Pressure Sensor based Event Data Recorder

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Abstract : Airbag Control Module (ACM) is designed to detect the vehicle crash, measure the severity and to deploy airbags if necessary. ACM's another function is to record the crash related data from vehicles internal accelerometers and sensors from different modules. The system is also known as Event Data Recorder (EDR). This paper describes the operations of an EDR, which detects the crash based on pressure, applied on to the vehicle during a collision, sensed by a pressure sensor. This paper also describes the operations and characteristics of vehicle speed and ultrasonic sensor during the time of crash.

Keywords: Airbags, Airbag Control Module (ACM), Event Data Recorder (EDR), Pre-Crash Data, Vehicle Crash Analysis

I. INTRODUCTION

Most vehicles are equipped with airbags. The purpose of the airbag is to help protect the occupant in a collision. Airbags are only effective and therefore only deploy in collisions of certain severity and direction. In order for the airbag system to know when and how to deploy the airbag, it must know what is going on and predict what is going to happen. The system accomplishes this by measuring specific data, such as vehicle speed and acceleration, collision direction, occupant seatbelt use, and other criteria [1].

Event data recorders (EDR) have been installed in vehicles for over 30 years, with General Motors (GM) being at the forefront of the use of this technology by introducing it in select vehicle models starting in 1974. The EDR's in these vehicles were primarily used to control and record airbag deployments [2].

Airbag equipped vehicles use a crash sensing algorithm to decide when to deploy the airbags. It is a predictive algorithm, typically making deployment decisions within 15-50 Millie sec after impact [3].

EDR's have been used for many years to record the crash related metrics, including deceleration characteristics of the vehicle, be it airplane, train, ship, or highway vehicle. Aviation has long been the proving gound for on-board recording devices. Crash protected flight data recorders have been around since the early 1950's, while the cockpit voice recorders were introduced in late 1960's. Significant improvements in safety have been realized in aviation as a result of flight data and cockpit voice recorders [4].

GM introduced the first regular production driver/passenger airbag systems as an option in selected 1974 production vehicles. In 1990, a more complex Diagnostic and Energy Reserve Module (DERM) was introduced with the added capability to record closure times for both arming and discriminating sensors as well as any fault codes present at the time of deployment. In 1992, GM installed sophisticated crash-data recorders on 70 Indy race cars. While impractical for high volume production, these recorders provided new information on human body tolerance to impact that can help improve both passenger vehicle occupant and race car driver safety. For the 1994 model year, the multiple electromechanical switches previously used for crash sensing were replaced by the combination of a single solid state analog accelerometer and a computer algorithm integrated in a Sensing & Diagnostic Module (SDM) [5].

Depending upon the year and model of vehicle, the SDM module may contain all or some of the following information [6]:

- Brake status and Throttle position up to 5 seconds before impact
- Vehicle forward speed and Engine speed up to 5 seconds before impact
- Air bag warning lamp, driver's seat belt buckle and right front passenger air bag suppression switch status
- Number of ignition cycles at the time of the incident and at the time of the investigation
- Other relevant times and longitudinal speed changes in relation to near deployment or deployment

Pre-crash sensing may well have the most impact in reducing injuries from night time accidents involving impaired drivers. However, the advanced safety features enabled by pre-crash sensing will provide a significant benefit in all cases of poor lighting, bad weather, or driver distraction [7].

Today's airbag and seatbelt systems will be more effective if advanced occupant sensors are added to pre-crash sensors, creating occupant protections with advanced restraints that adapt to whoever happens to be sitting in the vehicle and to the demands of a variety of crash scenarios [8].

II. PRINCIPLE OF OPERATION

In this section we discuss about the principle behind the operation of the proposed pressure sensor based pre-crash data recording system with respect to its flexibility, robustness, performance and complexity of the airbag deployment function.

During a crash, the system does not deploy the airbags unnecessarily. The system measures the severity of the crash against a set of pre-defined deployment criteria. The system deploys the airbags in real-time when the applied pressure crosses its threshold within the specified time. The Fig.1 shows the principle of operation behind the airbag deployment.

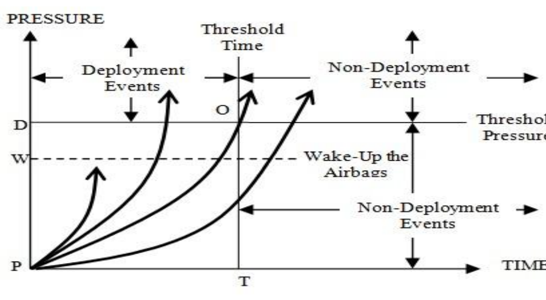


Fig.1. Airbag deployment operational characteristics

From the Fig.1, consider a vehicle moving at a constant speed collides with an obstacle at a point P. Due to the impact of collision, the pressure on the vehicle body increases quickly with time. The rising curves in the Fig.1 shows the rise in the pressure. The line originating from the point 'W' indicates the airbag wake up time and the line originating from the point 'D' represents the threshold pressure. The line originating from point 'T' represents the threshold time. The system measures the rising pressure to calculate the crash severity. The system measures the crash severity to decide the event as a deployment or as a non-deployment event.

When the pressure building on the vehicle reaches the threshold pressure within the threshold time, then the system considers the event as a severe crash and deployment criteria's are fulfilled. Then the system deploys the airbag. This is shown in the Fig.1 as when the pressure line crosses the threshold pressure line 'D' within the threshold time line 'T'. The point 'O' is an optimum point for the deployment. When the pressure on the vehicle does not reach the threshold pressure or when the pressure reach the threshold pressure after the threshold time, the system considers the event is of less severity and does not deploy the airbags.

When the pressure reaches the line originating from the point 'W', i.e., wake-up the airbags line, the system initializes the airbags. This is due to avoid the delay in opening of the airbags in a severe crash. In the Fig.1, the area above the line DO represents the deployment events.

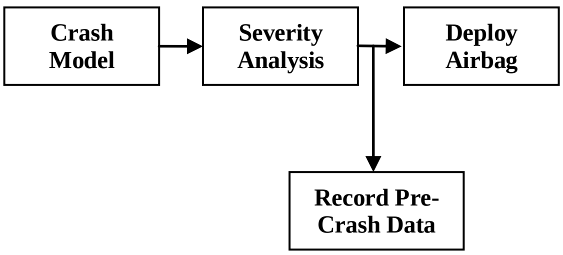


Fig.2. Functional Block Diagram

Fig.2 shows the functional block diagram of the system. Consider the Fig.2; the crash model consists of the required hardware and the software units. When the vehicle is collided with an obstacle, this unit detects the crash and crash sends the signals to the severity analysis unit continuously for which time the pressure on the vehicle body increases. The severity analysis unit measures these signals comparing with the predefined set of truth tables and algorithms to decide the event as a deployment event, near deployment event or as a non-deployment event. If the crash signals meet the deployment criteria, then the system deploys the airbags and simultaneously records the system status at the time of collision from different sensors of different modules and their trend at the time of crash for some time. If the crash criteria's does not meet the deployment criteria, then the system does not deploys the airbags and record the event as a near deployment event and records the pre-crash data.

III. Model Development

3.1. Hardware Organization

The Fig.3 shows the hardware organization of the system. Different sensors and simulators are connected to the Central Processing Unit (CPU) or a microcontroller using a suitable circuits, buses and protocols. The hardware details and their applications and utilization in the system are as follows.

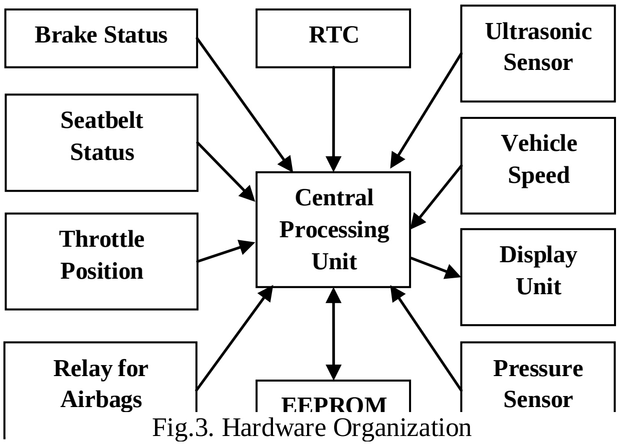


Fig.3. Hardware Organization

- Pressure Sensor: Pressure sensor is the main component in the system. When the vehicle collides with an obstacle it senses the increasing pressure on the vehicle body. It immediately generates an interrupt signal and sends it to the CPU. The CPU halts the current execution and waits for the further signals from the pressure sensor. The pressure sensor measures the impact and sends the signals to the CPU continuously. The CPU takes further action to measure the crash severity and to decide the event as a deployment event or as a non-deployment event.

- Central Processing Unit (CPU): The CPU or a microcontroller is the heart of the system. It controls and coordinates the entire system. The CPU executes the software instructions as required. The required software and the algorithms for the crash sensing and severity analysis are stored in the memory unit of the CPU. The CPU loads these instructions at the time of vehicle start or the system initialization and executes them. When the crash is detected by the pressure sensor, it receives the interrupt and halts the execution of the system and wait for further signals from pressure sensor. The CPU calculates the crash severity based on the pressure applied on the vehicle for a fixed period of time. If the pressure built reaches the threshold pressure within the threshold time, the system immediately deploys airbags. Simultaneously it writes the crash data from internal modules and sensors into the EEPROM. If the crash does not meet the deployment criteria's then the system does not deploy the airbags and writes the crash data into the EEPROM.

- Vehicle Speed: The vehicle speed is simulated using a rotary potentiometer. The vehicle speed is an important parameter in the crash analysis. The vehicle speed is measured to determine the speed of the vehicle at the time of crash and its trend before and after the crash.

- Ultrasonic Sensor: Ultrasonic sensor measures the distance between the obstacle in front of the vehicle. The distance between the vehicle and the obstacle has many applications in crash analysis. During driving, this sensor measures distance between the obstacle coming ahead to the vehicle and give information to the occupant.

- Relays for Airbags: Airbags are the balloon like structures, which are hidden in front and sides of the passenger seats. During a crash, if the crash parameters reach the deployment criteria, then they get ejected. The airbags should be ejected at correct time so that the occupant must be utilized optimally. Relay is a switch, which is activated by a CPU when the deployment criteria's reached, which turns ON the airbags.

- Display Unit: Display unit comprises of a Liquid Crystal Display (LCD) screen, which displays the actions that are going in the system continuously. It displays the speed of the vehicle, distance between the forward obstacle and the vehicle and other parameters such as temperature, engine speed. The CPU fetches the data from the vehicle modules and transfers the strings to LCD to display.

- Throttle Position: Throttle measures the amount of fuel flowing into the engine. The accelerator pedal controls the throttle. The throttle position is closely associated with the vehicle speed. The amount of throttle opened is equal to the amount of accelerator pedal is pressed. In the experimental environment, consider as a vehicle is moving on a smooth road at its topmost gear. The amount of vehicle speed simulating potentiometer rotated indicates the amount of throttle opened or the accelerator pedal pressed.

- Brake status: Brakes are used to stop the vehicle while moving. At the time of vehicle start, the system checks for the proper functioning of the brakes and displays the information. At the time of collision, the system records the braking variations for a fixed period of time.

- Seatbelt Status: Seatbelts are used to place the occupant on the seat during collision and helps the occupant to utilize the airbags so as to minimize the injuries. At the time of vehicle start, the system checks for the seatbelt status whether they are fastened or not. If they are not fastened, the system displays a warning string on the LCD.

- EEPROM: Electrically Erasable Programmable Read Only Memory (EEPROM) is a fast memory unit, which is used to store the pre-crash, crash and post-crash data. When the airbags are deployed, the CPU immediately writes the pre-crash data into EEPROM. The data include sensor and simulators status at the time of collision and their trends at the time of crash for a fixed period.

- RTC: Real Time Clock (RTC) is a clock that causes occurrences of regular interval interrupts on its each tick (timeout). In the system, RTC provides the current time. It gives the exact time of crash. It is associated with a battery, so it never stops.

3.2. Functional Modules Used

The software required to the system are divided into suitable modules and stored in the memory which can be accessible by the CPU. The functional modules and their functions are as follows.

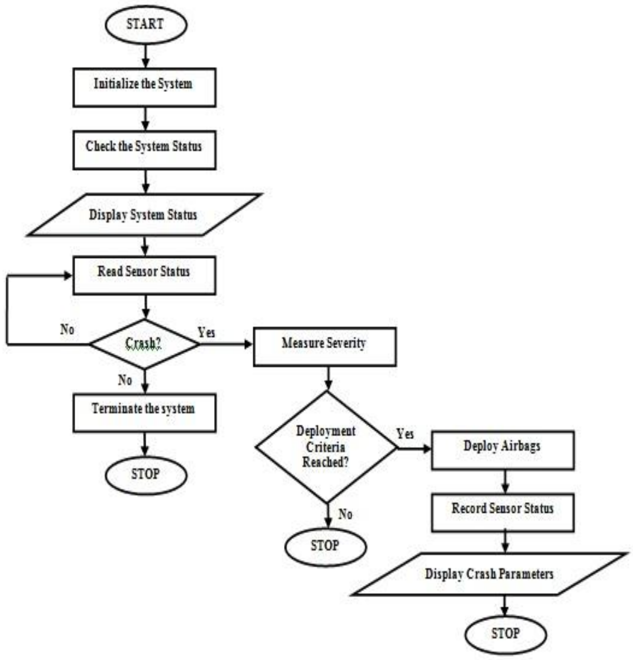


Fig. 4. Functional Flow Chart

- Analog-to-digital Conversion (ADC): This module manipulates the analog sensors such as potentiometers, ultrasonic sensors, pressure sensors and temperature sensors. This module assigns ADC channels of the CPU to different sensors and converts their analog values into digital values. These values are returned when they are called.

- Universal Asynchronous Receiver and Transmitter (UART): This module is used to retrieve the crash data using a Personnel Computer. This is also used to check the operations that are taking place in the system.

- Controller Area Network (CAN): This module is designed to test brakes and seatbelt at the start. This module also monitors and gives the result of how much braking is done at the time of crash. Before analyzing brakes and seatbelts, this module tests CAN for network malfunctions and breakages.

- Inter-Integrated-Circuit (I2C): This is a serial bus protocol used to connect different devices within the board. This used to write the crash data to the EEPROM.

- Interrupt: This module is activated whenever a crash is reported. When the crash happens, the pressure sensor sends an interrupt signal to the CPU which halts the current execution and calls the Interrupt Service Routine (ISR). The ISR actually measure the crash severity and returns its status to CPU to decide the event as a deployment event or as a non-deployment event.

Fig.4 shows the sequence of operations that take place in the proposed EDR.

3.3. Parameters being recorded

- Vehicle Speed: The speed of the vehicle at the time of crash and its trend for the period of 5 seconds before the crash.
- Distance between the obstacle and the vehicle: Using the ultrasonic sensor, distance between the obstacle and the vehicle is measured for a period of 5 seconds before the crash.
- Brake status: The amount of brake applied at the time of crash is measured for a period of 5 seconds.
- Seatbelt status: Seatbelt status, whether it is fastened or not at the time of crash.
- Throttle position: The amount of throttle opened at the time of crash and its trend before the crash for a period of 5 seconds.

IV. EXPERIMENTAL RESULTS

4.1. Vehicle Speed

The proposed system continuously read the speed of the vehicle since its initialization to its termination. The sample variation in the speed of the vehicle because of acceleration and deceleration in a sample period of one minute is shown in the Fig.5. Fig.6 illustrates the speed characteristics at the time of crash. The curve shows the decrease in speed due to the possible application of brakes or releasing the accelerator pedal at the moment of crash.

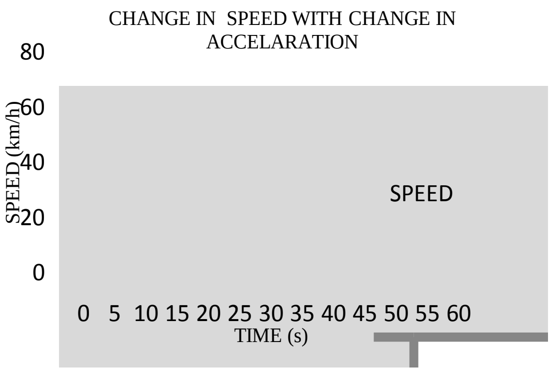
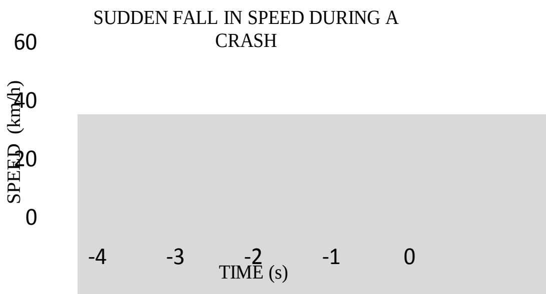


Fig.4. Speed variations during a normal drive

4.2. Throttle Position and Braking

The throttle position indicates amount of fuel flowing into the engine. This also shows the operators acceleration inputs and its trend while driving. In the experiment, consider a vehicle moving on a smooth road at its topmost gear. In normal driving the amount of braking can be ignored because braking will be at a moderate rate. The Fig.7 shows the sample variation of the percentage throttle during vehicle driving taken over a period of one minute.



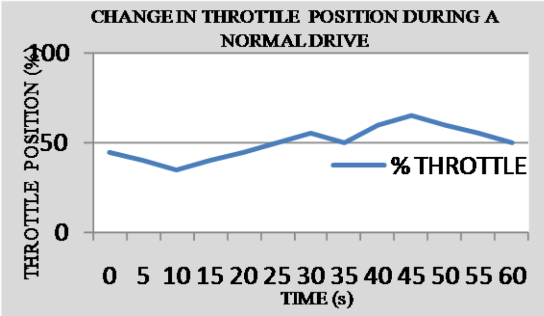


Fig.5. Sudden deceleration during a crash

Fig.7. Throttle position during a normal drive

During a crash event the operator's input to the accelerator pedal is most unpredictable. He can either press the pedal more or release his foot from the pedal and tries to put it on break. The characteristic of the throttle and braking during a crash is shown in Fig.8.

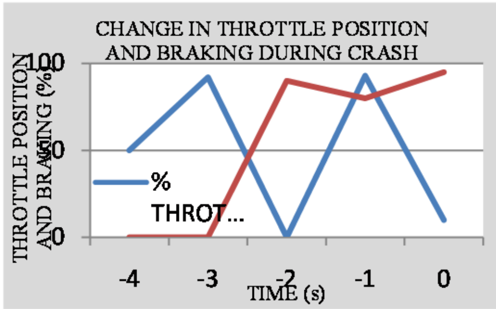


Fig.8. Change of throttle position and braking during a crash

4.3. Ultrasonic Sensor

Ultrasonic sensor measures distance between the vehicle and the obstacle in the line of the vehicle. The Fig.9 shows the sample variation of distance between the obstacle vehicle moving along the same line of the occupant vehicle which is incorporated with the proposed EDR, considering the vehicle moving at a constant speed. The simulation distance was taken in inches measured over a period of one minute.

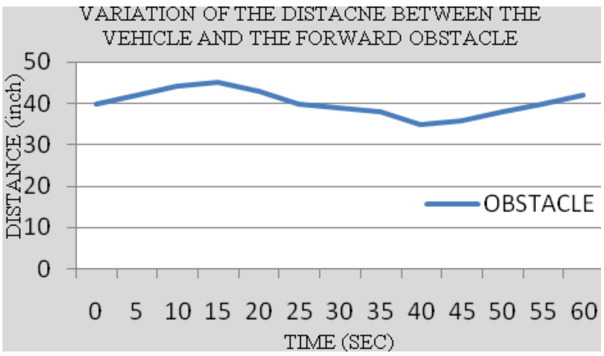


Fig.9. Variation of distance during a normal drive

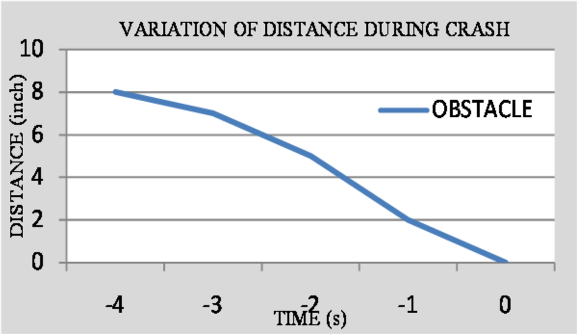


Fig.10. Variation of distance during crash

The Fig.10 depicts the characteristic curve of the ultrasonic sensor during a crash event. During crash event the distance between the vehicle and the colliding object becomes zero in a short period of time. The graph shows, the time taken to reach a distance of 8 inch to 0 inch is 5 seconds in the prototype by simulation.

V. ADVANTAGES

5.1 Pressure Sensor

The system detects the crash based on the pressure rather than the sudden deceleration as in traditional methods. By detecting the collision by sensing pressure has advantage over the collision detection by quick deceleration. The system can detect the collision even when the occupant vehicle is at rest and hit by an obstacle. The system can detect the frontal crash; rear crash, side crash, and roll over crash more accurately than the traditional deceleration technique. The system deploys the airbags only in the events of severe crash and at correct time. This avoids unnecessary opening of airbags and unwanted losses.

5.2 Ultrasonic Sensor

Ultrasonic sensor measures the distance between the forward obstacle and the vehicle. This sensor predicts the crash based on the sudden decrease in the distance and helps in waking up the airbags. If the measured distance become very less than the threshold, it gives a warning message to the occupant about its crash prediction. The ultrasonic sensor can also be used in the application of Adaptive Cruise Control (ACC) for the better comfort driving.

VI. SUMMARY

This paper describes the operations and functions of the pre-crash data recording system or an Event Data recorder (EDR) which detects the crash based on the pressure applied on the vehicle body by a colliding obstacle. The system is accurate, robust and flexible. The system predicts the crash using the readings from the ultrasonic sensor. The system wakes up the airbags at the time of collision to avoid the unwanted delay in deployment. The system checks for the brake and seatbelt status at the time of the vehicle start and give warnings to the occupant if there any malfunctions. The recorded pre-crash data is accurate and this data can be used by the governing authorities to improve the safety in vehicles and also can be used in legal issues.

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