



Analog Devices, Incorporated: Microelectromechanical Systems (MEMS)

From a conference room on the top floor of the four-story semiconductor manufacturing facility, Ray Stata briefly took in the view of the Massachusetts Institute of Technology (MIT) campus. In particular, he noticed the building under construction that would soon bear his name. Asked how this particular honor felt, Mr. Stata responded with a humble shrug. However, when asked about the Microelectromechanical Systems (MEMS) business, Mr. Stata was willing to show considerable pride.

Mr. Stata was Chairman of Analog Devices, Incorporated (ADI), a company which he co-founded in 1965. MEMS was one division. He had invested a tremendous amount of personal attention and energy to the success of MEMS – and risked his reputation. In fact, without his vision and dedicated leadership, this ambitious, entrepreneurial effort would have collapsed under mounting losses several years earlier. During one three-year stretch, from 1997 to 2000, Mr. Stata had decided to simultaneously serve as Chairman of ADI and General Manager of the MEMS division in order to keep the venture alive.

In 2002, Mr. Stata regarded the MEMS business as a jewel. With worldwide technical supremacy that had been built over fifteen years, the business was profitable, and the long-term growth prospects appeared tremendous. Still, he readily acknowledged that many of his colleagues disagreed with his assessment that the business was an unqualified success.

One such colleague was current CEO Jerry Fishman. MEMS, though in its second profitable year, had only recovered a small fraction of its total accumulated operating losses since it commercialized its first product in 1992. Wasn't the jury still out?

Franklin Weigold, current general manager of the MEMS division, commented:

“I can easily make the argument that we have dumped millions into this business, but that past investment should be ignored. It's spent,

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it's gone, why worry about it. Let's just look at the return going forward. That makes my numbers look a whole lot better, and makes people feel better. But in reality, if I put all that investment in my denominator, I still haven't done a very good job in returning that investment. Ignoring sunk costs is just a rationalization."

Figures 1 and 2 show summary financial data for ADI and for the MEMS division.

The MEMS Division

The heart of industrial Cambridge, Massachusetts was in transition. Around the periphery of MIT, the growing biotechnology industry increasingly dominated the neighborhood. With modern, clean, and quiet laboratory and office buildings, biotechnology stood in dramatic contrast to two long-enduring establishments, the Tootsie Roll and Necco candy factories. Nestled between old and new, in a building once owned by Polaroid, was the five-year-old semiconductor production facility operated by the MEMS division of ADI.

Visitors familiar with semiconductor manufacture immediately recognized their surroundings inside of this facility. In an environment controlled carefully to maintain cleanliness, workers shuttled lunch-pail size boxes full of silicon wafers, about the size of dinner plates, from one machine to the next, through over four hundred batch production steps. With programmable computer controls, workers carefully monitored and adjusted the machinery which etched microscopic circuitry into each wafer. The machinery was similar to that used throughout the semiconductor industry. Ultimately, each wafer was cut and packaged into thousands of tiny electronic components.

For visitors unfamiliar with the semiconductor industry, the exotic nature of the work processes, the environment, and the expertise of the employees left lasting impressions. In addition, some were overwhelmed by the incredibly high cost of incredibly small objects. Contained within a total production space roughly one-fourth the size of a football field was capital equipment valued at close to \$100M. And each lunch-pail sized box contained tens of thousands of dollars of work-in-progress inventory.

Whether one was familiar or unfamiliar with the semiconductor industry, however, there was no visible evidence whatsoever of the most unusual thing about *this particular* semiconductor facility. The magic of MEMS was that they had *microscopic moving parts*. This enabled a wide variety of new applications for semiconductor devices. A workforce of 400 people produced nearly one million MEMS devices per week. It was the only facility dedicated completely to MEMS production in the world.

The initial application for MEMS devices was an *accelerometer*, a device for sensing motion. ADI's first MEMS product, the ADXL-50, was able to sense sudden accelerations of at least 50 Gs¹, and was used to initiate airbag deployment in automobiles. Improvements to airbag safety systems have been largely dependent on continued advancement of MEMS technology. For example, newer sensors measured accelerations in multiple dimensions, which enabled side airbag deployment, and measured angular accelerations, which allowed for deployment of airbag systems in the event of a rollover.

In 2002, sales to airbag manufacturers still accounted for 85% of the MEMS division's revenues. ADI produced 35% of all sensors used in airbag systems worldwide. Their primary competitor was Motorola. Their customers were 1st-tier suppliers of airbags and other components to the automotive industry, such as Delphi in North America (formerly known as Delco), and Siemens and Autoliv in Europe. Some airbag manufacturers, including Bosch in Europe and Denso in Japan, also manufactured their own sensors. There were a few other lower-quality competitors, who competed strictly on price.

The list of non-automotive applications was long and varied, and included video games, appliances, navigational devices, security devices, and new interface mechanisms with personal digital assistants and cellular telephones that were based on motion of the entire device. Other promising markets were just starting to develop. For example, MEMS devices were being designed into the next generation of switches for telecommunications networks. A significant bottleneck in such networks was the process of converting light pulses traveling through optical fiber to electrical signals, and vice versa. This functionality had to be built into telecommunications switches, which were controlled electronically. The next generation switch was all optical. The role of MEMS devices was to control the movement of thousands of tiny mirrors, enabling this switching process. There were also MEMS applications in medicine, such as tiny implantable devices for releasing pharmaceuticals.

ADI and the Analog Segment of the Semiconductor Industry

Most devices produced by the semiconductor industry were all-digital; that is, they simply manipulated ones and zeros. The biggest category of semiconductor products was microprocessors for computers, a category that Intel dominated. ADI's focus was on applications that involved analog signals—those that were continuously varying.

¹ One "G" is equal to the acceleration due to gravity – about 32 feet per second per second.

Such signals were required for most interfaces between electronic devices and the real world. Humans see and hear in analog. Most measurements, such as temperature and pressure, are also analog. ADI's core products were amplifiers of analog signals, and converters that translated analog to digital and vice-versa.

From inception through the 1980s, ADI's components were used primarily in military and industrial products. Most ADI components were low-volume or custom designs for specific applications. Significant design expertise was required for each product, and margins were high. ADI believed that their solid brand reputation was a reflection of their engineering talent, and helped them keep prices high. Pricing in the analog semiconductor niche was also attractive because analog components generally represented a small fraction of the total system cost.

Mr. Fishman, CEO of Analog Devices, believed that from a pricing and profitability perspective, the analog segment was the best place to be within the semiconductor industry. But there had been periods during which growth seemed less than assured:

“Ray [Stata] has *always* felt that the analog business does not grow enough to make us a truly great company. And in the late 1980s, it was hard to disagree. Our customers were primarily in the military and industrial sectors, and it appeared that growth would never again exceed 10% per year. We wanted to find other ways to take our technology and build a large company. So we looked to diversify.”

Figure 3 shows the rate of revenue growth for ADI's analog products over the period 1980-2000.

At \$2.6B in revenues in 2001, ADI was tiny by comparison to industry giants such as Intel, at \$26B. There was no obvious way to get from \$2.6B to \$26B. An internal analysis had once shown that even if ADI could find markets that allowed their core business, based on low-volume, design-engineering-intensive products, to grow to ten times its current size, they would need to hire literally all of the electrical engineers graduating within the United States to keep up with demand.

Though these facts certainly created some motivation, Mr. Fishman was cautious about diversification efforts. In his experience, getting new ventures to profitability always required much more time and much more capital than anyone was ever able to anticipate.

Meanwhile, the company's founder, Mr. Stata, was more worried about the implications of *not* trying to diversify. In his view, it was the CEO's primary job to “manage the S-curve.” The S-curve described the tendency of new businesses to grow slowly at first, then accelerate, then taper off to a mature, slow growth rate. The trick in diversification was to move into new markets early in their S-curves—just as older products reached maturity. Mr. Stata described his philosophy:

“It is all about detecting and managing the points of inflection. One can always do that with greater wisdom in hindsight, of course. But nonetheless there needs to be a sensitivity to the fact that everything has a life, and you always have to be looking beyond that life. ADI has been through some very significant transformations. The primary job of the CEO is to sense and respond...with the benefit of inputs from the organization...and to be at least an encouraging sponsor for those who see the future.”

In Mr. Stata’s view, it was impossible to invest in several new ventures simultaneously—doing so would starve existing, profitable product lines of needed capital. He believed that investing 10-15% of the R&D budget in new opportunities that were at the margin of the core business (as opposed to opportunities either closely related or completely unrelated to the core business) was sensible in the long run.

Though their initial expectations for new ventures may have been consistently lofty, ADI had in fact reinvented its product line several times through its history. From its root as a manufacturer of amplifiers, it had moved to circuits with greater functionality such as converters, to digital signal processors (DSPs), to MEMS. The diversification to MEMS began long before DSPs matured. In fact, DSPs reached profitability in 1999, only two years before MEMS.

The DSP opportunity arose in part out of an increasing demand for multimedia functionality in computers and networks. As computer makers increasingly differentiated their end products by adding high quality audio and video functionality, their signal processing needs increased. Their system designers also needed to save space. Typically, a system included two chips sold by two different manufacturers, one for amplifying and converting analog signals to digital, and another to process the digital signal. ADI created DSPs that included amplification, conversion, and digital processing all on one chip.

The DSP created a shift in the semiconductor industry. Markets for digital and analog components, once distinct, began to overlap. Formerly all-digital component makers started to sell products with analog functionality.

ADI’s business experienced spectacular growth in the late 90s, through 2000, driven by the explosion of investment in the Internet. Their products were at the heart of many Internet devices, such as PC modems and asynchronous digital subscriber line (ADSL) switches. ADI also manufactured components of mobile phones and wireless infrastructure equipment, and components for PC accessories such as flat panel displays, CD and DVD players, and digital cameras. These applications created impressive growth in ADI’s DSP revenues. By 2001, DSPs were in a similar position to MEMS. They were profitable but still had not recovered their full investment.

The explosion in Internet investment also accelerated growth of ADI's analog products. In fact, in 2001, analog products still constituted 80% of ADI's revenues (down from 97% in 1990). It was also in 2001 that much of the Internet-driven growth vanished. This included one of the most promising MEMS applications, components within optical telecommunications switches.

Three product line general managers reported to ADI's CEO, Mr. Fishman: analog, DSPs, and MEMS. Figure X shows revenues over time for each segment. Mr. Fishman's other direct reports included heads of global sales and manufacturing organizations, plus a CFO, a Vice President of Human Resources, and head of research. Heads of marketing, product development, business development, and logistics reported to each product line general manager.

Intrapreneurship at ADI

ADI's business is highly technical. Perhaps its greatest asset is its highly educated workforce with areas of expertise in electrical engineering, materials science, solid state physics, and other related disciplines. To ensure that voices of technical staff with entrepreneurial ideas have an opportunity to be heard, Mr. Stata created the ADI Fellows program.

“I think a lot of companies get in trouble because there is too much power in the management structure. They don't make it clear that management has a role, but they are not the end of the world...they are just part of the puzzle. There are others who are just as important or maybe even more important.”

Less than one percent of ADI's technical staff were Fellows. It was a coveted honor that reflected top-notch technical prowess, years of expertise at ADI, and leadership ability. Fellows made their own nominations, which were subject to approval by senior management.

Fellows knew that they had a real opportunity to change the direction of the company. They had a direct channel of communication to the CEO and the Board. In Mr. Stata's view, it was impossible for the CEO to understand all of the possibilities in the market without the direct input of the Fellows, especially since the market was so technical. Mr. Stata described the rationale for allowing Fellows to bypass business unit managers:

“Customers want you to continue doing what you are doing, if you are doing it well, and of course the managers running successful businesses within the company just want more and more resources to serve their customers. Taking resources away from successful

businesses and devoting them to high-risk experiments is anathema to business unit managers...it can only be done at the top of the company.”

Furthermore, technical innovators were often quirky and unusual, and difficult for managers to deal with. Leaving middle managers with too much power created too great a risk that the senior management team would not be informed of good new ideas.

While the Fellows program was motivating, some members of the senior management team, particularly those that were financially oriented, expressed some skepticism. Taken too far, the attitude that “if you have a good idea, we’ll fund it” could bankrupt the company. It was more important to attend to the needs of the core business.

CEO Jerald Fishman was never an easy convert for an aspiring Fellow with an idea: “People exaggerate. I’m from New York. I’m a cynic.” Mr. Fishman had come to believe that entrepreneurs *always* underestimated the money and time required to reach profitability – that was the only way to get funded.

Having studied the venture capital industry in depth, Mr. Fishman had a particular viewpoint on the essential reality of venturing – it was a calculated bet on a *person* more than it was a gamble on a *technology, market, or idea*. The Fellows program helped identify the best technologists, which Mr. Fishman believed were often the best businesspeople as well:

“Our best technical people are good business people. They understand the applications, the markets, and customers’ technical requirements. Some of our best businesses, worth hundreds of millions, are being run by engineers. The idea that you are either an engineering person or a business person is a fallacy.”

The Evolution of the MEMS Business

The history of MEMS at ADI can roughly be divided into four distinct periods, marked by shifts in leadership.

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- Under Richie Payne and Goodloe Suttler (to 1992)
 - Under Richie Payne and Franklin Weigold (1992-1997)
 - Under Ray Stata (1997-2000)
 - Under Franklin Weigold (2000-2002)

MEMS Under Richie Payne and Goodloe Suttler (to 1992)

In the mid 1980s, Steve Sherman, a chip designer at ADI, was told about the possibility of designing moving parts into semiconductor components from a visiting university professor. There had also been a summer intern at ADI whose father had experience designing acceleration sensors for missile guidance systems. Fascinated, Mr. Sherman started spending some of his spare time on developing the technology with an eye towards acceleration sensing applications. Mr. Sherman later approached Richie Payne, whom he understood to have a good aptitude for business development, in addition to manufacturing expertise. Together, he and Mr. Sherman began to visualize some commercial possibilities.²

At the time, Mr. Payne reported to Tom Irwin, a ADI vice president in Europe, who was heading a research effort to identify industries that might promise new growth for ADI. The study showed that while the automotive industry was growing slowly overall, automotive electronics was growing at roughly 10% per year, and automotive sensors at 20%. Mr. Payne narrowed his focus to sensors for airbag systems.

Mr. Payne had actually turned down an invitation to be an ADI Fellow (though he later accepted it). He had general management aspirations, and didn't want to be branded as a career technologist. In fact, he had tried to get ADI to send him to a four-month executive MBA program at Harvard. Mr. Fishman ultimately decided that the program was too expensive, both in terms of money and Mr. Payne's time. Mr. Payne understood from their exchange that he wasn't going to get an opportunity to run one of ADI's existing businesses, but if he could build one of his own, he could run it.

Mr. Payne and Mr. Sherman scraped by on borrowed time and borrowed resources until 1989. Although they had no official budget, they were able to attract additional help in engineering and marketing. It is doubtful that anyone in senior management was aware of the extent of their activity.

² Leifer, Richard, Chris McDermott, Gina Colarelli O'Connor, Lois Peters, Mark Rice, and Robert Veryzer, Radical Innovation, Harvard Business School Press, © 2000, p. 28.

When ready, Mr. Payne was able to take the concept directly to Mr. Fishman, a Vice President at the time, who recalled first hearing about the project:

“They demonstrated that they could actually get these microstructures to deflect and measure acceleration or deceleration. Still, I would say at that time I viewed it as a science project. In those days we probably had five or ten percent of our people working on science projects.”

Still, Mr. Fishman was impressed with Mr. Payne’s gifted leadership and his technical expertise – he had a PhD in solid-state physics. Mr. Payne was able to get people to rally around him, to invest their time in a vision, even if commercialization might be a decade away. Two ADI Fellows worked with Mr. Payne on developing initial MEMS designs.

Mr. Fishman, together with Mr. Stata, then CEO, decided to give the project a formal budget in 1989. At the time, there was no clearly identified application for MEMS, though airbags had been identified as one possible market.³

With the official budget came assignment to one of ADI’s product divisions, headed by Goodloe Suttler. The division included a manufacturing facility in Wilmington, MA. The MEMS designers had intimate knowledge of the facility, one which Mr. Payne anticipated would have spare capacity for years to come. Mr. Payne now had administrative support, such as finance and accounting services. He also had a full-time functionally organized staff, including a marketing specialist and heads of sales and manufacturing.

Tensions developed between Mr. Payne and Mr. Suttler over the amount that was being invested in the program. Mr. Suttler was concerned about profitability targets for his division. Mr. Payne got Mr. Fishman involved to keep the project accelerating.

Mr. Payne attracted significant attention from automakers by predicting that ADI would be able to sell accelerometers for \$5. This was a substantial savings opportunity for the automakers. The existing system required multiple electro-mechanical sensors and lengthy cable runs, at a total cost of over \$100.

ADI began working directly with Siemens to develop airbag actuators. In 1991, ADI succeeded in signing its first MEMS contract with Siemens, for a Saab design. Siemens was relentless in the negotiation. The promise that Mr. Payne had made, that they would be able to offer sensors for \$5, became the target. There were also potential competitors (of ambiguous quality and capability) naming prices anywhere from \$3 to \$20. ADI had not mounted a significant effort to create patent barriers. A

³ Leifer, p.29

broad patent on the technology was not possible, and there were many possible designs. In their initial contract, ADI agreed to price declines from \$11 down to \$5 over a six-year period.

Mr. Payne's belief that MEMS accelerometers could be manufactured for under \$5 was based on expected improvements in the manufacturing "yield." The manufacturing process for semiconductors, particularly for new products, had many sources of error. Through measurement and refinement, engineers were able, over time, to increase the reliability of the process. At first, the MEMS manufacturing process had only a 10% yield—nine out of ten accelerometers were defective. This was not uncommon in the industry for a new product. (A yield in the neighborhood of 75% is typical of a mature product.) Ira Moskowitz, who would become director of manufacturing for MEMS, recalled the early manufacturing trials:

"Integrated MEMS were produced by engineers hand-carrying wafers through many of the steps. They literally went into a backroom and later came out with some wafers that worked."

Yield was the most important cost driver. There was no way that ADI could earn a profit at 10% yield, given the contract with Siemens. However, ADI had climbed the learning curve for new products in the past, and ADI executives felt that they could make reliable predictions of how long it would take to improve yields. Mr. Payne was very experienced in this area – he had designed processes for maximizing yields for other product lines.

MEMS Under Richie Payne and Franklin Weigold (1992-1997)

Mr. Payne continued to be the driving force behind the business as it was moved to the newly created Transportation & Industrial Products Division (T&IPD). As the product line director for MEMS, Payne reported to Franklin Weigold, the head of the division. Mr. Weigold was new to ADI in 1992, and recalled his first assignment:

"Here is a bunch of businesses that we don't really know what to do with. Some of them are probably good viable businesses that need investments. Some are probably dogs we should get rid of. Go figure it out."

Mr. Weigold was initially very uncomfortable with the MEMS business, because he was unable to see a clear path to profitability. Initially, to the dismay of Mr. Payne, he wanted to discontinue the business. Again, Mr. Fishman stepped in to keep the business going. At the time, he believed that ADI had a chance to create a truly extraordinary product – one that could never become a commodity.

Mr. Weigold did succeed in winning a short-term price concession from Siemens. He also demanded careful planning and accountability internally, and the first fully detailed business plan was created for MEMS.

The US Congress had been discussing the possibility of making airbags a mandatory feature, improving MEMS' prospects. Unfortunately, US automakers knew nothing of ADI, which had never been a supplier to the industry. The automakers were pursuing aggressive efforts to rationalize the number of suppliers they dealt with to reduce purchasing costs. With some help from entrepreneurial leaders at Delphi, ADI's unique technology and demonstrated success in Europe eventually got them in the door.

Again, negotiations were difficult. Though significant groundwork for the deal had been completed before his arrival, Mr. Wiegold argued for backing out of the deal. The path to profitability was still unclear.

The automakers knew that any one supplier could shut down their production lines, at tremendous cost. Mr. Weigold recalled one representative from General Motors: "You can shut our line down once and get away with it but the second time it will be career threatening." Ultimately, ADI agreed to a multi-year deal.

ADI's salespeople who owned the automotive accounts were highly motivated to win further contracts, because ADI's compensation systems were based on either volume or revenues, and there was no potential sale anywhere in the company that even approached the magnitude of a sale to an automaker.

ADI also searched for non-automotive sources of revenue, which in the original business plan were projected at 70% of total revenue. However, the non-automotive applications, such as gaming and appliances, never developed as expected. ADI consistently overestimated the revenues they could expect. Potential customers proved extremely price sensitive, believing that their customers placed low value on the functionality possible through MEMS devices. ADI could not be rewarded for its high quality and reliability in such markets. There was significant tension over whether non-automotive applications should be pursued at all. Each pursuit diverted additional resources away from ADI's core businesses. Developing new markets required talented and expensive sales teams that included engineering and product development skills.

As the automotive business grew, attention turned to manufacturing. Yield projections were the most critical estimates in the business plan, which originally projected profitability in 1995. Improving yields required practice, time, and attention. There was no way to throw money at the problem to accelerate learning.

To reach profitability as quickly as possible, the manufacturing team set aggressive operational goals. However, MEMS proved to be the most complex manufacturing process ADI had ever mastered.

Pressures were intense. On top of internal pressures, customers, because airbags were a safety feature, were pressuring ADI for incredibly stringent quality assurance standards. Early accelerometers deliveries had a defect rate acceptable for most ADI applications, but customers insisted on a defect rate several orders of magnitude smaller. Mr. Moskowitz recalled the demands:

"For a while, we were making almost weekly visits to Kokomo, Indiana, to appear in front of the entire senior management at the Delphi plant there. We were called in to apologize and explain what we were doing about the problem."

Complicating matters, MEMS devices were being manufactured in a facility in Wilmington, Massachusetts, that produced over 9,000 other ADI products, accounting for roughly two-thirds of ADI's profitable worldwide semiconductor business. It was very difficult to get a focused effort on improving the yield on MEMS with so many other distractions. Some of the manufacturing staff felt unfairly antagonized for not being able to produce accelerometers reliably.

Towards the mid-nineties, tensions increased dramatically as the Wilmington facility approached capacity. Mr. Payne and his team were fighting for capacity to produce MEMS while other product managers were furious that the growth of their own product lines were being constrained in order to support a business that was losing money. Capacity battles were fought on a weekly basis at production planning meetings. Jack Webb, the financial manager for MEMS, recalled the struggle:

"People from all product lines were coming to the meeting. I was representing T&IPD. It was chaired by the general manager of the factory. Discussion focused on profit margins – and for MEMS margins were negative. There were heated arguments."

Ultimately the power of the automakers as customers carried the day. Missing a single accelerometer delivery could end the MEMS business altogether.

Mr. Fishman, ADI's chief operating officer at the time, did not recall the period with any pleasure. He recalls literally being booed while addressing the engineering staff of several hundred in Wilmington, as he justified the decision to continue supporting MEMS. Mr. Fishman recalled the gist of their comments:

"Jerry, come on. We always knew Ray [Stata] lived at the fringe of new technologies. But you've always been the voice of reason! Quit giving money to divisions who have never made a profit!"

During down times in the semiconductor industry earlier in the decade, ADI's core products had held up nicely. As a result, there was a tremendous belief in the strength of the core business. A few threatened to quit over the decision to continue

supporting MEMS. Later, in less heated moments, most of the same engineers would acknowledge that Mr. Stata was almost always right about how the industry was changing, though the timing of changes was impossible to predict.

In 1996, Mr. Fishman was promoted to CEO, while Mr. Stata retained the position of Chairman. At that time, one year beyond the date of profitability originally predicted in 1992, the MEMS business was losing tens of millions per year, a significant fraction of ADI's total operating profits. MEMS had missed its yield and profitability targets every year.

A struggle was starting to develop between Mr. Stata and Mr. Fishman. Advocacy for MEMS was shifting to Mr. Stata, who was becoming more inspired by its potential. But Mr. Fishman was becoming more and more concerned about the ability of the business to ever return a profit. Mr. Fishman persistently asked Mr. Stata seemingly unanswerable questions. How much more time? How much more money?

Meanwhile, both men were becoming frustrated with Mr. Payne. His leadership charisma, so compelling in the early years of the business, seemed less effective in the intense environment. Under criticism from many directions, Mr. Payne became increasingly evasive, giving Mr. Fishman the perception that Mr. Payne felt unaccountable for his numbers.

At the end of one of many lengthy one-on-one debates, Mr. Fishman challenged Mr. Stata directly: "If you think MEMS is such a great business, why don't you go run it yourself?" Mr. Stata called Mr. Fishman's bluff:

"Nobody ever imagined that we would invest as much as we had. But there we were, in the water, and we could either drown or swim. We could see the shore! But Jerry Fishman was willing to sell or discontinue the business. I had been looking for a new challenge since I had stepped down as CEO, so I decided to become the acting general manager of the division."

Soon thereafter, Mr. Payne, who continued to believe he was the right man to run the MEMS business, resigned to pursue entrepreneurial opportunities outside of ADI. He had asked Mr. Fishman to live up to his promise that if Mr. Payne built his own business he could run it, but Mr. Fishman had replied that he didn't feel ready to do that yet. Several years later, Mr. Payne recalled the MEMS experience:

"I once invented an integrated circuit technology that definitely had a much bigger impact on the economy than MEMS ever will. But it was nowhere near as much fun. MEMS had all of the great successes, failures, and miracles of recovery. Problem solving is very rewarding when you have to do it quickly – or you're dead."

MEMS Under Mr. Stata (1997-2000)

Mr. Stata's first decision was to invest nearly \$100M to refurbish and reequip the Cambridge building, which had once served as an integrated-circuit facility for Polaroid. His rationale was that the only way to get yields to where they needed to be was in a dedicated, focused environment. It was simply too difficult to run the needed controlled experiments to improve the process in the complex, multi-product-line Wilmington environment.

Under Mr. Stata, the new facility was completed in roughly one year, exceeding expectations. The MEMS division almost completely isolated itself, and focused on the task at hand. The manufacturing group was organized into self-directed teams, to accelerate learning and growth, in contrast to the more hierarchical and stable structure in Wilmington.

MEMS was, for the first time, broken out as a separate business unit. This allowed funding to be controlled directly from the top, and meant that losses would not affect other business units. Staff meetings, run by Mr. Fishman, became the primary venue for discussing MEMS performance. Mr. Fishman recalls the tone of these discussions:

“Analog has very tough business reviews. They are very confrontational, especially towards businesses that are struggling. People don't like coming to them very much, because they are held accountable for results. The business heads were firing extremely difficult questions at Ray [Stata].”

The other business heads were anxious for more capital. MEMS had missed targets for years, and recorded record losses in 1997.

Mr. Fishman and Mr. Stata worked through a difficult year. In a conference room between their offices, they regularly met privately for long, heated discussions. Mr. Fishman recalled the tone of the exchanges:

“Ray would say: ‘Jerry you don't have any courage about diversification. You don't think about the future enough.’ I would respond: ‘Ray, you don't understand what it takes to operate a business. Your hero is an engineer with a story to tell.’ Ray always felt frustrated with management. He would occasionally call us the ‘fat cats.’”

But the two had built a solid relationship over many years that allowed for venting anger, and could survive such disagreements. They kept the content of their discussions to themselves. Mr. Stata stopped attending the staff meetings, “since Jerry was now running the show.”

Under Mr. Stata's direction, the MEMS staff worked extremely hard, and yields were rising, even meeting targets. Any time there was a problem, the group was immediately able to assemble the necessary team to solve it. There was one tremendous problem after another, but kept up with deliveries. Mr. Moskowitz described the lure of the challenge:

"People were willing to endure the pressures because this was an unusual job, and an unusual technology. This is the kind of life experience that you don't get every day. I used to tell people when things got particularly tough, 'Look, I know your life is difficult now. You have more crises on your hands every day. But ...ten years from now you are going to look back and appreciate the uniqueness and excitement of what we are trying to accomplish."

Because ADI as a whole was going through a mild downturn in 1998 and was cutting costs across the board, Mr. Stata made cuts within MEMS to show his group was part of the team. The MEMS staff was unable to make planned hires, but committed to overcome the shortfall through increased productivity. Otherwise, Mr. Stata stuck closely to his plan. He was even confident enough to continue increasing investment in new product development.

In 1998 and each year after, profitability improved as revenues continued to grow. By 2000, losses were only one-third of what they had been in 1997. By that time, yields were over 50%, and continuing to improve. With the business on much more solid footing, Mr. Stata was ready to relinquish control. Mr. Fishman asked Franklin Weigold, to whom Richie Payne had reported until Mr. Stata took over in 1997, to manage the business to profitability. (By 2002, Mr. Stata was still chairman of ADI, but had diminished input into the everyday management of the company he had created thirty-seven years earlier.)

MEMS Under Mr. Weigold (1999-2002)

The transition in leadership was difficult within the division, as Mr. Weigold's disciplined, manage-to-the-plan style contrasted sharply from Mr. Stata's vision-centered teambuilding approach. At the same time, some managers outside the division were very pleased with the transition. Mr. Stata recalled the sentiment, "Finally, we have someone in there who is worried about making some money." Comparing himself to Mr. Weigold:

"Frank and I are different. He is a plan man. It is a badge of honor with him. When he misses his plan, it is a terrible thing. Sometimes, incidentally, this is exactly what you want. In other cases, you just have to suck it in and live with it for another quarter or two."

Mr. Weigold reflected on the accomplishments of the division he inherited from Mr. Stata:

“Establishing this factory and getting it up and running as fast as they did, and then getting the yields up so quickly was a truly phenomenal performance. I think that the people that did that feel very proud. Ray Stata being here at that time was very instrumental in making people feel good even though the rest of the world was throwing darts.”

Mr. Weigold succeeded in managing toward increased productivity and efficiency. Yields approached levels consistent with other ADI product lines. The automotive product lines were the foundation of the business, producing 90% of the division’s revenues, which by 2002 were approaching \$100M. Most of the revenues came from only a few products.

Mr. Weigold continued to invest in future markets and products, but less aggressively. A staff of three was retained to support market research and development in the consumer-industrial markets, and continued to monitor dozens of possible opportunities. In general, these opportunities seemed unattractive to ADI because they would require ADI to compete with companies that were willing to sell inferior products at rock-bottom prices.

Research and development spending within MEMS was held to 12% of revenues, which was considered a normal allocation by the other operating divisions. Most of this budget supported the development of next-generation sensors for the automotive industry. ADI was often approached with ideas for new applications for MEMS devices, but turned most away unless a prototype had been built as a proof-of-concept. Mr. Weigold recalled a recent visit:

“I had a guy in here the other day who had an idea for a MEMS fuel cell. Theoretically you would never have to replace the battery in PCs and cellular phones. The concept is a great idea, and he had done a lot of simulation to prove that it could work. But he hadn’t built one. So we said ‘Go build that in a university laboratory somewhere. Once you have the early bugs worked out, we’d be happy to talk about volume production.’ We get those every day, but they want us to spend the money to prove the feasibility and we can’t afford that.”

Research and development for optical switching components had a separate budget, because it attracted development funding from the telecommunications network equipment industry. Two acquisitions were made to improve ADI’s breadth of expertise in this area. While this business collapsed in 2001, ADI continued to support development, albeit at only one-fourth the original budget, expecting that investment in advanced telecommunications networks would eventually recover. Mr.

Moskowitz expected that large-scale manufacture of optical switching components would present ADI with an entirely new learning curve. But having survived the early years in Cambridge, he is highly confident:

"People here have this mindset. They are used to crisis. They just look at it and say, 'Yup, that's a crisis.' They believe they can fix it because they have fixed so many."

Another opportunity was based on a new but related technology. Following interaction with a university professor, engineers within MEMS became intrigued with a new technique for measuring acceleration, one that used a thermo-chemical reaction rather than mechanical movement as the sensing mechanism. They made a proposal for funding to Mr. Stata and Mr. Fishman, but were turned down. The opportunity was highly uncertain, and MEMS was accumulating substantial losses at the time.

There was also resistance to the initiative within MEMS. Mr. Fishman reflected:

"The entrepreneur, when trying to protect his own jewels, can easily become the bureaucratic control freak – the non-supporter of innovation. Anytime you move on to the next thing, the incumbent complains bitterly."

The circumstance confronted ADI with the dilemma of what to do when a good opportunity arises that you can not or do not wish to fund. In this case, the champions behind the new technology insisted that they were ready to leave to start their own company. By asserting ownership of the intellectual property associated with the technology, Mr. Stata negotiated a 40% stake, and used his contacts in the venture capital community to arrange outside financing. ADI preserved the right to buy the new company, MEMSIC.

The new technology proved to work in certain applications at the low-price end of MEMS' product line, but it did not have the reliability required by the automotive market. ADI elected not to purchase MEMSIC. Because MEMSIC had emerged as a competitor to MEMS, Mr. Stata was left with a conflict of interest. He was a director in two competing companies. He resigned from the MEMSIC board. Mr. Stata commented:

"My hope continues to be that in the future ADI will acquire MEMSIC. It has the characteristics of a disruptive technology. Initially it offers the promise for low cost and low quality in other markets, but it may over time move up in performance."

Judging MEMS' Performance

By 2002, MEMS was approaching \$100M in revenues, and had an operating margin of approximately 12%. (ADI as a whole had an operating margin of 18%, and MEMS was spending roughly the same as a percentage of revenues as the rest of ADI on R&D). The internal debate over whether MEMS was a good investment or not continued. In fact, struggles among varying viewpoints regarding the performance of the MEMS business had existed throughout its history.

A variety of performance measures were highlighted in typical discussions, and these measures evolved. In the early years, from 1992-1994, "traction" with customers (a qualitative judgment of interest from potential customers) was the most watched indicator. ADI had identified all of the airbag manufacturers, and before long was supplying all of them except for Denso in Japan. Though yields were too low, they were expected to rise quickly, and learning would accelerate as the business grew.

Performance against forecasts was also important. In other divisions within ADI, it was critical, and every salesperson and product manager understood that personal performance evaluations depended upon it. Within MEMS there was substantially more leeway. Although MEMS was able to project revenues from the automotive markets, projections for non-automotive markets were regularly much too high. In addition, yield projections were consistently missed, until after the move from Wilmington to Cambridge.

There was also some discussion and concern over the gross margins that the business was achieving. Income statements for most products in ADI's catalog looked strikingly similar. Gross margins were in the neighborhood of 60%, product development 12-15%, and operating profit roughly 15-20%. However, it was accepted throughout the community of suppliers to automakers that gross margins greater than 35% were difficult to achieve. Many ADI executives cited this as evidence that automotive supply was an inherently poor business. Mr. Weigold recalled the pressure to show greater gross margins:

"We anticipated that the automotive market would generate gross margins in the mid 30s to low 40s. That was undesirable compared to the ADI financial model. It was our hope and belief that by also going after non-automotive markets, which might generate gross margins in the sixty to seventy percent range, we'd end up with a gross margin around fifty. That never materialized."

Of course, ROI was the ultimate determinant, but at early stages of a business, ROI was based on forward-looking estimates. Gross margin was simple, and immediately available. It was often the focal point of discussions about MEMS' performance. As it turned out, MEMS' gross margins never rose above 42%, and this was at a brief period in which the business was running close to full capacity.

Naturally, the magnitude of operating losses was another important driver of performance perceptions. Early on, however, these losses were not highly visible. The losses were small, and were “buried” within T&IPD. As losses increased towards the mid-90s, their magnitude became a topic of much more frequent discussion.

As frustrations mounted, the debate focused on short-term losses versus long term potential. Mr. Fishman, and many others, wanted to increase profits this year. The fact that MEMS had missed its financial targets consistently left those arguing for the long term potential of the business with very little credibility. There was an acknowledgement that new businesses were less predictable, but for how long could a business be considered new? At what point could performance expectations be set more rigidly? ADI had a disciplined planning environment. Investments had been made based on projections, and those projections had been missed by substantial margins.

Had Mr. Stata not agreed to run the business himself, the business would have been discontinued. He was less affected by the missed targets – every new business ADI had ever entered required more time and more capital than was originally anticipated. In addition, it was clear that the automotive market represented a stable, predictable, and growing revenue base. On the cost side, Mr. Stata was confident he could get yields up in an isolated environment. In short, he saw a path to profitability and continued growth.

Soon after Mr. Stata took the helm at MEMS, Mr. Fishman had to make some difficult decisions about how to communicate, or not communicate, the mounting MEMS losses to Wall Street. Some analysts had already come up with rough estimates, and voiced a clear opinion that the business should be exited. Mr. Fishman faced a dilemma – if he broke out the business cleanly in the annual reports, the magnitude of the losses would become clear to all. If he didn’t he risked analysts coming to the conclusion that the profitability of the core business was eroding. Mr. Fishman recalled:

“Analysts were thinking that we must be idiots in our core business. If they keep thinking that, the stock goes down relative to competitors, and all of a sudden you get acquired. So you can take the high road, focus on the long term, and say ‘Who cares about the stock price,’ but you have to care a little bit, or you may not survive.”

Ultimately, ADI disclosed enough to raise howls of disapproval from the Street. This led Mr. Fishman to make some firm commitments regarding how quickly the MEMS business would improve. Mr. Fishman would later regret these commitments. The episode increased internal perceptions that the business was ill considered.

Naturally, emotion also played a role in how the performance of the business was perceived. For those who had an emotional investment in the business, it was

extraordinarily difficult to even consider walking away from it. To them, past efforts were sunk costs, and additional investments had to be considered based only on future promise.

Mr. Stata also believed, based on interaction with several other companies, that “founders have the capacity to take risks that second and third generation managers typically don’t.” This allowed them to assess performance with a heavier orientation towards long-term potential. Mr. Stata explained:

“In my case, I just never worried about being fired. It’s not that I couldn’t have been. But I felt willing to figure out what I thought was the right thing to do, assessing the short-term and long-term tradeoffs, without a lot of care about who liked it or who didn’t.”

In Mr. Stata’s view, for those that succeed founders, worries about how errors might affect their careers, or might affect how they are perceived internally and by investors, were generally much more pressing concerns.

Building the MEMS Organization within ADI

ADI has followed a similar approach to staffing the new ventures that have reshaped their business. Typically, to the extent possible, they staffed new ventures from within. In Mr. Fishman’s view, this creates some necessary continuity, while external hires would create suspicion, and negatively bias performance perceptions. The exception to the rule is new businesses that require a specific, identifiable expertise (sometimes technical, sometimes marketing) that ADI doesn’t have. To “seed” new expertise, ADI typically “hired” by acquiring a small company, much as they had to accelerate the development of components for optical switches.

This approach created a culture that was consistent throughout ADI, which included the following values and beliefs:

- ADI creates leading edge, high-tech products.
- ADI products carry a high price, to reflect their industry-leading quality, reliability and support.
- ADI managers are held to tight, aggressive goals, but are given freedom to achieve those goals in whatever way they see fit.

Overall, an employee making a transfer from one division to another at ADI could be expected to acclimate quickly.

Although the MEMS business made some external hires to support its growth, it retained a culture consistent with that of ADI. There was some variation created by the differing styles of each in the progression of leaders. S

Finding ADI executives willing to move to the MEMS division was sometimes challenging. Some potential candidates perceived MEMS as a career risk. Why be associated with a business losing money? In some cases, Mr. Fishman had to convince prospective candidates that he knew their successful records well, he understood the nature of the challenge in MEMS, and would look after their next career step personally. Such arguments only succeeded in cases where Mr. Fishman already had a close, trusting relationship.

In terms of organizational structure, the MEMS division paralleled other divisions, each with a functional organization reporting to a general manager. The exception was manufacturing. ADI's manufacturing function was centralized. However, after moving to Cambridge, MEMS manufacturing operated more independently. MEMS manufacturing had a dual reporting relationship—to the general manager and the head of worldwide manufacturing.

Compensation policy within MEMS followed ADI norms. Everyone's bonus, throughout ADI, was based on corporate performance. In good years, the bonus could be as high as 30% of base salary for mid-level executives, and even higher for senior executives. ADI also compensated senior executives with stock options. This approach made it difficult for internal entrepreneurs to make huge sums. Nonetheless, Mr. Fishman felt that those involved with MEMS might have received a deal that was too good:

“They had the best of everything. They had options on ADI stock, which was rocketing. They had bonuses. They had the stability of ADI. And they were losing money. There was little consequence for failure. In the venture capital world, if you miss your targets you're either fired or severely diluted at the next financing round. Those are real consequences.”

MEMS operated on the same annual planning cycle as the rest of ADI throughout its history. Each division's budget was a result of available funds, which depended on ADI's overall performance, plus a competition for resources among divisions. When divisions failed to meet their targets for the previous year, their bargaining strength was diminished. The MEMS division was less affected by missed targets in the first two to three years of operation, during which time they were understood to be in “investment mode,” and were able to simply estimate their total spending needs.

Synergies Between ADI and MEMS

The MEMS division had benefited from being a part of ADI, and made contributions to the corporation in return. Beyond the conflicts over financial resources and capacity in Wilmington, the relationship between MEMS and ADI remained healthy.

In particular, MEMS borrowed most of its manufacturing know-how and technology from ADI, including their entire quality system and methods for systematically improving yields. When the new facility was opened in Cambridge, several experienced members of the manufacturing staff accepted transfers. The MEMS division contributed to ADI by opening doors to the automotive market—a significant portion of ADI's sales to this industry are now traditional ADI products. In addition, the extremely high standards for quality required for automotive safety applications created positive spillovers from MEMS to other product lines.

Final Evaluation

In Mr. Stata's view, it would not be long before ADI was faced with the opportunity, or even the necessity, to take a risk on a highly uncertain new venture to assure ADI's long term vibrancy. As his involvement in day-to-day operations diminished, he was naturally interested in what conclusions Mr. Fishman and others would draw from the MEMS experience. Mr. Stata described his own viewpoint:

“I believe that MEMS will prove to be one of the important technologies to sustain our long-term growth. We have to continue to avoid giving in to short-term pressures and choosing not to follow through on our investment. If there is one thing that I've learned about the technology business it is that persistence pays.”

At 2002 levels of revenue and profitability, another decade would be required simply to recover all of the capital invested in MEMS. To provide a healthy return, new sources of profitable growth would have to be identified.

In the automotive market, safety systems continued to add functionality, and required more sensors per car, and more sophisticated sensors. Beyond automotive, the most promising new market, components for optical switching, was expected to be dormant for at least two years. Longer-term markets in medicine were intriguing, but were perhaps a decade away, and as a result the MEMS division had only one person dedicated full time to investigating the possibilities.

Meanwhile, the interest in MEMS technology amongst scientists and engineers at ADI was building quickly. And ADI's panel discussions about MEMS at scientific conferences were standing-room-only.

Discussion Questions

1. What do you suspect would have happened to the MEMS business and to Mr. Payne had he negotiated an agreement with ADI that allowed him to start a separate, venture-financed company to commercialize MEMS devices in the late 80s?
2. Is ADI an environment in which corporate entrepreneurs can thrive?
3. What might you have done differently if you were Mr. Payne? Mr. Fishman? Mr. Weigold? Mr. Stata?
4. Was MEMS a success?

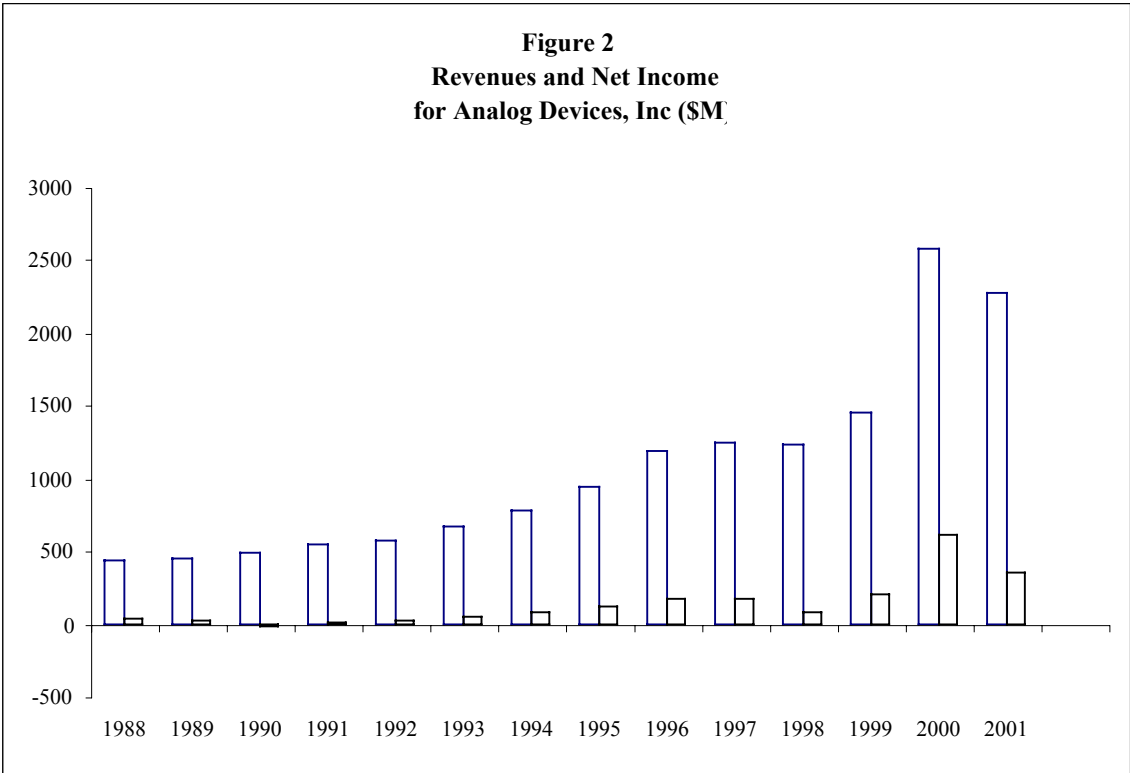
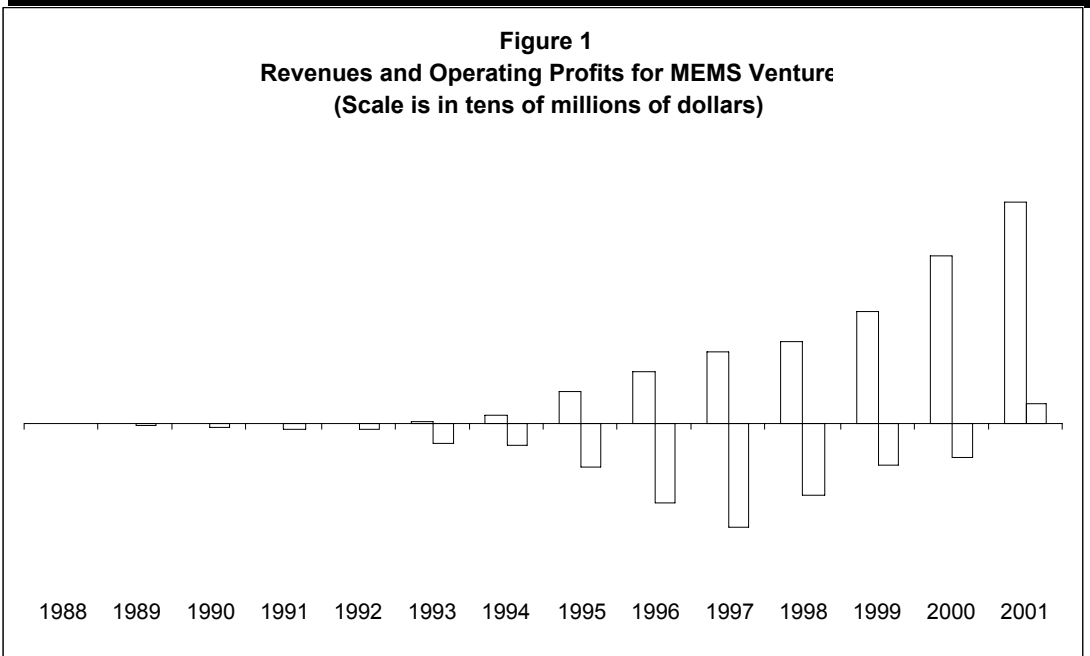


Figure 3

Growth Rates for ADI's Analog Products

| | |
|-----------|-----|
| 1980-1985 | 23% |
| 1985-1990 | 9% |
| 1990-1995 | 20% |
| 1995-2000 | 19% |

Source: ADI

Appendix

Interviews for this case included:

Ray Stata, Chairman, ADI

Jerry Fishman, Chief Executive Officer, ADI

Franklin Weigold, General Manager, Micromachined Products Division, ADI

Ira Moskowitz, Director of Manufacturing, Micromachined Products Division, ADI

Jack Webb, Chief Financial Officer, Micromachined Products Division, ADI

Craig Core, Wafer Fab Manager, Micromachined Products Division, ADI

Richie Payne, Former Product Line Director, Micromachined Products Division, ADI