ARM based Event Data Recorder for Automobiles

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Abstract: ***This paper discusses the composition and function of the car black box. The system can record the main driving data in real time which can help people analyze an accident rapidly and accurately after a collision. The Car Black Box can receive real time data including speed, engine rpm, acceleration, turning action, brake, gear position, and lane departure. The design consists of ARM processor, CAN controller, pulse counter module, A/D convert module, storage unit, I/O interface, UART and different sensing modules. IR sensors and UV sensors are used for gear and brake position detection respectively. Collecting, processing and storing the multiple signals at the same time need real time processor having ability to read and write with high speed. Large capacity and long term data storage like SD card is required to maintain data without any damage and lost. This event data recorder provides the snapshots of the entire pre-crash, crash and post-crash events. It can be used in court cases to determine precisely what happened during a car accident. Thus it can be used for 1) safety purpose, 2) crash investigation, 3) evidence, 4) insurance purpose, 5) driver monitoring and training.***

Keywords: Car black box, Event Data Recorder, Controller Area Network.

1. Introduction

Event data recorder is also known as a black box of the car. In aircrafts, it is called as a flight data recorder. This system gathers information from different parameters e.g. the time, altitude, airspeed and direction of the plane and records in the storage of flight data recorder. Similarly, the event data recorder in the car is beneficial for the car's owner. It records the events and actions of the driver before, after and at the time of collision. It is really useful in accident like conditions such as sudden decrease in velocity, airbag deployment, or slamming on car's brakes. Basically, it records changes in speed, acceleration and direction of travel. This vehicle data is helpful for car accident investigations. It can be used in court cases to determine precisely what happened during a car accident. It is also helpful for insurance companies.

Definition*:* An Event Data Recorder (EDR) is an on-board device or mechanism capable of monitoring recording, displaying, storing and transmitting pre-crash, crash, and post-crash data element parameters from a vehicle, event and driver [8].

Event data recorders (EDR) can be used to improve the road safety. It continuously monitors how car is being driven. This information is used for supervision and driver's training. Further this information can be used to activate safety devices such as airbags and anti-locking brakes.

Accident investigations are typically conducted by three types of entities including government agencies, law enforcement, and insurance companies. Each of these entities investigates an accident from a different perspective or for different purposes with one common goal. The goal is to determine the exact cause of accident based upon the information available to them. The data recovered from EDRs is an integral part of crash reconstruction. Hence all new cars in America are to be equipped with event data recorders by 2015.

The personal, social, and economic costs of motor vehicle crashes include pain and suffering; direct costs sustained by the injured persons and their insurers; indirect costs to taxpayers for health care and public assistance; and for many victims, a lower standard of living and quality of life. Use of EDRs can prevent many crashes and make the driving greener. EDRs are small and very cheap as compared to the savings they can achieve.

EDRs are classified into two major types: Type I and Type II [8].

Type I classification of EDRs should include essential set of data elements : 1) time,2) location, 3) direction of impact, 4) velocity, 5) occupants, 6) seat belt usage, and 7) crash pulse characteristic.

Type II EDRs include data elements targeting vehicle types. They are evolved with the emerging technologies. Type II EDRs are used to improve highway efficiency, mobility, productivity, and environmental quality.

Crash pulse is very important factor in the analysis of crash data. Crash pulse is the acceleration time which is represented by plotting a graph between acceleration and time in milliseconds. There are two types of crash pulses: 1) hard and 2) soft [8].

In a "hard" crash pulse, a vehicle's occupant compartment de a high risk of death or serious injury. In a "soft" crash pulse, there is a lower rate of deceleration and proportionately lower risk of death or serious injury. Generally, large cars have relatively mild crash pulses, while small cars have more severe crash pulses.

EDR or black box of the car is located under the front seat or central console. It provides the snapshots of the entire crash event --pre-crash, crash and post-crash. Thus it can be used for 1) Safety purpose, 2) crash investigation, 3) evidence, 4) insurance purpose, 5) driver monitoring and training.

While considering success or failure of implementing EDRs, one more aspect is very important i.e. privacy of the occupants. The right to individual privacy is a basic prerequisite for democratic society. EDR technologies must respect the individual's expectation of privacy.

2. Literature Survey

The author Se Myoung Jung, Myoung Seob Lim states the following functions of the car black box [1].
1. Data collection – The data may be driving data, visual data, collision data or positioning data.
2. Accident analysis and reconstruction.
3. Wireless communication.

In this paper, the design process of car black box system IC is described. The topic of this paper is to develop the embedded controller for Car Black Box using SoC (System on Chip) technique. SoC for Car Black Box system consists of 8051 processor, CAN (Controller Area Network) controller, JPEG compressor, SD controller for dumping the data from memory buffer to SD card, ROM for programming and SRAM acting as memory buffer.

The paper [2] by Liewei Jiang, Chunxuan discusses the composition and function of an advanced controller system of car black box. The author states that this system not only collects the main driving data accurately but also reconstructs the accident rapidly after collision. The paper analyses the main problems and development directions of car black box. The design includes CAN controller, pulse counter module, A/D convert module and GPIO interface, audio-out, RS232 interface and USB port. The author describes integrated design solutions and software structure of car black box. In problems and solutions it is stated that following techniques are very important for effective design: Collect, process and store multiple signals at the same time, rapid storage and large as well as long term storage.

In the article [3] by Mychajlo Lobur, Yuriy Darnobyt, the author describes methods of car speed measurement based on Doppler's ultrasonic ground speed sensors. The principle of operation is based on the Doppler shift in frequency observed when radiated energy reflects off a surface that is moving with respect to the emitter. The size and quality of the reflected signal reaching the antenna, to a large extent depend on the characteristics of the surface that reflects light. The surface must have a certain minimum roughness 'r', so part of the radiation can go back to the antenna. Since it uses ultrasound (relatively low frequency) then signal will be reflected even in the smooth a surface. Classical devices for speed measurement are the wheel sensors. As a result of rotation of the wheel they produce pulses or voltage magnitude proportional to speed.

They are highly reliable, but have several disadvantages. These disadvantages can be overcome by using ground speed determining techniques.

The paper [4] discussed in IEEE vehicular technology society describes IEEE 1616 standard. This standard includes different clauses that serve several distinct purposes.

Clause 1: Overview provides background for understanding the goals and objectives for this standard.
Clause 2: References, gives the references referred to in this standard.
Clause 3: Definitions, acronyms, and abbreviations, provides a glossary that defines the terms used by later clauses within the standard.
Clause 4: Applicability provides information about the different constituencies who will benefit from this standard and also notes use-case perspectives and applications.
Clause 5: Event Description, defines the meaning of an *event* as it pertains to motor vehicle crashes.
Clause 6: Output, defines common interfaces that may be utilized to extract MVEDR data.
Clause 7: MVEDR data attributes, describes how the crash sequence is examined in circumstances surrounding the event prior to the crash occurring, the circumstances involved during the crash, and those involved after the crash.
Clause 8: MVEDR data dictionary, explains how the data dictionary is comprised as a collection of entries specifying the name, source, usage, and format of each data element used in a system or set of systems.

This standard specifies MVEDR data dictionary which is a collection of entries specifying the name, source, usage and format of each data element used in a system or set of systems.

2.1 System Design

A. Structural map of the whole system: Event Data Recorder will record the pre-crash and post-crash events. Following are the parameters which we are going to record [4]: Speed, gear position, brake position, turning actions, engine rpm, acceleration and deceleration, time.

These parameters are very important for crash investigation and legal procedures as evidences.

Engine rpm and speed signals can be taken directly from the dashboard of the car. For time measurement, we are using RTC of the processor. All other parameters data will be gathered from different sensors e.g. IR TX-RX pairs, UV sensors, Accelerometer etc. [3], [6].

2.2 System Description

1) Data Collection Layer: The data collection layer is responsible for collecting various driving signals and status information of the car in the Car Event Data Recorder. The design of the system includes CAN interface, A/D converter, pulse/frequency counter module and I/O interface.
2) Data Processing Layer: The data processing layer is the main part of a vehicle black box. It is used to receive data information from the data collection layer. It consists of central processing unit (CPU), storage unit, and auxiliary circuit. The software of the system runs in this layer, which includes firmware and ANSI C library. Firmware is the application code written in embedded C. The storage unit includes SD card.

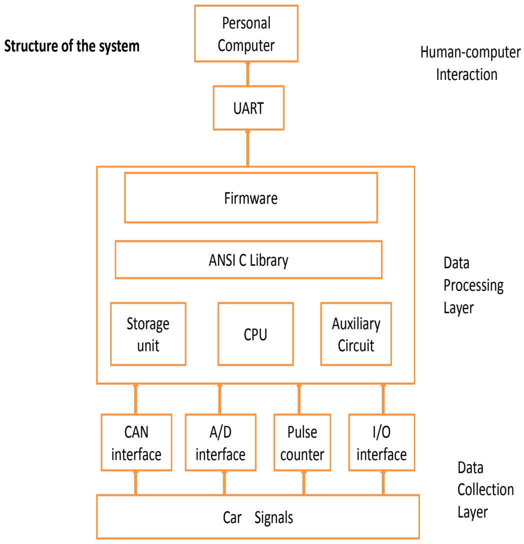

Figure 1: Structural map of the whole system

3) Human-computer Interaction Layer: The human computer interaction layer is the interactive platform for the human beings and the Car Black Box. The data information of a car will be displayed on the screen of personal computer after being received [2].

2.3 Flow chart to read input from sensor:

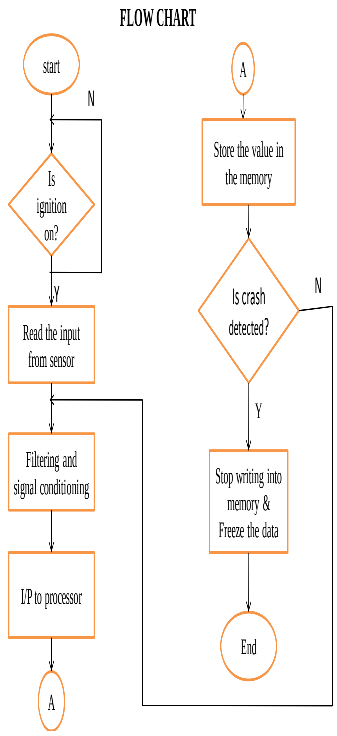

Figure 2: Flow chart to read single input from sensor

3. Hardware Description

A. Gear position detection*:* In most vehicles the first 4 gears form an 'H' appearance on the gear lever. Neutral is the middle position in the 'H' formation on the gear stick. To engage reverse gear you sometimes have to either push the gear lever down or lift it up towards you

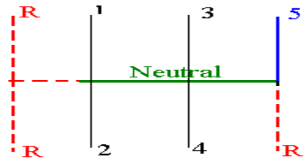

Figure 3: Gear positions of the car

Different vehicles have different setups. Reverse is often in one of the 3 positions marked in dotted red in the diagram. Most cars now have a 5th or 6th gear.

In our design, we are considering total 6 gear positions- 4 gears, one neutral and one reverse. For gear position detection, we are going to use six pairs of IR sensors, each for one gear position.

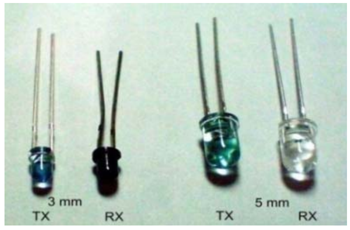

Figure 4: IR Tx-Rx pair

3.1 Circuit Diagram

This circuit detects only one gear position. Such six circuits are required to detect all gear positions. The output is in the digital form. It is given to processor and then it will be stored in SD card.

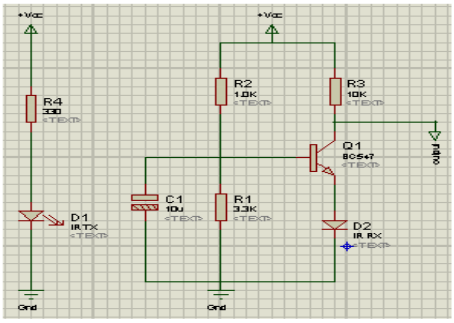

Figure 5: Circuit diagram for gear detection

3.2 Speed Measurement

The dashboard of the car shows speed of the car. We are deriving the output of the speed sensor directly from the dashboard of the car. The signal is a square wave in the voltage range of 0-12V DC with 50% duty cycle. For a typical dashboard the frequency range of the signal is 0-150Hz. It means that for 0Hz, the speed of the car is 0 Kmph and for 140Hz, it is maximum i.e.200Kmph.

The signals directly derived from dashboard contain lot of noise and require filtering as well as signal conditioning before applying to processor. The processor counts the frequency of the signal and compares the value with the values stored in look up table. This look up table is nothing but the calibration i.e. frequency Vs speed. Finally, the speed of the car at particular instant is stored in SD card.

3.2.1 Calibration table for speed measurement:

Table 1: Frequency Vs Speed calibration

Frequency in Hz	*Speed in Kmph*
8	10
14	20
21	30
29	40
36	50
43	60
49	70
57	80
64	90
72	100
78	110
85	120
93	130
100	140
107	150
111	160
120	170
130	180
135	190
140	200

3.1. 2 Timer circuit used for speed calibration:

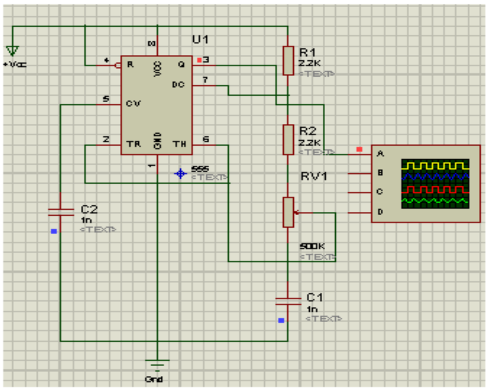

Figure 6: Timer circuit for speed calibration

3.2.3 Simulation for speed measurement:

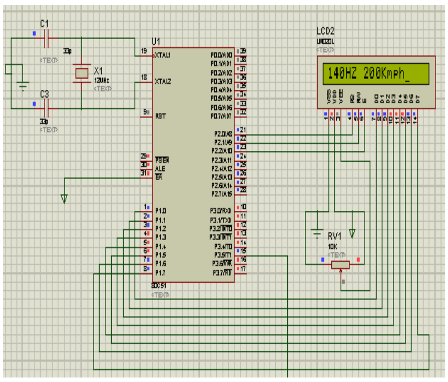

Figure 7: Simulation for speed and frequency

3.3 Engine rpm Measurement:

The dashboard of the car shows engine rpm of the car. We are deriving the output of the engine rpm directly from the dashboard of the car. The signal is a square wave in the voltage range of 0-12V DC with 50% duty cycle. For a typical dashboard the frequency range of the signal is 0-2KHz. It means that for 0Hz, the engine rpm of the car is 0 and for 1953Hz, it is maximum i.e.8.

The signals directly derived from dashboard contain lot of noise and require filtering as well as signal conditioning before applying to processor. The processor counts the frequency of the signal and compares the value with the values stored in look up table. This look up table is nothing but the calibration i.e. frequency Vs engine rpm. Finally, the engine rpm of the car at particular instant is stored in SD card.

3.3.1Timer circuit used for engine rpm calibration:

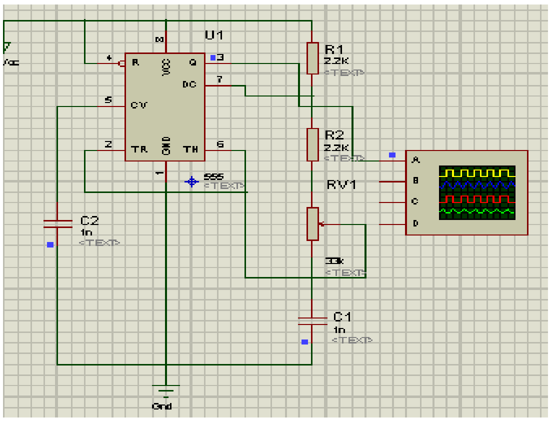

Figure 8: Timer circuit for engine rpm

3. 3.2 Calibration table for engine rpm measurement:

Table 2: Frequency Vs Engine rpm calibration

Frequency in Hz	***Engine rpm x 1000***
0	*0*
234	*1*
464	*2*
698	*3*
929	*4*
1168	*5*
1390	*6*
1614	*7*
1953	*8*

3.4 Measurement of braking position:

We know that pushing down on the brake pedal slows a car to a stop. When you depress your brake pedal, your car transmits the force from your foot to its brakes through a fluid. Since the actual brakes require a much greater force than you could apply with your leg, your car must also multiply the force of your foot. The brakes transmit the force to the tires using friction, and the tires transmit that force to the road using friction also.

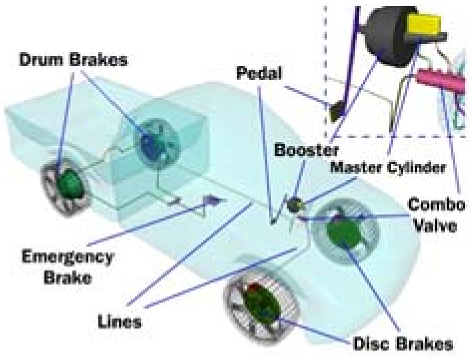

Figure 9: Brake system in a car

The braking position is detected using a pair of UV distance sensor. This sensor has minimum range of 10 centimeters and maximum range of 4 meters. Whether the brake is applied at the time or before the crash occurred is detected by this sensor circuit. The amount of force applied on brake is converted into distance in Centimeters using UV distance sensor. The processor will store a look up table in which different values of distances as well as minimum and maximum distance is stored. The processor will store that value in SD card.

Figure 10: UV sensor

3.5 Measurement of Acceleration/Deceleration:

The G-Sensor is a precision 3 axis accelerometer that constantly measures change in acceleration in the X, Y and Z axes. The unit of acceleration measurement is the "g," which equals the force of gravity (9.81 m/s2). So, when the G-Sensor reads 2 g, for example, this equals 2 times the force of gravity.

This sensor is used for crash detection. It is used to measure acceleration and car. When the crash occurs, there is sudden deceleration.

The GFORCE-LOWG model measures and records acceleration to at least +/- 7 g in each axis. The GFORCE-HIGHG model measures to at least +/- 38 g in the X and Y axes, and to at least +/- 7 g in the Z axis. The readings may be inaccurate if these values are exceeded.

When used standalone, the G-Force sensor repeatedly displays the maximum acceleration encountered in each of its 3 axes, on the built in 7 segment LED display. These maximum values are stored to non-volatile memory i.e. SD card.

3.6 Installing the G-Sensor

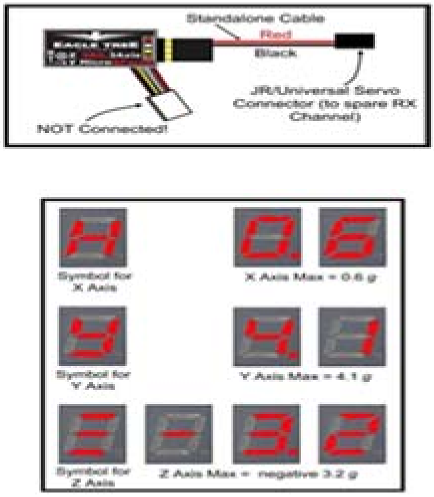

Figure 11: G sensor

The G-Sensor can be mounted with double sided tape, Velcro, or similar. The G-Sensor is normally mounted flat in the model, with the label down, and the "Y" arrow on the label facing toward the direction of travel. When mounted this way, the Y axis points in the direction the model travels, the X axis is horizontally perpendicular to the direction that the model travels, and the Z axis points toward the top of the model (normally toward the sky).

With this mounting configuration, acceleration in the forward direction will show up as positive Y values, and acceleration in the up direction will result in positive Z values [6].

4. Conclusion

The technical difficulties raised in this paper can be dissolved by several factors as discussed here.

Collecting, processing and storing the multiple signals at the same time is the major problem. The signals of turning light, brake and wheel speed change constantly in driving process. Therefore, the processor should be able to multiple interrupt, collect A/D data and process and store the data rapidly.

In rapid storage, the real-time data processor has the ability to read and write with high speed, which is the requirement of changing real-time data and high data sampling.

In Large capacity and long term storage, the storage system needs enough capacity to store the data so that it can be analyzed after an accident. The system should store the important data as soon as possible; otherwise, the data may be lost. The data in the Car Black Box should maintain soundly and completely in a long term without any damage and lost.

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