Deceleration-X Systems
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Simon Fraser University
Burnaby, BC
V5A 1S6

February 16, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

RE: ENSC 370 Project Functional Specifications

Dear Dr. Rawicz:

Enclosed please find a copy of the functional specifications for our ENSC 370 project. The enclosed document outlines the functionality our Automobile Deceleration Indicator system will provide. The goal of the project is to develop a system to provide drivers with a concrete means of determining the rate of deceleration of surrounding vehicles, which will translate into fewer motor vehicle accidents.

The enclosed document provides a functional overview of our solution accompanied by a detailed discussion of the function requirements of the various system components. System components considered include: the deceleration sensor unit, the display unit for visually indicating deceleration in an intuitive way, and the data logger for recording deceleration information during a collision.

Our project group consists of four engineering students with experience and expertise in various aspects of hardware design. If you have questions or concerns regarding the functional specifications, 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: Automobile Deceleration Indication System, Functional Specifications.

Deceleration-X Systems

Automobile Deceleration Indication System
Functional Specifications

Submitted by	Deceleration-X Systems: James Balfour, Randy Cho, Gary Wong, Steve Wong
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Date	February 16, 1999

Executive Summary

With the number of automobile accidents and their respective costs on the rise, there is an increasing need for reducing accidents and injuries. Deceleration-X is developing an Automobile Deceleration Indication (ADI) system for use on an extensive variety of automobiles. Once installed, the ADI system will indicate to other drivers how rapidly the vehicle is decelerating, allowing drivers to make more informed decisions as to an appropriate course of action.

The ADI system will additionally incorporate data logging capabilities, allowing deceleration rates prior to and during a collision to be recorded for subsequent analysis. The data logger will assist and benefit insurance companies and law officials investigating automobile collision.

The ADI system will be assembled from a combination of discrete and integrated analog and digital components. We anticipate using accelerometer sensors for detecting vehicle deceleration, as using accelerometers will provide maximum modularity, cross vehicle portability, and flexibility of installation. The remainder of the ADI system will provide signal conditioning, output generation, and data logging functionality.

The ADI system will observe a modular design paradigm, with system functionality spread across multiple physical units in order to ensure maximum flexibility in design and installation. The deceleration sensors and signal conditioning circuitry will reside in a single small unit mounted securely somewhere on the vehicle's chassis. The data logger will reside in a second unit, which may be mounted where it will be protected in a collision and can be easily accessed. The display system will reside in a third unit mounted at the rear of the vehicle where drivers following the vehicle may clearly see the display.

This document provides the functional specifications for the ADI system. The layout of the document has follows the major functional blocks of the ADI system.

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1 Introduction

Whether traveling to or from work, taking children to school, or going to the local supermarket, driving a motor vehicle is a daily routine for over eighty percent of Canadians[1]. Successfully piloting a motor vehicle requires not only interaction between the driver and the motor vehicle, but also interaction between the driver and others sharing the roadway. When breakdowns in the interactions between drivers occur, accidents causing motor vehicle damage or loss of life may result.

Frequently, driving interaction breakdowns occur as a result of the limited means of communication and feedback between drivers. Communication between drivers is currently limited to simple visual signals such as car lights and simple auditory signals such as car horns, while most feedback available to a driver comes through the perceived motion of other cars. This document provides the function specifications of a system intended to improve the means of communication and feedback for drivers, thereby reducing the likelihood of motor vehicle collisions.

Currently available means for communicating one's intent to decelerate or stop a motor vehicle is restricted to the illumination of stop lamps on the rear of the motor vehicle. However, the illumination of the rear stop lamps provides no indication of the rate at which the motor vehicle is decelerating; the stop lamps illuminate when the brake is engaged regardless of whether the motor vehicle decelerates or not. Furthermore, the brake lamps may not illuminate during deceleration because the driver fails to engage the brakes, as frequently occurs in sudden collision situations. The intent of our project is to develop a system to communicate the rate of deceleration of one motor vehicle to other drivers in an accurate and intuitive manner.

Providing an indication of motor vehicle deceleration in addition to the indication of brake application provided by stop lamps would provide improved communication and feedback in numerous situations including when:

1. A motor vehicle decelerates or stops rapidly without the driver applying the brakes
2. A motor vehicle fails to decelerate despite the driver applying the brakes
3. A driver must distinguish between another driver making an urgent stop involving heavy deceleration or gently decelerating for a gradual stop
4. A driver wishes to distinguishing between another driver "riding the brake" and braking to significantly decelerate or stop

The improved communication and feedback provided in the above scenarios improves the possibility of avoiding a collision or similar accident by assisting drivers in predicting the behavior of other motor vehicles. Substantial human and monetary benefits, such as reduced automotive accident related fatalities and insurance claims, would accompany any reduction in collision rates. Such benefits could be used to justify the expense associated with incorporating the deceleration communication system into new or existing motor vehicles, especially if the cost of incorporation is kept minimal.

2 System Overview

The ADI system shall determine the deceleration along the major axis of the vehicle on which it is mounted and visually display the determined deceleration to surrounding drivers. Figure 1 below depicts the functional block diagram of the ADI system.

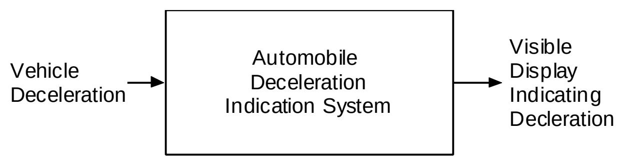

Figure 1: Automobile Deceleration Indicator Function Block Diagram

Figure 2 illustrates the orientation of a vehicle's major axis. The ADI system shall display only the component of the vehicle's total deceleration parallel to the vehicle's major axis.

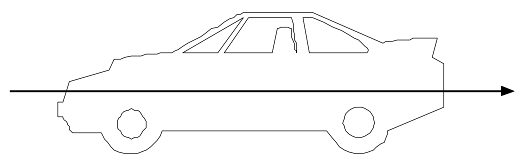

Figure 2: Orientation of Automobile's Major Axis

The ADI system shall provide a highly visible display capable of accurately indicating the deceleration throughout the range of deceleration achievable by current street legal vehicles. Our resident car enthusiast informs us that the Porsche 911 Turbo provides some of the best deceleration performance available, braking from 100 km/h to 0 km/h in 33.8 meters for an average deceleration of approximately 11.4 m/s^2 [2]. The ADI system will provide a display capable of displaying decelerations not exceeding 12 m/s^2 with sufficient resolution to allow an accurate estimation of deceleration from viewing the display.

The ADI system will provide data logging capabilities. Vehicle deceleration prior to and during a collision will be recorded by a data logging unit similar to the black box in an airplane. The recorded data can later be used in accident recreations. The data logger will continuously sample vehicle deceleration during vehicle operation at a rate of 40 samples per second, storing the samples in non-volatile memory. On system memory will allow a total of 20 seconds of data to be sequentially stored. The data logger will continuously overwrite samples recorded 20 seconds prior with new samples. However, the data logger will stop recording 10 seconds after a high probability of collision has been detected, providing 10 seconds of samples prior to the collision and 10 seconds of samples after the collision.

The ADI system shall incorporate a modular design at the physical layer to improve ease of installation and flexibility in cross vehicle portability. The physical layer of the ADI system will be spread across three separate units:

1. A Sensor Unit for detecting vehicle deceleration
2. A Display Unit for visibly display deceleration not exceeding 12 m/s^2
3. A Data Logger for recording deceleration information prior to and during a collision.

Figure 3 outlines the distribution of the functional layer across the physical layer.

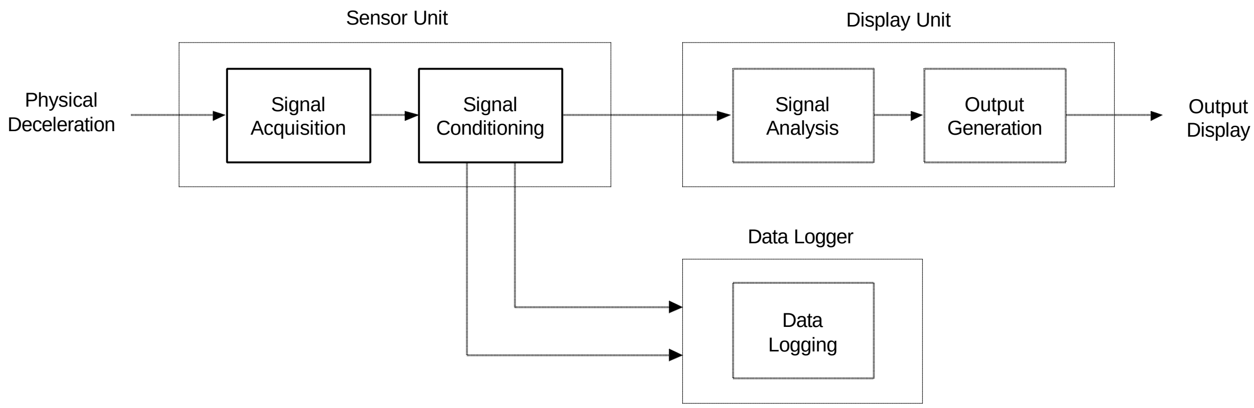

Figure 3: System Overview

The Sensor Unit shall be mountable anywhere within the vehicle provided:

- The Sensor Unit is not mounted within the engine block
- Proper orientation of the Sensor Unit relative to the vehicle's major axis is ensured
- The mounting point is rigid and not subject to undue vibration or risk of damage in a collision

The Data Logger shall be mountable anywhere within the vehicle provided:

- The Data Logger is accessible and may be removed without damaging the vehicle
- The location of the Data Logger does not expose it to undue wear or risk of damage in a collision

The Display Unit shall be mountable at the rear or front of the vehicle. Numerous Display Unit designs shall be possible on account of the modular design paradigm. Thus, it will be possible for vehicle manufacturers to customized Display Units designs for specific vehicles provided the custom Display Units adhere to the functional specifications for the Display Unit presented within this document.

3 Signal Acquisition

The signal acquisition stage shall detect vehicle deceleration and produce an electrical output signal proportional to the deceleration experienced by the vehicle. Figure 4 depicts the signal acquisition stage's relationship to the ADI system.

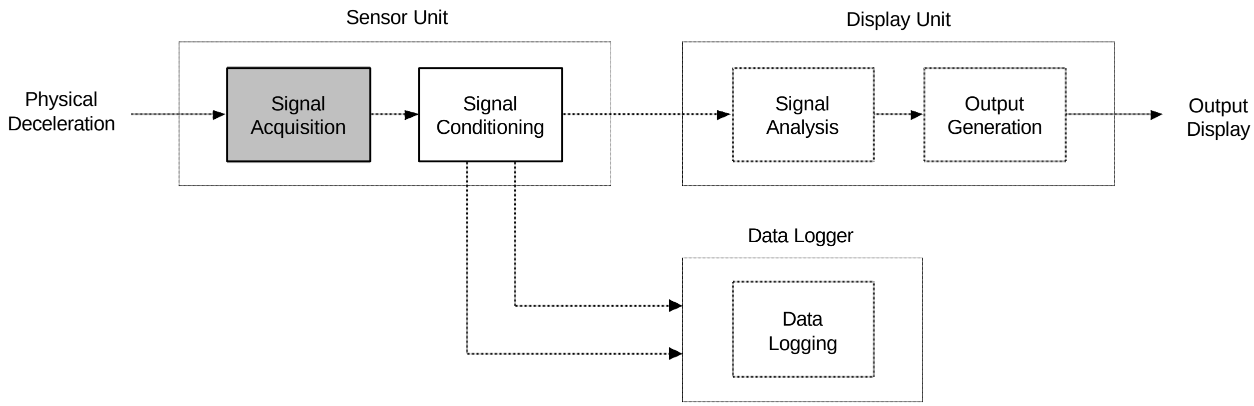

Figure 4: Signal Acquisition Context Diagram

The minimal signal acquisition stage shall detect the vehicle's deceleration along the vehicles major axis. An advanced signal acquisition stage will additionally detect deceleration experienced perpendicular to the road surface. The advanced signal acquisition stage may offer the following advantages by providing the signal conditioning stage with orthogonal deceleration measurements:

- Drift in the sensor output caused by temperature variations, which will affect all sensor outputs similarly, may be compensated for by comparing the orthogonal measurements
- Sensor sensitivities to orientation, as exhibited by sensors such accelerometers which are influenced by gravity, may be compensated for

Figure 5 below presents the function block representation of the signal acquisition stage.

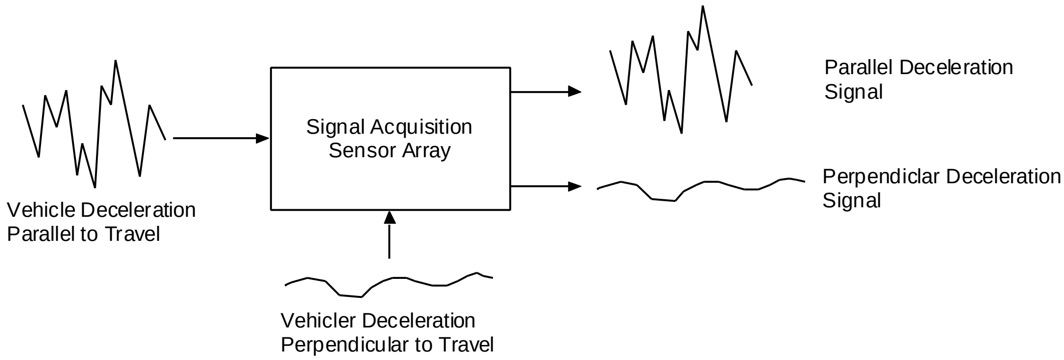

Figure 5: Signal Acquisition Functional Block Diagram

The signal acquisition stage shall use one or more sensors to detect vehicle deceleration. The sensor or sensors shall:

- Allow the Sensor Unit to operate independently of the vehicle to which the ADI system is attached, with the exception that the Sensor Unit may drawing power from the vehicle's electrical system
- Allow the Sensor Unit to be entirely contained within a single enclosure
- Produce an electrical signal proportional to the experienced deceleration
- Detect vehicle decelerations as low as 0.0 m/s^2
- Detect constant deceleration
- Provide signal to noise ratio and sensitivity levels sufficient for the signal acquisition stage to detect decelerations with a minimum resolution of 0.5 m/s^2
- Detect vehicle deceleration exceeding 30g to provide a wide range of deceleration rate detection during collisions
- Provide a minimal bandwidth of at least 500 Hz to ensure rapid changes in deceleration experienced during collisions are accurately detected
- Operate over a temperature range of at least -30°C to +70°C

The signal acquisition stage shall arrange the aforementioned sensor or sensors to:

- Ensure proper isolation of the sensors from the rest of the vehicle's electrical system to ensure optimal sensor performance
- Ensure the power supply for the sensors is properly regulated to ensure optimal sensor performance

The signal acquisition stage shall supply one or more signals indicating vehicle deceleration along a particular axis to the signal conditioning stage. The supplied signals shall allow the signal conditioning stage to generate a signal representative of the deceleration experienced by the vehicle parallel to its direction of travel

4 Signal Conditioning

The signal conditioning stage of the Sensor Unit shall accept the signals produced by the signal acquisition stage and generate the three output signals described below. The following context diagram highlights the relationship between the signal conditioning stage and the ADI system.

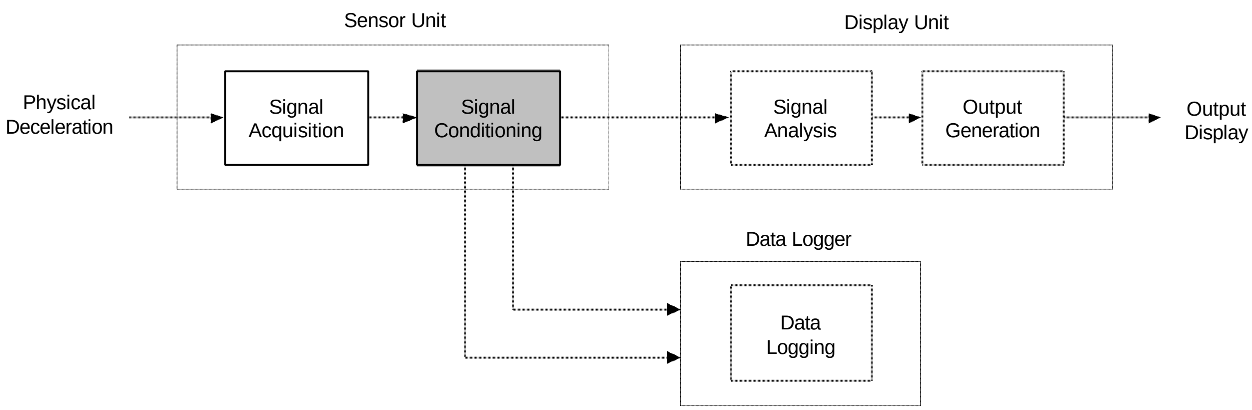

Figure 6: Signal Conditioning Context Diagram

The signal conditioning stage will produce the following three conditioned output signals:

1. A conditioned analog signal indicating vehicle deceleration over a limited range for use by the Display Unit. The signal conditioning stage shall assure the mapping between vehicle deceleration and output voltage approximates that depicted in Figure 7.

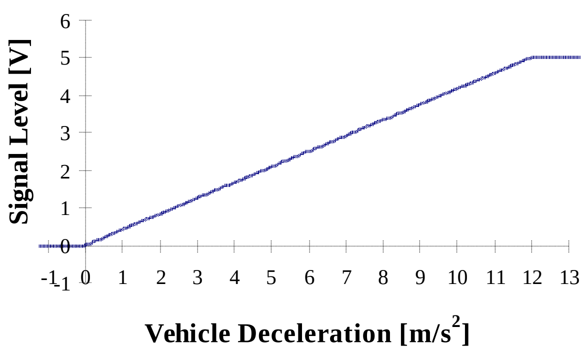

Figure 7: Deceleration vs. Display Unit Deceleration Signal

2. A conditioned analog signal indicating vehicle deceleration over a larger range for use by the Data Logger. The signal condition stage will assure the mapping between vehicle deceleration and output voltage approximates that depicted in Figure 8.

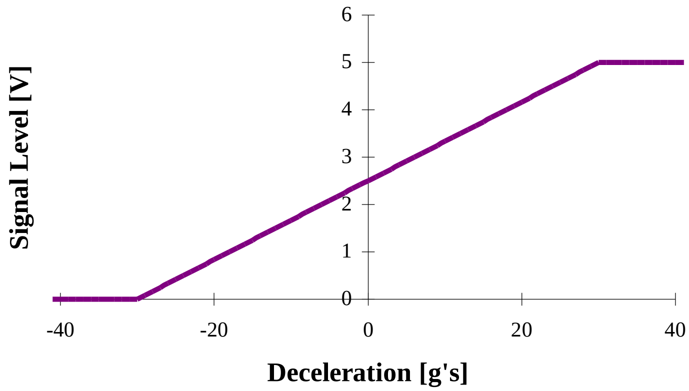

Figure 8: Deceleration vs. Data Logger Deceleration Signal

3. A digital signal Collision Interrupt Signal indicating a high collision probability for use by the Data Logger. A high collision probability will be indicated by a sustained deceleration exceeding a threshold deceleration level of 1.75 the maximum braking deceleration rate. The signal will be an active high, with a logic 1 indicated by a 5 volt output signal and a logic 0 indicated by a ground voltage. The signal will be driven to an active logic level when a high probability of collision is determined. The anticipated output characteristic of the signal is depicted in Figure 6.

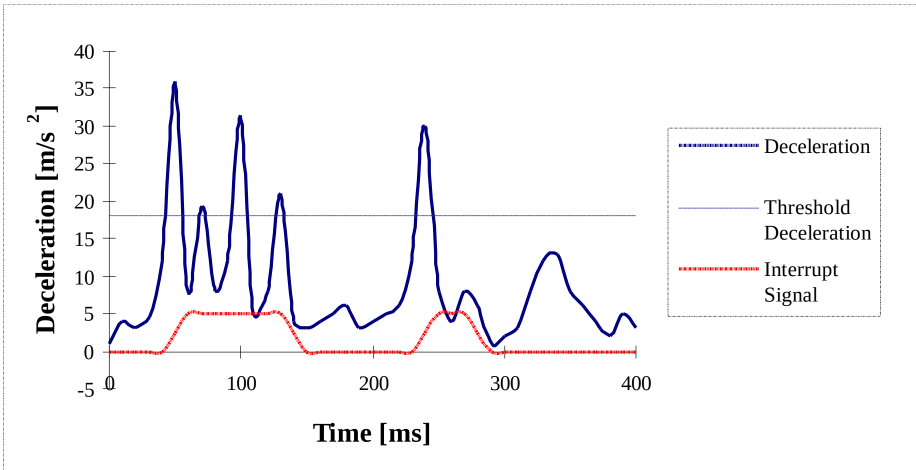

Figure 9: Collision Interrupt Signal Characteristics

Figure 10 presents the functional block representation of the signal conditioning stage.

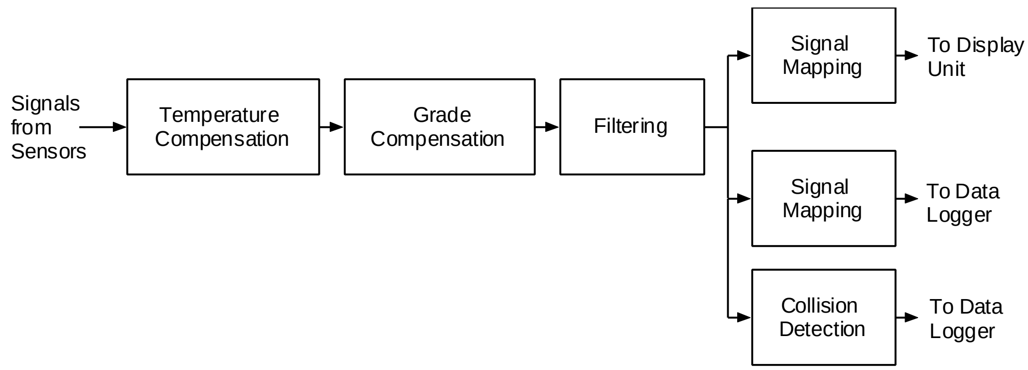

Figure 10: Signal Condition Functional Block Diagram

The minimal signal conditioning stage shall perform the following functions outline in the functional block diagram, including:

- Filter the input signals produced by the signal acquisition stage to improve vibration and noise rejection
- Map the conditioned signal levels to achieve the deceleration-output signal relationships depicted in Figure 7 and Figure 8
- Monitor and analyze the input signal levels to determine when a high probability of a collision exists
- Drive the collision interrupt output signal level according to whether or not a high probability of collision exists

The anticipated advanced conditioning stage will additionally perform the following functions outline in the functional block diagram:

- Buffer the input signals to avoid compromising sensor performance because of possible loading effects
- Provide temperature compensation to reject signal noise or drift due to sensor sensitivity to temperature variations
- Provide compensation for vehicle orientation when traveling on inclined surfaces to assure that gravity does not adversely contribute to the Sensor Unit's output signals. Such a problem is anticipated if devices such as accelerometers are used for sensing deceleration, as the alignment.

5 Signal Analysis

This stage of the system will receive a conditioned signal from the Sensor Unit as input, analyze the signal to determine the level of deceleration and generate the corresponding output signals based on the analysis. The context diagram of this stage is shown in Figure 11.

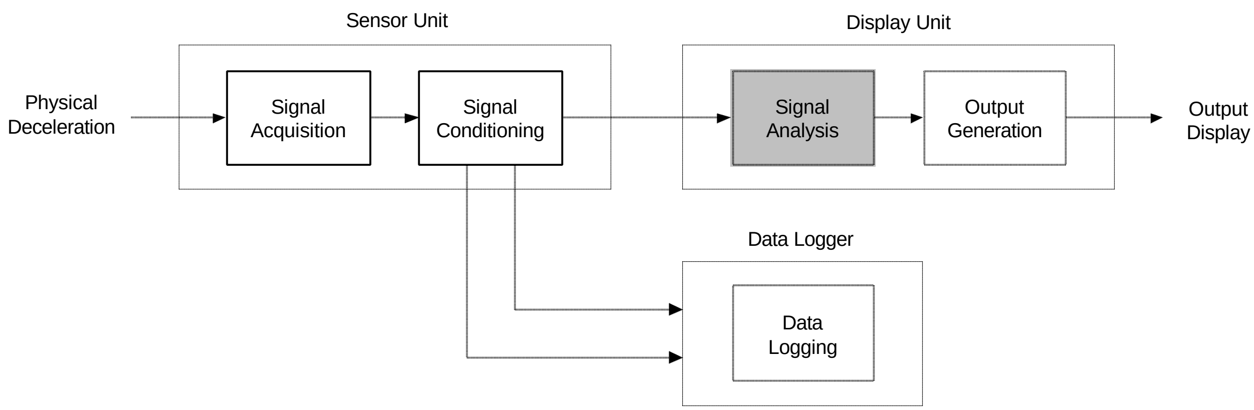

Figure 11: Signal Analysis Context Diagram

Figure 12 shows the functional block diagram of this stage.

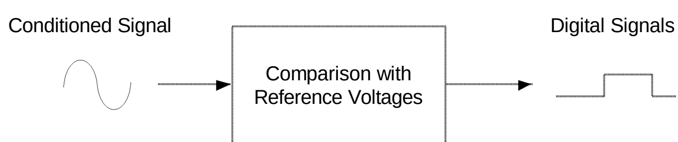

Figure 12: Signal Analysis Stage Block Diagram

The analog signal from the signal conditioning stage will range from 0 to 5 volts. This signal will be analyzed by comparing it to various predetermined reference voltage levels corresponding to different deceleration levels. The reference deceleration levels shall be equally distributed throughout the input range. Thus, a full scale input signal shall result in a fully illuminated output display, while a half scale input signal shall result in a half illuminated output display, and so forth. Each successful comparison (signal voltage exceeding the reference voltage) will generate a 5 volt, logic high signal to be outputted to the next stage. There will be a total of 8 logic signals delivered to the next stage – each signal corresponding to one output light level.

6 Output Generation

The final stage of the system will receive 8 logic signals from the Signal Analysis stage, with each signal corresponding to one output light level. A logic high signal will indicate that a particular light must be activated.

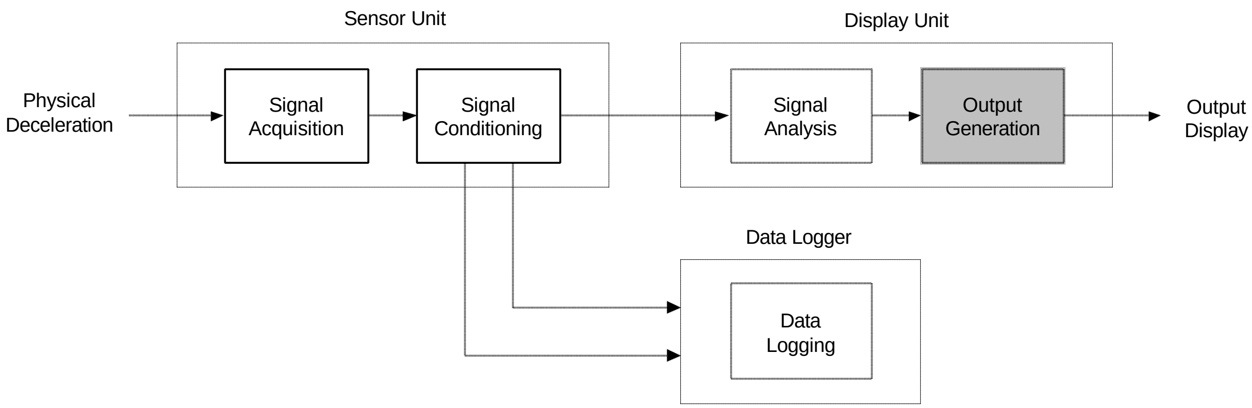

Figure 13: Output Generation Context Diagram

Figure 14 shows the functional block diagram of this stage.

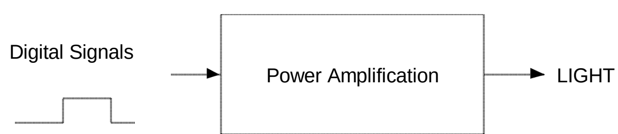

Figure 14: Output Generation Stage Block Diagram

The digital logic signals will be amplified, and used to illuminate the corresponding lights. The amplification stage ensures that the previous stage remains relatively unloaded, and that there will be enough current to brightly illuminate the lights.

7 Data Logging

The data logger is a separate physical unit. Figure 15 shows the relationship between the data logger and the ADI system.

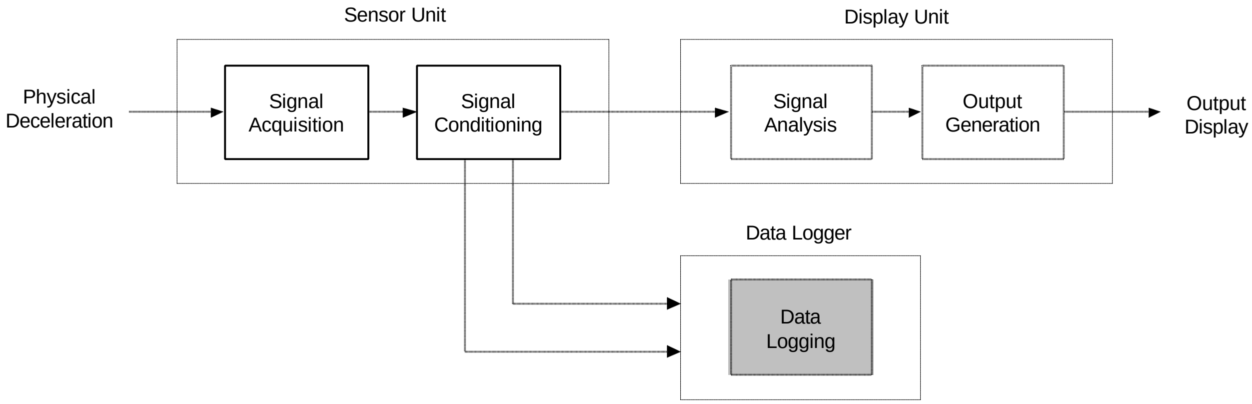

Figure 15: Data Logging Context Diagram

The data logging unit will record the deceleration of the automobile for use in accident recreations. The function block diagram of this stage is shown in

Figure 16.

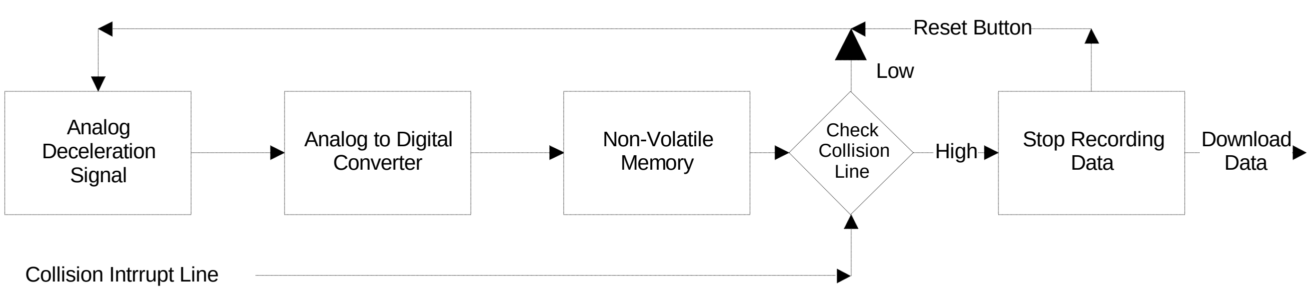

Figure 16: Data Logger Functional Block Diagram

The data logging unit will be physically separate from the sensor unit. The unit will also be modular so that the deceleration display unit will function correctly regardless of whether the data logging unit is functioning. The unit will be enclosed in sealed metal box intended to protect the unit from damage caused by an accident. The data logger will take two inputs from the sensor unit. One input will be the analog output from the sensor unit used to control the output stage. The other input, which will also originate from the sensor unit, will indicate when an automobile accident has occurred. When this signal is received, the data logging unit will stop recording additional data after a 10 second delay. The delay is necessary to ensure that relevant data immediately after a collision is recorded. The data remaining in memory will represent the deceleration of the vehicle for the time prior to and during the accident.

The memory in the data logging unit will be structured as a circular array. The newest data will overwrite the oldest data. The current address in memory will be tracked. This information will be used reconstruct the sequence of data stored in memory. In the event of an accident, the data stored in the data logging unit can be removed from the vehicle and the data can be extracted through a serial port to a PC. The memory will have a manual reset switch to re-enable the unit for normal operation.

The data logging unit will have the following additional specifications:

- Record the deceleration of the vehicle at 40 Hz
- The analog input signal will be digitized before being stored
- Memory will be non-volatile
- The total memory capacity will be sufficient to store 20 seconds of data
- The data logging unit is record data for 10 seconds after the collision
- A separate power source will provide backup power when needed
- A counter will track the current address of memory
- The data logger will reserve a sentinel value to indicate the starting location of stored samples in memory

8 Physical Requirements

The overall enclosure and casings of the ADI System shall be minimal for the Sensor Unit and Data Logger and large and visible for the Display Unit. Since the purpose of the display is intended to be displayed for other drivers, the physical requirement shall be small enough to fit into a small car and not too large to obstruct the rearward view of the driver. The weight of the entire unit should be minimized to prevent weighing down the vehicle and not affect gas consumption. The physical requirements are shown below in Table 1.

Table 1: System Physical Requirements

	Sensor Unit	**Display Unit (Typical)**
Height:	8cm max	5-15cm
Length:	10cm max	75cm min
Width:	10cm max	10 cm max
Weight:	1 kg max	2 kg max

The modular design of the ADI system shall allow different Display Unit designs tailored to particular models of automobiles to be developed so long as the developed Display Units adhere to the function specifications for the Display Unit presented within this document.

9 Environmental Requirements

The ADI system shall operate under all conditions for which automobiles are intended to operate. These conditions are listed in Table 2.

Table 2: System Environmental Requirements

Operating Temperature:	-20°C to 60°C
Shipping Temperature:	-30°C to 70°C
Heat Dissipation:	Minimal
Humidity:	Full range of ATM humidity

10 Electrical Requirements

The Advanced Braking System shall meet the environmental requirements listed in Table 3.

Table 3: System Electrical Requirements

Voltage:	15 V maximum
Power Consumption:	25 watts maximum

11 Visibility Requirements

The display unit shall adhere to the Transportation Canada Technical Safety Document No. 108, *Lamps, Reflected Devices, and Associated Equipment*, guidelines for minimum visibility requirements.

12 Safety Requirements

The Advanced Braking System shall meet the following safety requirements.

12.1 Enclosure

The enclosure shall not possess sharp corners or edges that would pose a danger to the user. The enclosure shall not contain protrusions or odd extensions of any form. The enclosure shall be made of durable material such that it can only be broken under high intense pressure or forces. The enclosure will also be water resistant from water spillage.

12.2 Electrical Isolation

The exterior casing of the system shall ensure electrical isolation from the internal circuitry. Internal circuitry will provide electrical isolation of the ADI system from the vehicle's electrical system. All wiring inside shall be neat and tidy and away from any possible sources of disturbance. All inputs and outputs to the system shall be shielded and protected from external static voltage sources. Wiring from the main unit to the display unit shall be minimal and durable.

12.3 Emission

The ADI system shall emit electromagnetic radiation in the visible light spectrum from the display unit. The ADI system shall not emit any other electromagnetic radiation. No form of electromagnetic radiation shall affect the proper operation ADI system.

13 Reliability Requirements

The Advanced Braking System shall work reliably under the environmental conditions under which an automobile can reasonably be expected to operate.

13.1 Accuracy

The indicated deceleration due to the display should be within 5% of the actual value.

13.2 Durability

The ADI system shall be robust enough to withstand daily use for a minimum of 15 years provided the ADI system is properly and routinely serviced. Since the ADI system shall operate mounted on a motor vehicle, it shall be designed to withstand the vibrations, jolts, and jarring which resulting from poor road conditions and accidents.

14 Standards

The Advanced Braking System shall comply with UL, CSA, CE, and Transportation Canada standards.

15 Training

The purchaser of the ADI System shall be required to have a trained automotive or electrical technician install and setup the system. The technician shall be trained and provided with detail instructions as per how to properly install the system. The technician shall be trained an provided with detailed instructions as to how to service and maintain the ADI system.

Concerned parties wishing to access the deceleration information stored in the data logger shall be require training as per how to properly remove the data logger, retrieve stored information, and replace the data logger.

16 Potential System Limitations

The Advanced Braking System will be limited by the following factors:

1. The eye sight drivers, which may affect their ability to see the ADI display.

2. The judgments of drivers, which may affect their ability to appropriately respond to the ADI display.

3. Tampering with the system, including disconnecting interconnects between the various units.

4. Limited visibility conditions close to the road surface due to fog, smog, smoke or similar fine particulate matter that may reduce the distance at which the ADI display is visible.

17 Conclusion

We have presented the function specifications for the Automobile Deceleration Indication system through this document. The ADI system will be designed to meet the functional specifications presented herein. We plan to develop a prototype for the ADI system which adheres to the function specifications for the ADI system to prove the concept of our design and demonstrate the potential for the ADI system.

18 References

[1] Statistics Canada. 1996. *Employed Labour Force by Sex Showing Modes of Transportation to Work, For Canada, Provinces and Territories, 1996 Census.* Statistics Canada Catalog Number 93F0027XD696019.

[2] Motor Trend. May 1997, Volume 49, Number 5. *High -Speed Gamble*. Pg. 70 –71.

[3] Transportation Canada. 1996. *Lamps, Reflective Devices and Associated Equipment*. Transportation Canada Road Safety Technical Standards Document No. 108.

[4] Transportation Canada. 1996. *Passenger Car Brake Systems*. Transportation Canada Road Safety Technical Standards Document No. 135.