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Reducing Accelerometer Susceptibility to BCI

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Automobile manufacturers require all system electronics to pass stringent electromagnetic compatibility (EMC) tests. Airbag systems are one of the systems that must perform adequately under EMC tests. There are different types of tests for EMC, one of which is testing the tolerance of the system to high frequency conducted emissions. One of the most stringent methods for EMC evaluation is the Bulk Current Injection (BCI) test. The entire airbag system must continue to function normally throughout the BCI test. This application note will discuss how to reduce susceptibility to BCI for the Motorola accelerometer but the information presented here can be applied to other electronic components in the system.

BCI TEST SETUP

The BCI test procedure follows a published SAE engineering standard, "Immunity to Radiated Electric Fields ~ Bulk Current Injection (BCI)", or SAE J 1113/401. For an airbag module, this involves injecting the desired current into the wiring harness by controlling current in the injection probe. The test frequency can vary from one to several hundred MHz. There are at least 20 frequency steps per octave required for the test, but as many as 50 steps per octave can be used. The injection probe is placed on the harness in one of three distances from the airbag module connector: 120, 450 and 750 mm. There is a monitor pickup probe present to measure the amount of current being injected. It is placed 50 mm from the airbag module. This feeds back to the system to ensure that the desired test current is being injected on to the wiring harness. Figure 1 shows the setup for the BCI test. (For more details, see the SAE J 1113/401 Test Procedure).

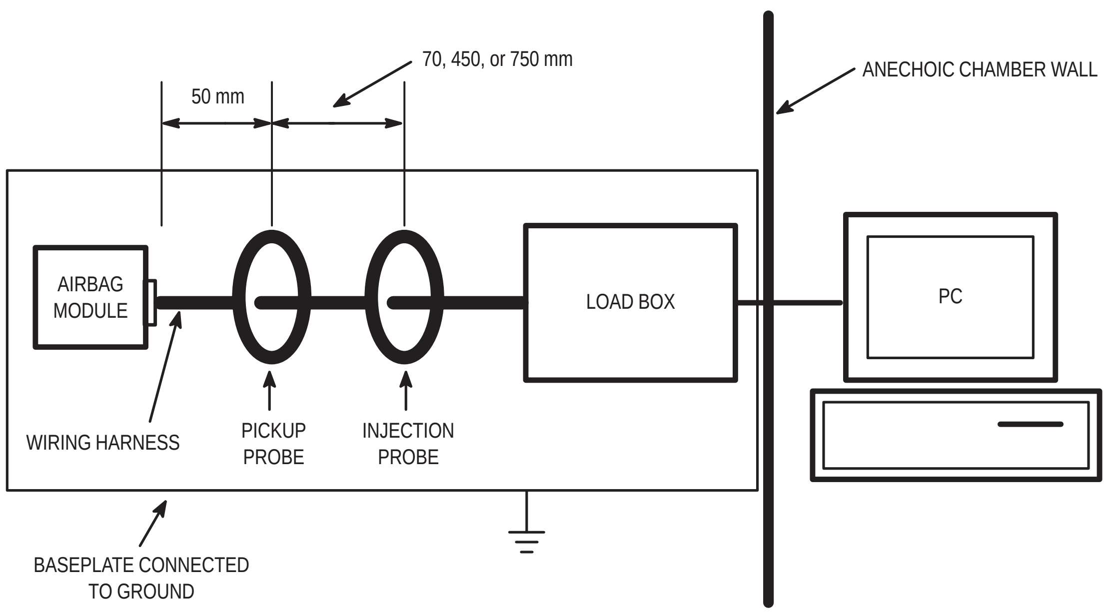

Figure 1. BCI Test Setup

The harness connects the airbag module to a load box. This load box provides simulated loads for terminating the remainder of the airbag system (firing ignitors, etc.). The data coming back is translated from J1850 to RS232 to be communicated to a dummy terminal on a PC. For safety reasons, this test is typically performed inside an anechoic chamber to shield high frequency emissions from equipment and humans.

BCI TEST PROCEDURE FOR THE MMA ACCELEROMETER

The accelerometer is evaluated in the following manner. In an airbag system, the microcontroller's A/D converter digitizes the accelerometer output. The microcontroller sends this value to the communication ASIC which translates the logic from board level logic to RS232, then sends the value back along the wiring harness. Once through the chamber wall, the data is translated to RS232 and fed to a dummy terminal. On the terminal screen, the A/D codes for the accelerometer can be monitored for unexpected performance.

Ideally, when the accelerometer is at rest (no acceleration applied), the output should be at 0*g*, regardless of what EMC testing the system may be subjected to. Depending on the crash algorithm of the airbag module software, there is some allowable offset shift that can be tolerated. Higher shift in output could create errors in the crash analysis software, perhaps causing the airbags to unnecessarily deploy when there is not a crash or not deploy when there is a crash.

The Motorola accelerometer must be able to meet the airbag system requirements throughout BCI exposure. It has a sensitivity of 40 mV/g and an offset (0*g* output) of 2.50 V. During the BCI test, the accelerometer output should be 2.50 V at 0*g* with as little drift as possible. A typical airbag system may have software that can tolerate from as little as 0.5 *g* up to 2.0 *g*. of deviation from the offset. The system would then expect the accelerometer output to be within 40 mV of the offset during the entire BCI test. Therefore, at any given frequency of the BCI test, if the output deviates outside this expected window of drift, it fails the test.

MMA ACCELEROMETER BCI TEST RESULTS

If a system has not been well designed for electromagnetic compatibility, the accelerometer, as well as other devices, can have performance problems. What has been found for the accelerometer is that in some system applications, it suffers from an offset shift when certain frequencies of BCI are applied. For example, in one airbag system being tested at a certain frequency, with the desired BCI current applied, the offset is found to shift down by 60 mV. This would equate to an error of 1.5 *g*. See Figure 2. At other frequencies, this shift is even higher. This DC shift plot was taken with an oscilloscope using a 20 MHz filter to remove the high frequency component of the signal. Probes are placed at the accelerometer in the system application. The plot shows the accelerometer output before and after BCI was applied (before and after the RF generator creating the high frequency signal was turned on).

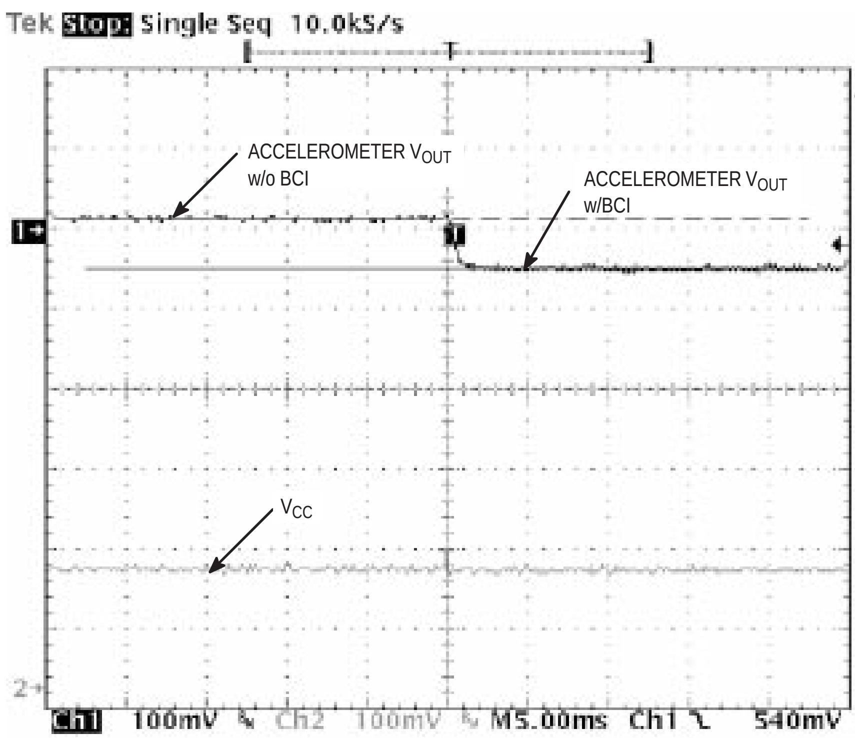

Figure 2. Accelerometer Tested Under High Frequency BCI

This phenomenon has been determined to be system level related. PCB layout and grounding for the accelerometer will affect its performance. This was found by testing the accelerometer outside of the airbag module. The device was put on a test board by itself with only the supply decoupling capacitor of 0.1 µF connected to it. To simulate the effect of BCI on Vcc, a frequency generator was used to inject a known high frequency sinusoid that caused BCI failure on to the 5.0 V supply voltage. The device was first tested in small test board with ground provided by one wire back to the supply. This grounding reproduced the failure due to BCI seen at the module level. The test board was then mounted down to a ground plane provided by a copper plate and the accelerometer ground was soldered to the plate (providing a low impedance path to ground). With this setup, the offset shift did not occur.

If a system does not incorporate a good PCB layout providing a low impedance to ground, the accelerometer output may shift at certain high frequencies. This output offset shift was caused by a shift in the 0–5 V supply window. Because the accelerometer has a ratiometric output, its offset is dependent on the supply voltage. Any change in the supply voltage will result in the same proportional change in the output. For example, if the 5 V supply were to change by 10%, from 5.0 V to 5.5 V, the accelerometer offset will change by 10% also, from 2.5 V to 2.75 V. This phenomena would also occur if the ground were to shift. A 100 mV change in ground would result in a 50 mV change in the output. If the accelerometer does not have low impedance path to ground and parasitics from a poor ground are present as a result, the ground seen by the accelerometer may change over frequency. So, during a BCI test, if the 5.0 V supply does not shift but the output of the accelerometer does, the ground to the accelerometer may be moving.

It was found with some experimentation that the offset shift can be eliminated with proper board layout techniques as described below.

PROPER LAYOUT TECHNIQUES

Since the Motorola accelerometer is a sensitive analog device that relies on a clean supply to function within established parameters, there are some techniques that can be employed to minimize the effects of BCI on the accelerometer performance. PCB layout is paramount to reducing susceptibility to BCI.

- A low impedance path to ground will provide shunting of the high frequency interference and minimize its effect on the accelerometer. The best way to provide a good path is by putting a solid, unbroken ground plane in the PCB. This ground plane should be shunted to chassis ground at the module connector. This will ensure that the high frequency BCI will be shunted before interfering with accelerometer performance.
- All accelerometer pins that require ground connection should be tied together to a common ground.
- Traces attached directly to the connector pins can receive high RF noise, which can couple to nearby traces and components. Increasing series impedance of the traces helps reduce the couple or conducted noise. High frequency filters on the supply line and other susceptible lines may be required to filter out high frequency interference introduced by the BCI test. Signal lines that carry low current can tolerate series resistances of 100–200 Ω.
- Decoupling capacitors on every input line to the common ground plane will help shunt the high frequency away from the system. These should be placed near the connector.
- Signal trace lengths to and from the accelerometer should be kept at a minimum. The shorter the trace, the less chance it has of picking up high frequency BCI signals as it crosses the board. Trace lengths can be reduced by placing the accelerometer and the microcontroller as close together as possible. Signal and ground traces looping should be minimized.
- A decoupling capacitor on the accelerometer Vcc pin will also help minimize BCI effects. The recommended value is 0.1 µF. This capacitor should be placed as close as possible to the accelerometer to achieve the best results.
- To maximize ratiometricity, the accelerometer Vcc and the microcontroller A/D reference pin should be on the same trace. The accelerometer ground and the microcontroller ground should also share the same ground point. Therefore, when there is signal interference due to BCI, the A/D converter and the accelerometer will see the interference at the same level. This will result in the same digital code representation of acceleration without signal interference.
- A clean power supply to both the accelerometer and the microcontroller should be provided. Supply traces should avoid high current traces that might carry high RF currents during the BCI test. The traces should be as short as possible.
- The accelerometer should be placed on the opposite end of the PCB away from the connector. The farther the distance, the lower the chance high frequency RF from BCI will interfere with the accelerometer.
- The accelerometer should be placed away from high current paths that may carry high RF currents during the BCI test.

Automotive customers will continue to require airbag systems to have high standards for EMC. One way to test for EMC is perform the Bulk Current Injection test. Because of the high current involved, BCI is one of the most difficult EMC tests to pass. Being part of the airbag system, the accelerometer must continue to function normally under application of high frequency BCI. The accelerometer is highly sensitive to placement on the board and its connection to ground. Poor design will caused the device to fail the BCI test. The practice of good PCB layout, device placement and good grounding will allow the accelerometer to function within specification and pass the BCI test.

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