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Planning for Successful MEMS Product Development

The world is waking up to the massive potential of MEMS. Those of us in the MEMS industry have believed in the promise and wonder of MEMS technology for decades, but until recently, MEMS devices played only anonymous roles, out of sight, in automobile safety systems and in the innards of ink jet printers. Now, thanks to the popularity of the iPhone and its many MEMS-enabled apps, engineers and product developers in all fields are aware of the benefits of MEMS and thinking about how the technology can be used in new and exciting ways. Many companies are now embarking on MEMS product development efforts.

This article provides some guidance to newcomers on how to plan appropriately for a MEMS product development effort. Our firm, A.M. Fitzgerald & Associates, located in Burlingame, California, provides MEMS product development services. We work with clients starting at the concept phase and perform design, modelling and small volume prototyping, squeezing out process risk and producing a robust design that can be quickly ramped to production at a foundry. After working with more than 70 clients on new MEMS products as diverse as long wavelength infrared imagers, tissue scaffolds, microphones, biological and chemical sensors, pressure sensors and optical waveguide switches, we have gained significant insight into how to successfully develop new products.

Technical challenges abound in MEMS, but this article will focus only on top-level business issues that are often overlooked. Fundamentally, executing a successful MEMS product development effort will depend on managing three things: the supplier ecosystem, time and budget.

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Building a Supplier Ecosystem

First, it's worth having a short historical review. Just 15 years ago, the MEMS industry was still quite young. Pure-play MEMS foundries did not yet exist. There were no MEMS-specific simulation software tools. Any company wanting to design, build and manufacture a MEMS device had to literally create all of their own resources from scratch. They had to build fabs, build specialised processing equipment and write their own code. Figure 1 illustrates the resources needed to build MEMS devices. 15 years ago, those resources resided only within MEMS companies, with the exception of suppliers who were already in the business of supporting semiconductor companies.

Back then, only very large companies had the money and resources to build an internal, integrated supplier ecosystem. And they did. The top MEMS manufacturers today, ranked by revenue, are almost exclusively large companies with captive fabs and internal resources, such as HP, Texas Instruments, ST Microelectronics, Bosch and Seiko Epson.

Since then, the MEMS industry has matured, and part of that maturation process has resulted in the emergence of MEMS-specific suppliers. Today, there are many MEMS-specific foundries (APM, Micralyne, Silix, etc.), MEMS-specific process tools (DRIE, XeF₂, HF vapor), MEMS-specific EDA tools (Coventor, Intellisuite, SoftMEMS) and dozens of other suppliers in all categories. A new MEMS company no longer needs massive capital and internal resources. That company, however, has to construct its own supplier ecosystem, relevant to its specific technology needs, by building relationships with each of the supplier companies (Figure 2).

Building that ecosystem takes time. Each supplier needs to be evaluated for appropriate fit, service contracts and pricing need to be negotiated, and the relationship needs to be actively managed. Choosing an ill-suited supplier will cause delays and cost overruns that can ripple throughout the entire development effort. Because MEMS is lacking in standards (at any level, from material specification up through reference designs), placement of purchase orders almost always requires

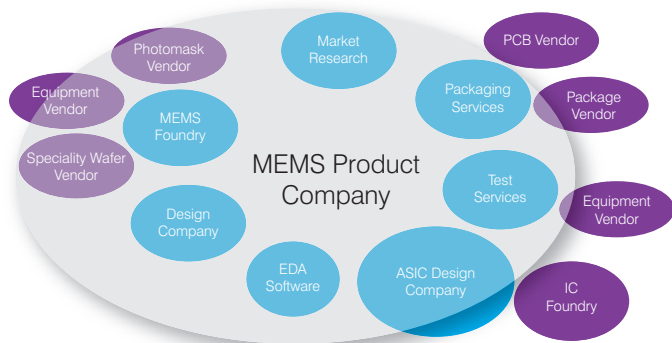


Figure 1. The MEMS Supplier Ecosystem, circa 1996. MEMS Product companies had to build and maintain many internal resources.

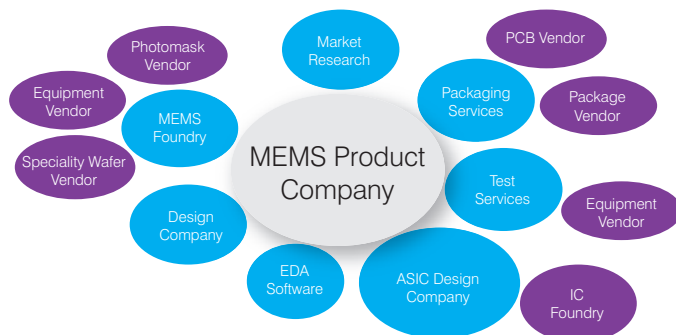


Figure 2. The MEMS Supplier Ecosystem today. Product companies no longer need massive internal resources, but must now assemble an ecosystem of external suppliers.

communication from engineer to engineer, not just between purchasing and accounting personnel.

The most critical supplier choice for a MEMS product company is that of the foundry who will manufacture the product. The foundry should be regarded as an important business partner, not just a vendor. The foundry's role will be to perfect the manufacturing of the MEMS product — improve yield, reduce manufacturing cost, delivery inventory on a timely basis — all functions which are vital to the success and profitability of the MEMS product company. It is a symbiotic relationship, so great effort should be invested in evaluating fit and long-term compatibility on both business and technical criteria. Because the foundry typically brings some process intellectual property to the MEMS product, a developed production process is usually not transportable. Switching foundries is tantamount to starting over — both in time and money.

MEMS product companies should also carefully consider wafer size when making a foundry decision. There is much talk and

excitement today about MEMS production on 200 mm wafers in high-volume foundries as being essential for long-term price competitiveness. While this is true for MEMS products manufactured in volumes exceeding 100 million units per year, any MEMS product that will fall short of that mark should carefully evaluate whether they truly need 200 mm wafers. Development on 200 mm equipment is far more expensive than development on 150 mm, and that NRE cost can generally only be recouped over very high volumes of wafers.

Furthermore, most 200 mm fabs will only accept high volume orders, typically 10,000 wafers or more per year. Figure 3 depicts the relationship between dies size, number of wafers per year, and number of units per year. Because MEMS die are usually small in size, wafer volumes tend to be low compared to semiconductor production volumes. Any company planning to sell fewer than 10 million units per year should give serious consideration to using 150 mm wafers only, unless the die size is very large.

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Planning a Realistic Schedule

In our experience working with clients on MEMS product development, we find a lot of unrealistic expectations about how long it really takes to do development and start production. While it's only human nature to be optimistic, we find that many people bow to pressure from upper management or investors to set aggressive schedules, or suffer from naïve assumptions based on experiences with the far more mature semiconductor industry.

One question we are often asked is, “Once we have a prototype, how soon before we can be in production?” Many think the answer to this question is less than a year, or even less than six months.

In Figure 4, all of the steps needed to first establish a relationship with a foundry partner, to transfer a prototype to the foundry, and then for the foundry to prepare for and ramp up to production are shown. The timeline illustrated below assumes that each step goes smoothly, and identifies which blocks are the responsibility of the foundry versus the MEMS product company.

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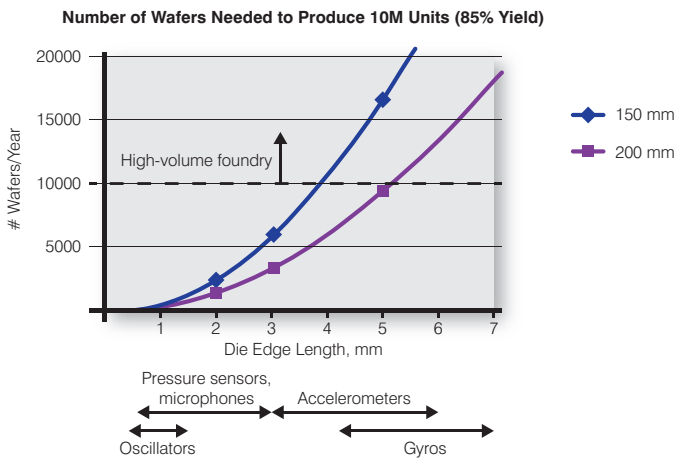


Figure 3. Not all MEMS products will need to be on 200 mm wafers. A company producing less than 10M units per year must have a die edge length larger than 5 mm before it makes sense to use 200 mm wafers at a high volume foundry.

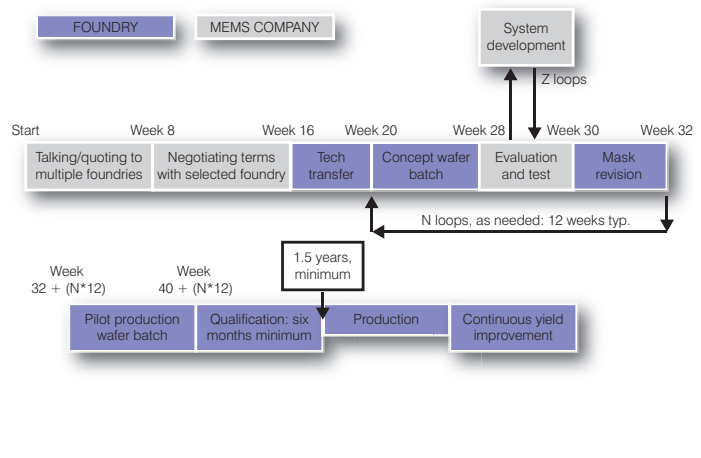


Figure 4. Expected timeline to take a mature prototype device into production.

To start, several months must be budgeted just for the process of meeting with and evaluating several foundries and for multiple rounds of both technical and business data exchange. MEMS product companies must understand that the foundries will also be evaluating their fitness as a potential customer. (For more insight on the foundry selection process, please refer to the MEMS Industry Group's "Foundry Engagement Guide.")

Once a foundry partner has been selected, the MEMS company's prototype and technology is transferred. First, a concept wafer batch will be fabricated using incoming knowledge. Because no two facilities have the same set of equipment, a process that successfully worked at a prototype lab may not immediately work well at the foundry. Adjustments must be made to process parameters, recipes, and sometimes the entire process flow to accommodate the foundry's equipment or standard process recipes. The first batch therefore may or may not produce working devices. Engineering batch production will continue until working devices yield, at which time the product company may need to

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do internal evaluation of the device performance and subsequently iterate the design. It's usually the case that many iterations are needed before both the foundry and the product company are ready to freeze the design and its process.

Once the design is frozen, the foundry's work is still not yet done. The next several months must be spent perfecting the process to improve yield and to establish process windows and quality criteria. Wafers produced during this period may be used as samples or be sold as product. Based on the timeline above, one should realistically plan to spend at least one and a half years going from prototype to production.

Of course, there are many other important steps to producing a product, such as packaging, test and system integration, all of which have their own timelines and risks.

Realistic Budgeting

In MEMS, there seems to be a constant underestimation of the amount of money it takes to bring a product to market. Part of the problem may stem from our semiconductor heritage; many

incorrectly assume that because MEMS are made on silicon wafers that they have similar wafer costs and development timelines as ASICs. The semiconductor industry, however, benefits significantly from standards and standardised processes, powerful simulation capability and well-established supplier ecosystems, not to mention 20 additional years for technology and operations optimisation.

Figure 5 illustrates bare minimum timelines and budgets for each of the major phases of a MEMS product development effort. This figure is only valid for simpler MEMS devices destined for niche markets that have less stringent testing and reliability qualifications. Producing a MEMS product for a high volume market (>100M units per year) could easily consume 4–10 times more money.

MEMS product companies need to bear in mind that end customers no longer want to buy just MEMS die; OEMs are seeking module-level solutions which require electronics, firmware, and mechanical and electrical interfaces. Appropriate time and budgeting must be considered for the entire system.

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In Summary

Jean-Christophe Eloy of Yole Developpment has famously quipped that for a MEMS company to succeed, it takes “4 years, \$40M, and 3—4 CEOs.” The examples and information presented in this article should provide some more insight into how and why one can spend a lot of time and money developing MEMS products. The good news is that it’s better than it used to be; the earlier pioneers in MEMS spent at least 10 years and well over \$100M to bring their products to market.

But the time to market is still much too slow and the MEMS industry risks missing out on exciting opportunities, particularly in the consumer electronics space, if it cannot find a way to make product

development more efficient at all levels. Part of the solution lies in developing appropriate standards, which when properly implemented, can streamline communication between all parties, make tools more efficient and squeeze cost out of production.

Our approach at A. M. Fitzgerald is to culture our own supplier ecosystem to support product development, so that we can save our clients the time and risk of having to develop their own. As the industry matures, we expect to see more consolidation and collaboration among suppliers, and the eventual emergence of Value Chain Producers, a business model that has been successfully employed in the semiconductor industry to speed new products to market.

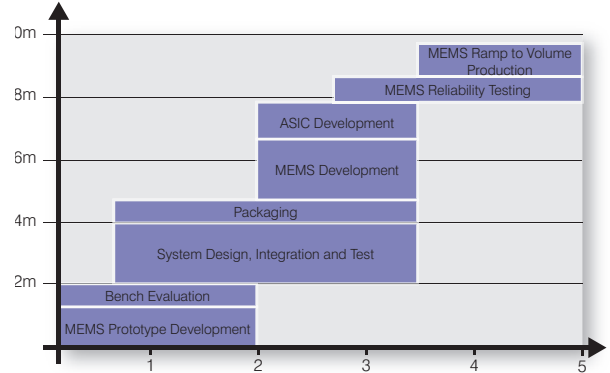


Figure 5: A fables MEMS company will need at least \$10M and 5 years to bring a product to market.

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a MEMS product development company located in Burlingame, CA, USA. Dr. Fitzgerald is a recognised expert in the areas of MEMS design, manufacturing and reliability. A.M. Fitzgerald is a member company in the MEMS Industry Group.