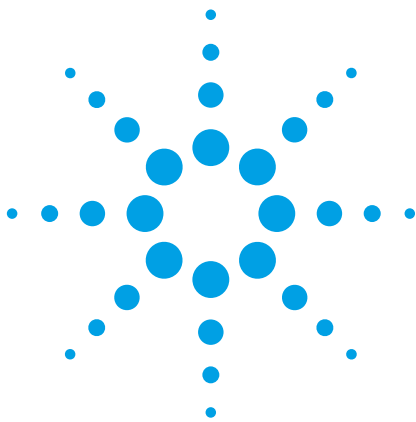




Agilent TS-5000 Family of Automotive Electronics Functional Test Systems

Supplemental Restraint Systems

Application Note

Agilent Technologies TS-5400 Series II and TS-5020 Automotive Electronics Functional Test Systems

Supplemental restraint systems

A unique aspect of safety electronics for auto-mobiles is the need for redundancy in design and for extensive monitoring, both internal and external, of embedded circuitry. Supplemental restraint systems (SRSs), which control airbags and sometimes seatbelt pre-tensioners, are an increasingly popular feature in cars. The SRS electronic control module (ECM) controls the deployment of airbags (and often seatbelt pre-tensioners) based on the input of electro-mechanical sensors.

Due to the function of the ECM, continuous monitoring and feedback of the power supply circuit, sensors/accelerometer, squib (the airbag igniter), and ECM serial communications is critical.

Monitoring these elements ensures that the ECM will:

- 1) Avoid accidental inflation of the airbag
- 2) Recognize and respond to a legitimate crash
- 3) Return reliable information on system status

Unlike other automotive electronics, SRSs are typically built to act only once during their lifetime, so running a full test of the airbag in production is virtually impossible.

The following is an overview of various manufacturing tests on an airbag ECM designed to increase reliability and system integrity, using the TS-5000 family systems.

Serial Links

Testing of the ECM involves manipulation and verification of its functionality via a serial link. The common serial interfaces include UART-based ISO-9141, J1850 (pulse width modulated & variable pulse width), and CAN/J1939 (controller area network). These links give the ECM the ability to communicate with external test and measurement instrumentation.

I/O check

An input/output check may be easily performed by verifying that the ECM correctly reads the states of a given input or output.

Testing

Testing the ECM's serial communications can be performed using one of several methodologies based on the ECM's design. Typically, the ECM designer determines the algorithm for setting the module in either TEST or RUN mode. This algorithm – a specific handshake, for example – is often executed in a given time window after the system is powered up (for example, ~500 ms), which is dependent on the specific serial interface chosen.



Agilent TS-5400 Series II and TS-5020 testing solutions

In an effort to include the most common serial interfaces, the TS-5400 and TS-5020 test systems feature an optional serial port adapter that supports ISO-9141, J1850, and J1939 serial communications. In addition, the test executive software (Agilent TestExec SL) included with the platform has built-in commands to facilitate serial communication by setting the ECM in either TEST or RUN mode. The software also includes easy-to-use commands for developing a test plan.

Aside from the normal Read/Write/Configure software provided, TestExec SL streamlines common process steps used in functional testing of the ECM – for example, sending the ECM periodic “keep alive” messages (referred to as a ‘group message’ below) to maintain TEST rather than RUN mode is easily executed via the following commands:

mComConfigGroup: configures any of the supported serial interfaces for a group message

mComStartGroup: specifies the time between groups, between group elements, group repeat count, and the group message itself.
GroupRepeatCount = 0: represents indefinite repetition of a keep alive message

System Operation

Two general types of airbag systems are in use in today’s automobiles – centralized and decentralized (see Figures 1 and 2). Both systems rely on a set of crash-detecting sensors and an electromechanical safing sensor (a sensor used as redundancy and/or crash verification). The crash-detecting sensor in a centralized system is a micromachined accelerometer that is usually housed in the dashboard. However, the crash-detecting mechanism in a decentralized system consists of a distributed set of separate electromechanical sensors in the car. The ECM assesses a crash scenario based on the output of its internal “judgment circuit,” which receives input from the crash sensors. Once a pre-defined safety response is determined (based on both occupancy and safing sensors), the squib fires and inflates the respective airbag. Judgment for the airbag deployment should occur in 10 to 30 ms, followed by full inflation of the bag in 30 to 40 ms. Upon total inflation, the airbag absorbs the impact of the individual and then deflates, such that the total time of airbag deployment is typically 100 to 150 ms. In addition, seatbelt pre-tensioners are activated for added protection of the occupants.

Sensors

In a centralized system, signals from a micromachined accelerometer require an amplifying and filtering circuit to relay the vehicle’s deceleration, while the output requires analog-to-digital (A/D) conversion for use by the ECM’s microcontroller. The electromechanical sensors of a decentralized system are distributed throughout the vehicle and wired in series with the firing squib so that they pass the firing current along when deploying the airbag. These external sensors close an electrical contact when they experience a certain amount of deceleration. Most systems use two to five sensors oriented in series or parallel, depending on their function.

Short/open sensor

In testing the electromechanical sensors of a decentralized system, the ECM must assess whether the sensor is properly connected (i.e., no opens or shorts). A fault in the sensor connection may result in accidental squib activation and inflation of the airbag.

Testing

In production testing, detection of sensor open (due to wiring or mounting), short, or short-to-chassis is done via relay-induced faults. The fault is verified by interrogating the ECM via the serial link and/or by the ECM turning on the warning lamp.

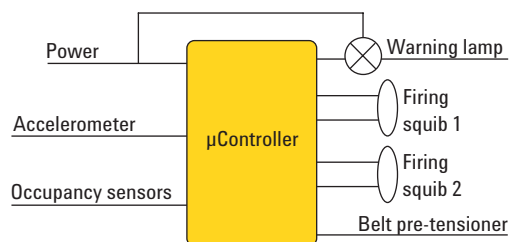


Figure 1: Centralized airbag system

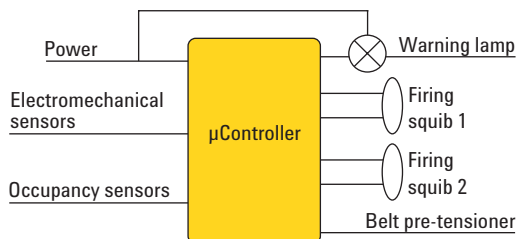


Figure 2: Decentralized airbag system

Occupancy Sensing

The occupancy sensor input common to both centralized and decentral-ized systems behaves like an On/Off switch (though electrical devices are also used). As illustrated in Figure 3, the ECM uses input on the presence of a passenger and status of the driver and passenger seatbelts to determine the appropriate safety response (i.e., full airbag deployment, selective deployment, or no deployment).

Monitoring of occupancy inputs

In accordance with the decision tree in Figure 3, the ECM responds to a given combination of switch closures with an appropriate action. This includes airbag deployment, activation of seatbelt pre-tensioners, switch-on of warning lamp, or other pre-defined actions in the event of "illogical" input (e.g., no passenger present but passenger seat belt on).

Many manufacturers allow for deactivation of passenger side airbags at the owner's request. Seatbelt pre-tensioners are activated only in the event seatbelts are in use. The feedback loops in Figure 3 show that use of passenger and driver seat belts increases the threshold for airbag deployment when the crash scenario is being assessed by the ECM judgment circuit.

Testing

Switching element operations are not actively tested. Rather, with a given combination of switch closures, the ECM provides a pre-defined response. Verification of this response is done by ECM interrogation through the serial link.

Agilent TS-5400 Series II and TS-5020 testing solutions

The TS-5400 and TS-5020 test systems can be configured to include load cards for either short/open sensor testing or occupancy monitoring. In particular, the E6175A 8-channel load card, E6176A 16-channel load card, or the E6177A 24-channel load card would be appropriate choices; the latter features bridge load capabilities as well. Serial communication from the cards to the ECM takes place through one of the interfaces supported by the platform – ISO-9141, J1850, or J1939.

The TestExec SL software supports a comprehensive signal and load routing architecture. In particular, the switch path editor provides a simple, easy-to-read path description. In addition, for test plans in which relay actions are repeated throughout various sections, relay state tracking recognizes the existing state of the relay, thus speeding the time of test.

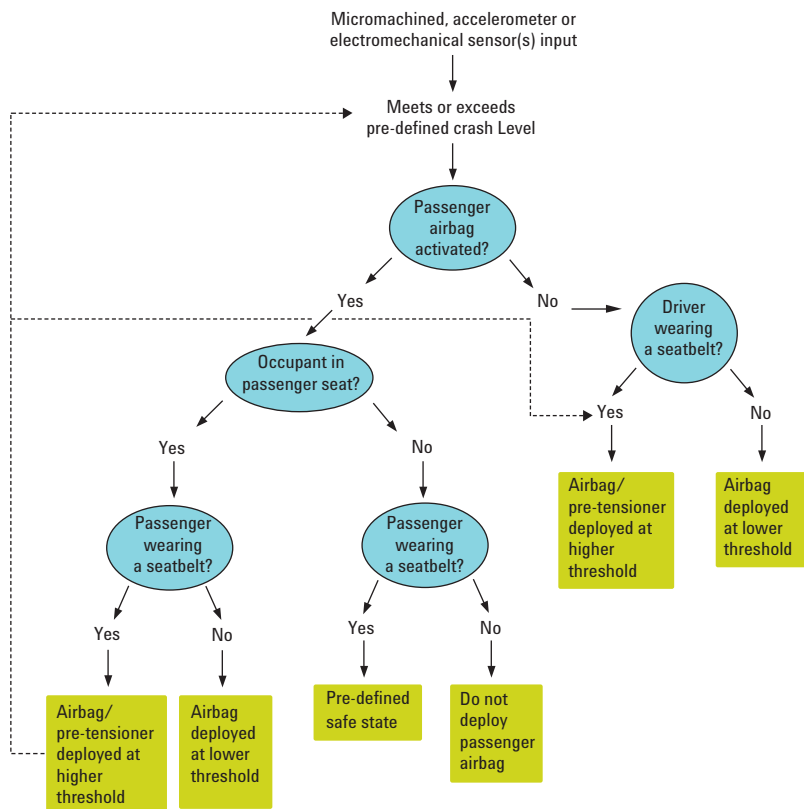


Figure 3: Decision tree used in ECM response determination

Battery Supply Voltage

In the vehicle, ECM activity relies on the health of the battery voltage (typically 14 V). The supply voltage is used to activate the warning lamp, the seatbelt pre-tensioners, the airbag (through squib firing), and more. In addition, the supply voltage is used by the ECM judgment circuit to establish a threshold value for response in a crash.

Verifying battery voltage

Verification of battery supply voltage will vary by ECM design. One possible method of testing involves measuring the battery voltage by a voltage divider, an analog-to-digital converter (ADC) reference voltage, and the ADC input of the ECM microcontroller (see Figure 4). The reference voltage is typically 5 V, while the expected ADC output is the ratio between the V_{batt} input level (battery voltage) and the ADC reference voltage. Another method involves a second, independent reference voltage source, as shown in Figure 5. In this case, the expected ADC output would be equal to a pre-defined value based on the voltage divider input and the second reference voltage input.

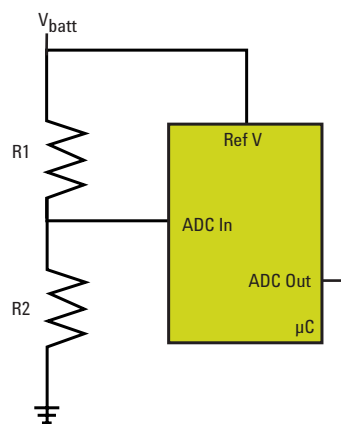


Figure 4: Measuring battery voltage with one reference voltage

Testing

As noted before, testing of the battery voltage will vary greatly by ECM design. However, in keeping with the two test methodologies shown in Figures 4 and 5, the battery voltage should be applied, followed by verification that the expected ADC output value based on that input matches the real ADC output value as determined through the serial link. For more involved testing, the voltage from the divider at the ECM microcontroller ADC input can also be monitored with a digital multimeter (DMM).

Agilent TS-5400 Series II and TS-5020 testing solutions

The TS-5400 and TS-5020 test systems feature an optional serial port adapter that supports ISO-9141, J1850, and J1939 serial communication for verification of ADC output. These systems can be configured to include either a GPIB or VXI-based measurement architecture for a DMM to meet these testing needs.

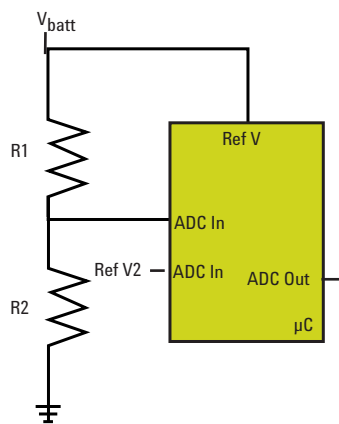


Figure 5: Measuring battery voltage with two reference voltages

Firing Loop For Airbag Deployment

To deploy an airbag in a crash, the ECM passes current through the firing loop into the firing squib to ignite the gas within the airbag. As illustrated in Figure 6, in addition to the cable and connector resistance, the firing squib is also modeled as a resistor in this loop. If the resistance in the firing loop falls above or below an established range, the warning lamp is activated.

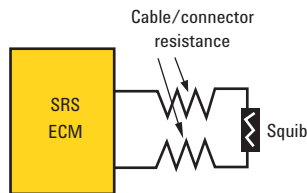


Figure 6: Airbag deployment firing loop

Verifying the Firing Loop Resistance

If the resistance in the firing loop falls above or below an established range of operability, the warning lamp must be activated.

Testing

Testing the firing loop involves several steps. First, the current from the ECM through the loop must be verified. Second, it is important to monitor the voltage drop across the squib (if using a real squib) or use a DMM to obtain the resistance of the cables and connectors (when the squib is modeled as a resistor). These values may be obtained based on several fault scenarios (e.g., open or short in the loop). Finally, with the advent of firing squib serial communication capability, verifying firing loop resistance via a serial link to the squib is also possible.

Agilent TS-5400 Series II and TS-5020 testing solutions

The TS-5400 and TS-5020 test systems can be configured to include several different load cards for this application. Emulating a short or open condition in this loop, therefore, may be done via relay-induced faults using any one of the load cards. However, the E6175A 8-channel load card and E6176A 16-channel load card also feature 50 mΩ-sense resistors for current sensing.

This added functionality facilitates current verification from the ECM through the firing loop. The voltage drop across these sense resistors can be measured by using a digitizer or DMM (also configurable with the platform).

For monitoring the voltage drop across the squib, the TS-5400 and TS-5020 test systems can be configured to include either a VXI- or GPIB-based DMM. When the squib is modeled as a resistor, the resistance at the inputs to the squib may be verified with the DMM's four-wire resistance capabilities.

Finally, these test systems include support for ISO-9141, J1850, and J1939 serial protocols when obtaining firing loop resistance information via the serial link.

A Supplemental Restraint System Test Solution

Optional throughput multiplier

The TS-5000 family of automotive electronics functional test systems may be configured to include an optional throughput multiplier, which is often used when testing low pin-count/low complexity ECMs. The throughput multiplier facilitates multiple-up UUT (unit under test) testing. Multiple-up testing results in decreased instrumentation setup time per UUT, consolidating delays in relay closures and overlapping time delays due to inherent UUT latencies. The TestExec SL software provides comprehensive support for this test strategy.

The automotive electronics manufacturing environment

The TS-5000 family of automotive electronics functional test systems offer support for factory automation. From a basic automation scheme to the use of PLCs (programmable logic controllers), the TS-5400 Series II and TS-5020 test systems have comprehensive serial communication support and digital I/O capabilities that allow the platform to be integrated into the overall manufacturing environment.

Overall solution

The test needs for a supplemental restraint system ECMs as generally outlined in this application note, may be satisfied by the following instrumentation.*

- Digitizer
- Digital multimeter
- Serial port adapter
- Select load cards

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*Note: This instrumentation list is presented as a general test solution profile, and is not for use as a direct ordering guide. For information on the detailed platform profile, please refer to the Product Note.

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Jurgen, Ronald. *Automotive Electronics Handbook*. New York: McGraw Hill, Inc., 1999.

Alfons, Hartl; Richard Vogt; and Anton Huber. *Airbag Systems: Their Permanent Monitoring and its Meaning to the User*. Conference, Society of Automotive Engineers, 1990.

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(fax) (65) 6755 0042
Email: tm_ap@agilent.com

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