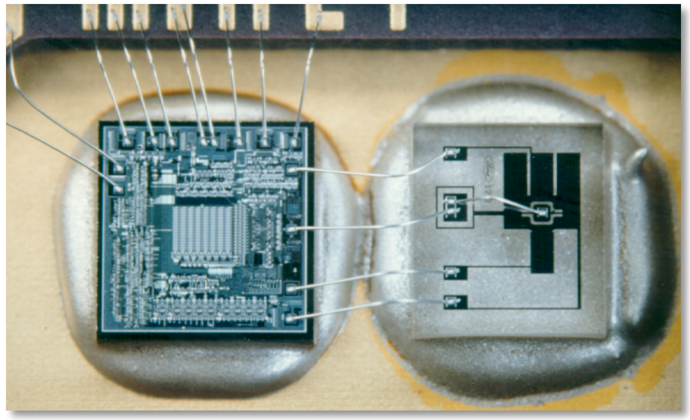
CASE STUDY

Integrated Silicon Automotive Accelerometer (ISAAC)

Design and manufacture a MEMS accelerometer for automotive applications.

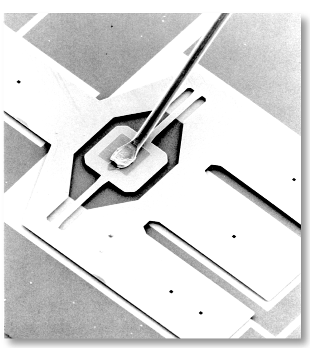


BACKGROUND: Until the mid 1990's automotive airbags used large mechanical sensors to detect an airbag worthy crash. MEMS technology provided a means to greatly reduce size and cost of these sensors while offering significant performance advantages. Despite the claims of accelerometer companies at the time, an accelerometer that met the size, performance and reliability requirements was not available.

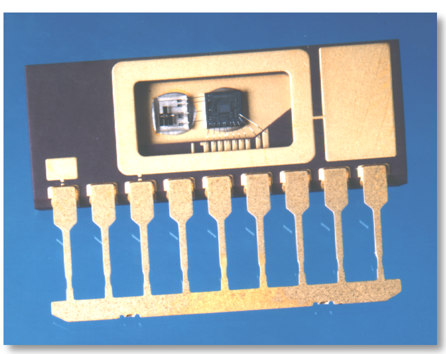
PROJECT DETAILS: The opportunity to develop a product in a highly vertical product development environment allows for a product to be optimized for the unique requirements of the system. Such was the case for the Ford ISAAC, which was designed to address performance and reliability shortcomings of other accelerometers being developed at that time. Starting with automotive airbag system requirements, an architecture for the accelerometer was selected that enabled the frequency response, temperature sensitivity and reliability objectives to be met within the time and financial limitations. This architecture called for a MEMS die, custom ASIC and package to be co-designed in a modular fashion to allow a wide range of accelerometers to be manufactured.

The initial version of the MEMS die used a glass-substrate, dissolved wafer process to realize a differential capacitive sense element. The sense element was over damped in a specific manner to provide the frequency response that was needed for the system. A central pedestal support and torsional flexures were critical in minimizing temperature sensitivity of the die, in particular that which would arise from the CTE mismatch between the die and the package. Electrical contact to the sense element was made via a wirebond to the pedestal.

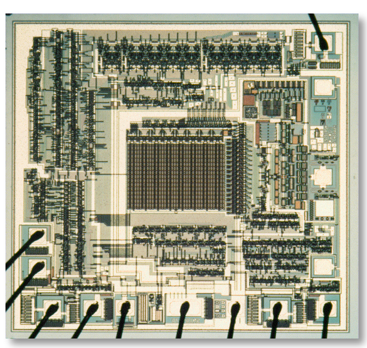
A custom CMOS delta-sigma modulator integrated circuit was also developed to convert the differential capacitance signal from the sense element into a standard output format. Non-volatile memory was incorporated on the chip to allow offset and gain calibration. The highly symmetric design was so forgiving that temperature compensation was not required. The two die were mounted in a custom CMOS package to provide the necessary orientation in the vehicle. This first version of the device met all specifications and was also proven to be well suited for airbag applications based on vehicle crash tests. This success led to the transfer of the program to Ford Microelectronics where the final development, qualification and manufacture of this first version of the product occurred.



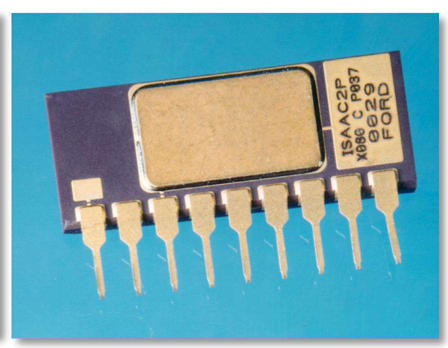
The glass substrate ISAAC sense element.



The first generation ISAAC in a ceramic SIP package.



The ISAAC interface chip with on-board calibration.

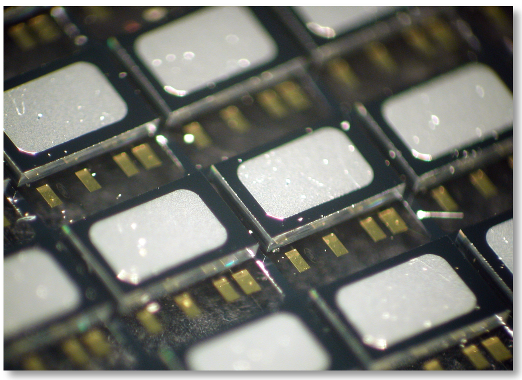


The completed first generation accelerometer.

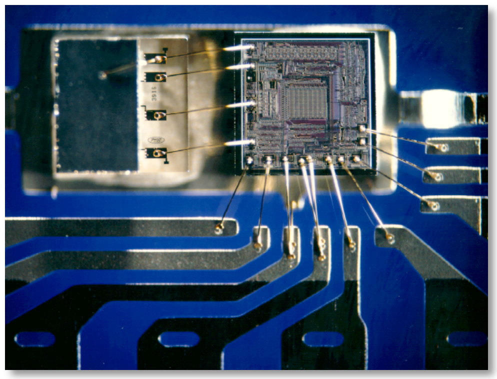
The next version of the device was aimed at reducing the cost of the package. A hermetic wafer-level packaging process was developed and combined with the previously developed MEMS die. Electrical connection to the MEMS structure along with horizontal feedthroughs was developed along with the silicon wafer capping process. A unique wafer-level test was developed to evaluate the hermeticity of the die in a production setting.

The subsequent MEMS die was combined with the original CMOS interface chip and packaged in a transfer-molded surface mount package. A special two-step molding process was developed to orient the die laterally to the mounting surface. After the die was assembled on the leadframe, a first molding step created a small protective housing. This was formed into a vertical orientation and molded a second time to put the die on it's edge. Lead trim and form operations along with ink mark completed the assembly process.

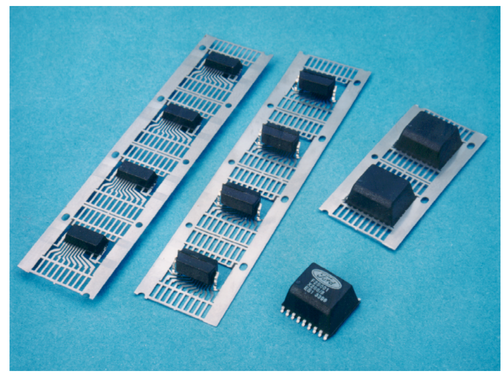
The completed devices were functionally tested and calibrated in a dynamic shaker table test apparatus. Both offset and gain calibrations were adjusted for the specific application requirements. Accelerometers were then mounted in airbag modules which were shipped to vehicle assembly plants throughout the world.



The wafer-level packaged ISAAC sense element after bond pad reveal.



An accelerometer prior to plastic molding



A photo showing each stage of package process to establish lateral die

RESULT: While the accelerometers of today are far superior to the ISAAC, it was one of the first accelerometers to be fully qualified and manufactured for use in the North American automotive markets. It was also the world's first wafer-level packaged accelerometer and the world's first plastic packaged surface mount accelerometer. Various models of the device were installed on over 12 million vehicles world wide within a 2-year time span. The mix and match design of the MEMS and IC die along with the packages allowed more than 25 different varieties of the accelerometer to be made covering a range from +/- 0.5g up to +/-200 g. Commoditization of the MEMS market specifically and automotive electronics in general lead Ford to sell the technology in the early 2000 time frame.