Tanner EDA

CUSTOMER CASE STUDY

MEMSIC

# ACCELEROMETERS IN THE BIRD'S NEST

## How does a designer make analog ICs and MEMS devices with the same tool, and get the resulting chip into the opening ceremonies of the Olympic Games?

It's hard enough to design mixed-signal processing onto the same chip as a MEMS device, but MEMSIC has managed to integrate these technologies on the same silicon and sell hundreds of thousands of accelerometers in a variety of industries.

The company has also overcome two other hurdles: keeping production costs low by sticking to a standard CMOS IC process, and standardizing development on a single, lean set of EDA tools.

### Detecting Acceleration and Motion

Most accelerometers depend on moving mass to determine motion, but MEMSIC differentiates itself from its competitors through its use of a thermo-mechanical sensor in silicon.

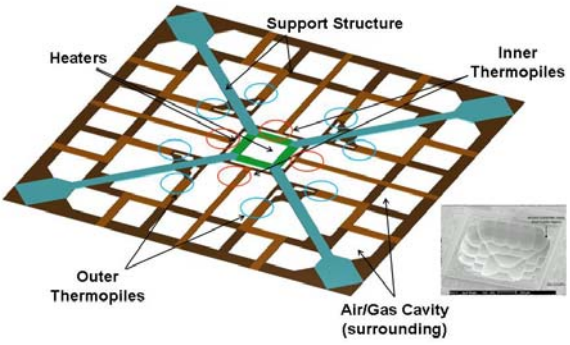
In the center of the 1mm-square sensor is a heater operating at 100°C above ambient temperature. Around the heater are symmetrically placed thermopiles for reporting temperature in different locations. (A thermopile is a series of thermocouples, or temperature-sensing elements, connected in a series to boost voltage.) The entire sensor is hermetically sealed in an air/gas cavity, outside of which is analog circuitry for amplification, control, analog-to-digital conversion and, in the 3-axis models, digital compensation/calibration circuitry.

In the absence of motion, the thermal profile is balanced among the thermopiles, but any motion or acceleration modifies the convection pattern around the heater, such that the thermopiles in the direction of the acceleration become hotter than the others. The analog circuitry interprets the resulting signal changes from the thermopiles as motion and acceleration.

**"Tanner Tools have been 100% reliable for us ever since we started using them in 1999. We can work in Tanner Tools on MEMS design one minute and analog design the next minute. Plus, we've never had a tapeout error due to verification."**

**- Yongyao Cai**
**Director, Technology Partnership and Development**
**MEMSIC, Inc.**

*Basic Accelerometer Structure*




With no moving parts, MEMSIC's accelerometers are longer-lasting, more reliable, and as much as 25 times more shock-resistant (up to 100,000 g) than their mechanical counterparts for measuring tilt, inclination, shock, and vibration. The chips appear in products that require the control or measurement of motion, such as car alarms, mobile electronics, global positioning systems, elevator controls, patient monitoring devices and head-mounted displays for gaming.

### One Toolset for Analog and MEMS

"Back in the 1990s our design center used Tanner Tools, so we adopted them and have used them ever since," explains MEMSIC's Director of Technology Partnership and Development, Yongyao Cai. "Our accelerometers combine MEMS IP and analog circuitry IP, and the Tanner Tools are flexible enough for both our circuitry and the sensor.

"We model the sensor as a resistor, and we can also model it as a polarized resistor because the thermopile has polarity. Tanner Tools have been 100% reliable for us ever since we started using them in 1999. We've never had a tapeout error due to verification."

For the current generation of accelerometers, MEMSIC engineers use MEMS Pro, an application from SoftMEMS built on top of L-Edit for

designing and analyzing MEMS. In fact, early MEMSIC products were even simpler and did not require full mechanical simulation, so the MEMS designers worked directly in L-Edit.

The engineers at MEMSIC use MEMS Pro for 3D mechanical model extraction for finite element analysis. They use L-Edit to modify the details of the sensor and for layout. After layout they use Tanner L-Edit LVS and L-Edit Standard DRC. Finally, they export from L-Edit to a GDS layout file and send the result to tapeout for TSMC.

## MEMS Designs, CMOS Fabrication

To take advantage of lower fabrication costs, MEMSIC designs its sensors almost exclusively with standard CMOS layers: for example, the heater is gate polysilicon and the first layer of the thermopile is metal and polysilicon.

“We have a tremendous advantage over our competitors,” continues Yongyao. “Our process is almost independent of the fabrication foundry because our design is 95-99% CMOS. We can easily change process and foundry to take advantage of better production pricing. Our competitors, on the other hand, use proprietary MEMS processes, fabricating either by themselves or through a specialized foundry, and that is always more expensive than working with a traditional CMOS foundry.”

MEMSIC also enjoys an advantage when changing geometry. Most of its competitors are still producing at 1-2 micron, and a change to .25 micron in MEMS would result in a completely different process and a costly conversion. MEMSIC has produced in .6 and .25 micron – with .18 micron on the roadmap – and its standard CMOS IC process allows it to ramp up volume and production quickly after a change in geometry.

## 92,000 Accelerometers in Beijing

The marquee application of MEMSIC’s technology was in the electronic “Waving Torch” distributed to all attendees of the opening ceremonies at the “Bird’s Nest” Stadium for the 2008 Olympics in Beijing.

The torch resembles a 20-30cm wand, with a linear array of LEDs. Shaken from side to side, the torch tricks the human eye into seeing iconic Olympic images – symbols for major sports, the Olympic logo, Chinese greetings, and the five Olympic mascots – displayed in mid-air as the LEDs switch on and off. The core technology in the torch includes a MEMSIC algorithm and accelerometer (designed with Tanner Tools) to detect the user’s back-and-forth hand movement and to fire each LED as needed for the image.

“We worked on this project for half a year as an Olympic promotional tool,” says Yongyao. “The user waves the torch through the air, and the LEDs display the pattern according to the motion. It’s a good example of how much information an accelerometer can provide on position, orientation and speed.”

### FEATURED CUSTOMER

MEMSIC, Inc.

Andover, Massachusetts, USA

### INDUSTRY/APPLICATION

Micro-Electro-Mechanical Systems (MEMS) built into high-performance, low-cost accelerometers

### DESIGN CHARACTERISTICS

- MEMS integrated with mixed-signal processing circuitry on single chip
- Standard CMOS IC fabrication process
- Inertial sensor with no moving parts

### THE SITUATION

To keep costs low and performance high, the company needs to design MEMS-based accelerometers for production in a standard CMOS IC process.

### THE SOLUTION

MEMSIC has relied on the flexibility of Tanner Tools since 1999 to design standard CMOS layers into 2-axis and 3-axis MEMS containing both a thermal sensor and analog circuitry.

### TANNER EDA TOOLS

- L-Edit (Physical Layout)
- L-Edit Standard DRC (Design Rule Checking)
- LVS (Layout Versus Schematic)

## About Tanner EDA

Tanner EDA is a leading provider of PC-based electronic design automation (EDA) software solutions for the design, layout and verification of analog/mixed-signal ICs, ASICs and MEMS. Its solutions help speed designs from concept to silicon and are used by thousands of companies to develop devices cost-effectively in the biomedical, consumer electronics, next-generation wireless, imaging, power management and RF market segments. Founded in 1988, Tanner EDA is a division of privately held Tanner Research, Inc.

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