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EMC Considerations for Automotive Sensors

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ABSTRACT

Electro–Magnetic Compatibility (EMC) is a qualification requirement for automotive electronic components. Meeting this requirement can be a challenge, especially for devices in plastic packages with minimal shielding. EMC has a twofold meaning:

a) radiation of electromagnetic energy below a certain level in order to prevent negative impact on electrical performance of surrounding devices, and
b) lower susceptibility or greater resistance to the present electromagnetic (EM) signals.

Our concern in this paper is “b)” susceptibility of pressure sensors with integrated signal conditioning including amplification. Electrical performance of these sensors in an environment that is more and more contaminated with EM energy is very crucial for a number of automotive applications. The Integrated Pressure Sensors (IPS) will be used as an example for EMC testing. The EMC test setups and characterization results of the IPS will be discussed.

INTRODUCTION

Micromachined piezoresistive pressure sensors have been used successfully for over a decade in automotive manifold absolute pressure and barometric absolute pressure measurements. The EMC of these units was usually assured by shielding inside the module or the module housing itself. More recently, piezoresistive sensors with integrated signal conditioning have been qualified for automotive usage. A block diagram of a micromachined pressure sensor with integrated signal conditioning is shown in Figure 1 [1]. The key to the IPS is a single small silicon area with all of the calibration trims performed on the chip itself. This small die size allows the chip to be installed in a small surface mount package for subsequent assembly in an automotive electronics module. A metal can package offers improved immunity to radiated EM interference when the package is well grounded but is more costly and does not provide a surface mount assembly. It does not provide improvement for lead–conducted EMC.

A plastic chip carrier package designed for high volume, cost–sensitive pressure sensor applications is shown in Figure 2 [2]. A single mold forms both the body and back of the chip carrier. This surface mount package provides low cost with few process steps and is applicable to relatively high pressure range (up to 724 kPa or 105 psi). The leadframe assembly technique allows easy handling of several devices at one time and the automation of assembly operations such as die bond, wire bond and gel filling operations. Automation allows tight process controls to be implemented and still provides high throughput.

EMC is a major concern for the plastic–packaged IPS, especially when it is installed inside a module that can have high frequency switching such as ignition coil drivers. Addressing these concerns through repeatable EMC testing requires: a careful test setup, well–defined test method and a documented data measurement technique.

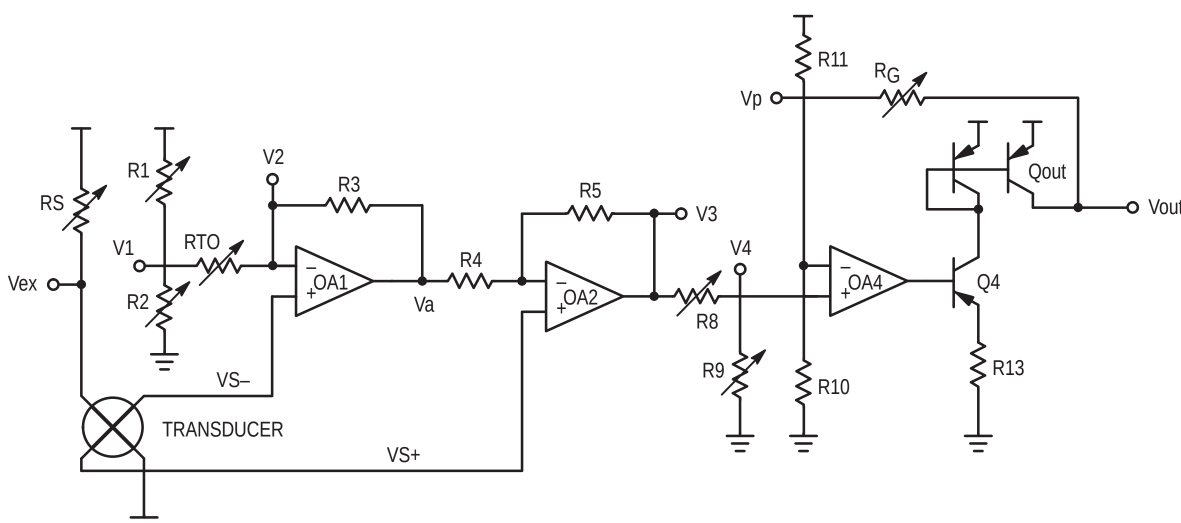


Figure 1. Integrated Pressure Sensor Block Diagram

REV 1

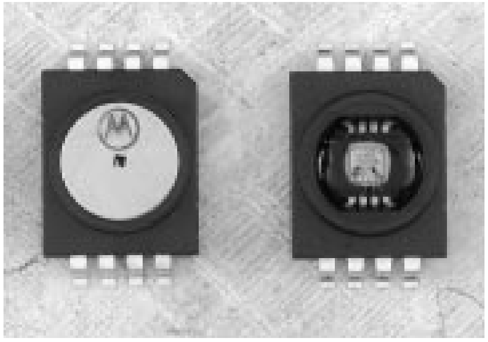


Figure 2. Plastic Package for Integrated Pressure Sensor. Shown with and without cover.

EMC TEST SETUP

One of the difficulties in EMC testing is ensuring that the test results can be repeated at different labs, conducted by different people and still give the same results. A test method which accomplishes this will be described in full detail. In the following section, where results will be discussed, other methods will be briefly mentioned and discussed as well.

Testing was performed within a USC–2 EMI anechoic shielded enclosure. The facility is a solid–wall shielded enclosure with filtered power. USC–2 is specifically designed with 1.2 meter (4–foot) anechoic cones to minimize shield room reflections.

The device under test (DUT) was mounted vertically in a socket on the top of the standard aluminum boxes (approximately 7.6cm x 10.2cm x 7.6cm or 3″ x 4″ x 3″) containing additional shielding (copper tape). The box is meant to reduce the effects of interface cabling and test the susceptibility only of the sensor package and die inside. SMA connectors are located at the side of the box to supply power and receive the sensor output. In the setup, semi–rigid cable was run directly to the SMA connectors (see Figure 3).

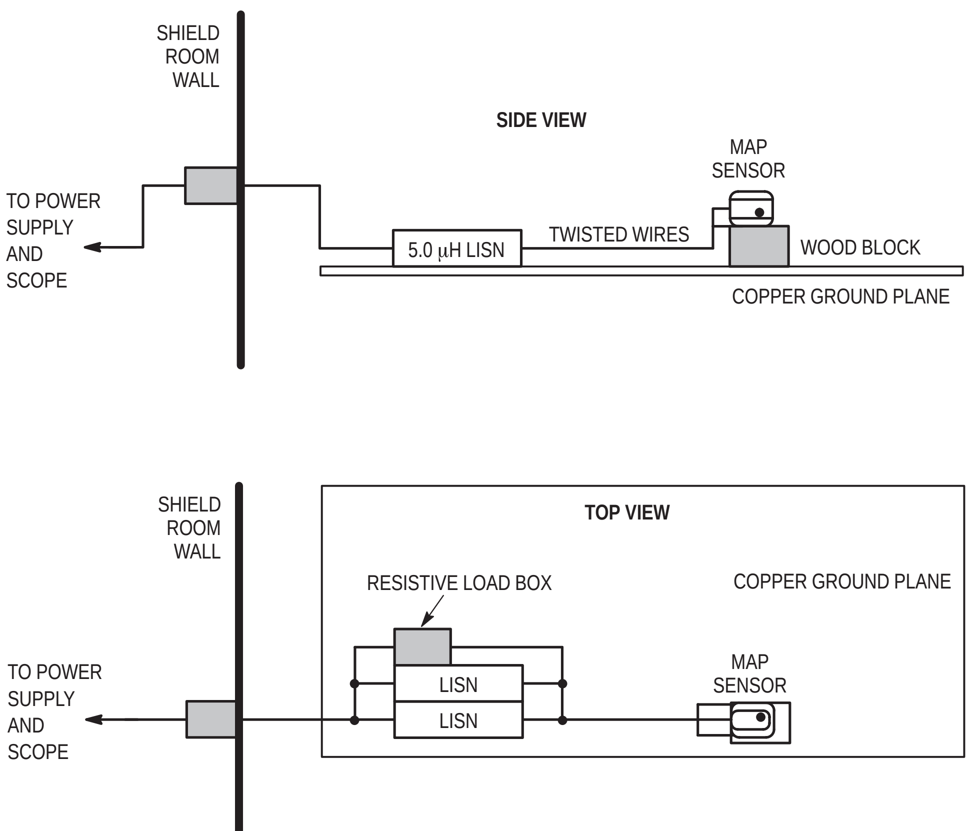
Qualification testing for the IPS required performance at 200 V/m radiated immunity — from 10 kHz to 1 GHz. This is one of the higher signal strength levels that is specified. However, required performance depends on the customer specification. Over thirty EMI specifications have been reported for engine control applications around the world — there is no common standard (3). The test was also extended to higher frequency to evaluate influence of the 1 to 18 GHz signals. The general test procedure selected was SAE J1113 AUG 87 — Electromagnetic Susceptibility Measurement Procedures for Vehicle Components (Except Aircraft).

Test Specification

The following field characteristics were defined:

Field Strength = 200 V/m
Frequency Range = 1 kHz to 1 GHz
Modulation = AM, 30% with 1 kHz sine wave.
Polarity = Vertical and horizontal

Criteria for acceptable performance of DUT:
AC ripple ≤ ±50 mV



Test Conditions:

a) Located in anechoically shielded room.

b) Interface wires routed 5 cm over ground plane, 10 cm away from front edge.

c) Interface wires twisted.

d) Sensor 10 cm above ground plane.

Figure 3. Test Setup for EMC Measurements

EMC TEST METHOD

From 10 kHz to 200 MHz the parallel strip line antenna was used to generate the required field strength. In the 30 MHz to 200 MHz region horizontal polarity was achieved by placing the components on their side.

From 200 MHz to 1 GHz the EMCO 3106 Double Ridged Guide antenna was used. Horizontal polarity was achieved in this range by changing the polarity of the antenna. From 1 GHz to 12 GHz the EMCO 3115 Double Ridged Guide antenna was used. From 12 GHz to 18 GHz a standard gain horn was used.

The incident field was measured using isotropic field monitoring probes (the IFI EFS–5 from 10 kHz to 200 MHz and the Narda 8719 from 200 MHz to 18 GHz) which were placed near the DUT and monitored in real time. Auto leveling was used to achieve a uniform field strength with respect to frequency.

DATA MEASUREMENT TECHNIQUE

Data collected from this test were as follows: (a) the amplitude of the ripple at the component output when the applied field strength is 200 V/m and (b) the DC output signal shift.

For the type (a) measurement, the component voltage output was run into a Tektronics 2440 oscilloscope, which was operated in the envelope detect and scroll mode. This enabled the oscilloscope to display the peak–to–peak Vout reading over a 50–second scan period. Since the scan frequency is directly related with time, the resulting plot showed an envelope of the output voltage with respect to scan frequency.

TEST RESULTS

Tested pressure sensors did not exceed either the AC ripple or DC offset susceptibility criteria over the 200 MHz to 1 GHz frequency range. Measurements were repeated several times over time periods as long as several days with the same test setup and results show very similar values. The DUT showed minor ($<$ 300 mV) DC variances in the above frequency range. Figures 4 and 5 depict the common AC response in the frequency ranges 200 to 500 MHz and 500 to 1000 MHz, respectively. Figures 6 and 7 illustrate typical responses in lower gigahertz range of the same parts. Notice the scale of the vertical axis in Figure 6 is 500 mV per division, while in Figure 7 it is 50 mV per division. The samples did not show a susceptibility greater than +/– 50 mV for frequencies between 2.5 and 18 GHz.

These results verify that the plastic packaged integrated pressure sensors are not very susceptible to the surrounding electromagnetic field. However, the test setup plays a significant role in defining the device response and real susceptibility. Furthermore, due to the number of specifications that exist and to verify acceptable performance of product in the plastic package for two specific applications, additional tests were conducted. The results for these alternate techniques will be discussed in the next two sections. IPS devices were tested both in GTEM testing and with RF directly injected into their leads which is more appropriate for automotive applications. Direct injection is known to be a more demanding test for EMC performance and a narrower frequency range is normally specified by customers for this test.

GTEM GTEM testing was carried out at a field strength of 100V/m with a frequency sweep from 2 MHz to 1 GHz. Products from the same family but not necessarily the same DUTs in the previous tests were used for this testing. Each device was fitted with a 5 cm harness, which acts as the antenna for the RF signal into the device circuitry. This harness was taped in a secure position parallel to the E–field in all tests. A standard load was placed on each DUT. This load consists of a 51K resistor and a 2200pF capacitor attached in parallel from the sensor output to ground.

Performance during this test was very satisfactory from 2 MHz to 500 MHz. Beyond this point the output fluctuations began to increase until a maximum peak was reached at approximately 930 MHz. This result shows that with simple additional filter circuitry, a module using the IPS device can have susceptibility well below the limits, especially for frequencies lower than 500 MHz.

Direct RF Injection Direct RF injection is performed by soldering the harness to an impedance network. The same signal level (100 V/m) used in the GTEM testing was injected directly into the leads. Results from this test were not surprising. As would be expected from an unprotected (no additional filter) element, its output was not immune to the RF interference. Fluctuations of the output signal were significant. If the EM signal is radiated directly onto the device, susceptibility is very low for frequencies below 600 MHz and above 2 GHz. Between 600 MHz and 2 GHz some AC as well as DC shifts have been noticed.

To improve the performance when the EM signal is injected into the device leads, additional passive components, such as three–terminal capacitors, can stabilize the response and almost fully eliminate susceptibility. This is a significant result for further development of the integrated sensors. Figure 8 demonstrates the performance with the addition of these components using the method shown in Figure 3 and the higher 200V/m field strength.

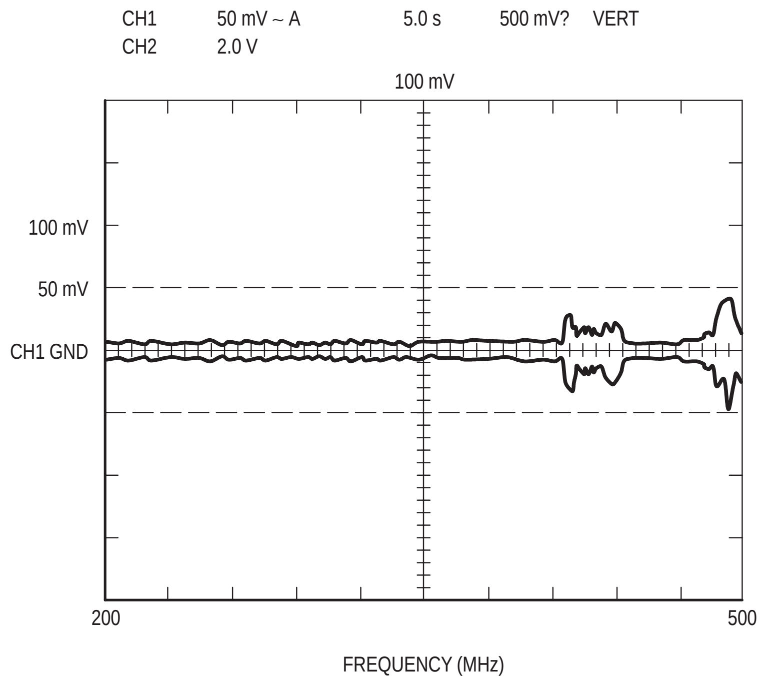


Figure 4. Common AC response in the 200 to 500 MHz frequency range.

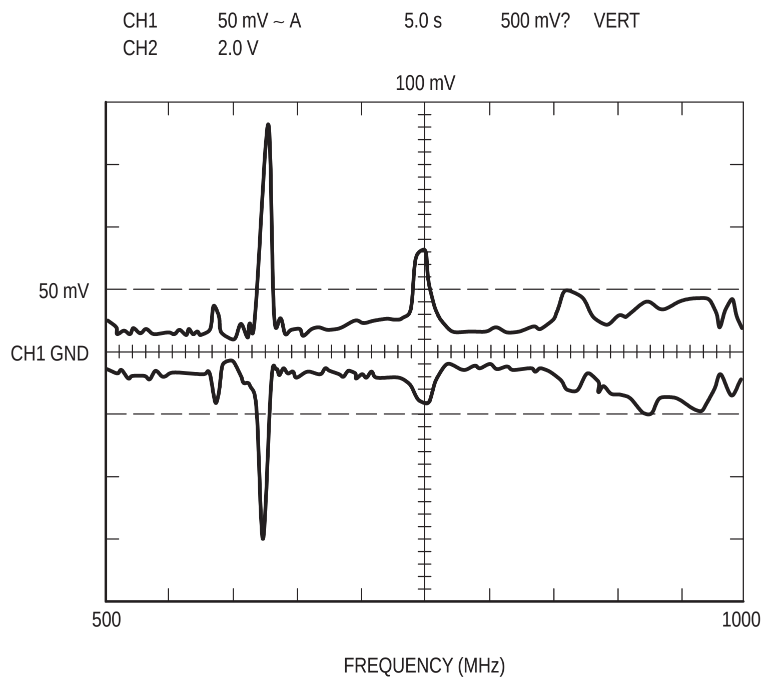


Figure 5. Common AC response in the 500 to 1000 MHz frequency range.

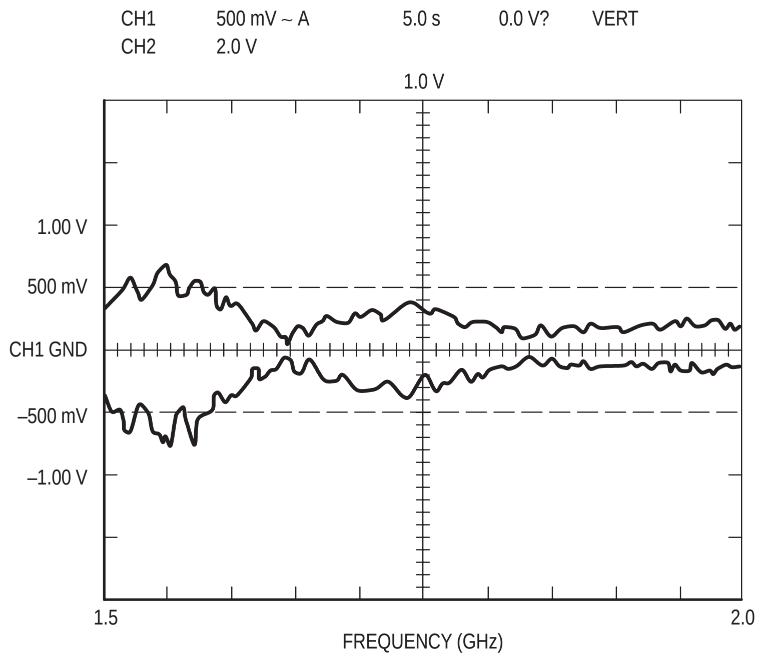


Figure 6. Typical responses in lower gigahertz range of the same parts. The scale of the vertical axis is 500 mV per division.

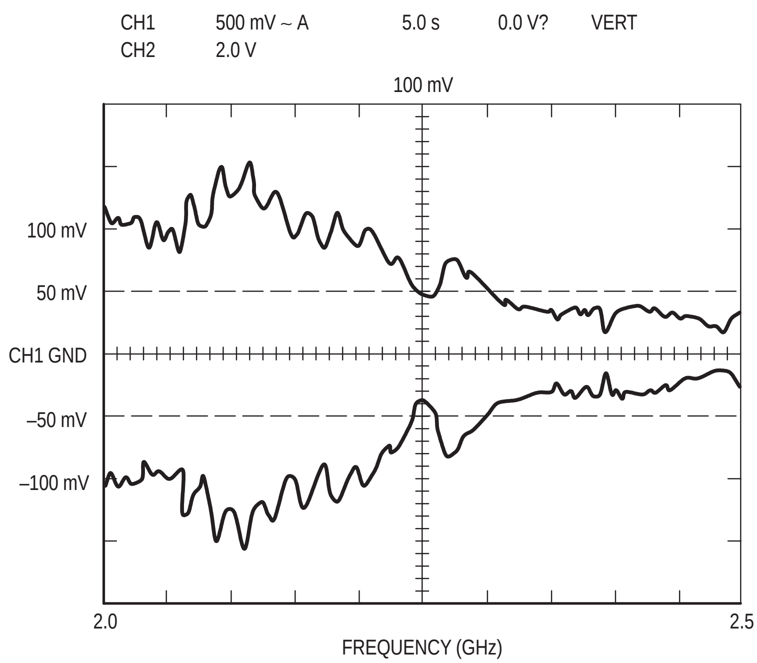


Figure 7. Typical responses in lower gigahertz range of the same parts. The scale of the vertical axis is 50 mV per division.

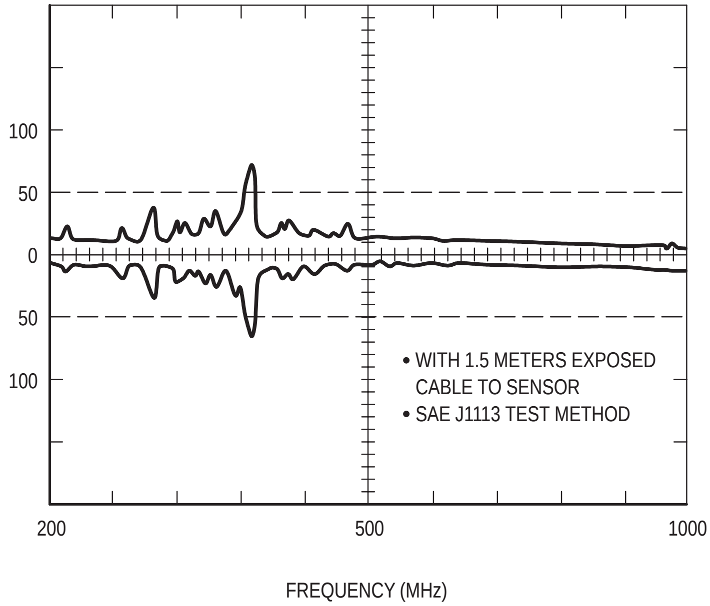


Figure 8. EMC results of MAP sensor with additional (external) filter.

CONCLUSION

The plastic–packaged integrated pressure sensor has demonstrated very good immunity to the surrounding electromagnetic field. The exact performance depends on the test setup. Due to the number of different EMC specifications, several tests may have to be performed to qualify a product for the same application but with different customers. A filter technique has been tested that greatly improves the IPS' performance even under the toughest testing including the direct RF injection test.

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