MEMS PHYSICAL SENSORS FOR AUTOMOTIVE APPLICATIONS

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The automotive market has been a key driving market segment for the development of micro-electro-mechanical systems (MEMS). This paper provides an historical perspective on MEMS in automotive applications, examples of devices in production, requirements for the applications, infrastructure and specific engineering disciplines that have been developed to address these requirements, and a glimpse at future production applications.

Automotive MEMS applications began with the manifold absolute pressure sensor (MAP), developed by many companies in the mid-80s. Only the non-invasive blood pressure sensor and the ink jet print head rivaled this application as the initial high-volume micro-electro-mechanical device. An example of the progression of the MAP sensor through the years is shown in Figure 1. It illustrates the progression from the initial uncompensated, bulk micromachined piezoresistive pressure sensors through bipolar integration [1] to a CMOS-integrated, bulk micromachined pressure sensor with non-volatile memory allowing the incorporation of state-of-the art digital signal processing to add features like three-wire interface, changeable rail voltages, and improved accuracy to within +/- 1%FSS [2].

In the 1990s, the airbag-deployment accelerometer started high-volume production. Several companies developed surface micromachined, capacitive accelerometers. Examples of two of the accelerometers are shown in Figure 2. These examples represent a BiCMOS integrated micro-electro-mechanical device and a two-chip surface micromachined "g-cell" and CMOS interface IC. In this example, variations in the choice of integration and system partitioning are shown. Regardless of the level of integration, one prerequisite to MEMS for automotive applications to drive low cost has been to standardize processes [3].

Automotive applications have some stiff requirements. High quality and exceptional reliability are assumed. Performance is important, but cost (system cost) is perhaps the most important requirement. Cost for MEMS is often quoted as 10-20% MEMS, 20-30% circuitry, and the rest packaging and test costs [4-5]. Furthermore, MEMS are often stress sensitive devices. So, not only does the package affect the reliability of the part, it could also have a profound impact on the performance of the part. Therefore, mechanical modeling tools for the transducer and its interaction with the package are essential. Circuit design skills are required to continually improve performance while reducing cost (e.g., the CMOS-integrated DSP pressure sensor in Fig. 1). Also, package and test development should be considered very early in the design process. And, reliability engineering must be considered throughout the development process.

Even with the challenging requirements of the automotive market, its high volumes (ca. 15 million cars/year in the US alone), have provided incentive for continued development of MEMS for automotive applications. Emerging applications include low g accelerometers and angular rate sensors for roll-over, vehicle dynamics control, and navigation; networked accelerometers for airbag deployment; and tire pressure monitoring. Figure 3 shows examples of devices that are being sold into these markets today. These applications exemplify trends for the future, including multi-sensor clusters with wireline communication to a central ECU and wireless microsystems.

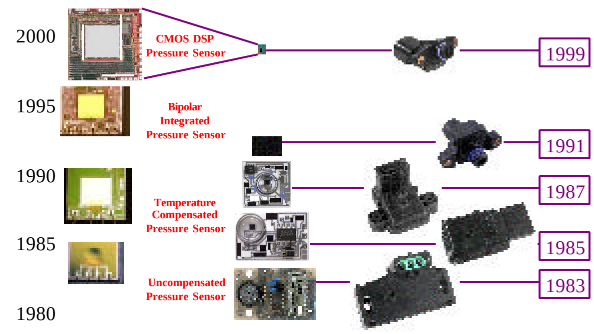

Figure 1. Examples of the Motorola manifold absolute pressure (MAP) sensor products from 1980 to the present.

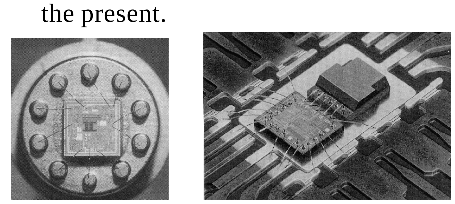

Figure 2. The initial Analog Devices (left) and Motorola (right) accelerometers for airbag depolyment.

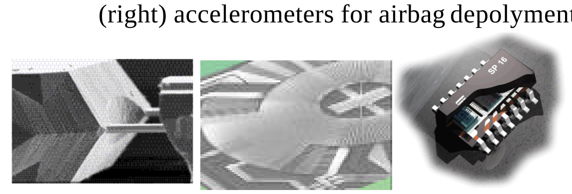

Figure 3. The VTI low g sensor (left), Bosch gyroscope (middle), and the SensoNor tire pressure monitor system (right).

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[5] J. Schuster and J. Swift independently in the "Rump Session," Solid-State Sensors and Actuators Workshop, Hilton Head, SC, 1998.

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