

Analysis of Pre-Crash Data Transferred over the Serial Data Bus and Utilized by the SDM-DS Module

2011-01-0809

Published
04/12/2011

Cleve Bare
Exponent Inc.

Brian Everest and Donald Floyd
General Motors Company

Douglas Nunan
Delphi Corporation

Copyright © 2011 SAE International

doi:[10.4271/2011-01-0809](https://doi.org/10.4271/2011-01-0809)

ABSTRACT

The primary function of an airbag control module is to detect crashes, discriminate and predict if a deployment is necessary, then deploy the restraint systems including airbags and where applicable, pretensioners. At General Motors (GM), the internal term for airbag control module is Sensing and Diagnostic Module (SDM). In the 1994 model year, GM introduced its SDM on some of its North American airbag-equipped vehicles. A secondary function of that SDM and all subsequent SDMs is to record crash related data. This data can include data regarding impact severity from internal accelerometers and pre-crash vehicle data from various chassis and powertrain modules. Previous researchers have addressed the accuracy of both the velocity change data, recorded by the SDM, and the pre-crash data, but the assessment of the timing of the pre-crash data has been limited to a single family of modules (Delphi SDM-G). This paper addresses the operation and performance of another family of General Motors SDMs; the SDM-DS and its utilization of the Class 2 intra module serial communication bus.

A series of vehicle test maneuvers were conducted while injecting non-deployment crash pulses directly into the SDM. These tests include acceleration, braking, and mixed acceleration and braking maneuvers. Pre-crash data was recorded directly from the serial data bus using a passive monitoring tool. Vehicle dynamic data was recorded by independent on-board instrumentation. The timing of the

SDM's recorded data was compared with data collected from the serial bus as well as the recorded vehicle dynamic data. Evaluation of this data provides a better understanding of the timing and asynchronous nature of the pre-crash data recorded in the SDM.

INTRODUCTION

While General Motors has experience with airbags on vehicles as far back as the early 1970s, GM's "modern era" of airbags started with the 1988 Oldsmobile 88. That vehicle and subsequent airbag equipped vehicles have had some form of airbag control module that also performed system diagnostics and acted as an energy reserve to deploy airbags in the event of a power loss. The earlier modules, starting in 1990 model year, were known as DERMs, Diagnostic and Energy Reserve Modules. Beginning with the 1994 model year, crash sensing capability was integrated into a new module known as the Sensing and Diagnostic Module (SDM). SDMs have continued to evolve, making use of improvements in technology and incorporating additional features. From the beginning, Event Data Recorder (EDR) capabilities have been an imbedded function within the airbag control module. The EDR has evolved from initially only recording diagnostics and sensor closure times to include time to commanded deployment, longitudinal and lateral velocity changes, and pre-crash vehicle system data. Previous literature (Chidester, Mercer et al [1] and the output of the NHTSA EDR Working Group [2]) provides further reading on the historical evolution of GM airbag control modules.

Currently, there are conservatively 30 different types of SDMs installed on GM vehicles in the U.S. While there are many similarities between the various types of SDMs, each SDM type has its own unique operating characteristics. Understanding these operating characteristics, data sources, and methods that modules use to acquire and record data is useful for analysts during their interpretation of the data recorded by the SDM.

In their analysis of SDM data timing, Wilkinson et al. [3] set out to measure three things about pre-crash data: time shift between the SDM-reported data times and Algorithm Enable (AE), sampling rate variation, and synchronization of the sensor data. The tests were performed on a 2002 Pontiac Sunfire equipped with a Delphi SDM-G and a Class 2 serial data bus. The authors triggered an event while the throttle position, engine speed, vehicle speed, and brake signals were being monitored at the source sensors. Two of their conclusions were: "The time intervals between the SDM data points were on average about 1 s..." and "The SDM-reported data from all of the sensors were not synchronized."

The original intent of EDR data was to aid engineers in understanding how restraint systems functioned during crash events. After a crash event with only information available from visual damage assessments or scan tools, parameters such as sensor closure times, times to commanded deployment, and diagnostic status at the time of the event are difficult to discern. The belief was that if something unexpected were occurring in the field, the phenomena would be exhibited in multiple vehicles. The engineer could detect trends based on accumulated crash data and take appropriate action. With the advent of crash severity data (ΔV) and pre-crash data like vehicle speed, crash data became interesting for a variety of other purposes and users [4]. Crash reconstructionists are particularly interested in the data, and use it to aid in analysis of crash situations. Users of this information need to understand the data and the performance variations of the individual modules and communication protocols being used in their crash-at-hand. This research provides further insight into the operation of the SDM-DS on a Class 2 data bus.

TEST VEHICLE

The test vehicle was a 2006 GMC Envoy Denali four-wheel-drive sport utility vehicle (Figure 1) equipped with the Vortec 5.3 liter 8-cylinder engine. The features of the Vortec engine include sequential fuel injection and Displacement on Demand (DoD). This engine was paired with a four-speed electronically controlled automatic transmission. The Envoy was equipped with a variety of safety systems including dual stage driver and passenger frontal airbags, automatic passenger frontal airbag suppression, and driver and passenger side roof rail airbags. The 2006 GMC Envoy's airbag control module was a Delphi SDM-DS. The vehicle

also possessed a variety of features including power windows, power locks, antilock brake system (ABS), vehicle stability enhancement system (VSES), cruise control, power seats, dual zone automatic climate control, rain sense wipers, daytime running lamps (DRL), and a driver information center. Overall, the GMC Envoy contained a high degree of electrical content with extensive communication between the various electronic control modules.



Figure 1. 2006 GMC Envoy

Electrical content is noteworthy because it represents the potential for increased communication bus traffic. The more controllers a vehicle has on the communication bus, the greater the potential there is for bus communication message latency.

Vehicle module communication on the 2006 GMC Envoy is conducted over the GM implementation of the SAE J1850 Class B serial communications bus, also known as the GM Class 2 communication bus. The GM Class 2 communication bus is the link the SDM uses to gather pre-crash vehicle system data from various chassis and powertrain control modules. The initial implementation of the GM Class 2 serial bus was in the 1995 model year and has been utilized in a number of vehicles over the years. The GM Class 2 bus is a single wire communication bus that is capable of operating at an average of 10.4 KB/second, and includes a Cyclic Redundancy Check (CRC) for message validation. The messages also contain a priority field, allowing higher priority traffic to take precedence over lower priority messages. The GM Class 2 communication bus can accommodate up to 100 transmitted 13-byte messages per second [5].

One of the primary reasons the Class 2 bus was introduced on GM vehicles was to facilitate the implementation of On-Board Diagnostic (OBD) II. OBD II started as a set of standards and practices developed by SAE and adopted by the Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) for vehicle electronic diagnosis of emission related systems. The introduction of the Class 2 bus also improved the reliability

of serial bus messaging and lowered vehicle production costs by reducing the numbers of wires, connections, and special-purpose circuits used in a vehicle. The Class 2 bus enabled nearly seamless cross communication of all the various Electronic Control Units (ECU) on the bus. For example, the Powertrain Control Module (PCM) can broadcast the vehicle speed on the bus, and that signal can be monitored by the display cluster and used to update the speedometer. That same signal can be monitored by the entertainment system and used to adjust the volume of the sound system automatically, based on the speed of the vehicle. Additionally, the vehicle speed can be monitored and buffered by the SDM. If there is a crash event, it can then be recorded by the SDM. By utilizing the Class 2 bus, it became practical to broadcast the various vehicle system data that the SDM collects in its pre-crash buffer.

SENSING AND DIAGNOSTIC MODULE (SDM)

Over the years, General Motors has used a variety of SDMs with designations such as the SDM-A, SDM-B, SDM-R, and SDM-G. Delphi's airbag control module utilized in the 2006 GMC Envoy, the SDM-DS, detects crash events, and discriminates whether airbag deployment is necessary. The SDM-DS can support up to 12 firing loops with inputs from up to four satellite sensors to support frontal and side impact crash sensing. The SDM-DS also supports communication with a standalone rollover sensor (ROS) module. Based on an input signal from the ROS module, the SDM may command roof rail airbag deployment, during a rollover type crash event, if the vehicle was equipped with this system. The SDM-DS also directly monitors the driver and passenger seat belt switch circuit status.

Internally, the SDM-DS uses a Freescale/Motorola microcontroller running at 20 MHz. The SDM-DS utilizes a dual axis $\pm 50g$ accelerometer package for frontal crash sensing and system safing. The dual accelerometer array is orientated in a manner that provides two independent inputs for both frontal and side crash sensing without having to use multiple accelerometer packages. This implementation provides a cost effective and robust design. At power-up, the SDM-DS conducts an initial series of diagnostic tests, confirming proper functionality of the unit. Additionally, diagnostic tests are conducted for single point electrical failure at regular intervals while the SDM-DS is powered.

The SDM data processing routine samples the accelerometer inputs at a 3.2 kHz rate using an A/D converter. The acceleration samples are converted to the corresponding longitudinal and lateral signals. The longitudinal and lateral signals are passed through various filter routines to produce the inputs used by the crash discrimination algorithm. When the filtered acceleration input signal exceeds a calibration threshold, the SDM begins calculating the change in velocity

(ΔV) by summing the filtered acceleration samples every 1.25 ms (i.e. 8 samples every 10 ms). The SDM does not record the actual acceleration data, but instead records the accumulated ΔV at 10 ms intervals.

Once the algorithm is activated, the SDM begins to compare the measured acceleration crash pulse against a set of predetermined deployment criteria. If the crash pulse exceeds these criteria, the airbag deployment is commanded and a deployment event is recorded and locked in the SDM memory. If the acceleration pulse and its calculated products do not reach a deployment threshold, a non-deployment event is recorded. The minimum SDM recorded vehicle velocity change that is needed to record a non-deployment event is about 5 mph (8 km/h). The SDM-DS is capable of recording one deployment event and one non-deployment event or two deployment events. The second deployment event would be recorded in the memory location allocated for the non-deployment event.

During either deployment or non-deployment events, up to 300 ms of integrated longitudinal and lateral acceleration, corresponding to vehicle velocity change (ΔV), is recorded. The maximum longitudinal velocity change for the entire event and corresponding time is also recorded for a non-deployment event or for the second deployment event.

In addition to the internally measured impact severity data, the SDM-DS records pre-crash data obtained from other modules (Figure 2). This data is collected by the SDM via the GM Class 2 serial bus and includes 5 samples of vehicle speed, brake switch circuit status, engine speed, and percent throttle at 1 second intervals.

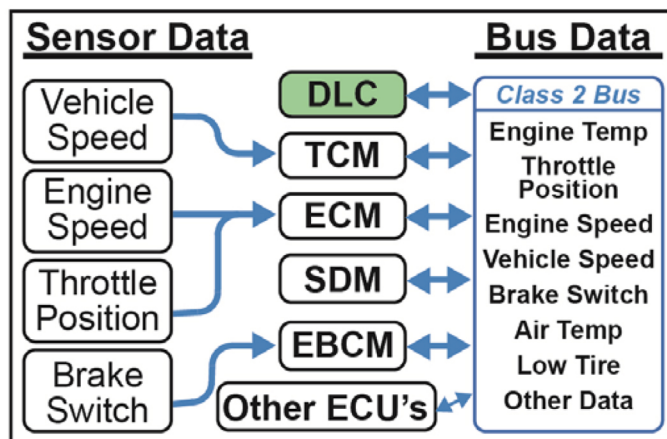


Figure 2. EDR Data Signal Flow to Class 2 Bus

The Transmission Control Module (TCM) broadcasts the vehicle speed on the Class 2 bus. The vehicle speed signal is generated by the Vehicle Speed Sensor (VSS) located on the transmission output shaft (Figure 3) [6]. The vehicle speed sensor provides a pulse count input to the TCM from which

the TCM calculates the vehicle speed in kilometers per hour (km/h) and broadcasts the data on the Class 2 bus.

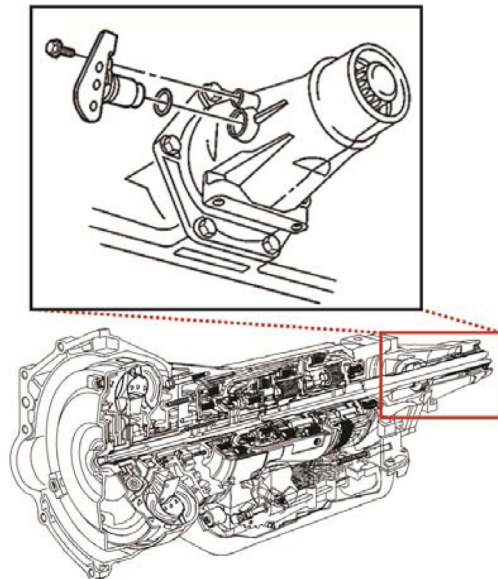


Figure 3. Vehicle Speed Sensor

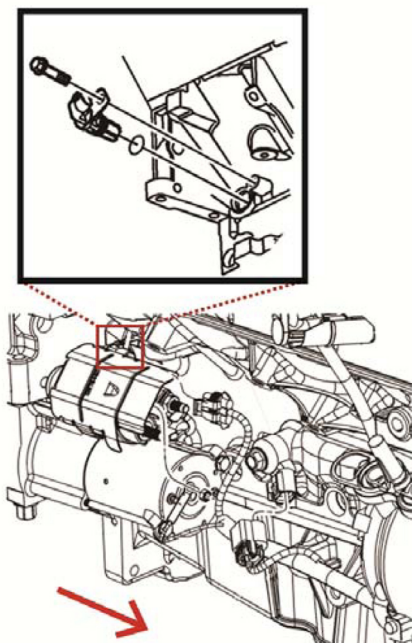


Figure 4. Engine Speed Sensor

The Engine Control Module (ECM) broadcasts the engine speed and percent throttle messages on the Class 2 bus. The engine speed signal comes from the Crankshaft Position (CKP) sensor located on the right rear side of the engine block (Figure 4). The CKP sensor sends a signal to the ECM

which calculates the engine speed in Revolutions Per Minute (RPM) and broadcasts the data on the Class 2 bus.

The percent throttle signal comes from the Throttle Position (TP) sensors (Figure 5). There are two TP sensors located within the throttle body assembly. The ECM monitors these sensors, calculates the throttle position as a percent open value, then broadcasts the data on the Class 2 bus.

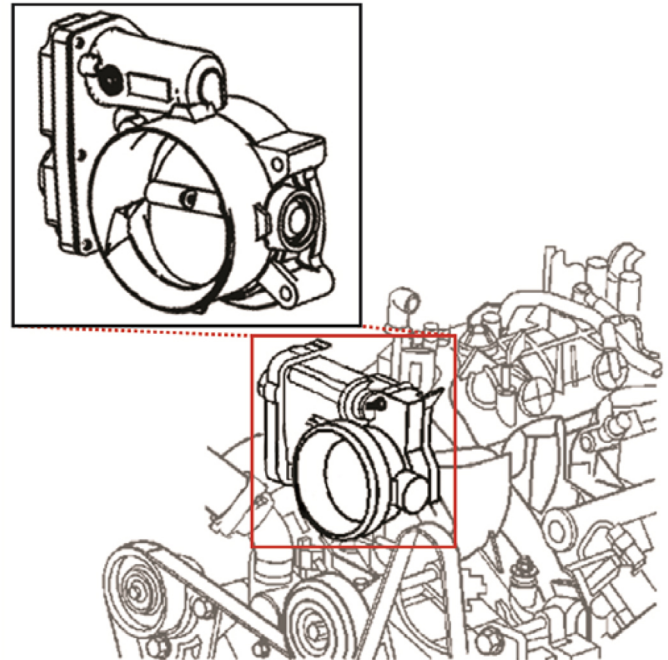


Figure 5. Throttle Position Sensor

Brake switch circuit status is obtained from the Electronic Brake Control Module (EBCM). The signal is generated from a switch activated by the brake pedal assembly (Figure 6). This switch is the same switch that controls the rear brake lamps. The switch input is monitored by the EBCM which broadcasts the data on the Class 2 bus.

The rate at which the Class 2 bus receives data from an ECU varies, depending on the length of the message, bus traffic, message priority, and ECU throughput capacity. There are, however, reasons that individual modules may not broadcast data at the maximum rate. Data broadcasting delays can occur if other higher priority messages are in the process of being sent over the data bus. Until these higher priority messages have been broadcast, the lower priority messages would have to wait in a message queue. In addition, there may also be signal processing logic built into an ECU's operating software that may create a delay in the messages being broadcast over the data bus. An example of this signal processing logic would be when an ECU attempts to compensate for contact bounce of a switch. The ECU may compare switch state

changes over a short time span and only broadcast the switch status after a steady state has been observed.

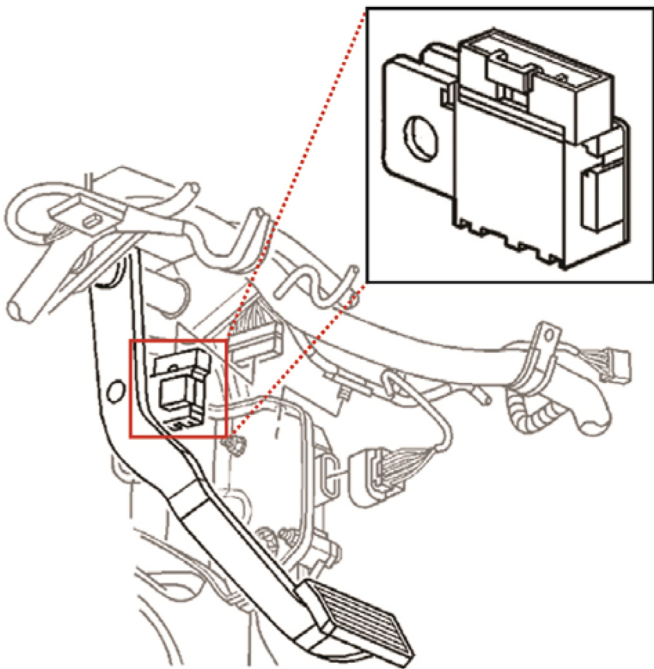


Figure 6. Brake Switch

Various ECUs continually monitor the data messages that are sent across the Class 2 bus. The messages are sent using an “update on change” method. The “update on change” method means that the data is not broadcast at a fixed update rate but new messages are sent on the data bus only if the data changes. The SDM-DS serial data handler processes the bus messages as they are received from the bus and places the individual parameters into the “Receive Data Buffers” in RAM.

The SDM receives the message and processes the message as listed below.

- Receives message from the Class 2 bus
- Determines if the message is applicable to the SDM
- Decodes the message
- Stores the data in the appropriate receive data buffers

The serial data handler of the SDM continually processes messages as they are received, independent of the EDR function of the SDM that records data during deployment and non-deployment crash events.

The SDM EDR function samples the values in each of the Receive Data Buffers at a one second rate (Table 1). This timing is based on the microprocessor clock which is generated by a 16 MHz oscillator crystal circuit. The

variation on the one-second timer is within 30 microseconds. The last five samples prior to AE are maintained in the EDR vehicle status data ring buffer and are recorded by the SDM.

Table 1. EDR Data Buffers

Sample #	Vehicle Speed	Engine Speed	Percent Throttle	Brake Switch
-5	km/h	RPM	%	On/Off
-4	km/h	RPM	%	On/Off
-3	km/h	RPM	%	On/Off
-2	km/h	RPM	%	On/Off
-1	km/h	RPM	%	On/Off

The SDM-DS also records restraint data such as airbag loop commanded firing times during deployment events, driver and passenger buckle status, and airbag system diagnostic information.

VEHICLE PREPARATION

The original equipment SDM-DS, found in the 2006 GMC Envoy, was replaced with a SDM-DS modified by Delphi to facilitate our testing (Figure 7). During the manufacturing process, SDMs are set to “factory” mode, which allows firmware to be uploaded and diagnostics to be performed. Prior to leaving the vehicle assembly plants, SDM's are set to “production” mode, affecting the ability to download programs to the module through serial communications and prohibiting the clearing of crash data. All modules found in saleable vehicles or replacement parts are in “production” mode.

In order to allow the clearing of crash event data, the SDM used in our testing was left in “factory mode”. Additionally, the SDM was outfitted with a series of four BNC type connectors, allowing an electrical pulse from a waveform generator to be applied to the circuitry. Testing was performed using this modified SDM, created by Delphi. A waveform simulating a long duration, low acceleration impact was constructed and applied to simulate a non-deployment event. The SDM could still record crash data and it could then be cleared using proprietary Delphi equipment, typically used in SDM development.



Figure 7. Test Sensing and Diagnostic Module

A test matrix was developed comprising of a variety of operator inputs including acceleration, braking, and mixed braking and acceleration. The acceleration tests were conducted from a stop and from an initial speed of approximately 20 mph. The braking tests were conducted from speeds between 50 and 80 mph with both ABS and non-ABS braking maneuvers. Several mixed runs were conducted, consisting of a period of hard acceleration followed by hard braking. Finally, a series of rapidly changing throttle and brake input tests were conducted to provide data with minimal vehicle speed change, but rapidly fluctuating engine speed and other inputs. These runs produced data that help narrow the timing of the pre-crash data recorded by the SDM.

The waveform generator was triggered approximately 5 seconds after the start of the maneuver, sending a crash pulse signal into the SDM which generated a non-deployment event. The SDM was subsequently downloaded using the Bosch Crash Data Retrieval (CDR) tool version 2.8. This data was compared to the data collected from both the Class 2 data bus and data that was measured from on-board instrumentation recorded during the maneuvers.

Serial bus traffic was monitored using the Systems Analysis Interface Tool2 (SAINT2) bus monitor designed by Delphi. The SAINT2 tool allowed for passive bus monitoring without adding additional bus traffic. In addition, the SAINT2 accepts a trigger signal from the waveform generator to allow the data to be synchronized between the start of the crash signal, the data collected from the Class 2 bus, and independently measured vehicle data. By comparison, the GM Tech 2, as well as other scan tools, typically used by automotive technicians during diagnostic evaluations, acts as a node on the serial bus. As a result, for a scan tool to receive data, it typically sends a request message to a specific module over the serial communications bus. This process of requesting data over the serial bus can affect serial bus traffic/speed. The

scan tool request message is a low priority message, and the module the request was sent to, *e.g.* the ECM, may not immediately respond to the message if a higher priority task is underway. The request message may also be interrupted by other higher priority messages.

The GMC Envoy was instrumented to measure vehicle responses during the maneuvers and to allow comparison to both the data acquired over the Class 2 bus and data recorded by the SDM. Data from the on-board instrumentation was acquired using a 12-bit, 16 channel National Instruments data acquisition card at a sampling rate of 100 Hz. The instrumentation for the Envoy is summarized below:

- Datron optical velocity sensor ([Figure 8](#))
- Systron Donner MotionPak® Inertial Measurement Unit (IMU)
 - Longitudinal and lateral accelerometer
 - Yaw rate and roll rate sensor
- Steering wheel angle
- Tape switch for brake application
- String potentiometer for accelerator pedal displacement (percent of maximum)
- Synchronization signal trigger

The accelerometer data was acquired using a 20 Hz anti-aliasing filter while the angular rate data was acquired using a 30 Hz antialiasing filter. The data was post-processed with a 10 Hz filter designed to test standards specified in the Society of Automotive Engineers (SAE) recommended practice J211. During post-processing, the velocity data was corrected to indicate the vehicle velocity at the center of gravity (CG) position.

The accelerator pedal position was instrumented with a string potentiometer to measure accelerator pedal travel ([Figure 9](#)). While this data does not directly correspond to percent throttle, it does directly measure the driver input requesting acceleration to the ECM. This data was compared to the Class 2 data and the recorded SDM data measured at the throttle body.