the cost of a system would be realized when devices were purchased in large quantities at reduced per component prices.

Time

The original schedule is shown in Figure 2.

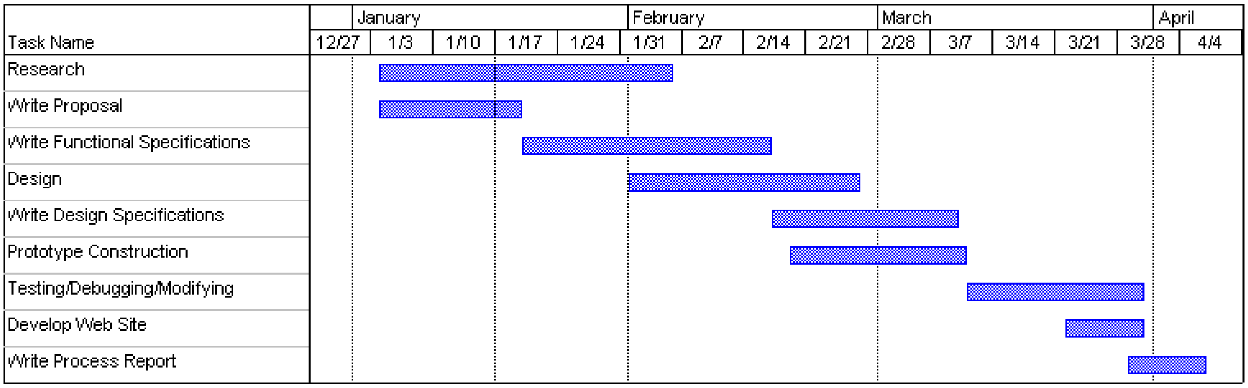

Figure 2 - Original Gantt Chart

We were able to adhere to the original schedule in the most part. All the documentation was completed on schedule, except for this Process Report. However, we underestimated the time required to construct the prototype and to test and debug our system. Even though we put a great deal of thought into the functional and design specifications, we experienced a few problems building the prototype. We expected that construction of the prototype to be a fairly straight forward exercise because design specifications were already quite detailed. However, we did not give due consideration to Murphy's Law. Most of our problems were not big, but there were many and that caused significant delays. Delays in obtaining the required components also played a part in the deviations from the original schedule.

As anticipated, testing and debugging required almost as much time as the prototype construction. Solving bugs in our system was challenging because we would not immediately know if the problems were hardware or software related. Final exams also interfered with the testing and debugging stage of development. During this period, we all put the project aside to concentrate on our exams. It wasn't until our exams were done, that we really focussed on our project.

Technical and Interpersonal Skills Development

The following sections outline our individual responsibilities in developing the ADI system and what we each feel we were able to take away from developing the ADI system and completing ENSC 370.

James Balfour

Duties:

- **Signal Acquisition Stage**
  - Determine system requirements for the Signal Acquisition Stage
    - Determine which physical inputs are required by the system
    - Determine means by which error compensation may be achieved
    - Select optimal transducer
  - Characterizing the ADXL250 accelerometer
  - Designed the Signal Acquisition Stage and associated circuitry
  - Prototyped and tested the Signal Acquisition Stage circuitry
- **Signal Conditioning Stage**
  - Determined system requirements for the Signal Conditioning Stage
  - Designed the signal conditioning stage
    - Designed Butterworth filters.
    - Designed Amplification stages.
  - Prototyped and tested the Signal Conditioning Stage circuitry
- Characterized and analyzed the prototyped Signal Acquisition and Signal Conditioning circuitry.

Skills Development Assessment

This course offered a unique and gratifying opportunity for self-directed study and development. The work I undertook during this course greatly expanded my technical expertise in the areas analog filter and amplification design and very low-power single-rail embedded system circuit design. This course represented my first experience designing and developing with transducer and analog instrumentation circuitry for an embedded system. I also received my first soldering and vector-board prototyping and debugging lessons from Steve during the course of developing our ADI system.

While developing the signal acquisition and conditioning stages, I learned the importance of fully understanding and characterizing the devices with which one is working. Proper characterization reduces the possibility of unanticipated behavior once the component is used in a system and makes design and debugging significantly easier. I additionally learned the importance of fully investigating and defining the requirements of any devices to be used in fabricating the circuit. For example, there exists a plethora of operation amplifiers which I could have selected for the signal conditioning circuitry. By carefully analyzing the requirements for the operational amplifiers, including the power consumption, operating environment, available supply voltages, and required output swing, I was able to determine the class of device best suited for the application. Proper component selection is critical for developing cost effective circuitry that behaves as anticipated and meets design requirements.

I also learned that designing a system is an iterative process in which successive approximations to an ideal system must be developed before a finalized design may be realized. Often full insight into a problem cannot be gained until a potential solution has been implemented and critically analyzed. The analysis frequently reveals significant improvements that may be made to current iteration.

In terms of group dynamics and management, I learned that it is crucial when tasks are divided among group members to ensure that each member fully understands the task required of him and what he is expected to produce for the group. Furthermore, it is critical to ensure that the group is kept informed of each member's progress and any changes in the required tasks or intended solutions. Occasionally we found ourselves as a group having to redo a certain task assigned to one member because the group member did not fully understand the task requirements. A greater emphasis on ensuring everyone fully understood what was expected of him and, more importantly, why it was expected may have helped to present such situations. Additional group meetings and improved attendance at meetings would probably also have reduced the number of such situations.

Similarly, it is critical when dividing a system in subsystems on which different members will work that the interfaces and performance requirements of each subsystem are explicitly defined and understood by all group members. If the required functionality of a subsystem is not fully understood by the developer, then there exists a risk that the developed subsystem may not meet the required functionality and thus have to be redesigned. As my experience in this course illustrated, having to redesign a subsystem is a frustrating and time consuming activity that most people will only do grudgingly.

On several occasions I witnessed members of the team unable to proceed with subsystem development and system integration and debugging because they were not fully aware of the interface or functionality other subsystems. Such a situation tended to lead to unproductive idleness. The idleness could have been avoided had members ensured that all members understood the functionality of each subsystem, or had those members uncertain of the functionality of certain subsystem asked for clarification. Along these lines, this course taught me that asking questions whenever something is unclear is critical to using time most efficiently. It is far better to track down a knowledgeable person and quickly ask them to clarify something rather than wasting time beating one's head against a table trying to figure out why something is not working or does not work the way one expected.

As far as the division of tasks amongst group members, I feel that the divisions we employed worked fairly well. When preparing documents, we typically first gathered to discuss what was required of the document. We then divided the writing such that each member wrote those technical sections on which he was most knowledgeable. Any remaining non-technical sections were divided up amongst members according to the amount of time each member could spend preparing the document. One member would then collate and format the individual contributions prior to a final group review for accuracy and cohesiveness. During development, we divided the subsystems amongst group members, assigning subsystems to members on the basis of what they wanted to learn from the course and where the expertise lay. In general this division worked well, as each member was interested in his assigned subsystem. In retrospect, it may have been a mistake to assign multiple members to one of the subsystems, since it seemed to result in a mentality that the subsystem could only be worked on when both members were present. Such a mentality hampers efficient development because the two members where often unable to synchronize their schedules and make time during which both could be present to work on the subsystem. As a result, delivery of that subsystem was delayed.

Randy Cho

Duties:

- Signal Processing Stage
  - Developed Processing Stage Hardware
    - Analyzed analog-to-digital Converter requirements.
    - Researched and selected appropriate microcontroller.
  - Co-Developed Processing Stage Software
    - Co-developed error compensation algorithm.
    - Programmed microcontroller.

Skills Development Assessment

ENSC 370 has been a tremendous learning experience for myself. It was a rare opportunity to be involved in a project from the very beginning through to the very end. After ENSC370, I honestly believe that I have come away with more than just an Automobile Deceleration Indication System.

My main responsibility in this project was to develop the signal processing stage with Gary Wong. This involved using an ADC to convert the analog deceleration voltages into a digital signal. The PIC then analyzes the digital information to perform grade compensation and output level determination. Coding the PIC in assembly language for a real-time application is a complex and rewarding experience. I learned a great deal from mistakes I made and the solutions we found to them. Writing assembly code is clearly not a simple task. Even though the algorithms we implemented in code were relatively simple, it requires more time than expected to write a completely bug free section of code.

Working on our project in a team also helped to develop my communications skills. As with any team, communication was an important contributor to success for us. At times we allowed stress and pressure to cloud our judgement, but in the end we were able to overcome these problems with communication. Each of our group members has different strengths and weaknesses. We worked hard to maximize all the strengths and mitigate our weakness with teamwork and cooperation.

Overall, I felt that our group worked well together. We were efficient in producing documentation and in developing the various sections of the project we were responsible for. The various parts of our project were split up when we began developing our project. When we integrated our project together at the end, there were relatively free problems. This exemplifies our superior ability to communicate the requirements and specifications of each separate part. Without this communication, we most certainly would have had many more problems trying to integrate our system.

Gary Wong

Duties:

- Signal Processing Stage
  - Developed Processing Stage Hardware
    - Analyzed analog-to-digital Converter requirements.
    - Researched and selected appropriate analog-to-digital converter.
    - Designed analog-to-digital converter and microprocessor circuitry.
  - Co-Developed Processing Stage Software
    - Co-developed error compensation algorithm.
    - Programmed microcontroller.

Skills Development Assessment

During the past 3-4 months, I learned many things. I learned that communication and listening skills are the most important things when working in a group. Misunderstandings and lack of communication usually leads to unnecessary work and wasted time. I also learned that defining and understanding the problem makes things smoother. It minimizes problems with designs and makes troubleshooting much easier and faster. Most importantly, I learned that following a planned schedule will minimize stress.

I find that all group members' interpersonal skills have improved. When someone talks, everyone listens and gives feedback. In general, our group dynamics were great except for one small occasion. One member was constantly distracted. It took some negative criticism to get that person doing work. At the end, it all worked out.

At first I thought most of the documentation was unnecessary but as the semester went on, I realized how important documentation is. Now I see documentation as an investment. You spend some time at the beginning at which you think is wasted time; in the end, you get a bigger return in the time saved than you invested originally.

Technical, I learned how to use MPLAB to program a PIC16F84 and integrate it with an A-to-D converter hardware wise. In the process I learned how hard it is to debug and test a real-time system. Using a debugger tells you if your algorithm is correct but it doesn't tell you if the timing is off. As expected, the writing of the program took 6 hours while debugging took much longer (numerous days). Even when the processing unit was functioning properly, bugs appeared when integrated with the signal acquisition stage. I learned that it doesn't matter how much testing and debugging you have done with simulated inputs, it will most likely not work when integrated because simulated inputs aren't the same as real environmental inputs which change in real-time.

In the programming process, I found working in pairs very helpful. You make really simple mistakes that you cannot see but your partner will pick up. When there is something wrong, the two of you can talk it over and try to find a logical explanation why the system behaves the way it does. In our case, we came up with hypothesis or guesses and tested to see if they were correct. This communication was essential because it kept frustration and stress to a minimum.

Overall, the project was a good learning experience and despite some minor bumps, it all ended up well. I wouldn't mind to continue further development on this project and we'll see how it turns out.

Steve Wong

Duties:

- Output stage
  - Researching and implementing an effective light display
    - easily viewable and non-confusing
    - power efficient
    - cost efficient
    - size efficient
  - Electronic circuitry
    - interpret signals from the processing stage and control the lights
    - user-selectable modes of operation (*normal* & *hazard*) and generation of *hazard* mode light pattern
  - Enclosure and wiring interface to the sensor & processing unit
- Main Unit (sensor & processor)
  - Enclosure and wiring interface to output stage

Skills Development Assessment

From a technical standpoint, I learnt about generic array logic, both its use and effectiveness, and about optimizing circuit designs for cost, size and power consumption. I now understand why in industry, research and development has such large cost. The number of components purchased to experiment for an effective light display was significant for a small project like ours, let alone a major project for a company.

I learned that the design process is very important to the success of a project and must be thought through as much as possible before implementation begins in order to reduce wasted costs. A well-thought out design also reduces the amount of time and resources required for debugging the project.

From a team perspective, I learned that communication is absolutely critical, especially between members working on different stages of the project. The members must know exactly what inputs their work will be receiving and what outputs they must produce. I learned that deadlines agreed upon by all members must be met. Failure to do so by any member results in significant amounts of wasted time by those who were able to complete their work on time. In terms of assuming a managing or leader position, I learned that it is important to put aside friendships when criticism on work and work effort must be made.

One thing I would change in the future is the number of meetings – more are required. While communication of requirements and design issues was not much of a concern among our group, monitoring of progress was. With more group meeting, delays can be better anticipated and resources can be relocated accordingly.

Overall, I enjoyed working with our team and have the utmost confidence in their ability to produce results. We were all able to bring unique skills and strengths to the project and contribute in significant ways. This project would not have been possible without the participation of any one member.