THE USE OF AUTOMOTIVE EMBEDDED SYSTEMS FOR FORENSIC ROAD TRAFFIC ACCIDENT ANALYSIS

Mr. James Long
Lecturer
Dublin Institute of Technology

Mr. Mark Maguire
Founder & Managing Director
Mark Maguire Motor Engineer Assessors Ltd.

Abstract
This paper presents an alternative model for Road Traffic Accident (RTA) investigation using Event Data Recorder (EDR) technology. We highlight the difficulties encountered when using established techniques on contemporary vehicles, and present a rationale for a computerised alternative based on EDR technology.

EDR is a sub-function of the Supplementary Restraint System’s (SRS) micro-controller, and is found on most vehicles manufactured after Model Year 1997.

Our work was undertaken in co-operation with the Rotterdam Rijnmond Police Force as part of a wider study “to find new and innovative solutions for the technical difficulties experienced in the activities of law enforcement” [1].

Key Words
Road traffic accident investigation, Event Data Recorder

Abbreviations
ABS – Anti-lock Braking System
ASR – Acceleration Skid Regulation
CDR – Crash Data Retrieval
CI – Collision Investigator
CIU – Collision Investigation Unit
DLC – Diagnostic Link Connector
DMA – Direct Memory Access
DTC – Diagnostic Trouble Code
EDR – Event Data Recorder
EEPROM – Electronically Erasable Programmable Read Only Memory
ESP – Electronic Stability Programme
FDR – Flight Data Recorder
NHTSA – National Highway Traffic Safety Administration
OEM – Original Equipment Manufacturer
RTA – Road traffic accident investigation
SRAM – Static Random-Access Memory
Introduction

The level of effectiveness in RTA investigations is largely determined by the assigned Collision Investigator (CI) being able to gather all of the pertinent facts pertaining to the incident [2].

Currently, there are two formulation methods employed:

- Deformation measurement, and
- Slide/skid factor.

Measuring vehicle deformation involves feeding crush data into a computer, and scrutinising this data, with the assistance of simulation software, to determine the velocity changes required to produce the degree of deformation displayed in the involved vehicle.

The later method, slide factor, is the predominant system, due to its simplicity and cost effectiveness. However, it is heavily reliant on the tyres of the involved vehicle leaving continuous skid marks on the road surface. The markings are studied by the CI, and mathematical formulae are applied to compute the pre-impact velocities.

Problem Description

Traditional RTA investigation methods have proved to be grossly ineffective where modern automobiles are concerned. Modern vehicles come equipped with vast arrays of active safety devices – e.g. Acceleration Skid Regulation (ASR), Anti-lock Braking System (ABS), Electronic Stability Program (ESP), etc. Consequently, they do not leave behind much in the way of tell-tale skid marks at the accident scene, Figure 1.

EDR Technology Explained

EDR technology is no stranger to the automobile. Indeed, General Motors (GM) has been equipping its vehicles since 1974 [3]. For several decades, EDR was installed on passenger vehicles for research purposes – and as a regular production option thereafter [4]. From its inception, EDR was employed to:

- Record events just prior to a crash,
- Record events during a crash, and
- Control air bag deployments.
In recent years, the U.S. auto industry has been collaborating with the National Highway Traffic Safety Administration (NHTSA) on ways to obtain crash information from vehicles using on-board collision sensing and recording equipment [3]. EDR technology is used to record data on airbag status and crash severity for impacts producing both deployment and near-deployment events. A near-deployment event is not severe enough to necessitate that the airbag(s) be triggered [3].

The EDR function has been adapted, in more recent years, to monitor and record additional vehicle operational parameters [5], such as:

- Vehicle speed,
- Brake on/off,
- Seat belt fastened, and
- G-forces as measured by the accelerometer.

For certain General Motors (GM) vehicles manufactured from model year 1999, the EDR function has some enhanced technical features, which allow it to record pre-crash vehicle events [4], Figure 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1990</th>
<th>1994</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>State of Warning Indicator when event occurred (ON/OFF)</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Length of time the warning lamp was illuminated</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Crash-sensing activation times or sensing criteria met</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Time from vehicle impact to deployment</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Diagnostic Trouble Codes present at the time of the event</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Ignition cycle count at event time</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Maximum ΔV for near-deployment event</td>
<td>☑</td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>ΔV vs. time for frontal airbag deployment event</td>
<td>☑</td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>Time from vehicle impact to time of maximum ΔV</td>
<td>☑</td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>State of driver’s seat belt switch</td>
<td>☑</td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>Time between near-deploy &amp; deploy event (if within 5 sec.)</td>
<td>☑</td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>Passenger’s airbag enabled or disabled state</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine speed (5 sec before impact)</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle speed (5 sec before impact)</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brake status (5 sec before impact)</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throttle position (5 sec before impact)</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2** Data Stored by Selected GM Airbag Systems
EDR Construction and Operation

EDR is an integral function of an automotive airbag micro-controller, Figure 3. The system does not record cabin voice conversations like an aeronautical Flight Data Recorder (FDR) [5].

The EDR is constantly supplied with a host of electronic data from various vehicular subsystems – i.e. sensors and other micro-controllers. A bus system is used to connect the various subsystems together to form a synergistic network. A data protocol is used to regulate the communications between the various controllers operating on this network.

EDR uses two kinds of external memory to store system data [6]:

- Static Random-Access Memory (SRAM), and
- Electronically Erasable Programmable Read Only Memory (EEPROM).

Static Random-Access Memory

SRAM is a type of semiconductor memory, which utilises bistable latching circuitry to store information. SRAM memory is volatile – i.e. data is lost when the memory’s electrical power supply is interrupted. SRAM acts as a fast access ring buffer recording system status data in a continuous loop, which is over-written every five seconds [7].

Electronically Erasable Programmable Read Only Memory

EEPROM (or E²PROM), on the other hand, is a non-volatile memory – i.e. data is retained even when the memory’s electrical power supply is removed. This is why SRAM data is transferred to EEPROM for secure storage. EEPROMs are also used by automotive micro-controllers to store small quantities of data, such as, calibration tables or device configuration settings. Stored EEPROM data can also be electronically erased and overwritten with new learned values if required [7].

The Rationale for Dual Memory Modules

SRAMs permits fast-access continuous-data-recording, but lose all of their data when powered down. EEPROMs, on the other hand, retain all of their stored data regardless of being powered down and rebooted. Conversely, EEPROMs due to their intrinsic latency inhibit fast-access. Furthermore, EEPROM chip architecture only supports a limited number of write/erase cycles; should this chip be employed as a ring buffer it would quickly wear out and fail [6].
Data Retrieval

When the airbag micro-controller’s crash sensor reports a critical event (deployment/near-deployment); the EDR instructs the SRAM to transfer recorded system status data to the EEPROM [3]. The transferred recording containing data of the critical event is locked in a five second freeze-frame, which stays in the EEPROM until another more serious event occurs and overwrites it. Conversely, should the critical event relate to an actual airbag deployment; then the data is permanently locked. It is not possible to return a locked status (crash data stored) micro-controller to service. The unit must be replaced, and the new/replacement micro-controller adapted to the repaired vehicle.

EDR data can only be extracted using a dedicated piece of equipment called a Crash Data Retrieval System. Until 2000, only the Original Equipment Manufacturers (OEMs) of the airbag micro-controllers, like TRW Automotive, had this capability. Since then, several generic crash data retrieval tools have been made commercially available, Figure 4.

The crash data retrieval tool generally connects to EDR via the vehicle’s Diagnostic Link Connector (DLC), Figure 5. Conversely, if this is not possible; the tool can also be directly connected to the airbag micro-controller with some jumper cables and a Direct Current (DC) bench power supply unit.

Analysing Retrieved Crash Data

The system generates a Crash Data Retrieval (CDR) file that stores and visualises the information downloaded from the EDR. The combined data is known as an event file. An event file typically contains the following items of information:

- Freeze-frame data,
- A pre-crash deployment graph,
- A post-crash graph showing the difference in velocities (Δv), and
- A deployment summary.
Freeze-frame Data

Freeze-frames are a set of image captures for a variety of sensor input values (variables) that were generated, and transmitted down the CAN bus lines, at the exact moment the fault(s) occurred. A maximum of three sets of data are saved. This, however, does not mean there will always be three sets of data. A Crash Data Retrieval (CDR) tool has the capability to read the freeze-frames along with their respective Diagnostic Trouble Codes (DTC) and definitions.

Figure 6 shows freeze-frame hexadecimal coding, and demonstrates how a CDR tool converts it into something more meaningful (definition) for the Collision Investigator.

The Event File

The following graphics are an example of an event file, which was downloaded using a Crash Data Retrieval Tool. It is poignant to note; that the driver of this vehicle was killed during this particular Road Traffic Accident.
Proceedings of the ITN2014
4-5th September, University of Limerick

LONG AND MAGUIRE: Accident Investigation

Figure 7  Sample Freeze Frames Containing Hexadecimal Data

Figure 8  Pre-crash Deployment Graph

Figure 9  Post-crash Graph for $\Delta v$
Airbag micro-controllers with recordable memories (EDR), Controller Area Network (CAN) connectivity, and data transfer using Direct Memory Access (DMA) are becoming familiar features in modern automobiles.

EDR technology is a useful support tool for law enforcement personnel tasked with Road Traffic Accident (RTA) investigation and reconstruction. The Collision Investigator (CI) now can see, in real-time, the sequence of events as they unfolded within a high degree of accuracy.

Our test results show the EDR method to be more descriptive and reliable than traditional techniques. Conversely, EDR data could also be used to provide valuable evidence in the absence of reliable witnesses. The assembled data could then be used to corroborate or refute witness testimonies.

References