Siemens Digital Industries Software

Designing MEMS microphones from concept

MEMS design

Executive summary

Knowles Corporation discusses how they use Tanner L-Edit to quickly design MEMS microphones that employ complex polygonal and curved-structure geometry. Pete Loeppert, Vice President of research and development presents his team’s approach to MEMS design. He states, “High–end EDA tools are better suited to Manhattan-style geometry and keeping things ‘square,’ but everything we do in MEMS is circular. With L-Edit, I can go from concept to finished GDSII in about two weeks. There’s never been anything as easy to use for this as Tanner tools.”

Tom Dewey

Abstract

About the MEMS microphone market

Knowles Corporation has been credited with boosting the MEMS market in 2003 with the first MEMS microphone. In a recent press release from the company, they announced a milestone of 8 billion units sold. So, by all accounts, they have been successful. In fact, they are the market leader for MEMS microphones. You most likely speak to your friends through a Knowles MEMS microphone in your smartphone.

Knowles MEMS microphones

Knowles' MEMS microphones require creation and manipulation of complex geometry and integration of mask layout data with automated component assembly software. Knowles relies entirely on Tanner L-Edit for the complex geometries and manipulation of thousands of repeating elements at the heart of their MEMS designs.

When you make audio transducers for more than 60 years, eventually you can design almost anything even a heat tolerant microphone that fits into electronic assembly flow like any other component.

It's not easy, but Pete Loeppert, Vice President of R&D for the Knowles Acoustics Division, leads a team that figured out how to increase the high–temperature survivability of microphones. This temperature robustness has played a key part in productizing their MEMS designs which provide significant revenue to his company.

Why a MEMS microphone?

Since 1946, the parent company, Knowles Corporation, has specialized in microphones and receivers for hearing aids. The Knowles Acoustics Division has built a new business around designing and manufacturing MEMS microphones used in mobile phones and consumer electronic devices, and is making inroads to the entire microphone market. The division's business revolves around its answer to a thorny electronic problem.

Traditionally, microphone suppliers stack up individual components and assemble microphones one at a time. Most are cylindrical, about 6 mm in diameter by 1-2 mm high, and inexpensive enough to go into everything from phones to toys.

The problem is that traditional microphones are heat–sensitive, which precludes the use of lead-free solder and the option for surface mounting into circuits. So, most manufacturers of high–volume products resort to some kind of offline task, such as hand assembly or a special insertion machine, at the end of the mainstream assembly line to get around the fact that the microphones won't tolerate high temperatures or reflow soldering.

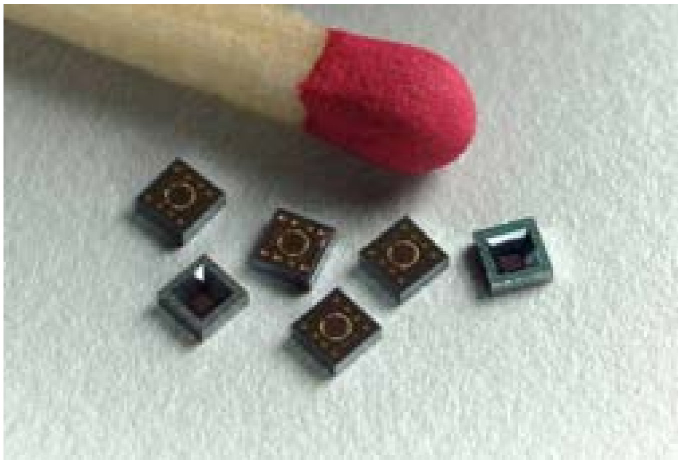

Figure 1: SiSonic™ MEMS devices.

Knowles' answer is the SiSonic™ MEMS microphone (see figure 1), batch–produced on silicon wafers and assembled like any IC, except for an air pocket that allows sound waves to vibrate the diaphragm. The SiSonic is re-flowable, so an assembler can place it on a circuit board with a chip shooter like any other component. Suddenly, microphones fit in with normal assembly flow.

The world of toroidal geometry

Loeppert describes the difference in design paradigm: ”In MEMS there are no circuits per se, so we don’t deal in schematic versus layout. MEMS in our group is all about drawing complex polygonal and curved structures.”

“I used other high-end tools for years because we were doing circuit work in the background, but when the task is mainly to render complex geometries in these microphones, those tools have a lot of overhead, and they are awkward. Most of what we design and make is circular, based on tori—toroidal elements and toroidal sections—and there are almost no right angles in our designs (figure 2). You’ll find some circular symmetry, but most of the design looks like modern art.”

In the late 1990’s Knowles Acoustics moved entirely to L-Edit for MEMS design. In particular, Loeppert cites the flexibility of manipulating thousands of repeating elements through L-Edit’s hierarchical architecture.

Said Loeppert, “L-Edit has saved me a great deal of time in creating all sorts of shapes that are parametrically driven. In fact, I always have my circles, pie wedges and tori instanced slightly differently in every layer, because I use them as primitives. I might have been able to do this in a tool like AutoCAD®, but I’d have wasted hours going back and forth between mechanical design and EDA tools. I want to create and analyze designs in one environment, then send them out for photomask fabrication.”

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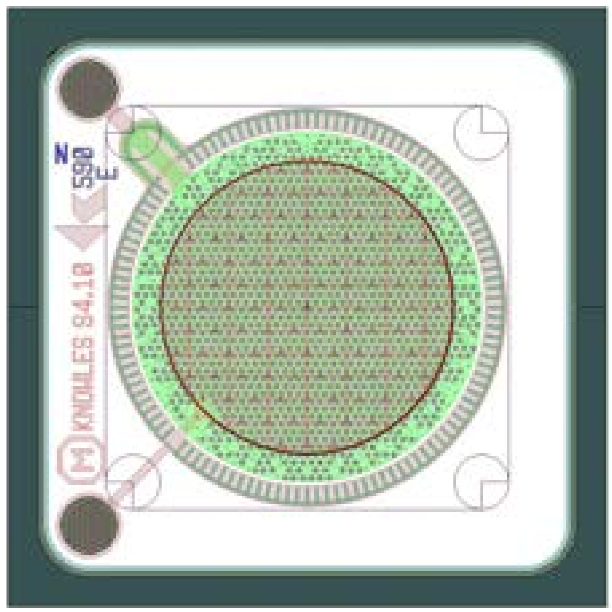

Figure 2: MEMS shapes.

Design meets scripting

Loeppert's designs are not especially small—the die size is about 1 mm—but they are intricate, and drawings with 10-12 million objects are common. While MEMS design flow today does not lend itself to direct object generation through standardized libraries, L-Edit's scripting function makes creating and managing thousands of parametric objects extremely easy. High-end tools have highly specialized scripting languages, but users of Tanner tools can write scripts using ordinary C/C++ code.

"L-Edit's scripting function is very flexible and I use it often to create primitives with a one or two-page script,"notes Loeppert. "For example, in MEMS we often etch holes through our wafers and we cannot have die-intersecting the edge of the wafer, so we need to array our die in a circular pattern. I start with an instance of a dieand use L-Edit to make that into a rectangular array. Then I use a script that I have written to clip the rectangular array to fit within the wafer extents leaving a few millimeter exclusion zone around the edge. This is a big timesaver for us."

Loeppert takes advantage of L-Edit's scripting function for other tasks as well, "I have made mapping programs for die bonding pick-and-place equipment. The script goes through the database of cells in the layout and-automatically generates a wafer map—this is particularly important when working on a matrix design that has lots of different designs in it. I create the maps and assign different letters to different design styles, then tell the diebonding engineers to pick a particular letter out of the map. Being able to generate the map automatically saves an enormous amount of time."

Conclusion

Getting to the FAB

Design rule checking (DRC) is also different in the world of MEMS because there are few set rules. Loeppert has to create his own rules, or work them out on the fly with the fab. The cross-sectioning tool in L-Edit helps with this because it allows Loeppert to visualize his designs in the third dimension of stacked layers.

Loeppert exports to GDSII for handoff to his fabs. He notes two limitations peculiar to many GDSII toolsand-explains how L-Edit helps him get around them: “First, the fab can have instances only at 90/180/270/360 -degrees, and when I rotate things, I don’t always end up with these particular angles. I wrote a script for L-Edit that scans the database for any acute or obtuse angles and flushes them out for me. I ungroup each one, change it to be rectilinear, then later regroup it as it was originally.”

“Also, L-Edit supports user-controllable fracturing of polygons. This allows me to set the limits for the various mask fabrication vendors. We’ve never had a tool–related problem. Even when we encounter limitations in our vendor’s systems, L-Edit lets us easily overcome them. We have a very smooth interface with the fab.” Figure 3 shows a fabricated MEMS microphone.

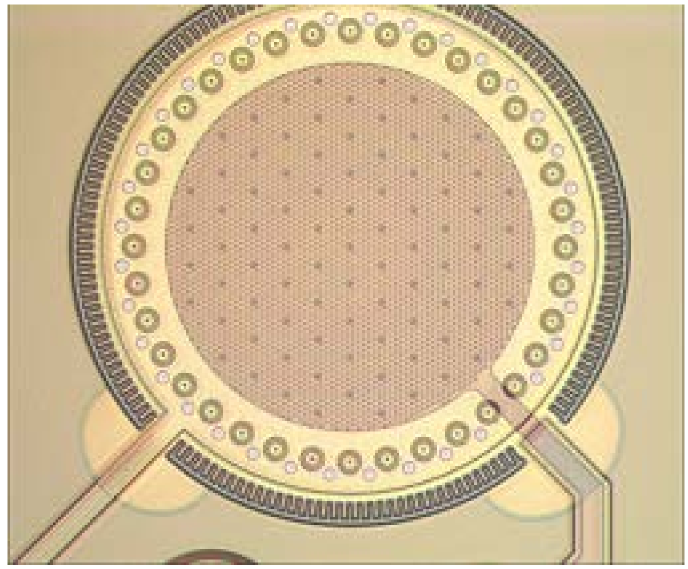

Figure 3: MEMS shapes.

According to the Yole Développement “Status of the MEMS Industry report for 2015”, Knowles dominates the smartphone microphone market. This report also predicts future growth in wearable devices, voice-controlled home automation, medical devices, and automotive systems. L-Edit will be right there to help develop MEMS microphone designs for these future markets.

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