SMART SENSE innovations

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April 24, 1999

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

Dear Dr. Rawicz:

The attached document, MAPSS Functional Specification, outlines the process with which we followed in designing and completing our ENSC 370 project. Our goal was to design and implement a Mobile Paging Auto Security System. The device alerts the car owner of the occurrence of a car alarm, the activation of the ignition system, or if the headlights have been left on. The module will deliver a unique mobile page for each such event.

This document details the current state of the device, our deviations from the design specification, and our future plans for the device. In addition, this document outlines some of the budgetary and time constraints we encountered and explains the inter-personal and technical experience gained from working on the project.

Smart Sense Innovations consists of four motivated, innovative, and talented third-year engineering students - May Huang, Shirley Wong, Caroline Dayyani, and Frederick Ghahramani. If you have any questions or concerns about this document, Please feel free to contact me by phone at (604) 941-0629 or by e-mail.

Sincerely,

Shirley Wong
President and CEO
Smart Sense Innovations

Enclosure: MAPSS Process Report

SMART SENSE
innovations

Process Report

Mobile Paging Car Security System

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Introduction

It's done. We finished! The MAPSS (Mobile Alarm Paging Security System) is no longer a dream or something that we use to stimulate dinner conversations. The project is actually complete and fully operational. This report re-examines the process that the SSI (Smart Sense Innovations) team undertook to transform the MAPSS project from a dream to reality. This document also highlights the personal experiences of each group member while working on this challenging project.

Current State of MAPPS

As was previously described in the project proposal, the MAPSS system alerts the car owner of the occurrence of a car alarm, the activation of the ignition system, or if the headlights have been left on. The module delivers a unique mobile page for each such event.

The MAPSS system obtains input from the car security, ignition, and headlight systems, and generates an output in the forms of an encoded mobile page. Figure 1 shows the MAPSS system block diagram.

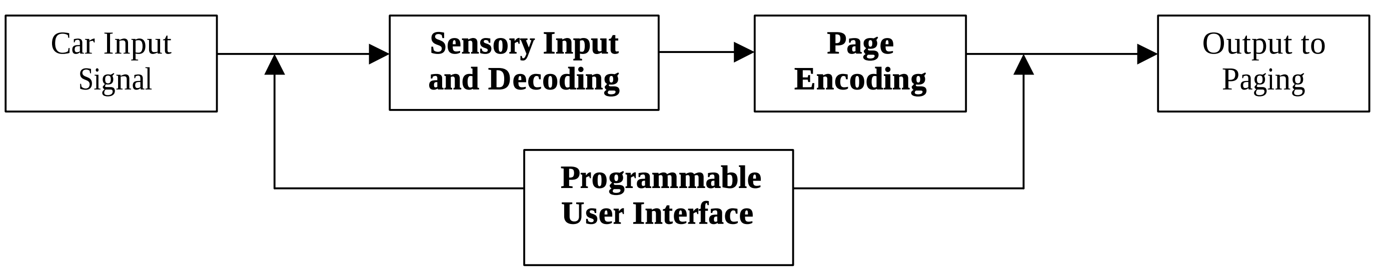

Figure 1: System Block Diagram

The sensor input and decoding stage is comprised of 3 isolated comparator circuits. The analog circuits filter the differential signals that are output by: (a) the headlights, (b) the ignition system (car battery), and (c) the alarm system's speaker. The decoding stage outputs a digital output to be used by the page encoding and dialing unit. The digital outputs are conditioned through a series of parallel combinational logic circuits, passing finally through a priority encoder. The sensor signals are sampled periodically using an ATMEL AVR 1200 micro-controller, and standard TTL multiplexer. The 1200 is used primarily to generate a 5 minute timer delay independent of the processor real-time of the larger 4414 micro-controller.

The "page encoding" module is composed of an ATMEL AVR 4414 micro-controller and SSI's customized telephone interface unit. Upon activation from the sensory input stage, the page-encoding module powers up the cellular telephone, and dials a phone number along with an appropriate sensor code. The sensor code references are provided in the system's user manual provided in the Appendix attached at the end of this document.

The programmable user interface consists of the same ATMEL AVR 4414 micro-controller as in the page encoding module, a Hitachi 4323 LCD screen, and a numeric keypad for user entry.

The above functional blocks have combined to satisfy the following system functional requirements (verbatim from the product's functional specifications)

The MAPSS system:
1) Interfaces with the existing car security system, car ignition system, and the car's headlights.
2) Provides a LCD display screen and keypad for the user to program the desired pager number
3) Utilizes the existing car batter for a power supply.
4) Has a power switch for the user to enable/disable the system
5) Has a response time of no more than 45 seconds; the response time for this system is the time required for the system to process the input from the car's subsystems and to generate and deliver a mobile page.
6) Is encompassed in a non-descriptive black box for ideal stealth integration into any car security system.

Deviation of the Device

Overall System

In terms of overall system functionality, we completed what we had intended. The system works reliably to the same requirements that we established in the functional specifications. Some partial deviations of the entire system include the fact that the prototype box is larger than was anticipated. As well the system was not specifically made to be mounted in the trunk of a car, it can also be mounted under a seat instead.

It was also our goal to construct a backup battery power system, in case the car battery was to fail, but this idea will be implemented after the ENSC 370 component of the project. Finally, we had intended on manufacturing PCB's for the product, but were unable to manipulate the PCB software efficiently enough to send in the PCBs by our presentation deadline. Instead, the entire MAPSS system was integrated into one tightly packed vector board, and one custom-made [in house] power supply PCB.

Figures 2 and 3 shows the intended design of the product, and the actual design. The finalized design is more optimized in terms of code efficiency, and microprocessor usage. The PIC micro-controller for controlling the LCD module was scrapped entirely. As was the AVR 2313 for phone controlling. We realized that we had enough I/O ports available on the AVR 4414 to control the LCD, telephone, and keypad. This change in design came about as a result of the realization that the PIC was accidentally placed reversed into the programmer and subsequently underwent what Fred Heep (the ENSC lab engineer) referred to as "a deep frying session".

General time constraints and hubris on behalf of the SSI engineers led to the redesign of the inter-chip transfer protocol. As a result, one 40 pin device controls almost all the components, and one small 20 pin AVR 1200 was used to generate a parallel processed 5 minute long time delay interrupt.

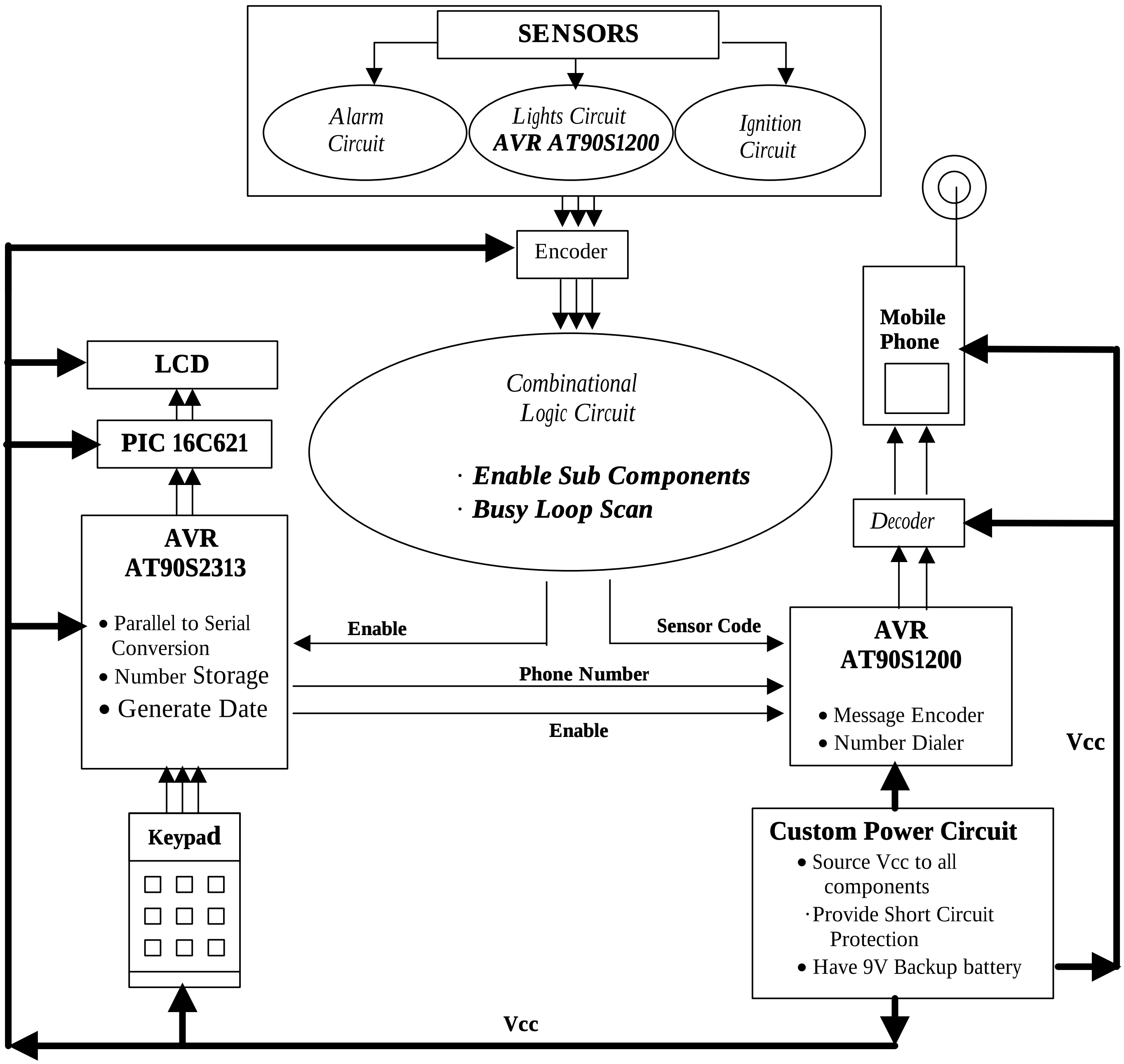

Figure 2: Intended MAPPS System Overview

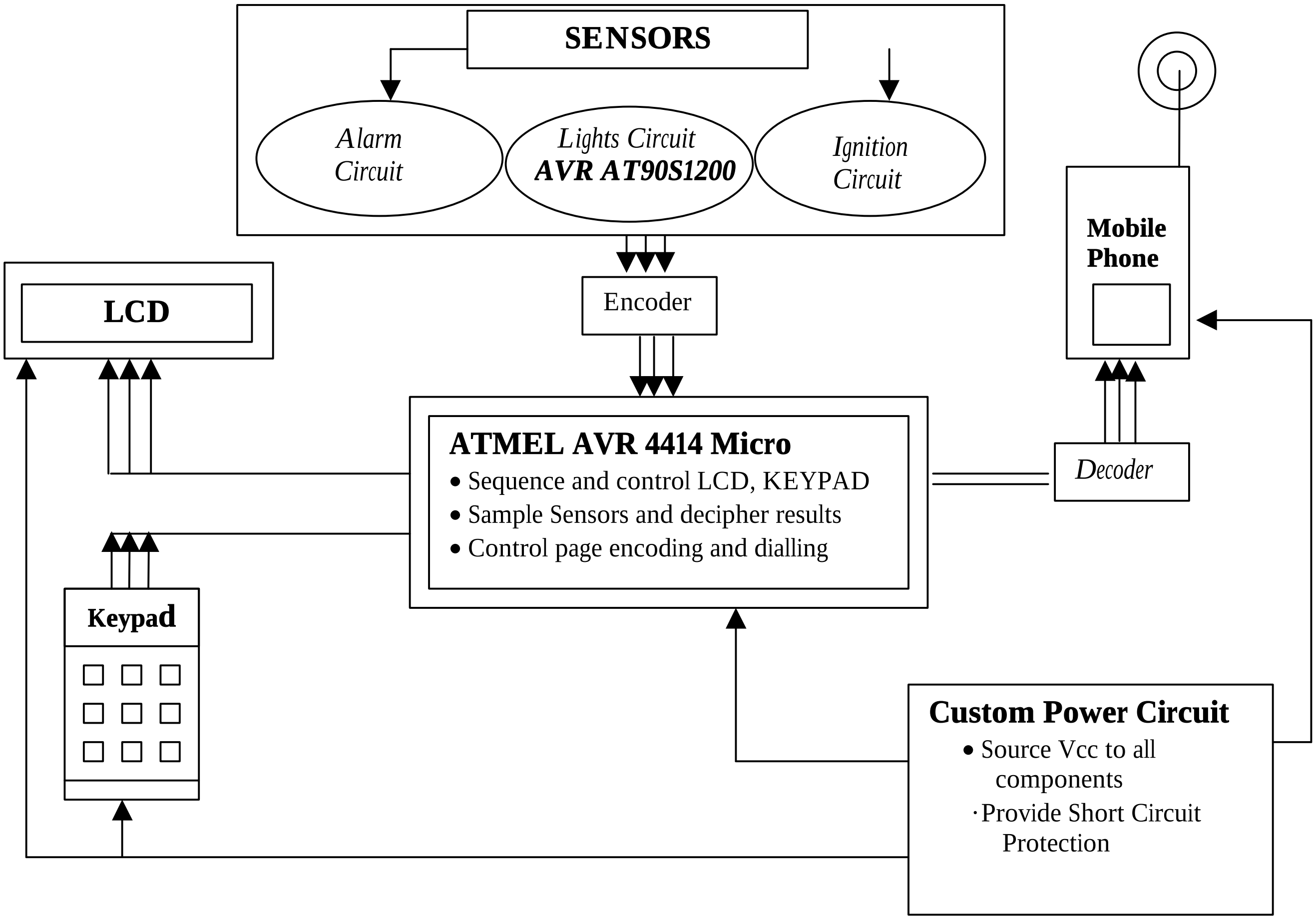

Figure 3: Actual MAPSS System Overview

Sensory Input and Decoding

The sensory input and decoding stage has not deviated from the original functional or design specifications. Several components were however changed and some sub-circuits were partially modified to facilitate higher reliability and efficiency for the MAPSS system. However, we had not expected to delegate the amount of time to testing our sensors as we have done in the past 3 months. The extensive testing was performed to ensure all components matched our high-reliability goal. The following changes in the custom power supply and sensing circuits are the deviations from the original plan as it was described in the design specifications.

Custom Power Supply

(a) Power supply is only used for regulating 12 V and not for any other value

The original plan for generating a 5 V supply using the 12 V regulated source caused many problems in the circuitry. The 5 V source was not able to maintain its value due to the loading effect from the TTL gates. In addition, using two regulators in succession is not reliable. The effect is similar to that of putting two amplifiers one after another which may cause non-linear effects.

(b) Adding a 5 V regulator

As a solution to the above, we decided to use a variable voltage regulator to obtain 5 V from the 12 V car battery, bypassing the 12 V regulated power supply.

(c)Adding a 7.5 V source for powering up the phone

In addition, we used another variable voltage regulator to obtain 7.5V for powering up the cellular phone. In case of both variable voltage regulators, the circuitry is the same except that the values of the resistors are changed to achieve the correct regulated voltages.

The advantage of using separate voltage regulators is that the current going through each of the regulators is reduced and therefore not exceeding the specifications of the regulators.

(d) Omitting circuit protection

Due to the limited time we had, we decided not to include the circuit protection in our design since this protection is not necessary for our system. However, it is a good idea to have a protection to avoid any damages due to shorting.

Sensing Circuits

(a) Ignition circuit compares the battery level to 12 V instead of 11 V

In our original plan, the ignition circuit was designed so that the voltage of the battery was compared to 11 V. Once the car is ignited, the battery voltage is dropped to 10 V for 1 second and will increase to 13 V afterwards due to the operation of the alternator in the car. However, after installing the car alarm, the battery voltage drops to 11 V (not 10 V) due to the loading effects from the alarm. So the ignition circuit is re-designed to account for this change. If it is slightly below 12 V, then the sensor will be activated. The drop of the battery voltage at the time of ignition also depends on the vehicle. The unregulated (i.e. battery) is compared to 12 V rather than 11 V regulated supply as mentioned previously in the design specification.

(b) Changing the sensing circuit for alarm

Due to experiencing a lot of problems from connecting the output of the siren of the alarm to the input of the multiplexer, we decided to use a buffer in between the alarm siren and the multiplexer. In this case the output of the alarm is about 4.7 V when the alarm is activated and it is at 0 V when the siren is not activated.

(c) Impact sensor is used inside the alarm sensor and not as a separate unit

The alarm that was donated to our group was slightly different from what we had expected and planned. Originally, we planned to have an impact sensor and alarm as two separate sensors. However, the alarm we received had the impact sensor inside it as one system. This limited our project to deal with only three sensory parts, and not four. But if a more expensive unit is chosen for this project, then impact sensor can be separated from the alarm sensor.

(d) AVR S1200 was changed to 5-minute interrupt, instead of 14-minute interrupt check ups

After considering that 14 minutes is a long time to check for the headlight, the interrupt for that part was changed to 5-minute check ups. This way, there is not a long delay in checking for the headlight and the battery drains will not be high.

Programmable User Interface

The functionality of the programmable user interface has deviated only slightly from the functional and design specifications. In terms of added functionality, the user interface now includes a "Power Failure" LED to inform the user if the car battery failed to correctly power up the system. As well, an extra simple LCD contrast switch was added to enable the user to modify the resolution of the LCD screen under different lighting backgrounds.
In terms of reduced functionality, the MAPSS user interface currently prompts the user for a new pager number upon each power up and power down. This pager number is only static, and is not stored to any form of permanent memory, a task that will be implemented after the 370 component of the project. This latter shortfall came about as a result of time constraints which are fully highlighted in the Future Plans section of this document.

Page Encoding and Dialing

The page-encoding module has not changed in terms of functionality. However, as of the printing of the design specifications, the physical telephone interface was not decided upon. Figure 4 shows the potential implementation that was suggested in the design specification.

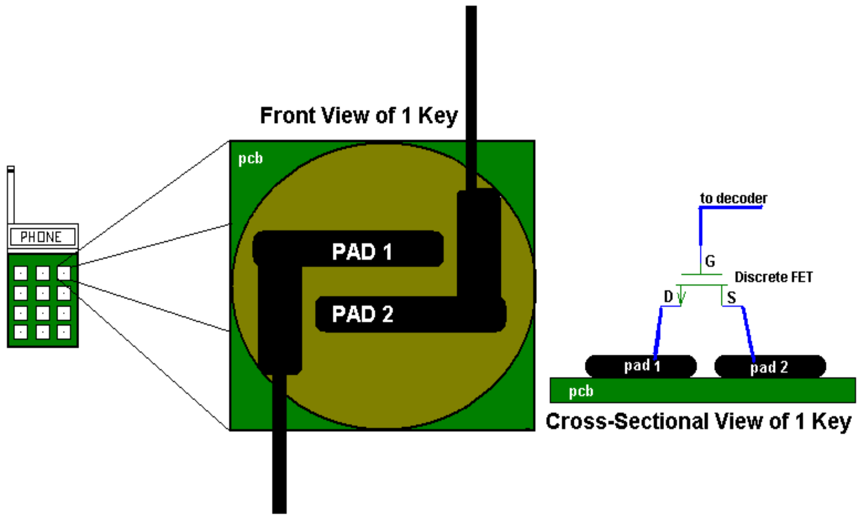

Figure 4: Proposed Physical Telephone Interface

However, this design was scrapped for its complexity. Specifically it was difficult to acquire surface mount logical MOSFETs that could be soldered onto the tightly packed PCB with any form of accuracy given the thick soldering pencils provided in the ENSC lab. Several other similar ideas were proposed and experimented with. The idea of using a conductive epoxy to draw each pad to the edge of the PCB on top of a mask was considered. However this idea was scrapped for our lack of confidence that an epoxy-to-conductive rubber connection would be reliable. Finally the entire keypad sub-circuit was reverse engineered from the PCB to see if we could alter some of the electronics of the system to achieve our goal.

What we discovered was that the circuit used to acquire the key pressed on the telephone was similar to the circuit show in Figure 5.

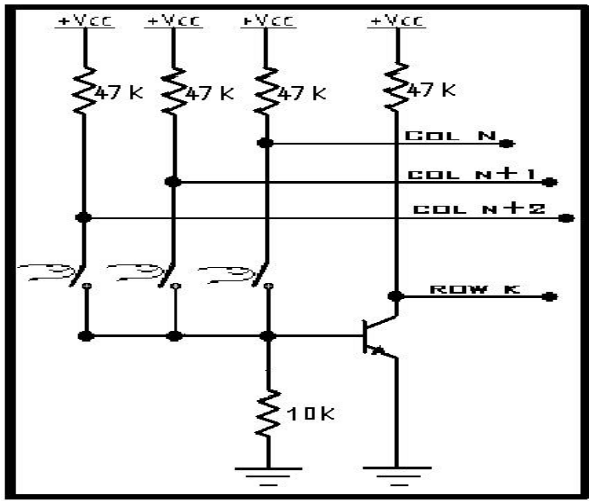

Figure 5: PCB extracted keypad circuit

The operation of the circuit in Figure 5 is as follows. Before a key is pressed, the probe points COL N and COL N+1 are at a logical high, since there is no voltage drop across the 47K resistor. Similarly, the probe point Row K is at a logical high because the transistor is not conducting, and hence the collector current is equal to zero. Once a key is pressed, indicated in Figure 5 by the fingers connecting the 2 spans of the circuit, current travels into the base of the transistor. The transistor begins to conduct, and subsequently, a current flows through the collector, resulting in the COL N and ROW K probes becoming a logical low.

To simulate this behavior with a micro-controller, the keypad connections were permanently shorted using a metal tab encased with a grommet placed in the original faceplate of the telephone. The metal interconnect was fed directly into the micro-controller. When the interconnect is placed at the same potential as Vcc, the current through the 47K resistor is pinched off and subsequently, the COL N probe point does not change its logical level. As well, the current through the base of the transistor as a result of the added 5V source is small enough so as not to generate a logical change at the ROW K probe point. Therefore, to simulate a dialing process with a micro-controller, all contact points are kept high, except the button that is desired to be pressed. This implementation is show in Figure 6.

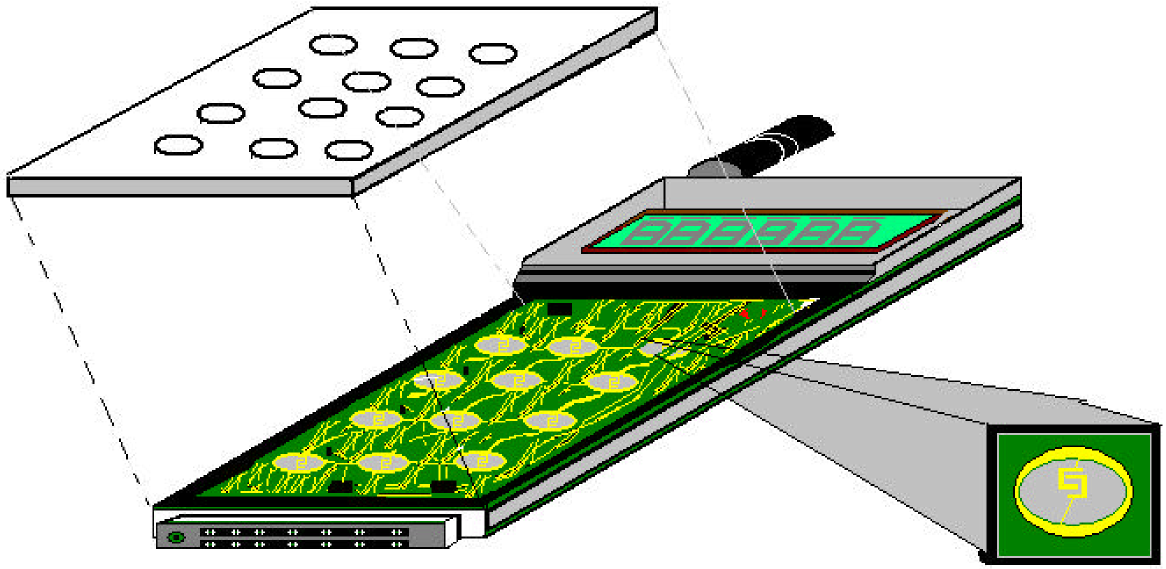

Figure 6: Finalized Keypad Interface

Future Plans

The MAPSS system has great potential for future development and marketability. It seems everyone likes the MAPSS idea very much, from parents and friends, to CEOs, presidents, and even taxi cab drivers. Whoever we shared the idea with, agrees that it's a good idea and that they'd be willing to invest in the system. As a result, the SSI group has agreed to work on this project for 8 more months. Our goal is to enter the project in the entrepreneurial design category of the Western Engineering Competition in January 2000 and hopefully push this product to market. With this potential in mind, we've summarized the following suggestions for future development.

Overall System

· ***Enable user to dial into car and turn off headlights***

The functionality of the entire MAPSS system will be increased. One way of doing this is by allowing the user to dial into the car and turning off the headlights remotely. This feature would fully compliment the headlight warning system already in place. The realization of this feature will require a modification to the telephone interface, and the design of a headlight actuation device. This feature will be incorporated into the MAPSS system by the end of August 1999.

· ***Incorporate Civilian GPS tracking into system***

The final end-user functionality of MAPSS will incorporate civilian GPS tracking. This feature will be added to fully secure and feedback to the owner the location of the car. The final product will allow the user to dial into the car, and interactively obtain the GPS coordinates of the car. This information would be useful in tracking a stolen car, as well as tracking criminal activity.

· ***Reduce the package size***

The current prototype as it stands is much larger than it could be. The size of the final product plays a big role in the stealth integration of MAPSS into any car. The desired packaging size would be approximately ½ of the current size. In order to facilitate this requirement, PCBs will be manufactured.

· ***Optimize power consumption***

The majority of the power consumption in the system is a direct result of the 3 combinational logic circuits. To optimize the power consumption, several hardware techniques can be employed to disable subsections of the circuitry when they are inactive. For example when the system is in phone number acquisition mode, the combinational logic circuit that conditions the sensory input, and the circuit that activates and dials the telephone do not need to be powered up.

As well, the use of lower power consumption components could greatly increase the efficiency of the power consumption. For example switching to the LS (low power Schottky) version of the TTL integrated circuits employed would reduce the power consumption of the entire circuit by nearly 40%.

Programmable User Interface

· ***Permanently store user settings***

Due to time limitations, the functionality of the Programmable User Interface is lacking in robustness. In specific, the user is prompted to enter a pager number every time the system is powered up and down. This shortfall in the system will be changed in the next month by interfacing external memory using the I2C protocol. The memory has already been sourced and purchased, and needs only to be implemented.

· ***Enable car swapping***

Ideally the MAPSS product will be so good, that you'll purchase one for each of your cars. However economic realities are often further than ideal. With big bank mergers and unprecident layoffs in the marketplace, it becomes difficult to fully afford proper car security for both your Beamer and Benz. For this reason, it would be ideal to enable the user to easily car swap MAPSS. The user settings will be stored for each car.

Sensory Input and Decoding

· ***Alarm***

Due to limitations of this project in terms of budget and time, we were unable to build a sensory circuit for the alarm (which would be efficient for all alarm systems). Our future plan is to generate a more generic alarm sensing system, which will be useful for all alarm systems. This means using more complex and expensive alarm systems that have different sensors separated from the siren part. From the design aspects of the circuit, our circuit has to deal with the sensors and the siren of the alarm being separated and not like our existing system that counts the shock sensor and the siren as a single unit. By corporation of the new alarm system into our system, we may increase not only the efficiency and accuracy of our product, but also the options of using more sensors in our system.

· ***Ignition***

Currently, the voltage comparator compares the regulated 12 V to the voltage of the battery. When the engine is ignited, the battery voltage drop will result in a logic high in the comparator. However, the current method is not as reliable as could be if we were to compare this drop in voltage with 11.5 V instead of 12 V. The reason is because if the battery is not at its optimal level, it stays at a voltage of just below 12 V. The drop in voltage can be interpreted by our sensor as having the engine ignited. This change can be done by adding a small resistor between the input of the comparator and the regulated 12 V. The resistor would have a voltage drop across it and therefore reducing the input of the comparator as a value of below 12 V. We didn't realize this problem until near the end of our testing and due to time constraints, we did not implement the change.

Page Encoding and Dialing

· ***Add time stamped voice mail functionality***

Under the current system, a busy signal is treated as a redial attempt. The system redials attempts to page the user again. But what about voice mail? Or answering machines? Removing the need for a mobile pager could increase the functionality and marketability of the MAPSS system. Alternatively, the system could be programmed to dial a specific phone number, and play a voice message to the receiving end.

· ***Incorporate e-mail paging functionality***

The functionality of MAPSS could be increased if an e-mail interface feature is included in the users mobile pager plan. This feature would be more useful to some users than a pager or a voice mail message. The realization of this feature depends on the level of automation that the e-mail paging service provider can support.

Reliability

Engineers are placed in a difficult situation when it comes to reliability. Analogous to the Heisenberg uncertainty principle where attempts at viewing a particle can themselves change the properties of the particle. Consciously redesigning a solution to be more reliable can in itself decrease the reliability of a product by adding more complexity.

The primary goal of a first prototype is functionality, not reliability. However some careful conscious decisions can be made to ensure a small level of reliability, which in turn increases the probability of a product's functionality.

The following are conscious, post design decisions that were made in the manufacturing stage to ensure the reliability of the MAPSS system.

Sensor Circuitry

The heart of the MAPSS system depends heavily on the proper execution of the sensor circuitry. The sensor circuitry must be sensitive enough as to sense signals that warrant a page be broadcast, but cannot be so sensitive as to causing false alarms. A fine balance must be sought by to ensure customer confidence in the product.

Upon the completion of the product, the sensor cueing circuitry was as shown in Figure 7.

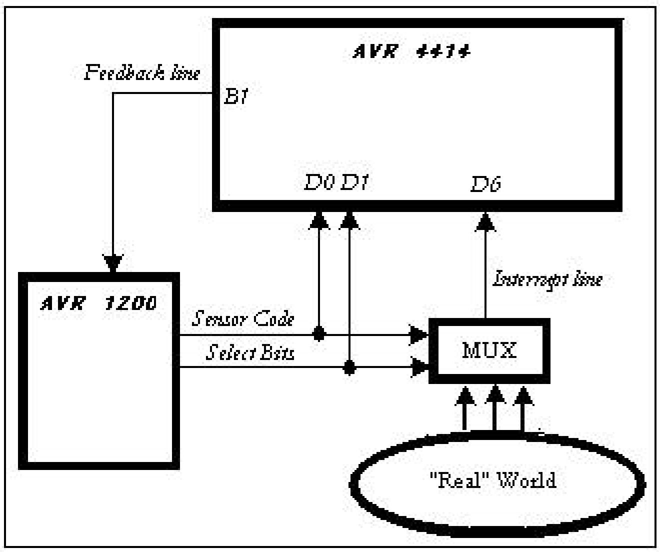

Figure 7: Originally Designed Sensor cueing circuitry

The sensor code select bits are toggled by the AVR 1200 micro-controller. The external processor was used to generate the appropriate 5 minutes interrupt sequence for the head light sensor signal. However this circuit poses a great deal of reliability issues. In specific, if the incorrect sensor code is selected or toggled for the incorrect interrupt line, an incorrect signal could be passed to the user. As well, since both processors are running at difference clocks speeds, timing issues could cause an interrupt line to be tripped after the sensor code has changed.

To increase the reliability of this circuit, 2 small after design additions were made. Firstly, a feedback line was put into place, to toggle the AVR 1200, and reset the chip once an interrupt has been caused. This would allow for confident and reliable readings of the D0 and D1 ports. Second, a hardware latch circuit was designed to latch the interrupt line. The reasoning behind this stems from the fact that all the sensor outputs that are input from the "Real" world would remain high for more than 100 clock cycles. To increase the reliability of the MUX output generating an interrupt line, a custom latch circuit was designed. The latch is strobed by the 4414 micro-controller for input. Only signals that are latched for more than 10 strobes are considered as genuine interrupts.
The latch circuitry is shown in Figure 8.

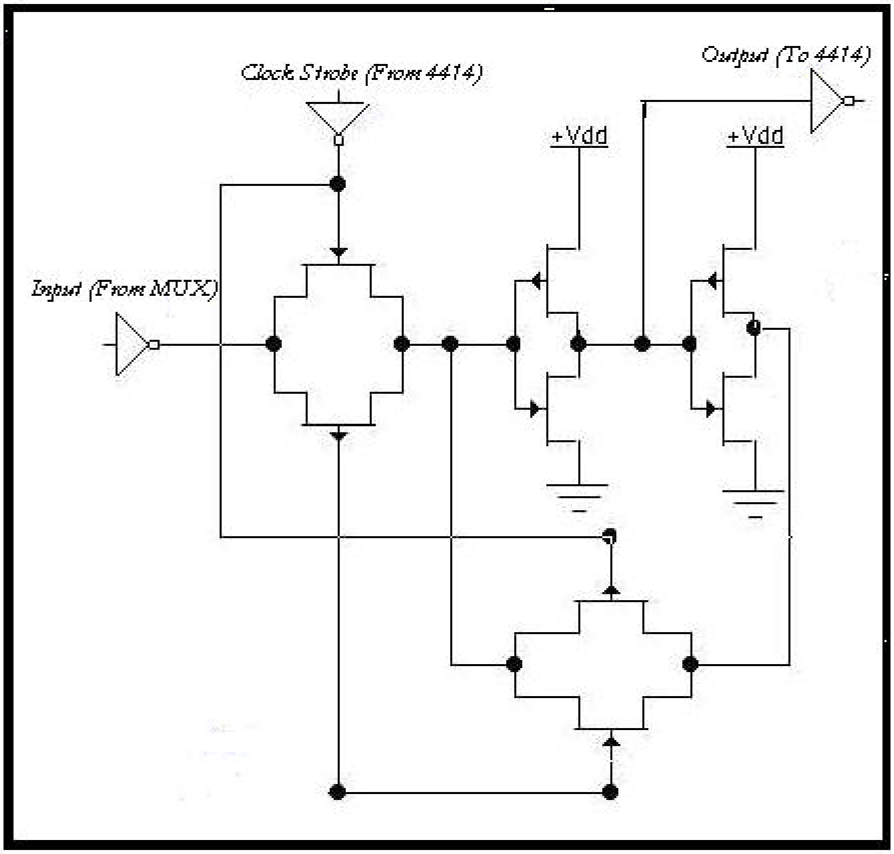

Figure 8: Latch Circuitry Increasing Interrupt Reliability

Budgetary and Time Constraints

Budget

Table 1 outlines the estimated cost and actual costs of the MAPPS project up to the date of April 22 1999. However, this table does not cover debits and credits that were accrued as a result of unplanned expenses and credits.

Table 1: Tentative Budget vs. Actual Budget

Equipment Name	Estimated Cost	Actual Cost
Mobile Phone and accessories	$ 400.00	Donated by sponsors
Signal Splitter	$ 20.00	$ 15.00
Car Security System	$ 100.00	Donated by sponsors
Microprocessor and EVB	$ 200.00	Donated by sponsors
User Interface	$ 50.00	$ 25.00
Cables	$ 15.00	$ 20.00
Case	$ 15.00	$ 25.00
Total Cost	**$ 800.00**	**$ 85.00**

Table 2 outlines the remaining debits and credits of the MAPPS project

Table 2: Budget for non-Forecast Events

Description	Credits	Debits	Balance Forward
Ballard Sponsorship	$ 200		$ 115
CREO Sponsorship	$ 200		$ 315
AGF Robertson & Associates Ltd. Sponsorship	$ 100		$ 515
EUSS Endowment Fund	$ 66		$ 581
Security System Installation		$ 57	$ 524
Phone Activation		$ 23	$ 501
Phone Re-Activation		$ 23	$ 478
Hardware Tools and Components		$ 376.41	$ 101.59
		Final BALANCE:	**$ 101.59**

Time

Due to various unexpected slippages, and over-confident project planning, the MAPSS system fell approximately 4 days behind schedule. As a result, we were granted a deferred grade. During the deferral period, we were able to implement some extra reliability assurances that we would not have been able to implement in the strict time regime dictated in our project proposal. As well, the extra grace period was used effectively to fully test the system under all battery levels and car system conditions. This testing was vital in helping us to isolate weak points in the system, and areas that we will have to redesign over the course of the summer.

Interpersonal and Technical Experience

By enrolling in ENSC 370 we have learned many aspects of designing and implementing an embedded system. We've also learned that in order to successfully finish a design, other factors such as time, and funding, and group dynamics must be carefully considered. In short, ENSC 370 has taught us that engineering is about more than just technical design.

During the course, the group met thrice weekly for project work and discussion. This constant communication enabled us to steadily progress through the design and implementation stages. From the beginning of the project, it was agreed upon that although we needed to manage time as effectively as possible, we all aspired to learn as much as humanly possible in a 4 month time frame.

Collectively we learned to effectively accept and provide proper constructive criticism. We learned to critically view all possible solutions, and to select the best ones. We learned that the "best" solution, is not always the intrinsically theoretically superior solution. Issues such as time, and economic factors must be calculated into each decision, but not so as to stifle the design process.

Caroline Dayyani

In my opinion, the Ensc 370 course not only gave me confidence in learning more hardware trouble shooting, but also helped me to learn more team working skills. I believe even if all the knowledge would be there for doing any projects, if there is no communication between the group members, nothing may be done quickly and efficiently. During the last four months, our group put a lot of effort to make sure that good communication between each group member was done. I am sure learning this skill benefited all of us in our future career paths since nowadays most companies are looking for people who can promote their business through communication channels inside the company.

In terms of technical skills, I enhanced my knowledge in the analog circuit design. During the last four months, working on the sensory part of this project helped me to learn more troubleshooting skills and different circuit design aspects which I am sure will be helpful for me in the near future. As well, by helping my other group members, I learned more about the operation of cellular phones. Also, I learned a lot in terms of mechanical skills by trying to take over the mechanical parts of the project.

It is very interesting to see that different sub-components combine together to build a new device which was fully originated from our thoughts. This part thought me how a project starts in the industry and after passing through a lot of ups and downs, you may see your final product.

Frederick Ghahramani

From a technical perspective, ENSC 370 has been an eye opening experience. I've increased my confidence in designing and debugging complex transistor circuitry. I've received a crash course in a foreign micro-controller assembler, and subsequently learned what it really means to process information in real time. I've been fortunate to play around with keypads and LCD's - a fun excursion in an otherwise grueling project. I've learned to effectively decipher commercial PCBs and reverse engineer complex circuitry. To effectively alter commercial PCBs and hope the product still works :-). Beyond this, there was also the research that I did (a continuation of personal interest) on how a cellular telephone works, and the various servicing techniques. The research I feel will help us along down the road, specifically when we attempt to integrate the civilian GPS into the system. Finally, my knowledge of combinational logic circuitry was really tested and reinforced throughout this project. Having said that, my role as Vice President Marketing was a complete success. Early on in the project, I placed a personal goal for myself to market this product like mad, and raise enough capital so as none of the group members had to spend any money for components or parts. This was a daunting task considering we expected our budget to be nearly $800. When the dust settled, the majority of expensive parts were donated by sponsors such as BC TEL, WASP Security Systems, and Atmel. We acquired $366 total in funding, with another $200 promised from another corporate sponsor for the summer component of the project. In short I learned how to catch the attention of executives, how to let people's dreams sell my ideas to themselves, how to effectively sell a product that didn't even exist yet. In short, how to sell an idea. For this experience alone, ENSC 370 was well worth the 4 credit hours that I paid for.

May Huang

Although 370 has caused much stress and sleepless nights, the amount of knowledge gained from doing a project like this is insurmountable. With respect to technical issues, I have learned the importance of putting emphasis on the interconnections of each sub-component in the circuit. The loading effect due to some components has caused the circuit to give incorrect results and thus many strenuous hours were spent to try to solve the problem.

Due to the relative size of my past projects, I have not been too concerned about the input and output currents of my circuits. However, because we were using many TTL chips and analog switches on the vector board, power consumption became an issue. Current limitation was also an issue. Due to my inadequate knowledge of voltage regulators, I was experiencing current limits during our initial attempts of powering up the circuit. Since then, I am more fluent with the operation of voltage regulators and the chips used for this project. In addition, I acquired the knowledge of designing and debugging complex TTL circuitry.

Using a less-well supported micro-controller has also given me many challenges. Using the AVR chips has given me greater understanding of the pipeline architecture and real-time execution of the codes. The research put forward into deciding which micro-controller to use has also given me a wider perspective of the micro-controllers in the market and their respective features.

Our group has initially planned to develop a PCB. However, due to our inexperience in this area, the work spent on developing the layout has gone to waste. This mistake has taught me to be more cautious of the applications supported by PCB manufacturers. Apparently MicroSim Pspice was not supported by the chosen PCB manufacturer. We will however, develop PCB for our circuitry, when we have more time to further explore this option.

Aside from the technical experiences, this course has also diverted my attention towards interpersonal communication. This intensive project has caused some disagreements and tension within the group, but overall, the group dynamic has been excellent. I realized that patience and understanding are the keys to a productive team.

Shirley Wong

The technical experience I gained from this course is gaining more exposure to programming in assembly (AVR) and also more experience with debugging. I grew to enjoy programming because I actually had the opportunity to apply my knowledge in real-life applications. I have only taken one assembly course during my 3 years in SFU, but have seldom had the chance to program in assembler. I found that I enjoy programming in low-level languages more than I do in high-level languages (such as C++). The part that I found fascinating is that a cellular phone can be activated and controlled without having someone physically pressing the keypads. This was accomplished through the use of a micro-controller (AVR), several analog switches, as well as some inverters. It amazes me what software can do. There are so many possibilities and until now, I thought software was just about writing silly test programs in school. I have gained, through this project, a better understanding of what software can do in the real world.

If I was to re-do this project from the beginning, I would not have a lot to change. The only thing that I would change is to have more faith in our circuit designs and to not doubt them as much. We have run into problems that cannot be easily solved and found out that the cause of these problems were not due to our design, nor to do with blown parts… but instead has to do with poor soldering connections. If I knew then what I know now, we would definitely not spend as much time trying to figure out what is wrong with our design. But instead, should focus on the connections between parts of our design.

One of the most important things I learned in this course is the importance of one's ability to work with others. I believe that no matter how brilliant one person is, and no matter how hard working that person is, one cannot do *everything* on his/her own. I learned that being able to work well with others is the key point of 370. If you cannot communicate with others about your ideas or are not willing to listen to what others have to offer, your project will not be a successful one. In the real world, people have to learn to work well with others. Even multi-billionaire, Bill Gates, worked with Paul Allen to start Microsoft and look where they are today! Therefore, the importance of teamwork cannot be stressed enough.

It was a pleasure to work with my group members for this project. Our group communicated very well with each other. Our thrice-weekly meetings kept everyone up to date with what everyone else was doing. I also learned to better handle stress and not to take criticism to heart. Especially during the last week of demo time, everyone in the group was stressed over finals and trying to put our project together so we can demo in time. The stress was getting too hard to bare and so we started to criticize one another without meaning to. But because we apologized and understood each other, we spent this negative energy into something more productive – that is, to finish our project. In the end, I believe we handled it quite well… after all, we're all still friends =Þ.